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Anita Khosla
Mohan Kolhe *Editors*

Renewable Energy Optimization, Planning and Control

Proceedings of ICRTE 2022

Springer

Studies in Infrastructure and Control

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Dedicated
to
Almighty

Preface

We feel great pleasure and honour to share that we had organized the prestigious Second International Conference on Renewable Technologies in Engineering (ICRTE 2022), in association with Springer Nature on 07–08 October 2022, at Manav Rachna International Institute of Research and Studies, Faridabad, India, in virtual mode. The aim of this conference was to bring together academicians, researchers, scientists, engineers and practitioners to exchange and share their experiences, ideas and the results in the area of renewable sources integration planning and control and their optimization solutions, smart structures for intelligent power with use of energy storage and transportation systems and industry innovation and automation in smart structures.

Energy is regarded as the most important building block in human development, and it is a key factor that influences the sustainable development of any nation. The conventional sources have an intimidating shadow on our present and future global safety, environmental values, health and society in general. Hence, there is an urgent need to promote renewable energy in Indian power sector. So to contribute in this field, the Department of Electrical and Electronics and Electronics and Communication Engineering, Manav Rachna International Institute of Research and Studies, Faridabad, in association with Springer had taken this initiative in successfully organizing Second International Conference on Renewable Technologies in Engineering, (ICRTE 2022), on 7–8 October 2022, and the first conference in this series was held on 15–16 April 2021.

During the conference, research scholars, academicians and industry experts, from different parts of the globe, deliberated for two days on the interdisciplinary areas like renewable sources integration planning and control and their optimized solutions, smart structures for intelligent power with use of energy storage and transportation systems for smart structures and industry innovation and automation in smart structures.

It is great pleasure and honour for us to bring the proceedings of Second International Conference on Renewable Technologies in Engineering (ICRTE 2022). All presented papers are arranged in a book *Renewable Energy Optimization, Planning and Control* under book series *Studies in Infrastructure and Control*.

ICRTE 2022 is our humble effort at establishing a base, platform, against which we can build a brighter tomorrow.

Faridabad, India Dr. Anita Khosla
Kristiansand, Norway Dr. Mohan Kolhe

Acknowledgements

We would like to extend our heartfelt gratitude to all who have been associated with this Second International Conference on Renewable Technology in Engineering (ICRTE 2022), as without their support it was not possible to conduct this conference and compile all the papers.

We are pleased to note the overwhelming response to our call of papers from the authors for the conference. Our sincere thanks to all the authors for their contributions. We are also thankful to International Advisory Committee, National Advisory Committee, Local Advisory Committee and Springer for their continuous motivation and support. We also like to extend our gratitude to reviewers who have worked arduously in selecting high-quality papers and writing review reports.

Our special thanks to dignitaries who graced the inaugural function and the keynote speakers who shared their experience. We would also like to thank the session chairs for their valuable support in the smooth conduct of technical sessions. We are also thankful to our management for guidance and liberal help for smooth conduct and success of conference.

We feel proud to share that organizing team of ICRTE 2022 has done a professional exercise in selecting the research papers and arranging them meticulously in technical sessions.

Dr. Anita Khosla
Dr. Mohan Kolhe

Contents

About the Editors

Dr. Anita Khosla is presently working as Professor in the Department of Electrical and Electronics Engineering at, Manav Rachna International Institute of Research and Studies, University, Faridabad. She has rich experience of 27 years in teaching. She did her B.Tech. in Electrical Engineering from National Institute of Technology, Kurukshetra, and Ph.D. in Control Systems (Electrical Engineering) from MRIIRS. She has guided four Ph.D. scholars and guiding six at present. She is Fellow IE(I), Senior Member IEEE, and Life Member of ISTE, India. She is Author of three books. She has attended and organized many workshops, FDPs, and seminars. She has also been Session Speaker in many conferences. She is Editor of two books *Renewable Energy Optimization, Planning and Control* and *Smart Structures in Energy Infrastructure* published by Springer which are proceedings of ICRTE 2021. She has published more than 50 research papers in national and international journals of high repute and conferences. She is instrumental in setting up of Authorized Training Centre for Automation in collaboration with Mitsubishi Electric India and is Director for the same.

Prof. Dr. Mohan Kolhe is Full Professor in smart grid and renewable energy at the Faculty of Engineering and Science of the University of Agder (Norway). He is Leading Renewable Energy Technologist with three decades of academic experience at the international level and previously held academic positions at the world's prestigious universities, e.g., University College London (UK/Australia), University of Dundee (UK); University of Jyvaskyla (Finland); Hydrogen Research Institute, QC (Canada); etc. In addition, he was Member of the Government of South Australia's first Renewable Energy Board (2009–2011) and worked on developing renewable energy policies. Due to his enormous academic contributions to sustainable energy systems, he has been offered the posts of Vice-Chancellor of Homi Bhabha State University Mumbai (Cluster University of Maharashtra Government, India) and Full Professorship(s)/Chair(s) in 'sustainable engineering technologies/systems' and 'smart grid' from the Teesside University (UK) and Norwegian University of Science and Technology (NTNU), respectively. He is Series Editor of *Springer Proceedings in Energy*. His research works in energy systems have been recognized within the top

2% of scientists globally by Stanford University's 2020, 2021 matrix. He is Internationally Recognized Pioneer in energy field, whose top 10 published works have an average of over 175 citations each.

Chapter 1
A Socio Inspired Technique in Nuclear Power Plant for Load Frequency Control by Using Cohort Intelligence Optimization-Based PID Controller

D Murugesan, K Jagatheesan, Anand J Kulkarni, and Pritesh Shah

Abstract Cohort intelligence optimization (CIO) technique is investigated in this article for tuning of proportional integral derivative (PID) controller for load supervision of single region nuclear power plant. To prove the performance improvement of the proposed CIO controller-based power plant, the response is analyzed with conventional, Ziegler Nichols, and particle swarm optimization technique (PSO)-based PID controller, while tuning the decision variables of PID controller by using the CIO technique, the appropriate determination of cost/objective function is most important. In this work different cost function are analyzed to know the supremacy based on the CIO technique. The CIO-PID controller strategy gives improved solutions to the extent of an objective function, computing time, function assessments, and dynamic system response-based ITAE objective function. Finally, proposed techniques-based PID controller gives improved dynamic response for 1, 2, 5, and 10% robustness validation. Also, sensitivity assessment of ± 25 to ± 50% nominal parameters changes applied to know the reasonability of the proposed methodology.

Keywords Load frequency control · Cohort intelligence optimization · Proportional integral derivative · Particle swarm optimization · Integral time absolute error

1 Introduction

Automatic generation control (AGC)/load frequency control (LFC) is the arrangement that prevailed in the power framework to stay aware of the frequency changes

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from its standard nominal values. It expects an essential part in the power scheme movement and restriction. To do the LFC/AGC an assistant controller is much expected to all the power structures either, interconnected or autonomous power system. In this way, countless researchers are arranged and execute an additional controller to control the frequency deviation of the organization. While executing the auxiliary PID controller, it takes more consideration about the frequency deviation of the power framework. There are different diverse time area boundaries are in the frequency deviation, settling time, top overshoot and pinnacle undershoot, and rise time. By minimizing the consistent steady-state error of the frequency deviation those boundaries are controlled and keep up with.

Gozde et al. [1] have proposed dynamic performance of thermal source framework investigation with nonlinearity in terms of real power control application with craziness-based particle swarm-optimized PI controller. Kulkarni et al. [2] examined with regards to fundamental structure cohort intelligence optimization methods. Murugesan et al. [3] authors have inspected cohort intelligence based PID controller structure in isolated and integrated thermal power system. In [4] one area, double region, triple area, and four areas thermal power system framework with ant colony-based PID controller planned and examination the framework execution distinctive objective capacity. Murugesan et al. [5] explained concerning the combined thermal power structure with a renewable source to reliant upon PIDD controller using ant colony strategy. In [6], the execution investigation of AGC for two areas reheats thermal interconnected plant framework is examined in the presence of ABC algorithm-based PI and PID controller. Decentralized load frequency control is formulated as multiple objective optimization problems using genetic algorithm is presented for three area control with the help of PI controller in [7]. Parmar et al. [8] have addressed the single region power framework involving reheat -thermal and hydro units environment is examined for real power control with an optimal output analysis controller.

In [9], authors have designed an ideal order control PID regulator for LFC in multiple area power plant employing ITAE-based (ICA) Imperialist Competitive Algorithm. The effect of composite objective enhancement utilizing ABC algorithm on the frequency regulation for two areas interconnected reheats thermal power framework has been done by Naidu et al. [10]. Mohanty et al. [11], demonstrated fruit fly optimization algorithm for PIDD controller tuning is proposed to study the robustness of the power framework. In [12], the authors examined the performance of a Beta wavelet neural network optimized cascaded control mechanism in a two-area interconnected assembly. In [13], it presents automatic gain control of hydrothermal interconnected control system considering minority charge carrier inspired algorithm would give better result under different loading condition of electrical governor than the mechanical governor. Dahiya et al. [14] have noticed disruption operator in gravitational search algorithm is used to enhance AGC problems of four areas interconnected power system. It reveals that FOPID-based tuning gives superior performance. In Pradhan et al. [15] LFC is analyzed means of best utilizing the unified power flow control and superconducting magnetic energy storage unit energy (SMES) in tie line will improve the dynamic behavior of large-area power framework utilizing firefly algorithm-based fuzzy PID controller. PID regulator for single region nuclear power station in [16].

The proposed research work was accomplished well, and it is explained by the accompanying areas as follows; Sect. 1 gives a sufficient show and composing review about the proposed work. Section 2 explains the showcase of the proposed system structure and the mathematical explanation of each block in the Simulink model. Section 3 frameworks the arranging method of the PID controller with the pre-owned cost work and clarifies the tuning procedures of traditional, Ziegler Nichols, PSO, and CIO advancement strategies. Section 4 gives the result examination of the proposed system and execution connection of standard ziegler Nichols, PSO, and CIO tuned PID controller. Section 5 is about the finish of examination work with the proposed strategy. Section 6 deals with the design parameters of proposed system in appendix.

2 Modeling of Single-Area Nuclear Power Plant

An isolated nuclear power framework is given in Fig. 1. The investigated system comprises of high pressure and Low-pressure turbine, water-driven amplifier, power system generator, and speed controller. The apparent limit of researched power framework in [16]. All examination is done using MATLAB transformation R2014b model. The structure of the framework under concentrate on displayed in Fig. 1 [11] is created in MATLAB/SIMULINK. The framework reaction is as far as automatic generation control and frequency management are improved by adding another secondary PID controller. To measure with the steady-state errors, controllers are thought of and the controller boundaries are upgraded by cohort intelligence optimization (CIO).

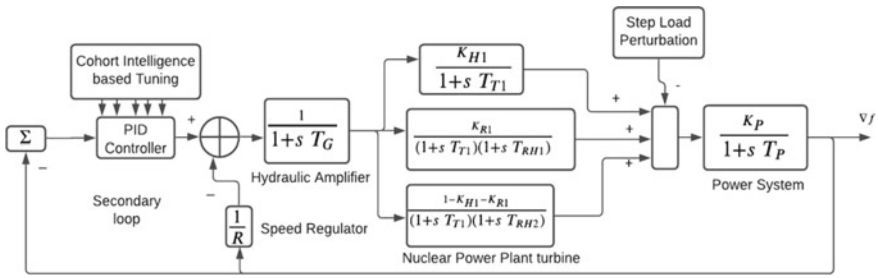

Fig. 1 Framework of single area nuclear power plant

3 Controller Structure and Objective Function

With concern, a nuclear power plant of the examined power framework is furnished with a PID regulator. This controller is created in the nineteenth decade, and it is broadly utilized in present-day ventures. The advantage of utilizing the PID controller is in effect exceptionally modest and more adaptable. The arrangement of proposed PID regulator is displayed in Fig. 2. The expression of the PID regulator is given in Eq. (1)

$$G_{\mathrm{PID(s)}} = K_P + K_I S + K_D S \text{ (or)}$$
$$G_{\mathrm{PID(s)}} = K_P(1 + 1/\mathrm{Ti}\, S + T_D S) \quad (1)$$

The error input to the controller is Area Control Error (ACE)/Figure of Demerit (FOD) is given in Eq. (2), B and ΔF are the bias coefficient and change in frequency, respectively.

$$\mathrm{FOD} = \mathrm{ACE} = \mathrm{B} \cdot \Delta\mathrm{F} \quad (2)$$

The projected evaluation of this controller is being justified by dissemination of peak overshoot and undershoots of modified frequency. In addition, the framework accuracy is estimated as far as settling time of frequency response. The articulation for region supervision error is mentioned in Eq. (2), and the control signal produced by the $\mathrm{U_{PID}}$ regulator is mentioned in Eq. (3). The control signal (U_{PID}) expression is mentioned below:

$$U_{\mathrm{PID}} = K_p \cdot (\mathrm{ACE}) + \mathrm{KI} \int_0^t (\mathrm{ACE})\, \mathrm{d}t + K_{\mathrm{D}} \frac{\mathrm{d_{ACE}}}{\mathrm{d}t} \quad (3)$$

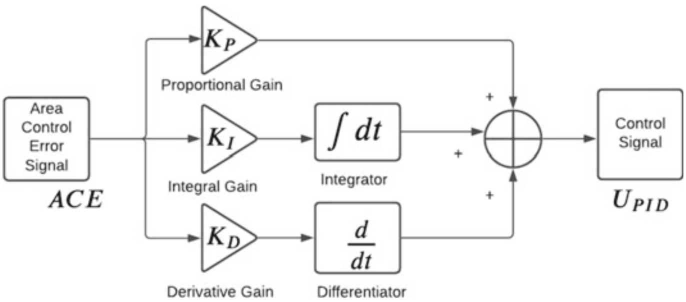

Fig. 2 Design of PID controller

3.1 Objective/Cost Function

The cost function determination with wanted specification and constraint is a more difficult task. The decision of cost action to streamline controller values depends on its action basis. These benchmarks are evaluated owing to the peak overshoot; peak undershoots, rise time, and settling time.

The transient execution of the closed-loop framework can be measured by using error functions such as Integral Square Error (ISE), Integral Time Absolute Error (ITAE), Integral Time Square Error (ITSE), and Integral Absolute Error (IAE). These cost functions are evaluated by using the following expression. The selection of the above function as an objective function mainly depends on the performance requirement values in terms of reduced time-domain parameters. The ISE gives smaller overshoot and takes a longer time to settle, and IAE will take a smaller time to settle with higher overshoot. The time-multiplying error criterion gives initial oscillation and then settles quickly. Minimize the objective function subject to Eqs. (4)–(6), respectively.

ITAE-based tuning makes the structure settle down a great faster than the other said tuning strategies. ITAE model additionally gives the least peak overshoot. Then again, the ITSE model-based regulator offers a huge regulator yield for the unexpected change in reference esteem.

$$\mathrm{ISE} = \int_0^t (\mathrm{ACE})^2|\mathrm{d}t \tag{4}$$

$$\mathrm{IAE} = \int_0^t |\mathrm{ACE}|\mathrm{d}t \tag{5}$$

$$\mathrm{ITAE} = \int_0^t t \cdot |\mathrm{ACE}|\mathrm{d}t \tag{6}$$

3.2 Conventional Method

The experimentation (ordinary) tuning technique is a customary strategy for acquiring ideal addition upsides of the regulator. In the ordinary tuning technique, gain esteems are acquired by preliminary and slip-up designs. The first ideal essential addition esteem (K_I) is found, then, at that point, the relative increase esteem (K_P) is determined by keeping K_I consistent. In the wake of establishing the K_P, both K_I

Table 1 Calculation of gain regard from Ziegler-Nichols procedure

Controller	K_P	K_I	K_D
P	0.5 Ku	–	–
PI	0.45 Ku	0.54 Ku/Tu	–
PID	0.6 Ku	1.2 Ku/Tu	0.6 Ku Tu/8

and K_P as kept as steady, do a similar tuning for subsidiary addition esteem (K_D). Traditional technique (experimentation) gain esteems tuning strategy:

Stage 1: Tune K_I by keeping K_P and K_D is zero.

Stage 2: Tune K_P by fixing the ideal K_I is constant and keeping K_D is zero.

Stage 3: Tune K_D by fixing ideal K_I and K_P are constant.

3.3 Ziegler-Nichols Method

Over the 1940s, numerous strategies have been produced for tuning the PID regulator boundaries. In 1942, Ziegler and Nichols proposed two test ways to deal with rapidly changing the regulator boundaries without knowing the exact powerful model of the framework to change. In this paper, the second technique for Ziegler-Nichols is utilized. It is a straightforward strategy to tuning PID regulator boundaries. The determined PID regulator boundaries are given in Table 1.

In root locus, follow taken by the foundation of the traits condition when gain K is changed from zero to unlimited quality. In the particular values k the root locus begins to oscillate from the normal point. That point is considered as essential increment Ku and individual period Tu. Those qualities can be accomplished by utilizing the root locus method through attributes condition.

3.4 Particle Swarm Streamlined Techniques

Particle swarm optimization (PSO) is a heuristic progression procedure reliant upon swarm information. It derives from analyze on the bird and fish surge advancement lead. PSO is a general population-based progression procedure is made in 1995 by Dr. Kennedy and Dr. Eberhart. Optimized controller gain values are analyzed from various researchers [16, 17]. With concern, Integral Time of Absolute goofs (ITAE) is employed as a cost work (the well-being work for PSO). The standard objective function for the PSO computation is given in Eqs. (4)–(6). In Table 2 is given limits using PSO and this moment is the ideal opportunity space limit.

Table 2 Comparison of time-domain and controller gain parameters with different techniques

Technique	ITAE			Time-domain parameters				FOD
	K_P	K_I	K_D	t_r(sec)	U_{Sh}(Hz)	Osh (Hz)	t_s(sec)	
Conventional	0.11	0.13	0.09	9.2	– 0.0155	0.25	41.5	0.1315
Zigler Nichols	0.1638	0.28888	0.0232	1.07965	– 0.019	0.006	32	0.08728
PSO	0.8085	0.986856	0.1889	0.71	– 0.0013	0.0015	45	0.01868
CIO	0.9626	0.6982	0.2547	4.1	– 0.0074	0.012	23	0.02951

3.5 Implementation of Cohort Intelligence [2–3]

The troop has a number of nominees where they wish to sustain in the troop out of their own characteristic analysis, and each characteristic material is an unknown trait being trained after continuous interaction with every other characteristic. Dependent on one's own characteristics, the trait development may be higher or sometimes lower. The trait assessment will be qualified based on the idealization (higher ideal and lower ideal). Idealization of the trait becomes higher only when the comparison of traits follows higher idealness. This condition can sympathize only if lower trait follows rather lower trait in order to obtain sustainability over its own troop. Once an idealness over the singular trait is achieved, the trait is effective to meet the global idealness on bringing sustained characteristics as its own trained idealness over the entire troop.

The troop characteristics under training will undergo idealness over an environment only on sustaining the higher ideal over the entire troop on depicting the idealization throughout the solemn troop with respect to the environment of its own concern. The system of the CIO technique can be summed up as follows.

Step 1: The controller gain esteems are viewed as quality of candidates c ($c = 1, 2, \ldots C$), reduction factor r, convergence factor ε, during the time spent (Ψ_{kp}, Ψ_{ki}, Ψ_{kd}). These qualities (Kp, Ki, and Kd) are haphazardly delivered inside the reach that is upper and lower search space.

$$K_P^C = \min(\Psi_{kp}) + [\max(\Psi_{kp}) - \min(\Psi_{kp})] \cdot \mathrm{ran}(.) \quad (7)$$

Step 2: Quality is assessed for every one of the up-and-comers and is alluded to as the cost function. On account of the control framework, the associated behavior of each candidates is given below as

$$\mathrm{ITAE}^{\mathrm{C}} = \int_0^t t \cdot |e(t)| \mathrm{d}t \quad (8)$$

Step 3: The probability for every candidate followed by different up-and-comers is assessed dependent on its objective function. The up-and-comer with the best objective function has the most extreme probability of being trailed by another candidate, and the other way around

$$P_C = \frac{1/\mathrm{ITAE}^C}{\sum_{(C=1)}^{C} 1/\mathrm{ITAE}^C} \; c = 1, 2 \ldots C \tag{9}$$

Step 4: All the competitor utilizes a roulette wheel way to deal with follow quality in the framework, and it works on the worth of its objective function by growing or lessening the lower and upper limits of the boundaries

$$\Psi_{kp} \;\; \left[K_P^C - \left\| \left(\max(\Psi_{kp}) - \min(\Psi_{kp})\frac{r}{2}\right) \right\|,\; K_P^C + \left\| \left(\max(\Psi_{kp}) - \min(\Psi_{kp})\frac{r}{2}\right) \right\| \right] \tag{10}$$

Step 5: The value of the cost function is expected to combine when the contrast between the conduct of every candidates becomes inconsequential

$$\left\| \max\left(\mathrm{ITAE}^C\right)^n - \max\left(\mathrm{ITAE}^C\right)^{n-1} \right\| \leq \varepsilon_1 \tag{11}$$

$$\left\| \min\left(\mathrm{ITAE}^C\right)^n - \min\left(\mathrm{ITAE}^C\right)^{n-1} \right\| \leq \varepsilon_2 \tag{12}$$

$$\left\| \max\left(\mathrm{ITAE}^C\right)^n - \min\left(\mathrm{ITAE}^C\right)^{n-1} \right\| \leq \varepsilon_3 \tag{13}$$

4 Results and Discussion

The designed system transfer function is created using MATLAB Simulink software. Table 2 disclosed the decision variables of the different techniques, CIO optimization parameters, and dynamic system performance. The developed model is simulated using CIO algorithm with simulation time of 120 s. Figure 3 clearly reveals that the CIO-based PID controller concerned with ISE, and ITAE objective function settles before 20 s for frequency supervision of nuclear power system.

The put forth conduction of PID is associated with the cohort intelligence optimization strategy. Figure 4 displays the supremacy of dynamic performances by analyzing the system to the proposed approach. The proposed evaluation of PSO, Ziegler Nichols, and conventional-based PID inline with CIO-PID has a threshold result (0–60 s) as mentioned in Fig. 4 for frequency deviation.

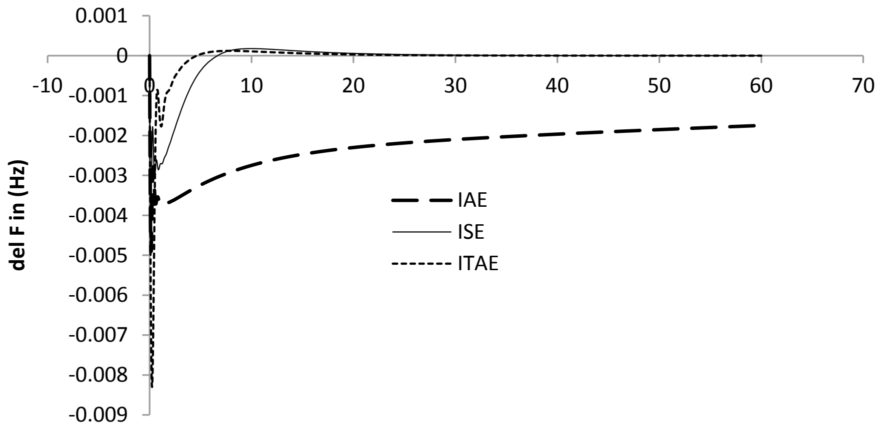

Fig. 3 CIO-based PID system response for different cost function

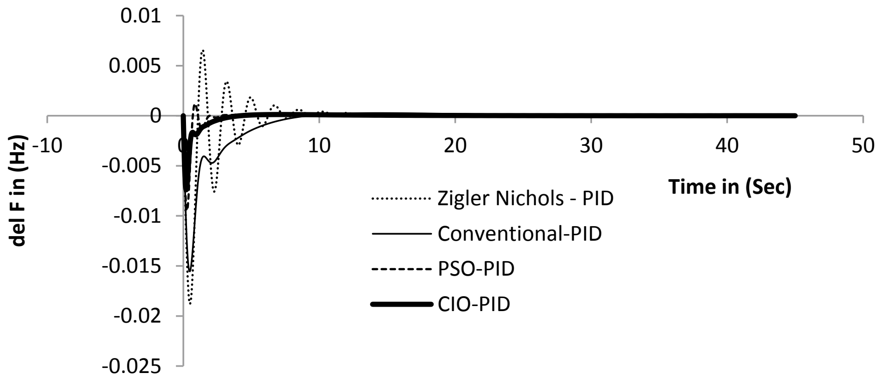

Fig. 4 Response comparison of nuclear power framework

It is visible that the Ziegler Nichols-based controllers give large damping oscillation and take huge time to settle with their nominal value compared to the proposed CIO-PID controller, as for as conventional and PSO-based PID gives very dead response with oscillations. Figure 5 bar chart comparison gives the settling time observation of frequency monitoring in isolated nuclear power systems are given in Table 2. It unveiled clearly that the cohort intelligence approach diminished effectively oscillations in their response compared to PSO, Ziegler Nichols, and conventional optimized controllers.

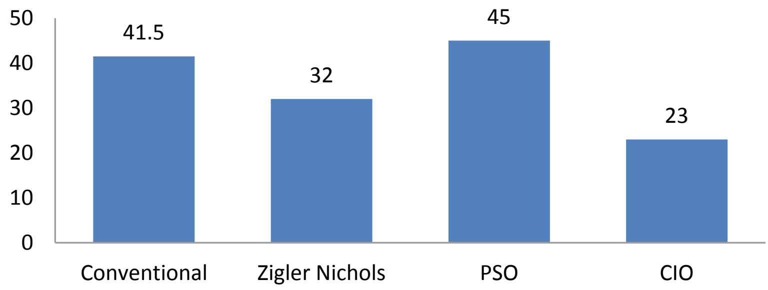

Fig. 5 Bar chart analysis of settling time

4.1 Analysis of System with Physical Constraint and Sensitive Analysis

A one percentage step perturbation is forced in the proposed model and the comparing execution list of Index and change a similar system for 2%,5%, and 10% step load. the exhibition for the disturbed proposed framework is displayed in Fig. 6.

Affectability is the capacity of a framework to perform viably while its factors are changed inside a specific passable reach. In this part, by fluctuating framework boundaries from their nominal qualities (given in the informative appendix) in the scope of ± 25 and ± 50% Table 3, obviously describe our proposed method will function well to work on the exhibition of nuclear power frameworks based on time domain parameters such as rise time (t_r), Overshoot desired (Osh), Undershoot (U_{sh}), and settling time (t_s).

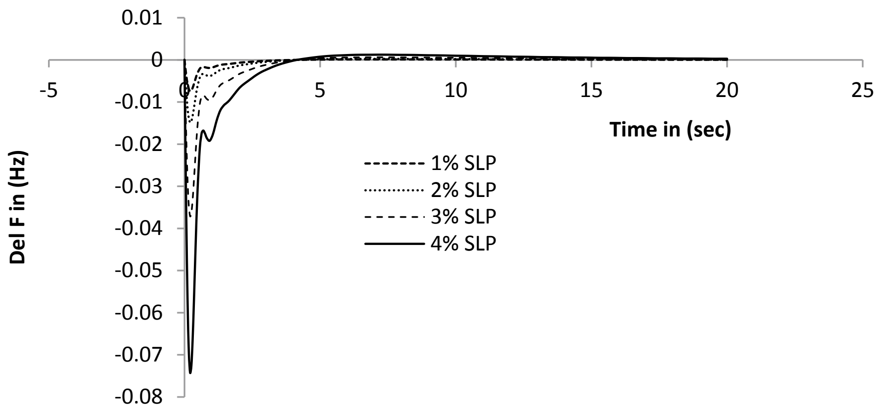

Fig. 6 Response of nuclear power framework with various perturbation

Table 3 Comparison of dynamic response with different system parameter changes

Robustness	Time domain parameters				ITAE
	t_r (s)	U_{Sh} (Hz)	Osh (Hz)	t_s (s)	
− 25%	4.185	− 0.0068	0.00012	23	0.02379
+ 25%	4.21	− 0.0079	0.00012	22	0.02887
− 50%	4.2	− 0.0062	0.000125	24	0.02542
+ 50%	4	− 0.0083	0.00013	27	0.02454
Nominal	**4.1**	**− 0.0074**	**0.012**	**23**	**0.02951**

Bold value indicates time domain parameters of the proposed system with 1% robustness

5 Conclusion

In this article, a new method for real power control using cohort intelligence optimization technique has been proposed to tune the secondary PID controller for real power control of nuclear power framework. This ITAE-based cost function for cohort intelligence techniques takes very lesser time to get optimize gain values by comparing with conventional, Ziegler Nichols, and PSO technique. Also, the proposed procedure gives better dynamic response parameters. In addition, the supremacy of the designed plan is proved by applying distinctive loading conditions from one percentage to 10% step load disturbance in the analyzed power system. The sensitivity investigation of the PID controller based on the CIO technique remains unaltered even after wide changes in the framework stacking condition by ± 25% and ± 50% framework boundaries esteems. Consequently, the proposed CIO-streamlined PID regulator can effectively ensure real power control despite variations in power generation and demand.

Appendix

(a) The normal values of bounds of framework under study are shown below: $Tp = 20$ s, $B = 0.4312$ Pu, $T_G = 0.08$ s, $K_{\text{H1}} = 2$, $T_{\text{TR1}} = 0.5$ s, $K_{\text{R1}} = 0.3$, $T_{\text{RH1}} = 7$ s, $T_{\text{RH2}} = 9$ s, $K_P = 120$ Hz/pu.
(b) The bounds of CIO are shown below: $C = 3$; $N = 3$; $r = 0.97$; $\varepsilon = 0.0001$.

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Chapter 2
Seamless and Smooth Power Sharing, Voltage, and Frequency Control of Islanded Microgrid with Droop Cum Supervisory Controller

Md. Shahnawaz Chisty, Ikbal Ali, and Mohd Faizan

Abstract This paper describes and analyzes the control of microgrid when it becomes isolated. In most cases, the microgrid is connected to the grid and has certain local loads. When a grid side anomaly occurs, the microgrid is isolated from the main grid, which is designated as Microgrid in Islanded Mode. In these circumstances, the microgrid would have to be powerful enough to run reliably. For steady, seamless, and unsupervised functioning of the microgrid in islanded operation, a droop control, and a supervisory control are employed. In this research, a MATLAB simulation of the control approach in island mode is performed, and the simulation results are examined. Once the microgrid is in Islanding Mode, the findings demonstrate that inverter-based DERs may effectively share electricity while ensuring a stable functioning.

Keywords Microgrid · Frequency control · Parallel inverter · Voltage control · Droop control · Supervisory control

1 Introduction

A Microgrid is a small power generation and distribution system consists of a group of distributed energy resources (DERs), energy storage system and local loads along with advanced controls, security and energy management systems. It generates and feed power to load locally and also injects or draws power from the main grid whenever is required. Micro-Grid provides a coordinated method to facilitate the penetration of Renewable Energy Resources (RESs) and Distributed Generators

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(DGs) into power systems in an efficient manner. For the deployment of a MG, its stability and control issues are to be taken care of. Various efforts are being made to design more efficient control methods in different types of control types and different types of protection program to make a reliable, safe, and economical operations of MG for its grid-connected as well as islanded mode of operation.

The need to reduce carbon emissions in the field of power generation, recent technological advancement in the field of micro power generation, and the restructuring of the electricity sector are the key factors responsible for the increasing increase in the use of micro power generation [1]. In reality, linking small-generation units of less than a few 10 kW with low-voltage networks, improves the efficiency and reliability potentially for users and brings various advantages for global system operation by reducing cost for future grid strengthening and development. This conventional power system model suffers significant technological and environmental drawbacks such as power loss from long transmission lines, decreased capacity, costly and difficulty in control, maintenance and global warming etc. On the other hand, distributed generation (DG) located near the load center or user. Distributed generation is usually a small-scale power generation unit capable of delivering electricity reliably and safely with less environmental impact than the conventional electricity generation system with low-cost electricity. The standard power generation capacities of small-scale DG technologies ranging from a fraction of 1 kW to around 10 MW [2]. Some of distributed energy resources are fuel cells, photovoltaic system, micro combined heat and power, wind power systems, small-scale hydropower generation units, and so on. Smart grid technologies now a day's provide secure, reliable, efficient power with a decentralized, user interactive and demand repressive manner by using various technologies of modern era. It uses smart metering technology (AMI), consumer participation (DSM) techniques, remote sensing technologies, network communication technologies etc. to operate more cooperatively and responsively [3, 4]. In essence, it smartly integrates and manages various power system components to enable electrical power systems to operate sustainably, securely, and economically. Traditional large coal-based power plants operate as base load power plant allowing for supply of base load demand. Diesel and natural gas generator-based generation units are used as peak-load power plant to compensate for the peak load demand. Thus the electric power system can ensure a balance between electricity generation and demand. Renewable energy resources are main focus of DGs. Volatility and intermittency effects associated with renewable energy resources based on DER. Intermittency associated with renewable energy sources can effectively manage by smart grid technologies such as use of energy storage system technique, demand side response, and management techniques to compensate for any volatility associated with such distributed energy resources (DERs). Therefore, the smart grid technologies will allow an integrated management platform that incorporates various power system tools and mitigate the effects of intermittency and volatility. In addition, smart grid infrastructure with continuous and real-time monitoring will provide various information with real-time data to allow the DERs to function efficiently and effectively. Microgrids therefore integrate the various distributed energy resources (DERs) with the existing grid and provide power to the local load and feed the extra power to main grid by using monitoring, control, and management strategies. The microgrid definition is as follows “a cluster of loads and DERs units connected to each other and behaves as a separate controllable entity apropos of the main grid and can be connect or disconnect from main grid for enabling grid connected or Islanded operation [5]. The MG operates in two modes-one is grid connected and another one is Islanded mode.

- Grid-connected mode: Supply power to the main grid or draw power from the main grid, depends on generation and load on the microgrid.
- Islanded Mode: Disconnection from the main gird, the MG functions autonomously feed the power to the local load only.

2 Microgrid Structure

A microgrid is basically a LV network consisting of a cluster of several small generation system called distributed energy resources (DERs) and loads with advanced controls, security and energy management systems to run in grid-connected mode, Islanded mode [6, 7]. Microgrid distributed energy resources (DERs) consists of DGs and ESS [8, 9]. The main building blocks of microgrids are DERs and local loads, along with various control and management techniques. Microgrid distributed generations (DGs) mainly consist of photovoltaic, wind, microturbines, fuel cells and diesel gen-set. Distributed generations two categories classification are as follows: (1) direct-coupled generations traditional rotating machines (synchronous generators coupled with diesel eng), and (2) electronically interfaced generation (PV, fuel cells, micro-turbines, etc.). It is also possible to group the distributed generations (DGs) based on their controllability [10, 11]. Dispatchable DG units like diesel generators set can be controlled for power outputs as per requirement, whereas nondispatchable DG units like wind power generator and PV generation are intermittent in nature, and their outputs are usually dependent on natural climatic condition, wind and sun [12–16]. Energy storages system like batteries, supercapacitors, flywheels, etc., are used for power balancing in Islanded mode of operation between microgrid demand and generations [17–19]. In addition, it is also used for balancing renewable energy based variable and intermittency nature DERs. Two major types of loads can be grouped: (1) critical loads and (2) non-critical loads. Critical loads need uninterrupted power supply. Non-critical loads are curtailable loads which may be interrupted during emergency operations with microgrid [20, 22] (Fig. 1).

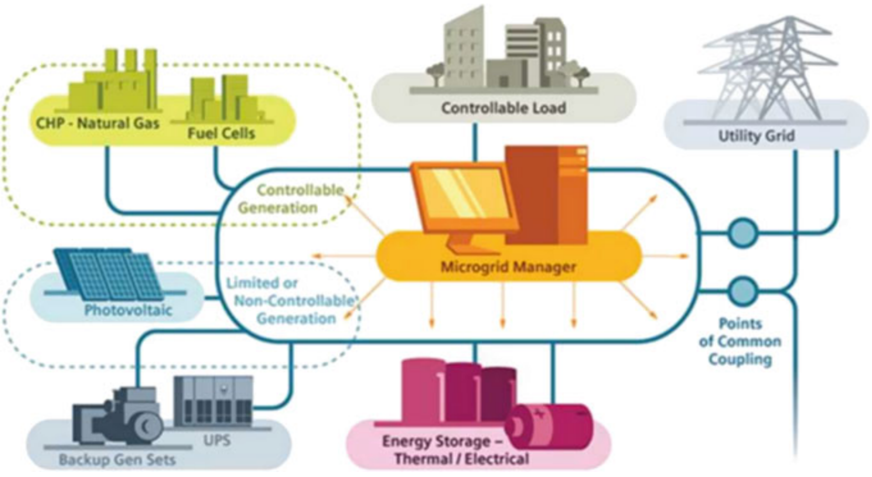

Fig. 1 Microgrid architecture [21]

3 Microgrid Inverter Control Strategy

There are mainly two control strategies adopted for controlling microgrid inverter [22]:

3.1 Grid-Connected PQ Control

The PQ control inverter in grid-connected mode is used for maintaining real and reactive power according to the reference. With reference voltage and frequency of main grid, inverter operates by a current controller along with power controller. The voltage and current are transform into d q coordinate system. The grid voltage vector is in d-axis orientation, then reference power produces the reference current. This reference current and inverter output current produced the control signal for invert and accordingly the real and reactive power output of inverter is controlled.

3.2 Droop Control

When the microgrid is in Islanded mode, the grid voltage, and frequency references are not available for inverter then droop control inverter controls the microgrid. The P/f and Q/V droop control scheme can be implemented for smooth power-sharing control of all the inverters within the microgrid.

4 MG Control in Islanded Mode

Islanding of the microgrid can occur through planned actions such as maintenance requirements. Therefore, the MG's local generation profile should be adjusted for balancing the local load demand and generation. A voltage source inverter should act like synchronous generator and control frequency and voltage during Islanded mode through the droop control strategy. The grid-connected microgrid smoothly operates as the frequency and voltage reference are available for PQ mode of operation of inverters. When the MG is disconnection from the grid, all the PQ control inverter loss their references and fails to operate which yields the failure of microgrid thus loss for balancing load/generation, a droop control inverter is needed which regulates frequency and voltage. With the help of voltage and frequency reference of VSI inverter MG can stably and smoothly operate in Islanded mode [22].

4.1 Fundamentals of Droop Control

Droop control technique is very common and well-known controlling method for power sharing control of inverters in an Islanded Microgrid. Figure 2 shows an inverter-based DER unit connected with PCC along with impedance, $Z = R + jX$.

The real and reactive power equation can be expressed as:

$$P = \frac{EV}{Z}\cos(\theta - \phi) - \frac{V^2}{Z}\cos\theta \tag{1}$$

$$Q = \frac{EV}{Z}\sin(\theta - \phi) - \frac{V^2}{Z}\sin\theta \tag{2}$$

where

E & V	Inverter voltage & AC bus voltage (grid side)
ϕ	Inverter side voltage angle
θ & Z	Impedance angle & magnitude.

For lossless line, $\theta = 90°$ and $Z = X$ so, the Eqs. 1 and 2 becomes

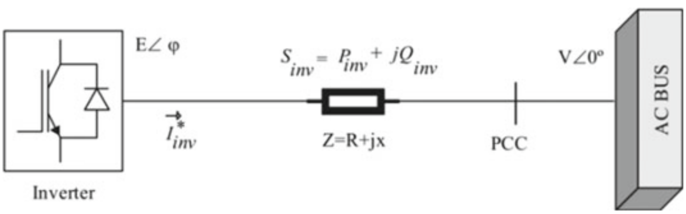

Fig. 2 MG Equivalent circuit

$$P = \frac{EV}{X}\sin\phi \tag{3}$$

$$Q = \frac{V}{X}(E\cos\phi - V) \tag{4}$$

Considering, power angle ϕ is very small then sin ϕ and cos ϕ becomes $\sin\phi \cong \phi$ and $\cos\phi \cong 1$.

Hence, Eqs. (3) and (4) can be written as:

$$\Phi = \frac{XP}{EV} \tag{5}$$

$$E - V \cong \frac{XQ}{E} \tag{6}$$

From Eqs. (5) and (6) it is clear that angle ϕ depends on active power and *E*-*V* drop depends on reactive power. Thus, the frequency and voltage of the MG can be control by *P* and *Q* adjustment. As the demand of real and reactive power increases, the frequency and voltage amplitude reduces [25].

Thus, a droop-controlled inverter behaves as a virtual synchronous generator, and voltage and frequency have inverse linear relation with reactive and active power demand similar to the synchronous generator [26]

Figure 3 shows the steady-state frequency (f) vs real power output (P) and output voltage (V) vs reactive power (Q) droop characteristics.

Mathematically,

$$f = f_0 - k_f\, P,\; V_{\text{ref}} = V_0 - kv\, Q \tag{7}$$

where, P, Q & f are active power output, reactive power output & output frequency of inverter respectively, V_{ref} refers to common bus voltage. f_0 and V_0 are the no-load/nominal frequency and voltage respectively. k_f and k_v are the frequency droop coefficient and voltage droop coefficient respectivley.

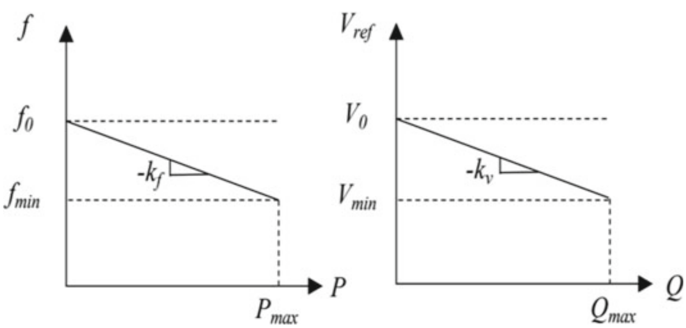

Fig. 3 P-f and Q–V characteristics for droop control

The working of droop control: consider n sources are acting in a microgrid with droop controller and all are in equilibrium. So, the frequency of all the sources consider to be same. In this condition, the real power output of each source must hold the following relation:

$$k_{f_1} P_1 = k_{f_2} P_2 = \cdots = kf_n P_n \tag{8}$$

In general:

$$Pi \propto \frac{1}{kf},\ i \in [1, n] \tag{9}$$

Therefore, the total active load is shared by each source is equal to inverse proportion of its frequency droop gain/coefficient [27].

4.2 Three-Phase Inverter Modeling

A three-phase droop-controlled inverter is fed with an ideal DC source. This DC source is actually DC link of usual renewable energy generation system (Photovoltaic array, BESS, wind turbine, etc.) and an LC filter is designed to filter out the total harmonic distortion at the output side. Then the output is fed to the common AC bus as shown in Fig. 4.

Power measurement block measures the real and reactive power drawn from the inverter, and based on that the frequency and RMS voltage set points are dictated by the droop controller. The measured powers are first passed by a first-order LPF.

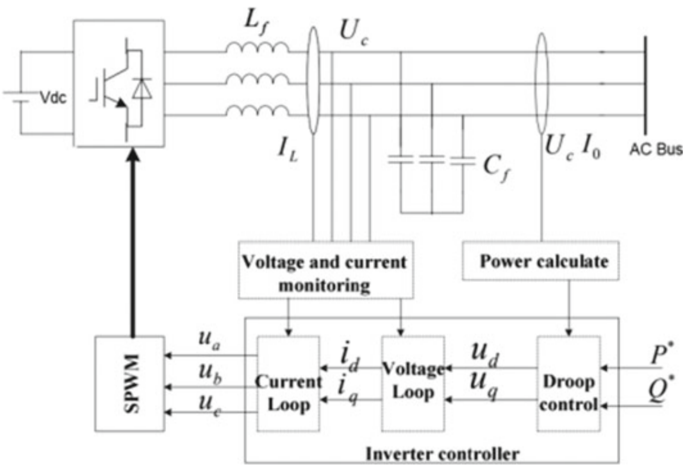

Fig. 4 Droop control three phase inverter

According to active power requirement, the power angle δ of the inverter changes. This rate of change of δ decides the output frequency set point. According to reactive power requirement, the voltage value changes. The voltage first transform in *d q* axis then passed through voltage and current controllers. While designing current controller and voltage controller, the bandwidths of droop controller, voltage controller, current controller, and PWM controller should be is in ascending order, i.e., every stage should be slower than its succeeding stage [28, 29]. Considering f_{sw} and L_f be the inverter switching frequency and filter inductance with very small filter resistance R_f. Therefore, the design of current controller ($k_{pi} + k_{ii}/s$) is as follows:

$$k_{pi} = L_f\,\omega B_i,\ \ k_{ii} = R_f\,\omega B_i \tag{10}$$

where ωBi = (2πfsw)/10 − current controller bandwidth.

Similarly, for the voltage PI controller parameters, i.e., $kpv + kiv/s$ is as follows:

$$k_{pv} = C_f\,\omega B_v,\ \ k_{iv} = \frac{\omega B_v}{R_{load}} \tag{11}$$

where $\omega B_v = (2\pi f_{sw})/\alpha_2$, the bandwidth of the voltage controller. Finally, the droop controller is designed with a very low bandwidth range (2–15 Hz), i.e., the slowest controller. Figures 5 and 6 shows the detailed and complete model of the inverter with droop-controller [30].

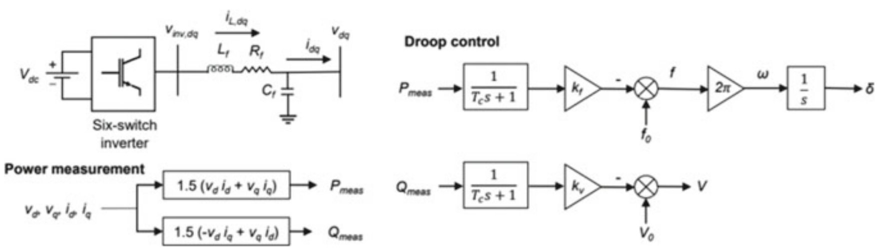

Fig. 5 Single line diagram of three-phase inverter with Droop control

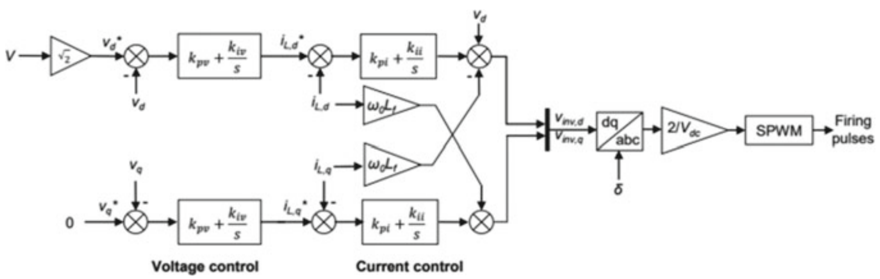

Fig. 6 Voltage and current control loops for droop controller

4.3 Supervisory Control System

Droop controller control the voltage and frequency of respective inverter according to their droop and fixed set point references like voltage, frequency, real, and reactive power references. From Eq. 7 the modified droop equation are as follows:

$$f = f_0 - k_f(P_{\text{meas}} - P_0) \tag{12}$$

$$V_{\text{ref}} = V_0 - k_v(Q_{\text{meas}} - Q_0) \tag{13}$$

where, the subscript 'meas' and '0' indicates the measured/calculated value and the no-load/nominal value

And these fixed references are unable to modify by droop controller so, whenever the load fluctuation more or beyond the capacity of inverter then droop controller fails to control the voltage and frequency. So, to resolve this issue a new control technique along with droop controller should be implemented for smooth and stable operation of microgrid inverter in Islanded mode.

In these situation new references for voltage and frequency is required for droop controller thus requires a new controller design.

A supervisory controller as shown in Fig. 7 is designed to generate a new references for voltage and frequency. It consists of frequency and voltage regulator. Simplified mathematical expressions are as follows:

$$f_{\text{ref\_New}} = f_0\, K_p + f_0 \frac{K_i}{s} - f_{pcc}\, K_p - f_{pcc} \frac{K_i}{s} \tag{14}$$

$$V_{\text{ref\_New}} = V_0 K_p + V_0 \frac{K_{is}}{s} - V_{pcc}\, K_{pv} - V_{pcc} \frac{K_i}{s} \tag{15}$$

This controller modifies *P*/*f* and *Q*/*V* droop characteristics while maintaining the same droop coefficient and sends it to each droop controller of respective inverter.

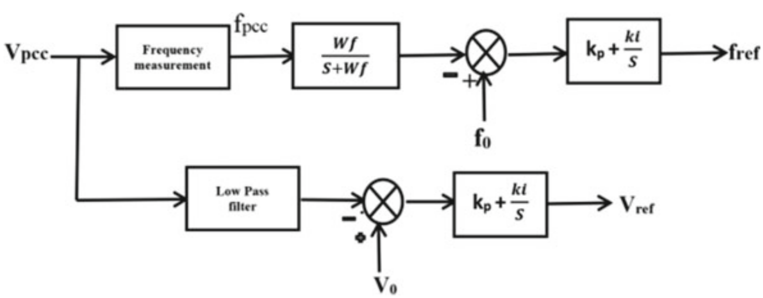

Fig. 7 Supervisory controller

Thus, supervisory controller smoothly restored the frequency and voltage of microgrid to its nominal values.

5 Simulation and Result

The Islanded Microgrid model as shown in Fig. 8 proposed in MATLAB simulation platform as per above analysis is proposed in MATLAB simulation environment [31]. The strategies and methods as explain above, can smoothly control the microgrid in islanded mode and maintain the load demand and stability. Figure 8 shows the line diagram of the microgrid for Simulink. Three three-phase DER-based parallel inverters are used to investigate the control strategy as proposed for islanded microgrid mode (Tables 1 and 2).

The nominal voltage and frequency of microgrid is 415 V and 50 Hz, respectively. Power ratings of inverters 1, 2 and 3 are 500, 300, and 200 kW, respectively, all are connected to a single AC bus called PCC bus. Two types load models are considered here, one is fixed, i.e., static and another one is variable, i.e., dynamic load model. Dynamic load model varies the load of dynamically.

Inverter subsystem shown in Fig. 9, each having a three-phase power converter, a low pass LC filter, and a 800 V DC source which actually represents a DC link of renewable energy generation system based DER (like wind turbine, Photovoltaic, Fuel cell, wind energy generation system, BESS, etc.). Simulation results of the aforementioned model are shown in Figs. 10 and 11, respectively.

Initial load on the Microgrid is 400 kW + 100 kVAr. At 1 s load on the Microgrid starts increasing and rises up to 800 kW + 200 kVAr. As the droop control is not enabled, Voltage and frequency start fluctuating. At 4 s droop control is enabled and

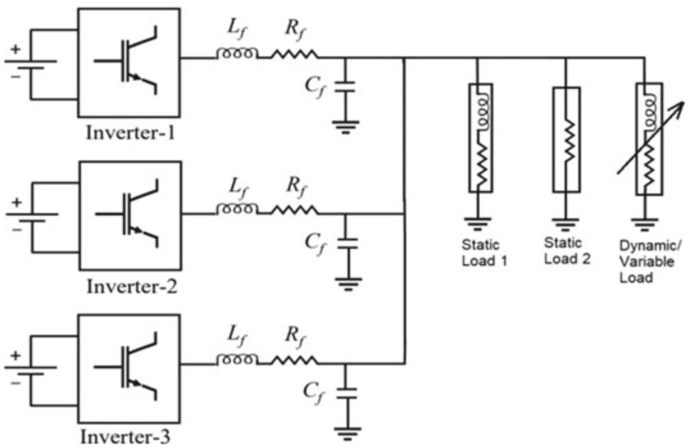

Fig. 8 Microgrid single-line diagram of for Matlab Simulink

Table 1 System parameters

Parameters	Values
Inverter 1	
Power	500 kVA
Voltage, V_0	415 V
Nominal frequency, f_o	50 Hz
Frequency (Switching)	10 kHz
Filter parameters	
L_f	0.22 mH
C_f	345.4 μF
Nominal droop gains (k_f, k_v)	1%, 4%
Inverter 2	
Power	300 kVA
Voltage, V_0	415 V
Nominal frequency, f_o	50 Hz
Frequency (switching),	10 kHz
Filter parameters	
L_f	0.37 mH
C_f	207.24 μF
Nominal droop gains (k_f, k_v)	1, 4%
Inverter 3	
Power	200 kVA
Voltage, V_0	415 V
Nominal frequency, f_o	50 Hz
Frequency (switching)	10 kHz
Filter parameters	
L_f	0.55 mH
C_f	138.16 μF
Nominal droop gains (k_f, k_v)	1, 4%

Table 2 Load parameters

Load parameters	
Voltage	415 V
Frequency	50 Hz
Real power	400–800 kW
Reactive power	100–200 kVAr

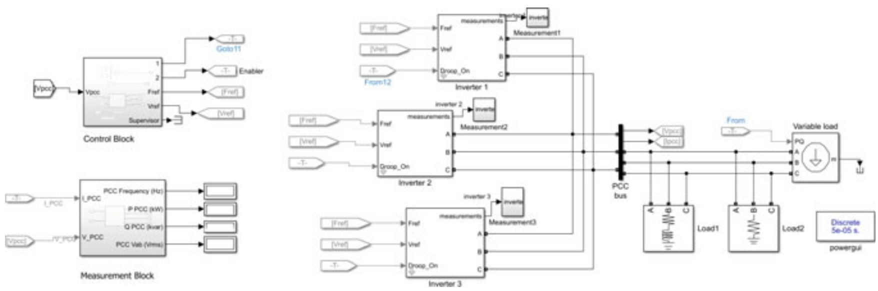

Fig. 9 Matlab Simulink model of Islanded Microgrid

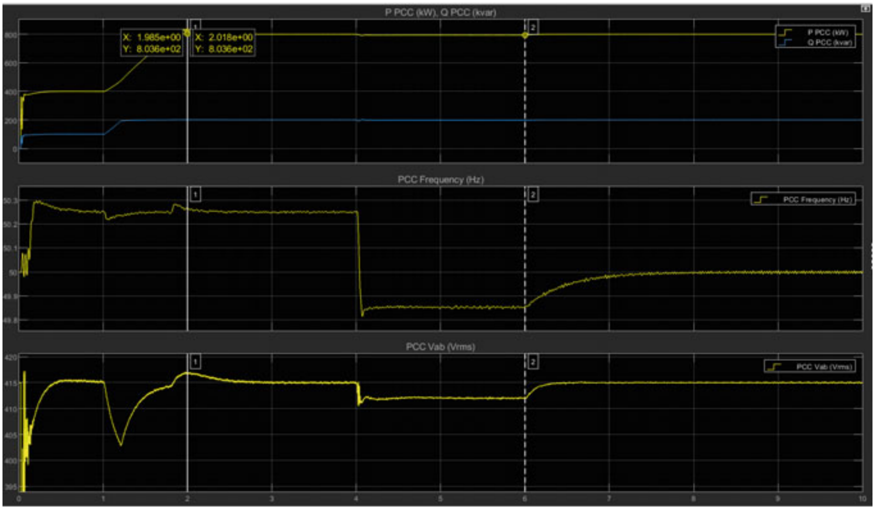

Fig. 10 Voltage, frequency, and load at PCC

then voltage and frequency start decreasing and settled at some lower values. At 6 s supervisory controller is enable and control all the inverter and settle the frequency and voltage to its nominal values, i.e., 415 V and 50 Hz, repetitively.

6 Conclusions

In this paper, the droop along with supervisory control strategies is used for smooth control all the three DERs in the Islanded microgrid to alleviate the effect load change. Droop controller control the voltage and frequency of respective inverter according to their droop and fixed set point reference like voltage, frequency, real, and reactive power references. And these fixed references are unable to modify by droop controller

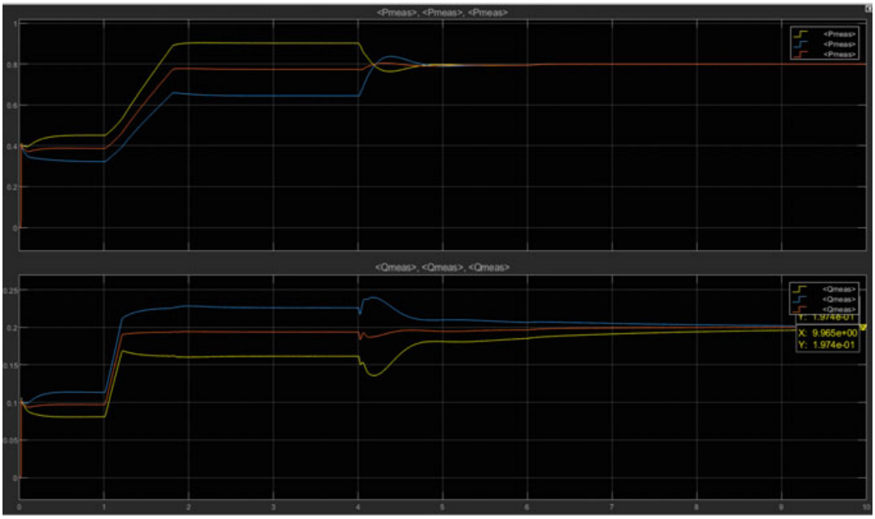

Fig. 11 Load share by all three inverter-based DERs

so, whenever the load fluctuation more than the droop controller fails to control and manage the voltage and frequency within the stable limit. A supervisory controller modifies reference voltage (E^*) and frequency (f^*) and sends it to each droop controller of respective inverter and thus smoothly restored the frequency and voltage of microgrid to its normal values. The proposed droop controller was implemented with predefined set point and droop characteristics. The proposed droop controller controlled the Islanded Microgrid effectively by tracking and balancing the real and reactive power demand quickly and the proposed Supervisory comptroller acts as a master and quickly restored the frequency and voltage to its nominal value. The simulation results of PCC voltage, frequency, and power obtained from SIMULINK platform.

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Chapter 3
Genetic Algorithm for Economic Load Dispatch with Microgrid to Save Environment by Reduction of CO_2 Emission

Leena Daniel, Krishna Teerth Chaturvedi, and Mohan Kolhe

Abstract The continuous reduction in fossil fuel resources, the Distributed Generation Technologies have recently fascinated more attention. Microgrid technologies are also employed to join such sources into the main network by pointedly enhancing energy utilization through local production and load control. As a result, quality and reliability have improved. Most of such network studies focus on operating and investment expenses but ignore the environmental impact. An optimization model is developed based on these two criteria to estimate the feasibility and environmental involvement of microgrid. Renewable energy sources have a high penetration rate in this model. The genetic algorithm is utilized to perform hourly optimizations on microgrid in order to achieve environmental benefits as well as financial gains.

Keywords Distributed generation · Fuel cell · Genetic algorithm · Microgrid · Microturbine · Photovoltaic cell

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1 Introduction

The modern power generation system may consist of more than one generating unit. These generating units may be integrated to provide power to a wide variety of loads. Hence, it is essential to minimize the operating cost for all load schedules for each generating unit [1]. Engineers across the world are concerned to develop

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products and services at the lowest cost possible. Efficient and economical operation of electrical power generation and distribution is one such problem. Due to more and more integration of electric networks and increasing energy crisis across the world, the energy prices are ever rising. It is essential that we always look for the scope of reducing the cost of energy even small savings represent a very significant cost reduction. The optimum scheme in power system, generally, involved the deliberation of economic processes, protection strategies, various gas emission with conventional fuel plants, and optimum discharge of water at hydel power generation, etc. These factors are mostly incompatible, and an optimum solution needs to be provided [2].

Along with cost, people, nowadays, are more concerned about environment impact of power generation too [3]. Central Pollution Control Board (CPCB) must impose strict and binding environmental regulations because of high contaminant and pollutant gas liberate in the environment. Major pollutant gases include CO_2, SO_2, and NO_2, which are mainly release, due to burning of fossil fuels. Hence along with minimal cost of generation, pollutant emissions must also be minimized. To add cost to this pollution, a parameter is added to cost function called price penalty factor. Thus, balanced economic and emission dispatch (BEED) is a difficult issue to be implemented by meeting the requirement of economic dispatch and fulfilling the condition to decrease the pollutant elements. Along with fossil fuel-based generation sources, renewable sources are also gaining popularity. When power system hybrid renewable sources with non-renewable sources, it must face many predictable and unpredictable challenges. For example, wind energy is unexpected and non-predictable in nature. According to research, wind power may contribute 10–40% of total energy generation [4].

Distributed generation (DG) is one of the emerging technologies to meet the load requirements with the distributed energy sources (DER), which also provide the environmental benefits [5, 6]. The use of distributed generation (DG) in utility lines and downstream of meters at low and medium voltages (MV and LV) is gaining popularity in industrialized countries around the world. The economic potential of DG applications was assessed at customer sites by utilizing locally available energy sources such as waste heat recovery from primary fuel conversion, reciprocating engine generators (gensets), gas turbines, microturbines (MTs), or fuel cells (FCs) via small-scale combined heat power (CHP) equipment [7]. As a result, significant progress has been made in the optimal usage of modest (kW-scale) CHP. To meet future electricity demand, these systems, along with solar photovoltaic (PV) modules, wind turbines (WTs), other modest renewable (such as methane digesters), heat and electricity storage, and regulated loads must all play a substantial role. These technologies were grouped together as distributed energy resources (DERs) [2].

In the power sector, the effective and optimal economic procedure and scheduling of electric power generation arrangements have always played a significant role. The recent restructuring of electricity utility, growing concern about environment and system security require changes in the optimal planning and operational philosophy of the power system networks. The optimal operation and planning of power system networks have traditionally been viewed as a cost-benefit analysis. Most utilities computer-aided dispatch centers use economic load dispatch (ELD) for this purpose.

However, increased concerns about maintaining power quality and a clean environment have compelled power system engineers to explore additional objectives in the optimal management of power systems, such as improving system voltage profiles and reducing emissions dispatch.

Economic load dispatch (ELD) is a method of allocating generation levels to the various producing units in a system in order to fulfill load demand in the most cost-effective manner possible while respecting system and individual unit limits. Economic load dispatch is critical for obtaining maximum usable power with the least number of resources. Years ago, several solutions were used to solve the basic challenge of economic dispatch for thermal systems.

Over the last several decades, there has been a lot of research into ELD optimization models and algorithms. Artificial intelligence methods like genetic algorithm (GA), chaos optimization algorithm (COA), and particle swarm optimization (PSO) have been successfully used to solve ELD problems [5], in addition to traditional methods like equal incremental method, dynamic programming (DP), and Lagrangian relaxation method (LR). However, if the number of generating units grows dramatically, existing stochastic algorithms may suffer from the curse of dimensionality, increasing the difficulty of optimizing calculations as well as the time it takes to complete them. As a result, traditional load optimal dispatch methods cannot be used in large-scale load dispatch optimization issues right once. Although linear programming is quick and accurate, it approximates cost functions in piecewise form. As a result, the output answer's optimality cannot be guaranteed. Similarly, the complexity and convergence problem plague the non-linear programming technique. Although this strategy can solve specific types of economic load dispatch problems, it cannot solve large-scale problems and take too long to produce results. Techniques based on derivation, such as the Lagrangian methodology, are also disliked. Because of the non-differentiable nature of restrictions, these strategies are unable to take into consideration operational constraints such as ramp rate, banned zones, and valve-point effects [8]. The mathematical character of the problem, in general, makes it impossible for analytical mathematic methodologies to address it properly. Soft computing approaches such as artificial neural networks, fuzzy logic, and genetic algorithms have surpassed conventional methods in terms of finding similarities between vast sets of data and synthesizing system models for non-linear, partially unknown, and noisy systems. Soft computing techniques, which take their cues from biological systems and are modeled to resemble the human mind, offer efficient solutions to tough inverse issues. Soft computing guiding idea is to take advantage of imprecision, ambiguity, and partial truth tolerance to produce tractability, resilience, and low-cost solutions [9]. Due of their flexibility, ability to perform effectively under unknown conditions, and speed considerations, soft computing solutions are being proposed here.

This work proposed genetic algorithm (GA) for economic load dispatch. Due to GA's versatility and efficiency, a global optimization model known as the genetic algorithm has proven itself as a choice for so many optimization applications, according to reference [10]. It is a search algorithm with a high probability of success. This technique was created by John Holland (1975). GA is an example of a global search heuristic. Genetic approaches like inheritance, mutation, selection, and crossover are used in these types of evolutionary algorithms. GA is a natural selection and genetics mechanics-based search strategy. They use Darwin's idea of survival of the fittest among strings structure and a structured but randomized flow of information to produce a search algorithm that mimics human search in some ways. Every generation, a new batch of artificial lifeforms (strings) is created, using bits and pieces from the previous generation's fittest; an occasional new portion is added for good measure. Despite the fact that they are randomized, genetic algorithms are not conventional walk algorithms. They efficiently use historical data to estimate which advanced search points would perform better. A population's members have gone through an evolutionary process. In terms of difficulty reduction, adaptability, and solution approach, the advantages of the genetic algorithmic technique are also investigated.

A microgrid is a confined power grid with all control competency; it can be developed to operate autonomously and disconnect from the upstream grid [11]. Microgrids are generally low voltage networks in coordination with DG sources, with all control devices like air conditioning, water heaters, controllable loads, storage devices, etc. Furthermore, microgrids improve system consistency and increase power quality by assisting voltage backups and reducing voltage slopes. With all the system benefits of microgrid, it provides financial gains also [12].

It has the capability to run standalone, and in case of extra generation, it is capable to sell the power to the main grid, or it can reduce the cost of electricity for their consumers or customers. On the other hand, it improves the environmental aspects also and decreases the greenhouse effect gases like CO_2, SO_2, NOx, etc. Hence, microgrid technologies are eco-friendlier than traditional methodologies.

This work primarily emphasizes economic load dispatch (ELD) and environmental conditions. According to the case study network (Fig. 1), it utilizes fuel cell (FC), microturbines (MTs) and photovoltaic (PV) cells as DG units in microgrid.

2 Objective Function

Objective function includes the formulation of cost equation, CO_2 emission equation, revenue equation, and constraint equation. J1 represents cost optimization equation and is given by following Eq. (1)

$$J_1 = A^* X + \sum_{i=1}^{N}\left(a_i + b_i * x_i + c_i{}^* x_i^2\right) \tag{1}$$

The cost covers the cost of power acquired from the upstream grid as well as the cost of production by various distributed generating sources in the microgrid. A represents open market energy prices, X represents active power purchased from the upstream grid, N represents the total number of DG units in the microgrid, and X_i

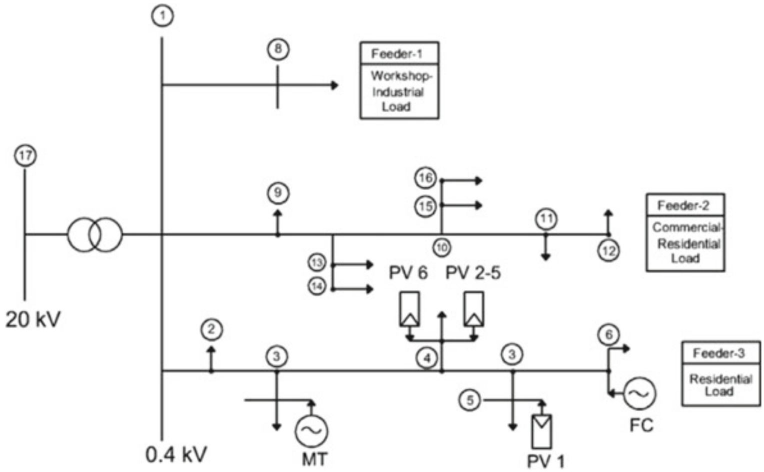

Fig. 1 Network for analysis

represents the generating power of the ith DG source, while a_i, b_i, and c_i represent cost coefficients in €/h, €ct/kWH, and €ct/kWH^2, respectively. J2 represents CO_2 emission and is calculated according to the following Eq. (2).

$$J = \sum_{i=1}^{N} (\alpha_i * P_i) \tag{2}$$

This Eq. (2) calculates the total CO_2 emissions in Tons from all DGs on an hourly basis. N is the total number of DGs, α_i is the CO_2 emission coefficient of the ith DG in tn/MWh, and P_i is the power generated by the ith unit in MWh. Now, objective function is combinedly given by the Eq. (3)

$$J = \omega_1 J_1 + \omega_2 J_2 \tag{3}$$

However, in such instances, the weights ω_1 and ω_2 should be carefully chosen because they have a direct effect on the performance of the solutions provided. This is because different objectives express values with vastly different absolute values. Finally, the optimization goal is to minimize the total function J, which is provided by Eq. (3).

Revenue equations are framed by including the income produced through export the power to grid and expenditures occurred in main grid and microgrid operation. Equation (4) calculates the total revenue earned by microgrid owners. This is simply planned by deducting total expenses from total income. Total income is (price * total power generated), while cost is already calculated by the cost equation above. Hence, revenue equation can be formed as

$$J_3 = \text{Income}-\text{Expenses} = A\sum_{i=1}^{N} x_i - \sum_{i=1}^{N}\left(a_i + b_i * xi + c_i * x_i^\wedge 2\right) \tag{4}$$

For proper functioning of the system, three constraints are taken into consideration for different scenarios.

A minimum and maximum boundary range of power generated by all DG sources are $P_{\min}$ and $P_{\max,}$ respectively. This can be shown below

$$P_{\min,n} \le P_n \le P_{\max,n} \quad \text{where } n = 1 \ldots N \tag{5}$$

Here, $P_{\min,n}$ is the minimum power that must be generated by the nth DG, while $P_{\max,n}$ is the maximum power that can be generated by the nth DG.

If a microgrid is unable to sell electricity back to the upstream grid, the total power generated by DG sources plus power purchased from the upstream grid must equal the total load demand. It is given by Eq. (6). Hence,

$$X + \sum_{i=1}^{N} Pi = P_{\text{demand}} \tag{6}$$

If a microgrid is permitted to sell electricity back to the upstream grid, the total power generated by DG sources plus power acquired from the upstream grid must be more than the total load demand. It is given by Eq. (7). Hence,

$$X + \sum_{i=1}^{N} Pi \ge P_{\text{demand}} \tag{7}$$

3 Network Description

As described in [13], a case study network has been chosen and is depicted in Fig. 1. Low voltage (LV) network with three feeds was chosen as the study case network. An industrial load is fed by the first feeder. The second one serves a mix of commercial and residential customers. The third, on the other hand, caters to a domestic consumer. The third feeder, which functions as a microgrid, contains one microturbine (MT) unit, one fuel cell (FC) unit, and photovoltaic cells (PVs).

It also chose four situations for simulations, which are as follows:

1. Scenario 1: In this scenario, we assumed that the entire load requirement is met by purchasing from the upper grid. This scenario is being used to calculate savings from microgrid installation as a comparison case. This is considered a reference scenario.

2. Scenario 2: In this scenario, the microgrid's running costs are minimized. There is no consideration for the environment. Furthermore, if microgrid generates excess electricity, it is unable to sell it to the upstream grid.
3. Scenario 3: This scenario featured the environmental impact scenario, which involved lowering both cost and CO_2 emissions by allocating a cost to CO_2 emissions.
4. Scenario 4: This is the same as scenario 3, except that the microgrid's excess electricity can be sold to the upstream grid.

Electrical loads on the power plants frequently change, but their values are mostly predictable. Load demand is mainly dependent on the weather conditions and follows a similar pattern day to day. So that these continuous changes are easily predictable. Optimization can be conducted on an hourly, daily, and monthly base.

The Fig. 2 shows the load demand monthly basis for the year. In this daily load curve, the maximum value and minimum value for the load are 222.7 and 46.3 kW considered, respectively, for the simulation. The analyzed data is taken from reference [13]. The power factor for the stated electrical load is presumed as 0.95. Table 1 shows cost coefficients for fuel cell and microturbine units.

Installed capacity for connected DG units is taken as the data given in Table 2. More data can be referred to in references [13, 14].

All DG units are supposed to function on a unity ($\cos \Phi = 1$) power factor. The main grid's CO_2 emission coefficient is 1.1tn/MWh. The CO_2 coefficients for fuel cell and microturbine are 0.4894 tn/MWh and 0.7246 tn/MWh, respectively.

For the grid, it is assumed that the lowest power purchased from the grid is zero ($P_{\min} = 0$), and there is no limit for highest power. A simulated network can take as much as power it requires to fulfill the load demand from the grid. Most of the data are taken from the Hellenic Operator Electricity Market [15].

Fig. 2 Monthly load demand curve

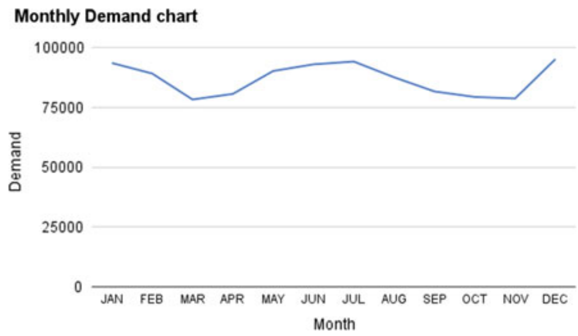

Table 1 FC and MT cost coefficients

DG units	a (€ct/h)	b (€ct/kWh)	c (€ct/kWh^2)
Fuel cell	0.8415	2.41	0.033
Microturbine	0.01	4.37	0.01

Table 2 Installed capacity of DG units

DG units	Pmin in (kW)	Pmax in (kW)
Fuel cell	10	50
Microturbine	6	50
PV_1	0	3
PV_2, PV_3, PV_4, PV_5	0	2.5
PV_6	0	15

4 Results and Discussion

Simulation results are presented according to the scenarios with genetic algorithm methods. Cost is calculated for each scenario, and comparative analysis has been done for the purchase cost from main grid, CO_2 emitted through the main grid, CO_2 emitted through the microgrid, CO_2 cost for main grid and microgrid both, revenue generated when microgrid sells power to the main network.

Table 3 shows the load shared by each microgrid unit and main grid for different scenarios. For scenario 1 which is the reference scenario, load demand is fulfilled by the main grid only. When moving to scenario 2, fuel cell, microturbine, and PVs also introduced and share the load demand. The drop in load demand from main grid is 33.81% in scenario 2. Slight change in scenario 3 is noticed, but in scenario 4, it is 34.25%.

Each scenario's annual cost is computed as indicated in Fig. 3. For the reference scenario, the annual cost for the allocated load is 93,833.57 Euros. When the load is allocated to FC and MT units in scenario 2, the noticeable cost cut is 33.81 percent with economic dispatch rules. Annual savings of roughly 31,616.33€ can be achieved by using scenario 3. In scenario 3, the cost rises by a small amount, to 115. 34€. When the system is operated for scenario 4, the maximum load is shared by DGs, resulting in significantly lower power purchases from the main grid than in scenarios 2 and 3.

If we look at the CO_2 computation using GA, the CO_2 emitted from the main grid in scenario 1 is 1146.9 tons, according to the graph as shown in Fig. 4. To meet the load demand in scenario 1, just the main grid is supplied. As a result, the CO_2 level is at its highest in this scenario. Changes in CO_2 emissions in scenarios 2 and 3 are 387.8 tons and 386.4 tons per year, respectively. Scenario 3 has a slight increase in emissions since the consequences of CO_2 emissions are factored into the

Table 3 Yearly load shared by the main grid and DG units for each scenario

Scenario	Main grid (kW)	FC (kW)	MT (kW)	PVs(kW)
Scenario 1	1042.5	0	0	0
Scenario 2	690.01	120.07	87.94	144.55
Scenario 3	691.30	120.11	89.78	141.38
Scenario 4	685.44	121.35	90.49	145.30

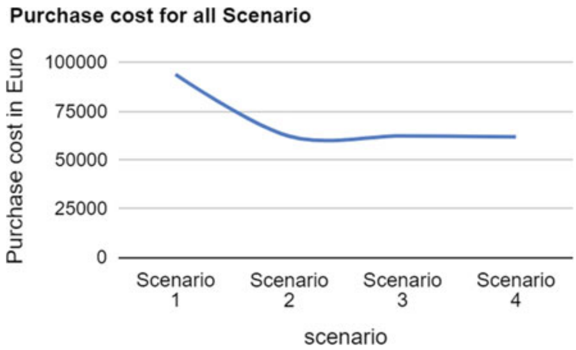

Fig. 3 Purchase cost from the main grid

cost calculations in this scenario. In comparison with scenarios 2 and 3, emissions in scenario 4 are reduced by 5.09 tons and 6.4 tons, respectively. As a result, when we evaluate scenario 4, we see a significant drop in CO_2 emission is approximately 34.2%.

This is our main objective to maximize the profit. To gain profit, the service provider role is to manage the DG units in such a manner that they can generate greater than the load demand, and excessive energy can be traded with main grid. Only if the upstream grid allows bidirectional power flow can this precondition be met. This optimization problem is simulated here through GA with respect to scenarios.

The income created graph using GA, which indicates savings for each scenario, is shown in Fig. 5. Because DG units are not involved in generating in scenario 1, the value is -5809 Euros. When the DG unit is operational in scenario 2, the income is 93,833 Euros, and the expenses are 74,018 Euros, according to the simulation findings. As a result, removing these two prices yields revenue. Similarly, revenue earned in scenarios 3 and 4 is 19,604 Euros and 20,082 Euros, respectively.

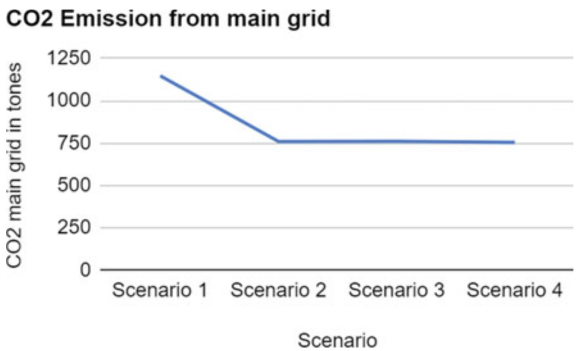

Fig. 4 CO_2 emission from the main grid

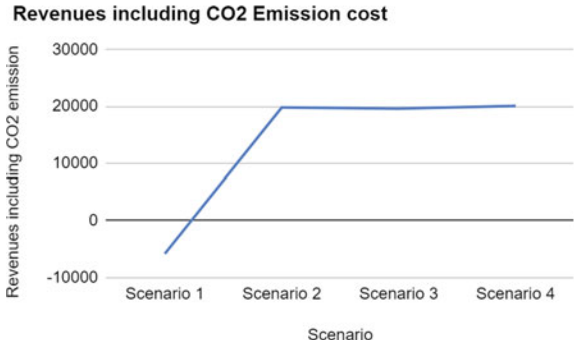

Fig. 5 Revenue raised including CO_2 emission cost

5 Conclusion

The load demand is met by both the main grid and the microgrid in this study. This is accomplished through the use of various scenarios. In scenario 1, all of the demands are met solely by the main grid, resulting in no financial gain. DGs are operational in scenarios 2 and 3, but selling to the grid is not considered. In scenario 4, it is simulated that when DG units create more energy than demand, power backflow occurs, and energy is transferred to the main grid, resulting in financial gains. More electricity can be dispatched through the microgrid, and less power needs to be purchased, by placing more DG units in the microgrid, such as wind turbines. As a result, the monetary benefits could be increased. Other scenario combinations can also be used to do the analysis. To solve the ELD, many alternative hybrid evolutionary strategies can be used.

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Chapter 4
An Electric Vehicle Integration in Distributed Generation with an Island Detection Technique to Meet Critical Load and Non-critical Load

Mohd Faizan, Ikbal Ali, and Md. Shahnawaz Chisty

Abstract With the inception of microgrid idea, as well as the rising penetration of distributed generation (DG), renewable energy usage, and the instigation of the microgrid concept have manipulated the form of traditional electric power networks. By constructing a microgrid, most of the new power system networks are transitioning into the DG model, which integrates renewable and non-renewable energy resources. Islanding detection is a daunting problem in distributed generation, raising a number of security and safety concerns. In this paper, we have integrated parked electric vehicle (PEV) with microgrid operating in an islanding mode along with DGs. Paper also discusses the critical and non-critical loads in islanded operation with passive islanding detection technique. A parked EV along with other DGs can be connected to the critical load and run independently (stand-alone). The microgrid works as an autonomous power island that is electrically disconnected from the main utility network while in stand-alone mode. A smooth islanding detection is thus required for effective and dependable microgrid functioning. In this paper, a diesel set of 1MVA and integrated EV storage battery are used while working in islanding mode. This paper also elaborates its future scope in the global energy market in the prospective varied applications.

Keywords Island detection · Renewable · Generator set · EV storage · Distributed generation · Critical load · Integration

1 Introduction

Islanding is indeed the practice of establishing a power island, similar to a utility system sector, in the event of a severe disruption in the national electricity grid. Even in the event of a utility grid breakdown, continuous power delivery to key

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loads (in this case critical load) is ensured throughout islanding situations. In this paper, loads are segregated into two parts critical and non-critical loads. Critical loads are combination of those load which need uninterrupted power supply. In islanded mode, it utilizes the energy storage of parked electric vehicle (PEV) along with solar PV and diesel generator to meet the critical load demand. This paper is mainly focusing to tackle the critical load demand without any failure by using energy stored in the battery within in the allowable threshold of electric vehicles available in the parking lot. In this paper, eight electric vehicles are used to meet the critical load demand with state of charge of EVs battery within the permissible limit. In the event of a main grid outage, grid sectionalization occurs automatically, and the DG source energizes the critical load till the main grid is resynchronized with DG [1]. Electric vehicles (EVs) may very well be the solution to the concerns stated if correctly controlled, since they will have storage capabilities that may be utilized to assist network management in certain crisis situations. When parked and plugged in, electric vehicles either receive and store energy or give power to the grid once frequency alters, for instance. An efficient logical-based islanding detector is used in the simulation to achieve the desired consequence. When a three-phase fault develops, an islanding measurement device, according to IEEE standard 1547, detects the fault when voltage and frequency exceed the allowed limits [2]. Key demands are disconnected from the grid system, and parked electric cars, a diesel generator, and a PV cell begin generating power to satisfy the critical loads, ensuring uninterrupted power supply and the security of electrical energy in crisis situations. This study is primarily concerned with the operation of the islanding detection approach.

Islanding research may be classified into three categories:

1. The creation of an island.
2. Operations during islanding.
3. Return to mains and island merging

1.1 The Creation of an Island

The schematic illustration for the establishment of an islanding state can be seen in Fig. 1. The factors of island creation may be split into two categories:

(i) *Failure islanding*
(ii) *Servicing islanding*

Islanding occurs as a result of a malfunction in the main distribution system. Therefore, in circumstance, electricity will be interrupted for a brief moment in time, and the distributed generation will separate from the grid system and eventually restore to the critical load to create the island. The biggest challenge in creating the island is the disparity in DG source capacity and load demands. An island could be produced if the DG output is almost equivalent to the combined load [3]. This

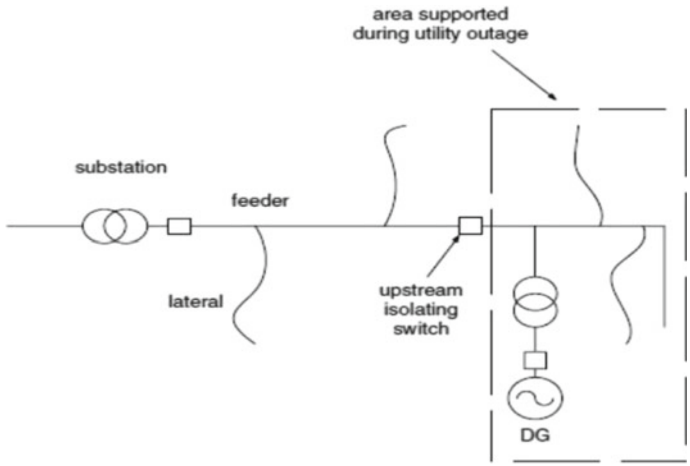


Fig. 1 Creation of an island

is a relatively uncommon occurrence. Assume that when the islanding does not materialize in during faulty state, the defective section is detached from the main grid and has no power supply, which diminishes power distribution resilience. To ensure resilience, islanding is produced just by isolating the DG from grid system and would then progressively restoring loads to the distributed generation.

The separation of portions as from grid system is for inspections and maintenance while islanding by servicing. In this instance, too, the expected total load can be almost equal to the output of the DG source, or that the frequency difference would be large, and the generator's safety mechanism will activate [4].

1.2 Operations During Islanding

It is an analysis of how DG performs whenever islanding happens. The following factors of DG's competence are examined and can be seen in the Fig. 2.

(i) *Load Following*—Once the load changes, the generator shall adapt the grid frequency to the suitable level to meet the entire power requirements.
(ii) *Large Load Rejection*—Whenever a machine is turned on abruptly or a big load is removed from the main grid, the DG ought to be able to readily change system frequency and voltage to the correct level.
(iii) *Fault*—If a defect occurs in the electrical network while it is islanding, the issue should indeed be disconnected even before power system becomes unsustainable. That is, when the problem is cleared, the DG should restore the network frequency and voltage to the level equivalent.

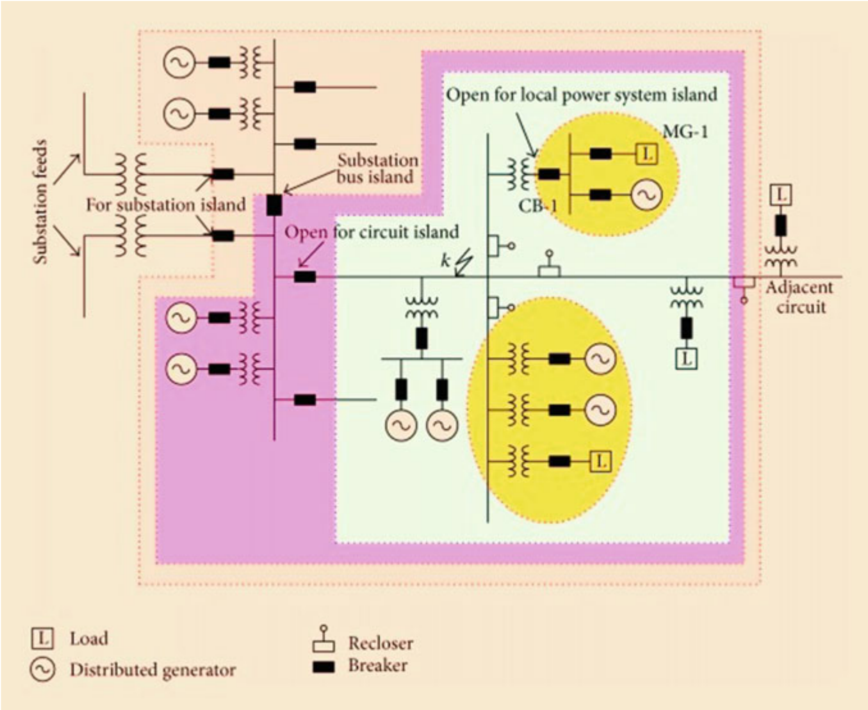


Fig. 2 Operations during islanding

1.3 Return to Mains and Island Merging

This involves the exchange of demand from faulty sections directly to the central grid. DG must generally be disconnected before to reconnection of the islanding portion to the main grid. For the time being, the islanded region will be de-energized. Whereas if demands are essential, and the frequency of disruptions impacts the consumer, islanding will not increase their resilience [5]. We could employ distant DG resynchronization there at station to solve this problem.

2 Methodology

The following technique was created to analyze the future growth in parked electric vehicle with diesel generator and PV cell or an isolated system where PEVs are accessible to serve critical load demand:

(a) In terms of available generation and demand, the isolated system was described. These components were modeled with the assumption that they will be coupled to a single bus system.
(b) PEVs prevalence was then measured, and a model for PEV connections with V2G was created. This approach was then included into the single bus system.
(c) A three-phase failure was simulated, and the effect on system frequency was assessed once EVs are solely in charge mode and when they engage in main frequency management with other DGs in islanded mode.
(d) The proportion of PEV storage power generation using a diesel generator and a PV cell to fulfill critical load demand requirements, as well as the viability of this new circumstance, was determined by repeating step c).

3 Scenarios Characterization

The eight PEVs that will be included into the grid under investigation were chosen based on the findings of [6]. A smart management technique for PEVs integration was compared to other DGs in the cited research. The EV fleet under consideration consists of eight fully charged electric vehicles, each having a rated power storage capacity of 100 kW for a medium-sized EV. The medium-sized EVs are designed to depict automobiles with various driving ranges manufactured by automakers to meet the demands of various customers. PEVs will account for 61.5 %, while PV cells with a capacity of 500 kw will account for the remaining 38.5 % to fulfill the 13kw critical load demand. Owing to the stochastic nature of generation capacity due to PEVs, the island has one diesel generator (with a capacity of 1MW) and 0.5MW of disperse solar PV plants to satisfy critical load needs in the event of PEV and solar PV outages.

4 Block Diagram of the Proposed System

The suggested system's block diagram is shown in Fig. 3. PEVs voltage source, non-critical loads, breaker, logical island detector, and critical loads diesel generator PV cell are all shown in the block diagram. Solar PV panels, PEVs, and other DC sources can be used here. Loads are divided into two categories. There are two types of loads: critical and non-critical. Figure 4 whenever urgent power is required for important loads, non-essential loads may usually be shut off.

Healthcare demands, sensor loads, industries, digitized telecommunication networks, Web servers, and other critical electrical loads are examples. When this equipment fails, the financial distress will be significant, and it is possible that this disruption could result in further losses such as personnel, loss of production, and

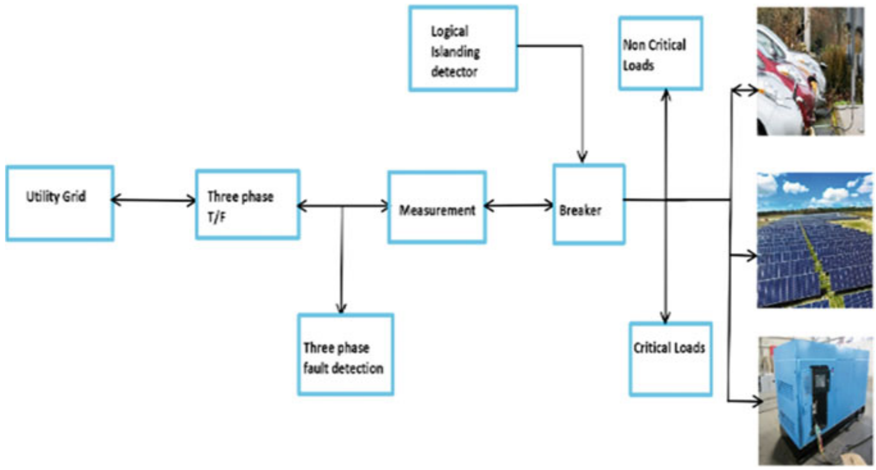


Fig. 3 Integration of EV battery with critical load and non-critical load

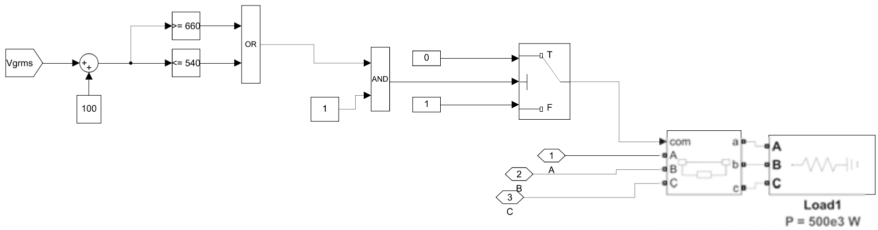


Fig. 4 Non-critical load

equipment failure. As a result, these systems have a high requirement for uninterruptible electrical power. Non-critical loads mostly consist of household loads [7].

There will be two sorts of operating modes: grid linked mode and islanding mode. There are two sorts of control schemes premised on these categories. The DG in the microgrid will operate in constant current control mode during regular operation or when linked to the grid. Whenever the microgrid disconnects from the grid system, and when islanding happens, the current control mechanism is shifted to voltage control scheme.

5 Techniques for Island Detection

Passive approaches and active methods are the two basic types of islanding identification strategies. Islanding detection is performed using passive approach for under/over voltage, under/over frequency, voltage phase shift detection, and harmonic detection. Active techniques are utilized to identify islanding during negative sequence current injection, impedance evaluation, impedance measurement at a certain frequency, and slip mode frequency shift, the passive technique primarily comprises transitory variations on the grid, which are based on a comprehensive probabilistic judgment of whether or not the grid has failed or there was a malfunction. By providing an external signal to the system and assessing whether or not the external signal has changed, active techniques discover power system grid faults. Active approach is more challenging than passive method [8]. Under/over voltage detection and under/over frequency detection are simple to implement compared to other detection methods. As a result, the majority of inverters employ this mechanism to detect fault conditions. The logical-based islanding detector is primarily intended to detect islanding situations. For detection, islanding detector utilizes the concepts of under voltage/over voltage and under frequency/over frequency with logical-based operation like AND, OR, and NOT gates are inherently used in this detector.

5.1 Under/Over Voltage

Because voltage is one of the inverter's most important functions, under/over voltage detection is one of the best islanding detection tactics in grid interactive inverters. When the load changes or a fault occurs, the voltage magnitude changes abruptly. As a result, this voltage magnitude may be used as the input for islanding detection [9].

5.2 Under/Over Frequency

Another reason for grid loss is if the frequency is either low or too high. Detection is achieved in this scenario by detecting if the grid frequency was well within

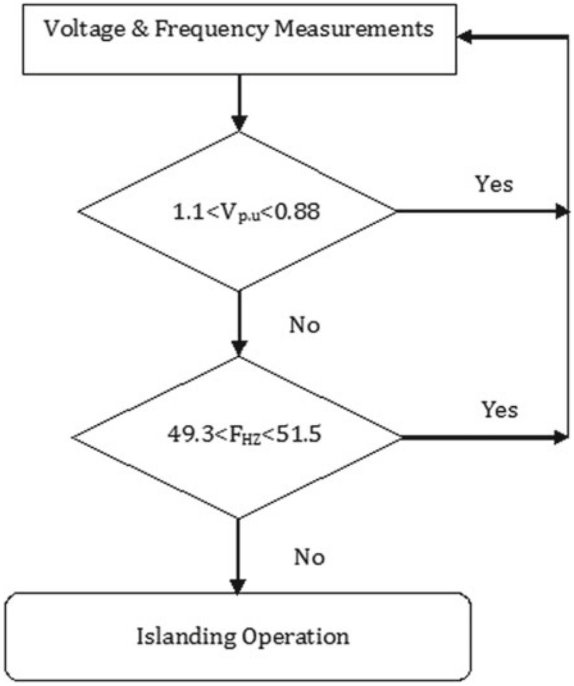


Fig. 5 Flow chart

the range. That whenever a breakdown occurs or servicing is necessary, the grid is disconnected, and the power frequency falls to the island's naturally resonant frequencies [10]. This approach has the benefit of taking into account both voltage and frequency characteristics. The highest and lower constraints of voltage are 1.1pu and 0.88pu, respectively, while the values of frequency are 49.30Hz and 51.50Hz, which is between. They would go into islanding mode if such grid frequency and voltage are below or over this range. The flowchart for such suggested approach is shown in Fig. 5.

6 Simulation and Result

MATLAB Simulink software is used to validate the effectiveness of the suggested solution for the islanding detection approach. The simulated schematic of the system is shown in Fig. 6.

This system was tested under the following conditions:

Power rating (PV):	500 KW
Power rating (PEVs):	800 KW
Voltage rating:	415 V
Nominal frequency:	50 Hz

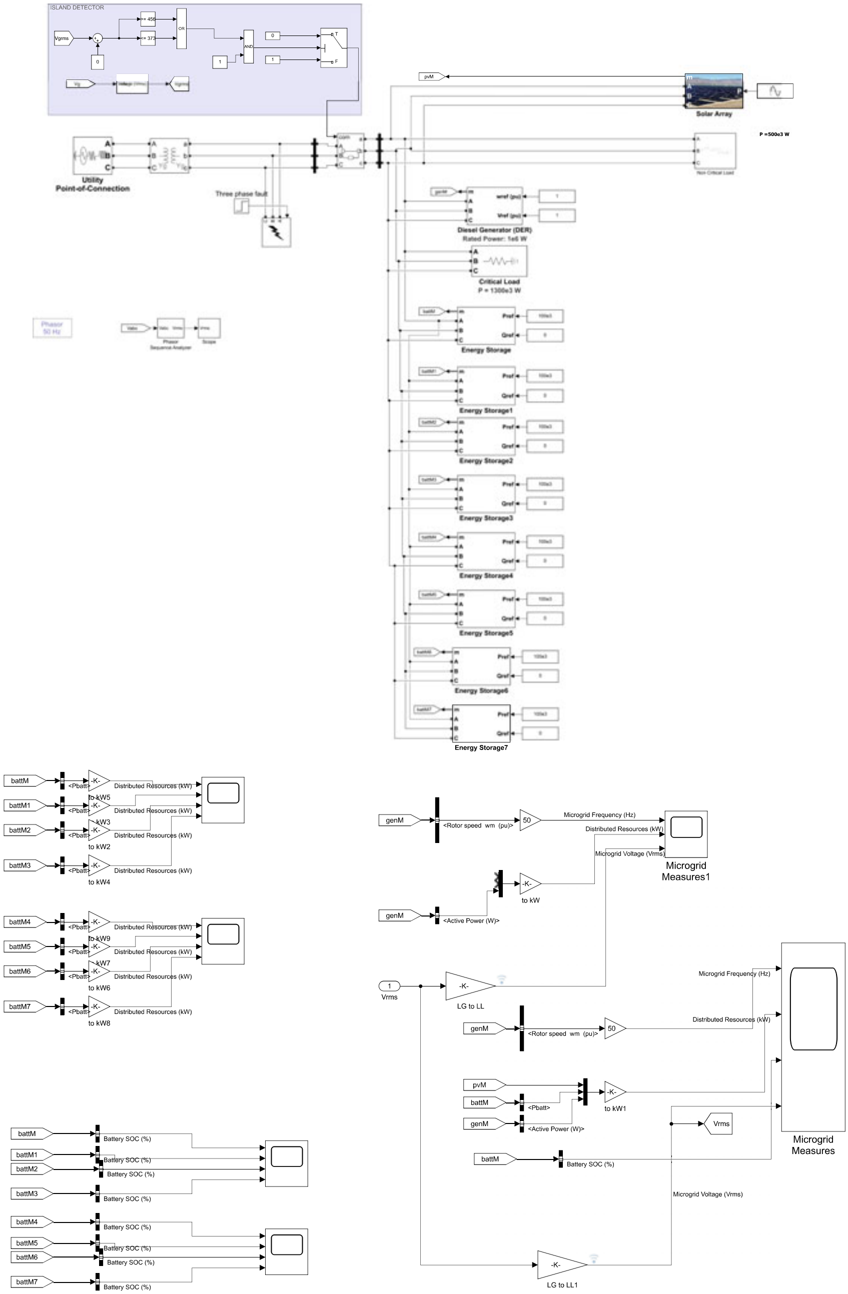


Fig. 6 Simulated diagram

Critical loads:	1300 KW
Non-critical loads:	500 KW
Diesel generator:	1 MW

Loads are linked on both the microgrid and the main grid side to assess the islanding state. The procedure begins in grid connected mode, commonly known as constant current control mode. When the system is in grid linked mode, an islanding issue occurs. Whenever an anti-islanding event occurs, the microgrid disconnects from the main grid and shifts from current to voltage control mode of operation. The system only serves the critical load while operating in voltage regulated mode. Based on the main grid's frequency and voltage constraints, a breaker switch is utilized to separate the microgrid from the main grid. The highest and lower limits of voltage are set to 1.1pu and 0.88pu, respectively, while the upper and lower limits of frequency are set to 49.30Hz and 51.50Hz, respectively. The system is put into an islanding situation if the grid frequency and voltage fall below or beyond this threshold, as determined by the breaker switch.

6.1 Calculation Diesel Generator Governor

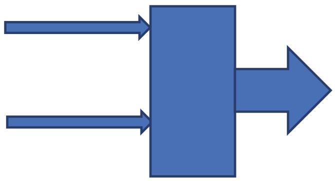
400 V,50Hz,1MW

Initial Power, $[P_\circ, Q_\circ]$ [0.5,0]$W_{ref\ (p.u)}P_{mech\ (p.u)}$

Load Flow PQ

$Vt = \sqrt{(Vq^2+Vd^2)}$ $W_{grid\ (p.u)}$

$W_{in(p.u.)}$, I_{fd}



Diesel generator governor regulator transfer function,

$$H_c = \frac{k(1 + T_{3s})}{\left\langle 1 + T_{1\cdot s} + T_1 T_2 S^2 \right\rangle}$$

Throttle actuator transfer function,

$$H_a = \frac{(1 + T_4 s)}{s(1 + T_5 s)(1 + T_6 s)}$$

Regulator gain $K = 29$, regulator time constant

$$[T_1 T_2 T_3]_\mathrm{s} = [0.01, 0.02, 0.2]$$
$$T_1 = 0.01, T_2 = 0.02, T_3 = 0.2$$

Actuator time constant $T4$, $T5$, $T6$ in seconds.

$$T_4 = 0.25, T_5 = 0.009, T_6 = 0.0384$$

The motor engine represents by time delay Td function

$$\begin{aligned} &\text{Td(s)} = 0.024 \quad \text{engine time delay} \\ &\text{Torque limit } [T_{\min},\ T_{\max}]_{\text{P.U.}} \\ &T_{\min} = 0 \\ &T_{\max} = 1.1 \text{ v} \end{aligned}$$

Initial value of mechanical power.
P_{m0} (PU) $= 0.050008$

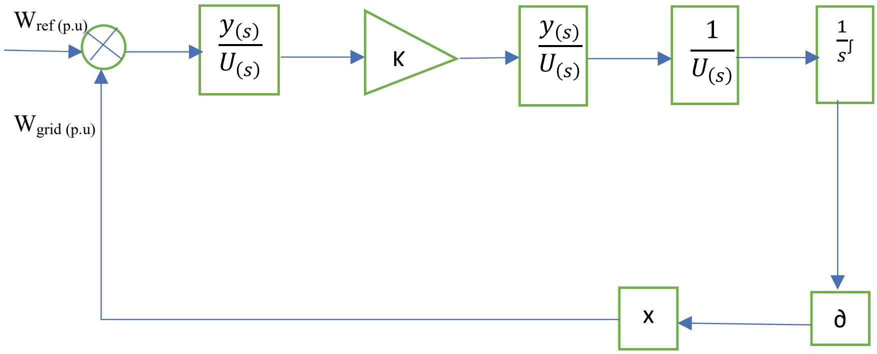


Figure 7 shows the SOC of the battery, supply voltage of the main grid, frequency, and distributed generations. The system was initially linked to the grid. When a three-phase fault occurs, there is a 0.2 s fluctuation in the main grid due to a voltage shift. As a result, there is a change on the inverter side, which represents the islanding. Purposely causing a disruption in the main grid, which itself is coupled to the micro-grid, for the voltage shift. The logical-based island detector detects the disruption and activates the breaker switch by continually monitoring the measurement result, which detects the main grid voltage and frequency. The voltage limitations are being exceeded at 0.2 s. As a result, the breaker disconnects the microgrid from the main grid. All of the system's characteristics, such as voltage, current, and power, would fluctuate. During in the islanded operating mode, the DG system balances the variations in voltage, current, and power (Figs. 8 and 9).

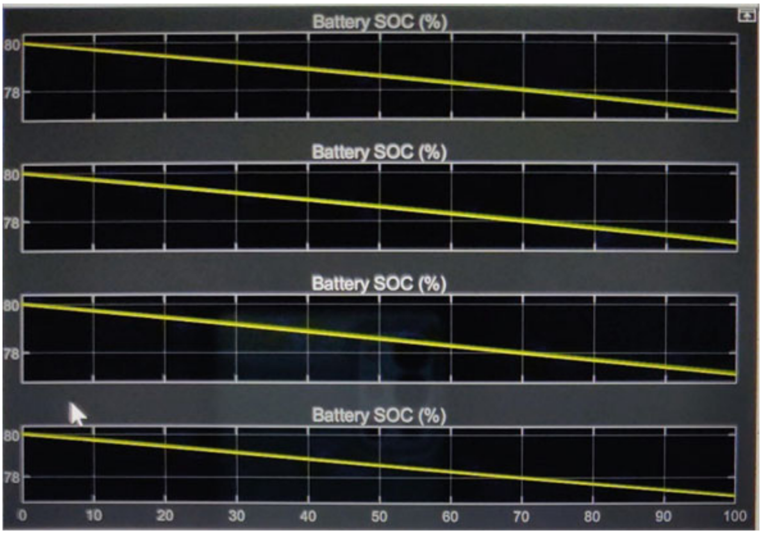


Fig. 7 SOC of the PEVs

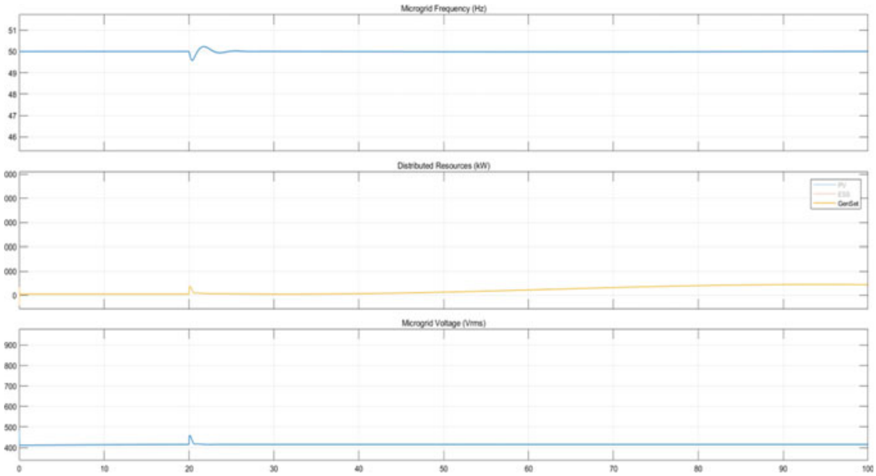


Fig. 8 Diesel generator in microgrid

7 Conclusion

Smart grid-interfaced electric vehicles can improve operational resilience to power system dynamic behavior. The availability of significant storage capacity coupled at the distribution level enables the functioning of independent distribution grids. Indeed, the availability of storage devices will enable load following to occur in such

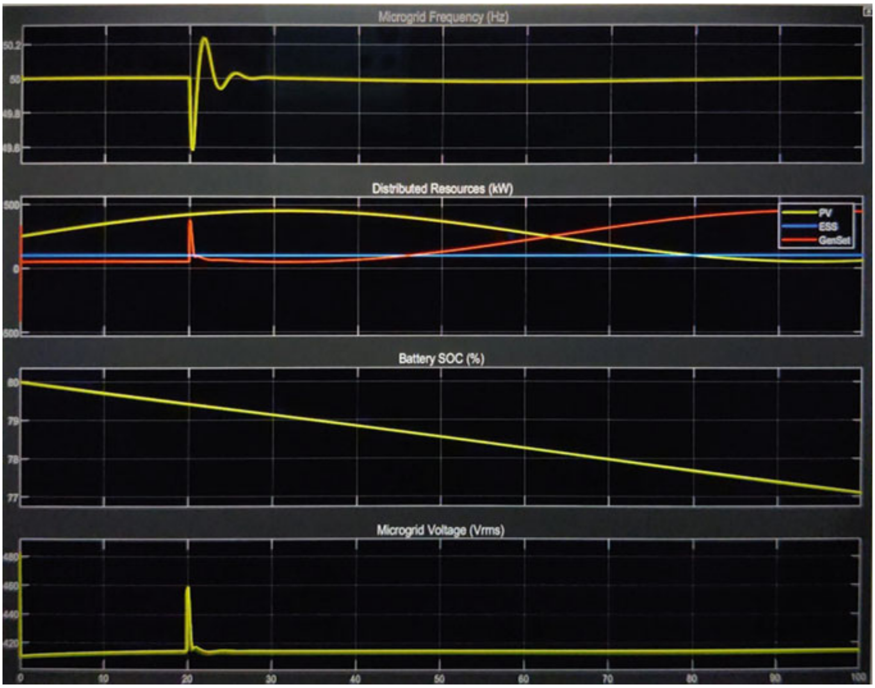


Fig. 9 Simulation results

scenarios, because the batteries of the EVs will provide energy to quickly balance these networks. The use of integrated parked electric vehicles (PEVs) for logical islanding detection has been proposed for the islanding mode of operation, and this work has been validated using MATLAB Simulink software. The battery's SOC is also taken into account and modeled using MATLAB Simulink. The islanding detection technology is primarily used to govern two modes of operation. It also allows you to switch from constant current to constant voltage management. The simulated diagram's output clearly depicts the islanding issue and its detection. The demand from integrated PEVs and solar PV is met by critical and non-critical loads.

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Chapter 5
Green Communications: A Review of the Current Situation

C. Nithyanandam, K. Siva, V. Senthil Murugan, and K. Sriharrish

Abstract This paper reviews the recent studies conducted on green networking and communication for next-generation networks with adverse effect on the climate. Technological advancements will follow suit as smartphone usage grows. Communication technology must become more energy-efficient as a result. The paper presents a literature review on energy efficiency, mobile communications footprint, and energy consumption within ICT devices in green communication networks.

Keywords Green communication · CO_2 emission · Energy consumption · Energy efficiency · ICT

1 Introduction

Global warming is one of our most pressing global challenges. Over the past century, the earth's average temperature has grown significantly. Accumulated greenhouse gases (GHGs) in atmosphere are responsible for this temperature rise caused by global warming. Emissions of pollutants, such as GHG, including carbon dioxide (CO_2), increase with increasing energy consumption. Greenhouse effect, fueled with carbon dioxide results in natural disasters like floods, typhoons, changes in sea levels, floods, etc. According to estimates, CO2 emissions increased 73% over the past 30 years. Among countries on the list of GHG emissions, India is ranked 5th, with China and USA contributing nearly four-times as much emission as India. A commitment to

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reduce greenhouse gas emissions by 5% was included in the 1997 Kyoto Protocol, which was signed by 160 nations, including India.

In 2012, the level had increased from 1990. India has reduced greenhouse gas emissions and energy consumption worldwide, among many other countries. India stands strongly on its commitment of reducing the intensity of carbon in the air by 20–25% starting from 2005.

According to a recent study, most of the world's population mobilized. It was assumed by the tele-communication market that in coming years, there would be an increase in the number of subscribers, per subscriber rate of data, rolling out additional base station in terms of the mobile networks. Development and increase in the mobile networks are aimed on decreasing the consumption of energy by the terminals, whose battery power impose requirements in this regard. Recently, the technology of wireless technology has brought in the increase in equipment exploitation each year that has triggered innovation in energy-efficient communication methods. The total base stations used by mobile companies have also increased to meet subscribers' requirements, leading to increased traffic of data.

Energy efficiency, mobile communication's global footprint, and network consumption are examined in the paper. According to Ericsson's recent research, half of mobile operators' operating expenses equal their energy costs. Hence, applications of tele-communication have a sustainable and direct impact on decreasing the emission of greenhouse gases, consumptions of power, and wireless transmission methods which makes use of energy efficiently.

2 Energy Efficiency

Energy efficiency is the proportion of a device's energy intake that is put to useful use and not squandered as heat. Cellular networks may benefit from the energy efficiency of renewable energy sources. Fuel usage results in significant CO_2 emissions, which pose a serious risk to the environment. Additionally, the oil reserves are rapidly diminishing. Cellular networks may be made more energy-efficient by using energy harvesting. Energy harvesting enables the remote powering of equipment. It is still challenging to monitor power usage since it also requires the installation of technology to allow energy conversion from ambient sources like solar and radio frequency. Researchers and businesses are working hard to identify the most practical green communication strategies. We studied the topic a bit to get a better idea.

Among the four critical approaches discussed by Nabeel Ahmed Malik et al. [1] are the green Internet of things (IoT); heterogeneous networks (HetNets); massive multiple input multiple output (MIMO); and device-to-device communication (D2D).

Azari et al. [2] is considered as an expert of modeling networks for better consumption of energy, analyzing the battery lifetime, and lifetime-aware design of network for massive MTC over cellular networks. He suggested machine-based MTC, which would allow for local machine organization, the formation of machine clusters, and communication with the base station (BS) through the cluster heads. He also looked at how energy efficiency for the access network affected the battery life of machine-type devices. For simulating the uplink transmission from a green base station that supports two different kinds of traffic with severe restrictions on latency and lifetime of battery, he offers a queuing mechanism. Then, we explain the trade-offs between energy life and energy delay and establish closed-form expressions for base station consumption of energy, data transmission delays, and battery life expected of a machine device. The effects of energy savings for the access network on the presented trade-offs are shown by numerical findings, which also help to determine how to exchange the tolerated lifetime/delay of the users for energy savings in the access network.

Venturino et al. [3] worked on the energy-efficient allocation issue of resources in OFDMA cellular network downlink. For system design, three definitions of energy efficiency are taken into consideration for both circuit and radiated power. User's power allocation and scheduling are optimized on a group of coordinated base stations on maximum transmission of power (either base station or per sub-carrier). A noise-limited asymptotic regime is discussed as a particular case. Optimal energy efficiency at small communicates power values similar to optimal spectral efficiency. At the same time, for a broad range of maximum share power levels, a minor data rate drops results in a significant reduction in energy dissipated.

An investigation of GSM in Nigeria was conducted by Bakare et al. [4]. GSM history, trends in Nigeria, the effect so far, areas for reconsideration, and future expectations were reviewed. As a result of the demand for wireless communication, some emerging technologies have been developed. This paper discusses several challenges faced by engineers and professionals in their fields. Consequently, there is an insufficient supply of electricity. The government is taxed more than once, and there is a shortage of skilled workers. In order to overcome these challenges, research and development will also be discussed.

3 Communications on Mobile

A carbon footprint is a measurement of the output units of CO_2 (carbon dioxide) and CH_4 (methane) for a specific individual, product, activity, or organization in terms of their environmental effect. It is most common to express carbon footprints in metric tons/year.

There are several ways in which the carbon footprint harms the environment. This includes contributing to climate change, causing urban air pollution, causing acid rain, acidifying the oceans, and melting glaciers and polar ice caps.

Bakare et al. [5] quantify the worldwide carbon footprint of mobile communications and analyze its ecological and economic consequences. They anticipate a threefold rise in emissions between 2007 and 2020, reaching around 235 M CO_2e. A growing portion of emissions from data transmission over the backbone will be added to the production of mobile devices and worldwide RAN operation as the primary sources.

Vinay et al. [6] present an overview of issues with consumption of energy in green communication networks and describe energy-saving methods. Green communication networks are a common energy consumption problem, and this section describes the methods used to improve their energy efficiency. It is critical to focus on designing and developing wireless access networks as communication networks expand exponentially on a global scale.

In a recent article, Vergara et al. [7] described a multiplatform implementation of random-walk gossip, a multicast protocol for spreading messages in disaster zones. During their research, they focused on how the footprint of commercially available devices influences their functionality. Thus, several elements of the protocol affect the impression, which affects performance.

Lloret et al. [8] analyze the design, development, and performance testing of wireless sensor networks for fire detection and prevention in rural forest environments. An infrared radiation and smoke detection system based on a Linksys WRT54GL router were developed by the researchers. A fire alarm can be activated by both physical sensors. The sensor alarm is transmitted to a central server when a wireless IP multisensor detects a fire. As a result of the software application on the central server, the nearest wireless IP cameras to the affected zone are notified and receive real-time images. Firefighters can verify the source of the fire using real-time visualization of the place where it started.

Based on our bandwidth consumption measurements, each access point supports up to 34 wireless IP cameras. According to their results, the control messages developed resulted in minimal use of bandwidth. The network's energy consumption during packet transmission and reception was also examined.

According to Oh et al. [9], it can reduce the energy utilization of wireless cellular networks. Dynamic base station (BS) was explored by developing an energy-saving switching-on/off technique (SWES), with various on/off decisions made. As a result, energy consumption was reduced by 55% during the week and 80% during the weekend.

O'Farrell and Guo [10] addressed minimizing energy use while preserving its quality of service (QoS). A vertical sector antenna and sleep mode operation were used in their solution. In order to achieve this, they conducted an energy reduction gain (ERG). Based on vertical segmentation, active and sleep modes were introduced. Based on their findings, energy will decrease by 50–90% in sleep mode (in a small cell). Whereas, reduction would be between 10 and 40% (in medium to large cells).

According to Shakir and Qaraqe [11], cellular communication could be improved to reduce the green index or carbon footprint. By deploying the two-tier "heterogeneous small-cell network" (HetSNet), they proposed a method for increasing a network's capacity and decreasing interference and carbon emissions. During the experiment, macro-only network (MoNet) and cell-on-edge (COE) were deployed. Compared to MoNets without energy control, COE implementation reduced CO_2 emissions by 82%.

Sharon et al. [12] examined how to reduce BS energy waste. According to traffic demand, the proposed load balancing method determines whether BSs should be active or idle. Their method is to send messages across BSs to determine if they should be active or idle to reduce energy waste by implementing message passing with load balancing algorithm).

Alsharif et al. [13] reviewed their findings on sustainable and green wireless base stations, which consume most of the energy in cellular networks. Over the past decade, they have examined the architecture of the BS as well as the power consumption model for green cellular networks. This paper also examines wireless communication systems in terms of sustainability and ideal environmental conditions. Due to these two key issues, cellular network operators may be able to reduce not only their OPEX costs but also their environmental impact.

The MPL algorithm for reducing energy waste is used to decide whether BSs should be idle or dynamic based on comparisons [14]. During load balancing, information rate is distributed equally across all users in order to ensure quality of service. Load balancing and sleeper switches can reduce energy consumption by 50%. Both BSs can sleep, and cells can be resized based on traffic pattern analysis. The transmission power of microcell BSs can be adjusted during peak traffic hours to save energy. Energy savings can be achieved by making idle underutilized microcells idle during low traffic periods.

The study on 5G wireless networks by Yang et al. [15] studied how energy is consumed. A two-stage BS sleeping strategy was proposed to minimize energy usage in non-homogeneous cellular networks. It was done using Markov decision process (MDP). Tests were conducted to determine the effectiveness of the two-stage sleeping strategy (TS) and the light sleeping strategy (LS). According to their analysis, the TS approach might save you up to 150% compared to the LS approach.

The new approach developed by Alnawayseh et al. [16] is used to effectively distribute users across cells in cellular systems. Users are evenly dispersed between cells using distance and power equations in this manner. The major objective of such an approach is to lessen the likelihood of calls being blocked in a cellular system and improve cellular system capacity as effectively as feasible. This prevents degradation in the QoS offered to consumers. Furthermore, as compared to a randomly distributed user population among cells, both the CO_2 footprint and power usage are significantly reduced. As a result of using the proposed technique, 29% more users may be allocated. While using the same resources, this system is more effective since blocking is decreased by 43% for 70 users.

4 ICT and Energy

Information and communication technology (ICT) equipment uses energy on its own and may have an influence on the energy usage of almost all sectors; hence, ICT is a key factor in future of global energy consumption. ICT device and service demand are expanding faster than device efficiency improvements. The cumulative potential for ICT-induced savings is many times more than the total energy utilization of ICT, according to earlier research. More studies are looking at energy efficiency caused by ICT than there are looking at energy consumption connected to ICT. However, the few studies that do take into account both factors often do so individually, without correlating the two components.

ICT plays an imperative role in the energy efficiency discourse as a monolithic technology. To achieve low energy usage, it is crucial to focus on technologies with soft energy efficiency potential. These are not suffocating technologies with high energy efficiency potential and limited power consumption. An ICT device is a machine that processes inputs and outputs information and energy. Based on this viewpoint, energy transformations and energy dissipation via heat generation can be seen as two sides of the same coin, namely the nano- and micro-scale management of energy.

Salahuddin and Alam [17] examine the short- and long-term impacts of ICT usage, as well as the energy consumption aspects of the subject. In this research, the pooled mean group regression method is used, as well as panel unit root tests to determine cross-sectional dependence, an analysis of panel co integration, and a Dumitrescu-Hurlin causality test. Power consumption increases over the long- and short-term as both ICT usage and economic growth increase. It is also suggested in the report that OECD nations support green IT and IT for green, which can result in significant reductions in CO_2 emissions by improving energy efficiency and eco-design.

ICT's energy sustainability is a topic that Fagas and Paul [18] examine, and they make the most of ICT's potential for resource efficiency. ICT-energy communities are required to combine devices, ultra-large-scale integration, micro-architectures, high-performance computing (HPCs), energy storage, energy harvesting, efficient electronics, embedded systems, computation, and static analysis.

5 Conclusion

This paper examines various research challenges (energy efficiency, mobile communications, and ICT energy). Using green communications, it reduces energy requirements and CO_2 emissions, which are harmful to the environment. The energy-saving potential of many systems and networks remains unclear. In future, green communication needs more research on cost, spectrum efficiency, and bandwidth savings.

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Chapter 6
PV System Design and Solar Generation Implementation

Manish Mwango, Yugvansh Shrey, Harpreet Singh Bedi, and Javed Dhillon

Abstract Energy may be quite valuable in today's technology development. Therefore, we need to improve the electricity device and find out the cause of power loss. Industrialization may result in a rise in inductive load usage, which will reduce the performance of energy-saving devices. Therefore, we must improve the power aspect using a suitable method for automated electricity aspect rectification. This study designs and simulates an automatic energy factor adjustment that is enhanced by the use of capacitors. Line voltage and line cutting-edge are read by an automatic energy component correction device to determine the power thing. This article discusses a simulation using MATLAB and Simulink that includes setting up a new diode equivalent circuit model of a solar cell and analysing the replicated latest information (I-V). The purpose of this work it to design a complete stable, reliable, and working DC-based test system for future research.

Keywords PVDCM · THD · DG. I-V characteristics · Power factor · Energy efficiency PV panels

1 Introduction

Due to challenges with low energy, the majority of sectors are experiencing problems related to excessive electricity use. The government will fine the industry for keeping the strength component low. Commercial costs that are in line with unit electricity costs are now preferable to home costs [1]. As the industries with the highest inductive load, such as induction furnaces, induction heaters, induction automobiles, transformers, incandescent and fluorescent lighting, arc welding equipment, and so on. These loads will occur immediately impact the energy problem and make it smaller. There can thus be issues brought on by the defective. Because of the low

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energy components, machine activities need more energy [2, 3]. Based on the automatic power factor correction (APFC) panel, mechanisms are employed to lessen the effects that avoiding utilising the authorities for weak points [4]. As a result, the automatic power factor correction technique is one of the most effective ways to address the energy problem [5, 6].

Due to the rising concern about climate change and the rise in oil prices, photovoltaic (PV) and sustainable power sources (RES) have seen tremendous growth in recent years [7]. As a result, several countries have adopted new regulations to promote this type of energy [8].

Photovoltaic cells have very low double-dealing costs (essentially free fuel), little maintenance requirements, are reliable, quiet, and easy to install [9].

Solar energy provides an endless supply of clean energy, and it is predicted that it will soon satisfy a significant portion of our energy needs [10, 11]. Globally, the PV industry has been expanding very quickly, and by 2050, it is expected to reach TW-scale maturity [6]. Such rapid development has created a lot of employment prospects. According to the 2016 solar-based work evaluation, the US PV industry employed more than 260 thousand people [12]. In the coming decades, this number is expected to rise [13, 14].

In this method, the current and voltage phase difference is monitored, and the capacitor will add reactive energy and increase the power thing closer to its team spirit rate in accordance with the observed price [15]. The capacitors will automatically turn on when the inductive load rises and maintain energy use to the solidarity cost [16]. The difference between the current and voltage sections is detected, and the capacitor will provide reactive strength and enhance the energy problem in close accordance with the recorded value [17]. Since induction motors are frequently utilised for specialised industrial tasks, there may be an issue with bad electrical components and reduced performance in industries [18].

2 Simulink Model

A solar cell can be electrically modelled as shown in Fig. 1. Of which it is made up of a DC source (Iph), a diode (D), a shunt resistor (Rsh), and a series resistor (Rs). The DC source is directly proportional to the incident light intensity (Figs. 2, 3, 4, 5, 6, 7 and 8).

The results show us that the power flow main peak is at Pmax, that is, 3.4 approximately [19]. So, for us to obtain maximum power and efficiency of the solar cell, it is to be operated at that point. That is just for a single solar cell but different values of irradiance can be put to obtain maximum efficiency and power [20].

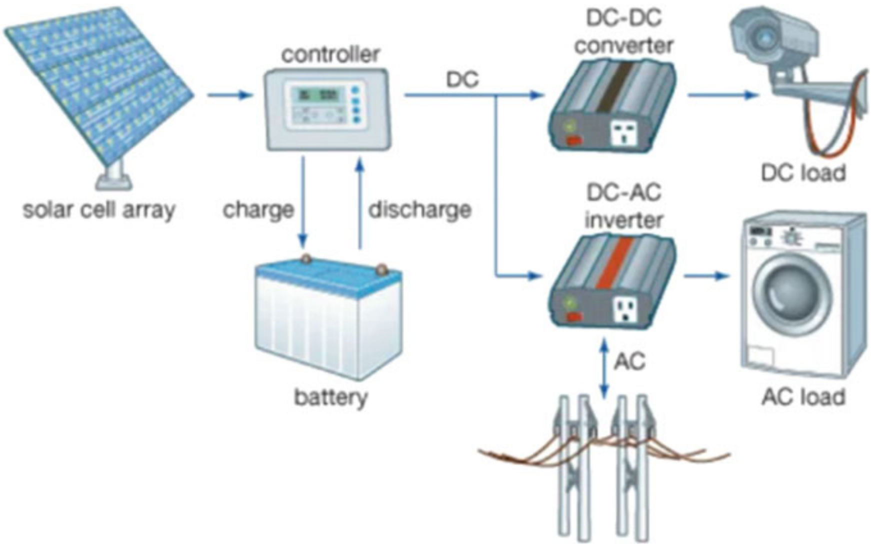


Fig. 1 Solar panel installation

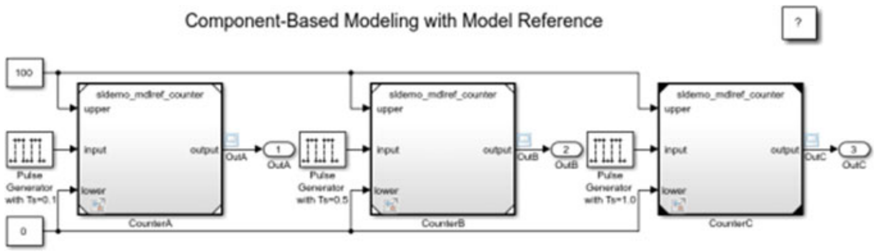
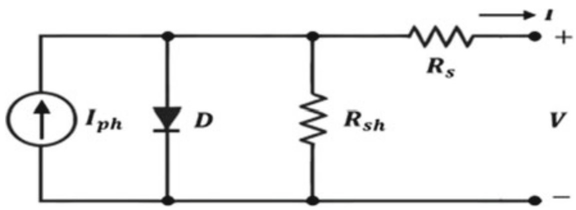


Fig. 2 Component modelling

Fig. 3 Single diode of a solar cell



3 Conclusion

In this paper, AC voltage is supplied to the current and voltage sensor, then the strength is supplied to the divider and further, it is far taken by way of the benefit, RMS fee integrator, then it will be displaying the cost of the energy issue correction

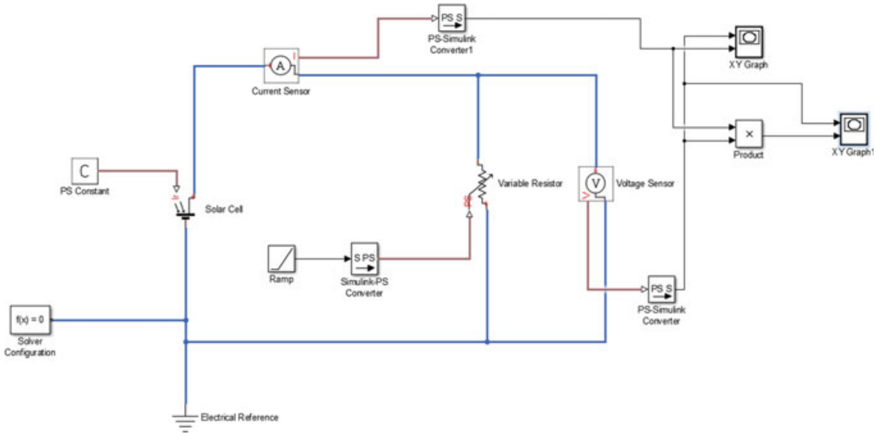


Fig. 4 Simulink model of the solar cell

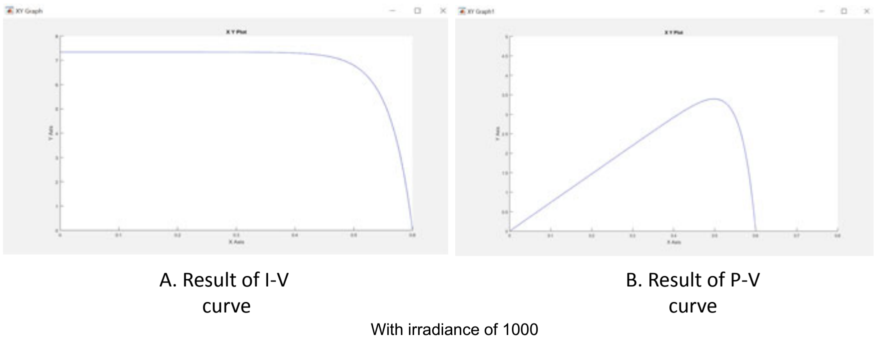


Fig. 5 Simulated results of irradiance of 1000

[13]. And if we similarly need to correct the electricity thing, then through changing the cost of the capacitor the power issue may be corrected as according to, we are required [21]. After plotting the I-V and PV characteristics, it was found that solar radiation has a direct effect on the solar cell power, the Isc, and the Voc. The value of radiation which was set was that of 1000 W/m^2, and the output current and voltage behaviours were observed [22]. It is safe to say that the obtained results can aid us to further maximise the efficiency of the solar cell as well as apply many other techniques. As the belief, energy element of electrical can be decided primarily based on impedance price of electrical [23].

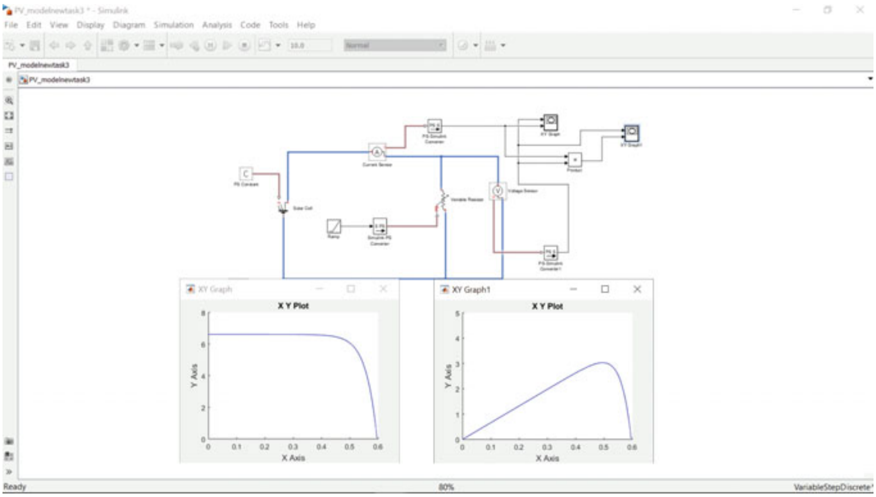


Fig. 6 Simulated results of irradiance of 900

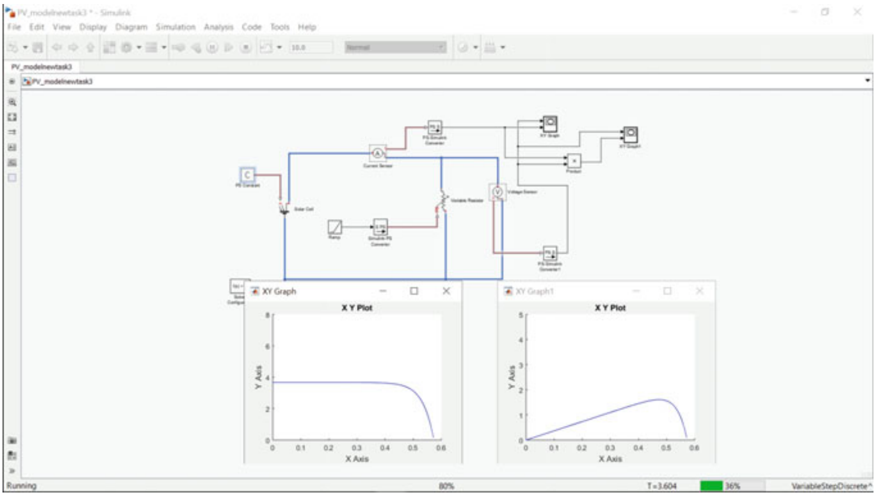


Fig. 7 Simulated results of irradiance of 500

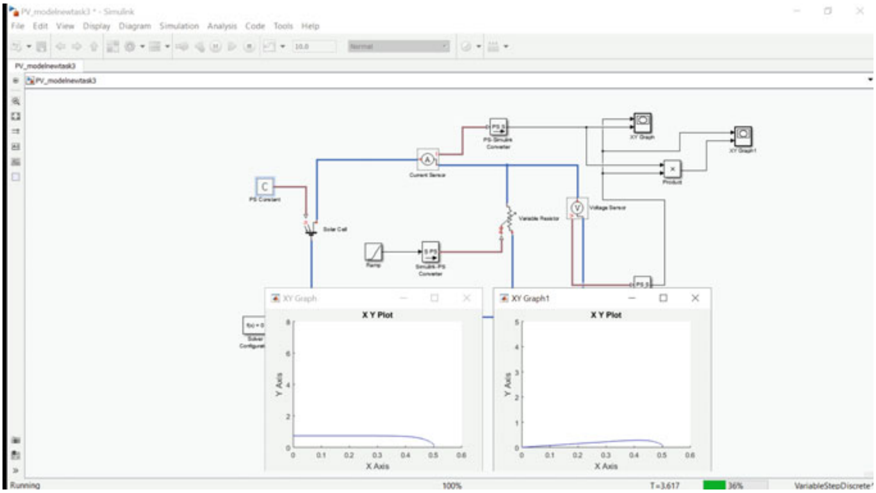


Fig. 8 Simulated results of irradiance of 100

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Chapter 7
CoviDistBand: IoT-Based Wearable Smart Band to Ensure Social Distancing

Vraj Bhatt, Jaimin Topiwala, Smita Agrawal, and Parita Oza

Abstract COVID-19 has spread worldwide, and this pandemic has ruined the routine lifestyle of human beings. It is impossible to live in isolation forever, but one can keep themselves safe by maintaining proper social distancing. In this paper, we proposed a novel IoT-based solution to keep a safe distance. We developed an IoT smart wearable device that can wear to the user, and it will buzz whenever social distancing rules are broken. At the same time, the human position coordinates of the alert event are noticed and redirected to UI, and it will also show in Google Map. The device is tested manually, working accurately, which is used to maintain social distance in large gatherings like healthcare centers, schools, stadiums, playgrounds, and other places.

Keywords IoT · Social distance smart band · Pandemic · Wearable device

1 Introduction

As COVID-19 spreads from person to person, reducing the habits people interact with more closely is fundamental. From notable open locations, where at hand, contact of people is about to happen, that is why the suggestion to avoid roaming out, going to work, drop traveling and social gathering, and more than 20 activities added. It is the reason for which many educational institutes have moved to virtual learning. For buying an essential need like food products, the centers of desires control and prevention recommend wearing a mask and other stuff to cover the node and mouth.

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They also suggest maintaining the distance of 6 feet approximate [1]. Also, it is significant that end-users follow the government's standard guideline. Either people are attending a large gathering or not [2]. In any case, social separation possibly works if we work all as a team. Also, easing back down or obstructing escalate of infection may save lives. The spread of coronavirus has been the fast and managing state, and neighbor governments are doing whatever is required to protect [3]. Youngsters appear to be less influenced by the infection than senior citizens. We are liable for ensuring those at higher risk. Steps such as evictions can feel like a burden. However, it is the appropriate way to protect our family, companions, and neighbors who might be helpless. From the World Health Organization (WHO) research, pneumonia of unknown reason found in Wuhan, China, was initially answered in China's WHO Country office on 31st December 2019 [4]. The existence of the coronavirus was announced on 30th January 2020. On 11th February 2020, the identity of a virus was given as coronavirus (COVID-19) by WHO [5]. The situation was observed continuously based on active cases globally. In the days and weeks to come, it is expected that the number of cases, the "WHO" number, has described COVID-19 as a pandemic. It spreads through the novel coronavirus [6]. As per the COVID-19 guidelines, wearing a mask, washing hands for the 20 s, and keeping social distance are essential requirements. Though vaccines and some treatment of COVID-19 are available, keeping a safe distance from each other can help us control the spread. Even after vaccination, it has been advised to wear a mask and keep social distance [2]. As they say, prevention is better than cure, and it is appropriate in the current situation. The best way to avoid infection is to get adoption by following a community distance. Our proposed novel approach focuses on one of its requirements to maintain social distancing. We proposed a novel product prototype that helps maintain social cohesion and warns the user to follow to implement physical indifference among the crowd and decrease the ratio of people in proximity.

2 Proposed System Model

As shown in Fig. 1, the proposed system model provides the complete flow of the designed model and its working. For example, the figure shows the proposed model that maintains social distance in large gatherings. It will be worn to the end-user and will buzz whenever social distancing rules are broken. At the same time, the human position coordinates of the alert event are noticed and redirected to UI, and it will also show in Google Map.

The social distance smart band contains several components and tools based on user reliability and R&D reviews. The functionality of the components is compared and used accordingly, for example, which sensor is best for alert detection or which microcontroller is best suitable as a wearable [7, 10, 11]. In Table 1, we comprised different components used in the system based on their effectiveness and complexity.

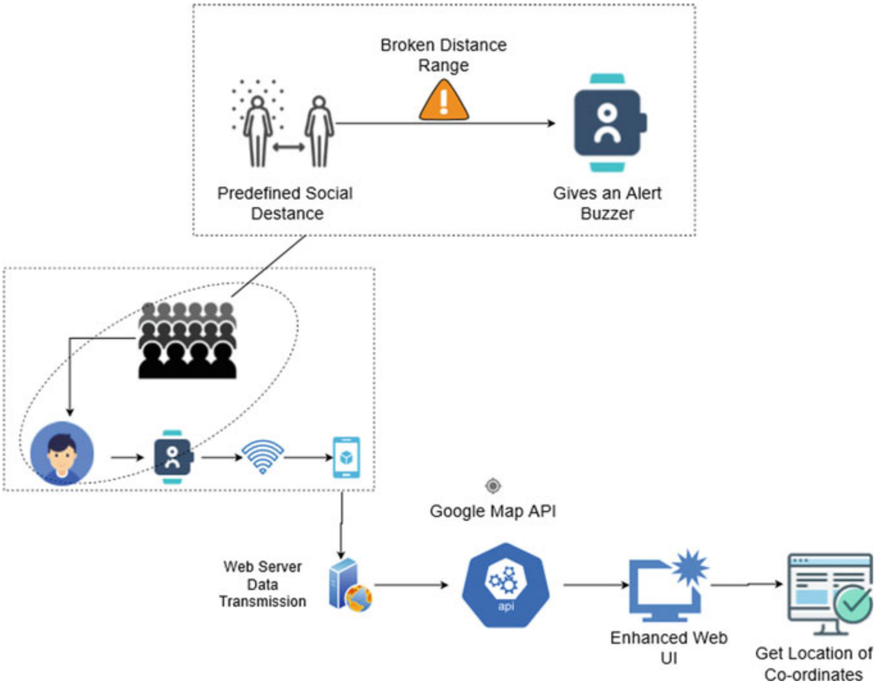

Fig. 1 System model

Table 1 Various sensors and hardware description

Sensor/hardware	Image of sensor/hardware	Mechanism	Major use
PIR sensor [7]		Radiant heat based on passive infrared	Infrared-based motion detection, living moving object detection
Ublox Neo6M [8]		The NEO-6 module series is an independent GPS receiver with a high box six positioning engines. The ublox neo 6 m is flexible as well as cheap	Gathering GPs live longitude and latitude
Esp8266 or node MCU [9]		Network connectivity and board operation	Can be operated as controller and able to connect to open Wi-Fi or Internet

3 Proposed Model Architecture

In this section, we aim to represent the proposed system's layered architecture and architectural diagram.

3.1 Layered Architecture

The proposed system's multi-tier architecture shown in Fig. 2 gives relevant solutions. Later on, if one layer unit can be replaced or added, there is no need to upgrade the whole module or system [12, 13]. For example, for the proposed system, the multi-layered architecture of workflow has been generated below:

Layer 1: Exterior hardware module components and sensors: component that the end-user can directly operate.

Layer 2: Microcontroller and Internet Wi-Fi/Bluetooth: Data gathered from the sensors will be processed, and meaningful content will be published.

Layer 3: Webserver: Operation task proposed by the end-user or operator transferred to the Webserver via the microcontroller.

Layer 4: Application: User interface via which user can view and perform visual interactions. For e.g., giving geolocation output or buzzer alert

Use of Proposed Model:
The proposed model can carry a considerable area of use in routine tasks. Area of application is huge in the daily life of a normal user. Those are the following:

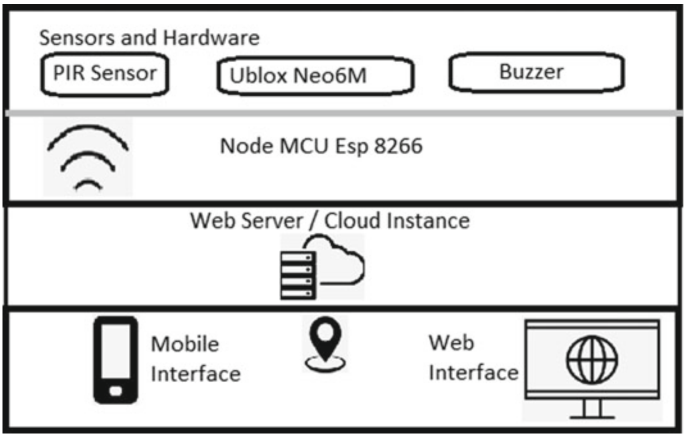

Fig. 2 Layered architecture of social distance smart band

healthcare centers, social gatherings, courtrooms, live sports events at stadiums, railway stations, airports, political party gatherings, etc.

3.2 Architectural Diagram of Social Distance Smart Band

The proposed system's architecture diagram is shown in Fig. 3 which provides the connectivity of various components of the band. NodeMCU is an open-source and language-based LUA system designed for the eESP8266 Wi-Fi module. In addition, Espruino, Mongoose OS, Arduino's Expression, and ESP8266 software development kit are a development platform with the eESP8266.

The ESP8266 had great onboard processing capacity and sufficient storage to program ESP8266 assisted in managing the program or deploying a Wi-Fi network from another system processor using an independent Wi-Fi communication solution. Allow it to experience slight improvements in precise and small loads during operation using GPIOs and sensors of a particular device. The meager price and high features of ESP8266 make it an entire Internet of things item. It is used in any application that requires the end-user to attach the device to an extranet, client-server, or the Internet.

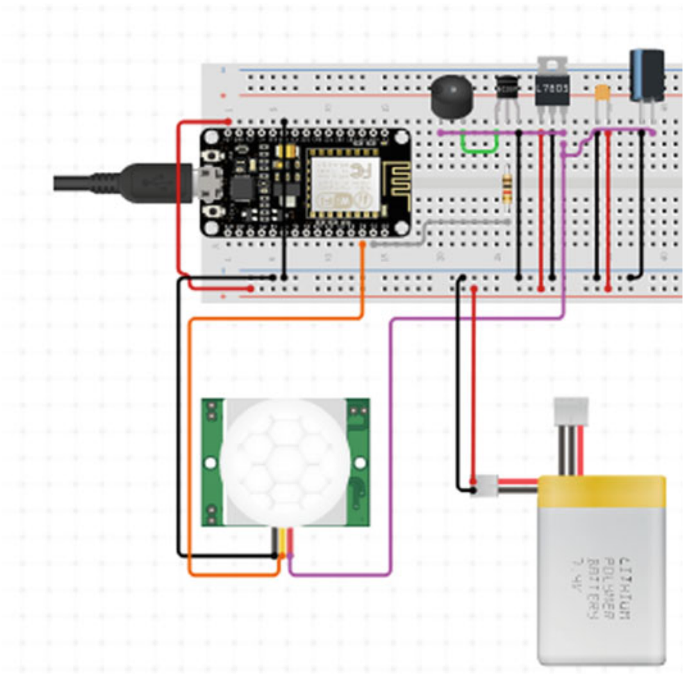

Fig. 3 Architectural diagram of social distance smart band

4 Product Prototype

The product prototype is shown in Fig. 4 as a social distance smart band. When other users come in a range of wearable devices, it gives a buzzer alert to the user who wears this prototype model.

The proposed system also consists of a user interface, as shown in Fig. 5a and b , in the form of mobile or Web-based applications that can show the output simultaneously when certain events occur. Simultaneously, the coordinates of the alert event will be noticed and redirected to UI and shown in Maps (Google Map) or similar such applications. Future enhancements can also track the record of coordinates and can be surfed or investigated in future when required; furthermore, implementation of replacing battery or rechargeable battery can be enhanced.

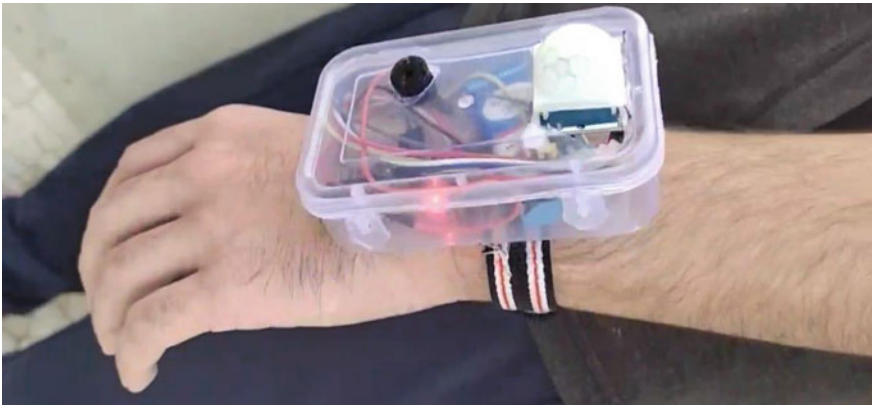

Fig. 4 Prototype product–wearable device

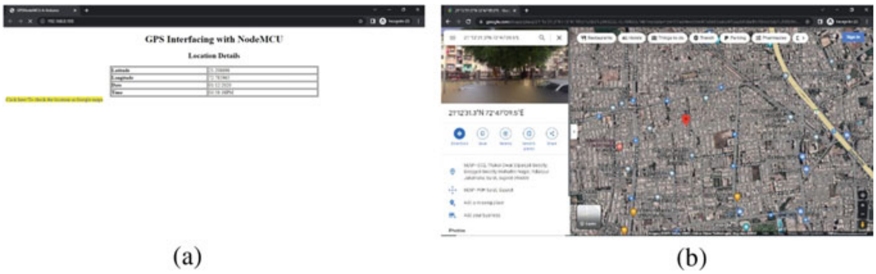

Fig. 5 **a** Output results on user interface. **b** Visual geolocation output (satellite view)

5 Challenges and Research Opportunities

The primary challenge is to integrate devices with the space complexity and make them cost-effective. We are also maintaining high throughput data with continuous integration (CI) systems. We can approach certain cloud database services or local device services [14]. Some of the challenges and research opportunities are mentioned below:

Cloud Computing: Cloud computing can be adopted by the proposed system for future work to support the storage, processing, and computational environment with high availability. We can host databases on cloud instances, EC2. Also, we can integrate or deploy Webservers to integrate the whole module with DevOps Technologies and tools with CI/ CD.

Continuous Integration (CI): IoT technology provides automation and deployment tools like Jenkins and Docker. We can enhance it because here, we are getting continuous data from sensor nodes [15]. Also, it is easy to integrate with cloud platforms like AWS and Azure.

Database: Continuous streaming data by the sensors can be challenging to manage [16–19]. We can host databases like RDS or Firebase on cloud instances or scalable instances [20].

Future Resources: One of the critical challenges of any device depends on its battery life with rechargeable or replaceable in different aspects. For sustainable power resources, we can enhance it with rechargeable batteries. But also we can add-on like solar reachable and renewable resources. So it can be taken as a futuristic opportunity.

6 Use of Renewable and Reusable Technology and Energy

Here, we have found such Era of Technology which will be implemented as part of rechargeable and renewable energy:

Rechargeable Battery: We can use the rechargeable battery as part of a rechargeable resource, which can help to decrease the amount of emitting carbon footprint. The rechargeable battery cell contains less toxic waste compared to the other regular batteries.

Recycle PCBs: As part of the PCBs used in this project, it can be recycled and downcycled. Also, we can extract the copper used in PCB and use it again as part of an electronic conductor. We can remake PCB boards by shredding existing PCBs and reusing them for further manufacturing.

7 Conclusion

We proposed a novel product prototype that helps maintain social cohesion and warns the user to follow to implement physical indifference among the crowd and decrease the ratio of people in proximity. The accuracy of the device also increased by improving the design of the sensor. The proposed model will help persons working in the same field. During pandemic times, the system helps maintain contactless habits, which reduces the infection ratio, makes virus infection controllable, and makes people habitual of maintaining social distance.

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Chapter 8
Gesture Recognition Glove for Speech and Hearing Impaired People

M. Neela Harish and S. Poonguzhali

Abstract Communication is an essential need for every person in society. This socializing can be in audio, video and text forms. Gestures are the natural expressions of communication to facilitate a specific meaning. These gestures are combined with facial expressions to form a tool for the speech impaired and the hearing impaired which is known as Sign language. It varies according to the country's native language as American Sign Language, British Sign Language, Japanese Sign Language, Indian Sign Language, etc. The researches in the field of SL recognition have been increased tremendously in the last 10 decades. This paper mainly aims at developing a Human Machine Interface based on gestures. Indian Sign Language is a visual-gestural language used to bridge the gap of differences within society and speech and hearing impaired, exclusion of translators and independent expressiveness. This system is designed with a wearable glove utilizing ten flex sensors and two accelerometers to recognize the words in the sign language vocabulary. The classified results are sent to voice module, where the voice corresponding to the gesture is played back through a speaker. The results of the first version of glove without accelerometers had an accuracy of 74.12%. The accuracy was improved to 97.2% in the second version by the placement of accelerometers over the back side of palm on both hands. Both the versions were verified with datasets varying with gender and signer. The proposed glove excels the existing gloves on constraints of sign misclassification, expenses and others related to image-based gesture recognition. Future extensions of this glove would be modification for other country's sign language recognition or gesture-based controlled devices.

Keywords Accelerometer · Flex sensor · HMI · Indian sign language · Speech and hearing impaired people

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1 Introduction

Sign Language plays a pivot role in the social life of speech and hearing impaired people. To exchange the information between normal people, the gestures of SL are translated into English words text or voice outputs by Sign Language Recognition (SLR) using HMI. Fingers and hand shapes possess maximum information related to HMI. The input forms of HMI can be gesture voltages or images. The common hindrances in image-based gesture recognition were complex backgrounds, fixed Field of View (FOV), more number of cameras required, overlapping of face expressions with hand movements and occlusion. The most preferred SLR is sensor-based because of cost effectiveness, portability and less power consumption. Sign language is not universal all over the world. There exist 135 legally approved Sign languages like Ukrainian Sign Language (USL), Japanese Sign Language (JSL), Arabic Sign Language (ArSL), etc. In this paper, ISL gestures are considered. ISL is a combination of verbal and nonverbal signs, a combination of single and double handed gestures and it has its own grammatical structuring style.

According to India's National Association of the Deaf, there are about 1.3 million populations are speech and hearing impaired people. Among them the working percentage as main, marginal and non-workers are shown in Fig. 1. It depicts that due to the inconvenience of expressing themselves they could not obtain good education and occupation facilities available in the society. Hence, an ISL-based prototype has been designed to excel the obstructions of the technology and the emotional issues of the speech and hearing impaired people.

The other sections of this paper are organized as follows. Section II provides the related papers dealing with SLR based on sensors and stimulation results using Lab VIEW. Section III describes the components used in this setup, workflow of the glove and the generation of two datasets. Section IV presents the results of

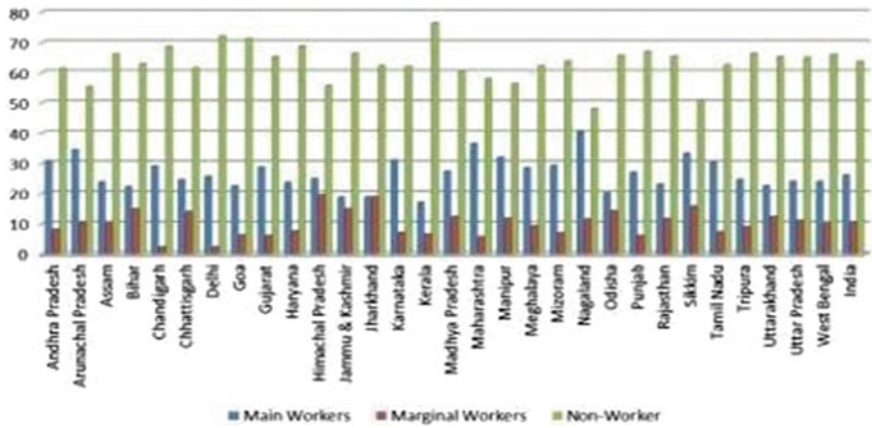


Fig. 1 Disabled worker population state wise in India. *Source* 2011 census

sensor over two datasets, variation between them and the classification procedure using MMSE algorithm and it discusses the recognition rate based on sensor fusion. Finally, Section V includes the conclusion of this study.

2 Literature Survey

The studies in the field of SLR started in the early 70’s itself. Researchers have developed glove-based systems for sign languages and other gesture control applications. A word recognition in time normalization using slope constraint and symmetric form algorithms [1]. The Markov model was used to recognize a 40-word lexicon for American Sign Language (ASL) images [2]. The gray scale images of the American Sign Language (ASL) by morphological filtering to classify hand gestures [3]. The gestures were recognized for the survey of feature extraction and acquisition for transitions and adoptions [4]. German Sign Language (GSL) was analyzed by intrinsic mode entropy by three native signers and differentials processed [5]. ISL was recognized for 10 images including ‘UP’ and ‘DOWN’ positions feature point method into text [6]. For the conversion of Unified Arabic Sign Language (UASL) to the American Sign Language (ASL), a dictionary was designed on the basis of a web-based application. It was presented using a graphical interface for 1400 signs and various categories as colors. These video sequences were captured at a width and height of 1920×1080 [7]. A set of 18 gestures were described and recognized using a 3-axis accelerometer and determined the corresponding actions by the concept of random projection [8]. A sign language recognition system based on Hindi language was designed with Cepstral features. The images were processed for two models processed using Support Vector Machine (SVM) and Neural Network (NN) and testes for best score efficiency [9]. The converted gestures of British Sign Language to text output using sensor gloves for single handed. Adithya et al. [10] designed a neural network with the images of finger spelling of ISL gestures [11]. The detection of the finger bending using piezoresistive sensors and by the method of MMSE text converted to speech [12].

The principle of surface electromyography signals was used in Bayesian classifier to manipulate mobile phone working [13]. The multisensory techniques developed to train a classifier to learn hand positions and orientation with a higher pose of reduced error by 30% [14]. The Arabic Sign Language alphabets captured by both image processing and sensor gloves and both were compared on the basis on cost, efficiency, user preference, etc. [15]. An Urdu Sign Language system was designed which has been captured for 9 images whose features have been extracted and classified by PCA [16]. A LabVIEW–VI-based glove was designed and developed for paralyzed patients based on their hand and eye movements. Commands translated were water, food and pain [17]. A rehabilitation robot was proposed for hand for data acquisition from five hands in the VI [18]. A robotic arm was implemented for limb disabled people using servo motors, working based on commands from the flex sensor on the other hand for lifting and other purposes [19]. A gesture controlled vehicle based on

Ultrasonic sensors. Any obstacle on the path detected then vehicle would go around the obstacle [20]. A numerically evaluated rehabilitation device for specific set of four exercises were designed from a set of 12 subjects. Based on the degrees of freedom for the shoulder, elbow and wrist joints, different flexions were planned accordingly, to improve an automated therapeutic treatment [21]. Levenberg Fractional Bat Neural Network (LFBNN) was proposed for voice-based recognition system. Evaluation is based on the metric such as FAR, FRR and accuracy achieved till 95 % for any voice-based operating models [22]. A sign language recognition system based on Hindi language was designed with Cepstral features. The images were processed for two models processed using Support Vector Machine (SVM) and Neural Network (NN) and testes for best score efficiency [9].

Summarizing the blocks in the recognition techniques were as follows. The gesture image-based processing, only alphabets detected, implemented for the other countries' sign languages, words were detected concatenating each letter's gesture. The general hand gestures were recognized by application based and mostly single handed symbols. In some papers the types of movements were limited to up and down positions only. To overcome the above mentioned problems, this glove is designed and developed.

3 System Design Flow

3.1 Hardware Design

In this SLR an Sign and Sound (SS) glove is designed for both hands as shown in Fig. 2. In the first version of SS Glove, it is equipped with flex sensors stretched over the ten fingers to measure the bending degree of the three joints in the finger phalanges (Distal, Medial and Proximal). These flex sensors can accommodate within age group varying from 18 to 50 years and distinct sizing of fingers. In the second version of SS glove it is included with accelerometer to measure the rotation, orientation and tilt positions of both the hands. The 3-axis accelerometer is located over the metacarpal bones and carpal bones to obtain the entire hand inclinations. These accelerometers are light in weight and accurate in angle outputs. Sensors are stitched to the glove in a fit manner, as it remains fixed even during hand movements. The two different types of flex sensors employed in SS glove are 2.2 in.' flex sensor (only for baby finger) and 4 in. single axis digital flex sensors are shown in Fig. 3. The bending resistance exhibited by the 2.2 in. is 10 K ohms and 4.5 inch ranges from 60 to 110 K (Source:www.sparkfun.com). Each 4.5 in. flex sensor cost 3800 Rupees and 2.2 in costs 680 rupees.

Sensor glove selected material was neoprene nylon glove due to the following reasons:

- o Provides fine grip and good tensile strength to fingers attached with sensors.
- o Light in weight and durable for long term usage and frequent finger movements.

Fig. 2 Glove (First version without accelerometer)

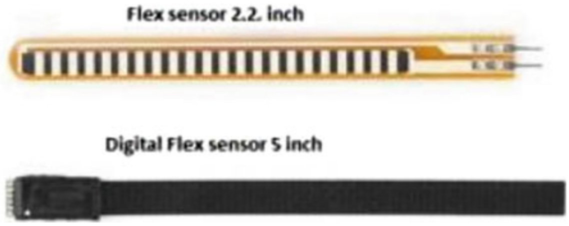


Fig. 3 Two variations in the flex sensor

- o Easily stretch back to the original size when fingers are bent fully.
- o Absorbs sweat produced by the fingers and reduces the hazards of electrical shocks.
- o Does not get affected by any oily substances, as the glove repeals these substances.
- o On a large scale usage, Neoprene nylon glove does not provide any allergic to the user's hand or finger.

The SLR system for this specialized glove has been divided into three units: a sensor acquisition unit, processing unit and voice module and LCD unit as shown in Fig. 4. The flex sensor and the digital flex sensor are operated at 5 V and 3.3 V @10 Hz respectively to produce an electrical output proportional to the bending of finger. The sensor data are preprocessed prior to feature extraction and then provided to SVM classifier for the recognition of ISL gestures. This SLR is mainly designed to recognize the 18 words of ISL as presented in Table 1. Gestures of the selected words according to the standardized ISL are illustrated in Fig. 5. These words are detected as the output of SVM and they are transferred to the text and voice units using ZigBee technology. The recognized words equivalent to gestures were displayed in LCD and corresponding voice outputs played through speaker. The power supply of 5V for the entire SLR system is provided by the rechargeable Lithium batteries.

3.2 Experimental System Flow

Trained 24 subjects from speech and hearing impaired educational institutions have participated in the survey. The subjects taken into consideration were in the age

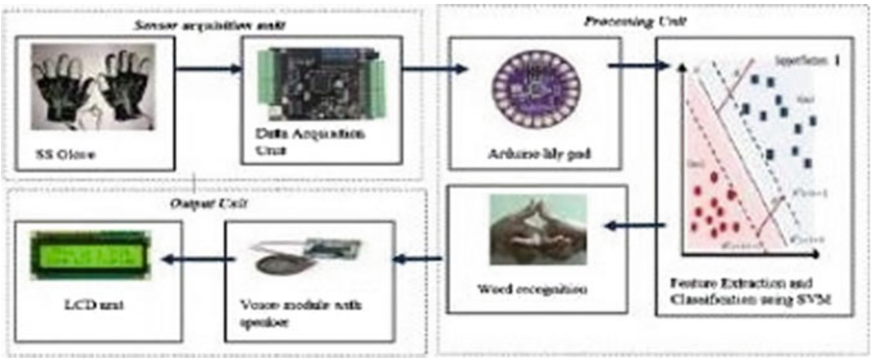
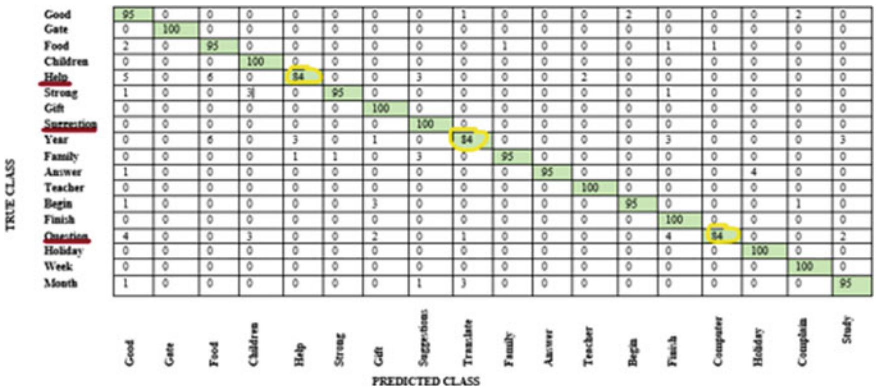


Fig. 4 Overview of SLR system divided into three unit

Table 1 Word dataset

S. No	Word dataset		
	Home	Public	Work
1	Good	Gift	Begin
2	Gate	Suggestions	Finish
3	Food	Help	Holiday
4	Children	Family	Week
5	Question	Answers	Month
6	Strong	Teacher	Year



	Good	Gate	Food	Children	Help	Strong	Gift	Suggestions	Translate	Family	Answer	Teacher	Begin	Finish	Computer	Holiday	Complain	Study
Good	95	0	0	0	0	0	0	0	1	0	0	0	2	0	0	0	2	0
Gate	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Food	2	0	95	0	0	0	0	0	0	1	0	0	0	1	1	0	0	0
Children	0	0	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Help	5	0	6	0	84	0	0	3	0	0	0	2	0	0	0	0	0	0
Strong	1	0	0	3	0	95	0	0	0	0	0	0	0	1	0	0	0	0
Gift	0	0	0	0	0	0	100	0	0	0	0	0	0	0	0	0	0	0
Suggestion	0	0	0	0	0	0	0	100	0	0	0	0	0	0	0	0	0	0
Year	0	0	6	0	3	0	1	0	84	0	0	0	0	3	0	0	0	3
Family	0	0	0	0	1	1	0	3	0	95	0	0	0	0	0	0	0	0
Answer	1	0	0	0	0	0	0	0	0	0	95	0	0	0	0	4	0	0
Teacher	0	0	0	0	0	0	0	0	0	0	0	100	0	0	0	0	0	0
Begin	1	0	0	0	0	0	3	0	0	0	0	0	95	0	0	0	1	0
Finish	0	0	0	0	0	0	0	0	0	0	0	0	0	100	0	0	0	0
Question	4	0	0	3	0	0	2	0	1	0	0	0	0	4	84	0	0	2
Holiday	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100	0	0
Week	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100	0
Month	1	0	0	0	0	0	0	1	3	0	0	0	0	0	0	0	0	95

Fig. 5 Confusion matrix of ISL word dataset

group of 15 to 50 (ranging from school, college, trainers). The subjects should not have Upper Limb Disorders (ULDs): Carpal Tunnel Syndrome (CTS), tendonitis and Hand-Arm Vibration Syndrome (HAVS). Four datasets were formed variation in gender and signer.

- First set (24 male participants signer dependent with varying age groups)
- Second set (24 male participant signer independent with varying age groups)
- Third set (24 females' participant's signer dependent with varying age groups)
- Fourth set (24 females' participant's signer dependent with varying age groups).

All the subjects performed each word's gesture repeated 6 times with a duration of 5 s for each word performed. The entire datasets sensor voltages are stored in memory card for further processing.

In the second version of SS glove flex sensors are combined with 3-axis accelerometer to acquire the inclinations of the hand. It is placed on the dorsal (i.e., back side of palm) side of SS glove.

ACC monitors angle, rotation and orientation of each gestures. ACC works on the principle based on a small mass over silicon surface suspended by beams which produces a force. This force displaces according to the movements of the MEMS accelerometer placed over glove and produces X, Y and Z axes measurement. ACC inclusion improves the accuracy of the SS glove without affecting cost and weight parameters.

4 Methodology

Four dataset's results inferred that sensor outputs vary depending upon subject's hand size. As for small size variations among results are less and for large hand sizes vice versa. Normalization of data avoids all these problems, subject's sensor outputs are estimated to mean, standard deviation based on time domain approaches as in Eq. (1). These normalized sensor outputs for two ISL word gesture are shown in Table 2.

Table 2 Improvement in accuracy of words by sensor

Subjects	Question	Gift	Help	Year
1	95.3/74.1	96.4/66.7	94.3/79.1	97.1/76.4
2	96.6/70.2	94.1/62.8	97.6/76.3	98.5/69.5
3	95.7/78.9	99.5/79.9	97.7/78.9	97.7/69.7
4	97.1/65.1	95.3/77.5	98.1/69.2	94.3/74.3
5	96.4/65.8	96.5/75.5	97.4/75.8	96.3/69.1
6	96.6/62.6	98.5/66.1	98.6/73.6	97.7/72.1
7	97.2/65.8	97.5/68.7	97.2/75.8	97.3/79.1
8	98.5/75.3	96.3/77.3	98.5/76.3	97.9/80.1
9	98.7/77.1	97.3/63.1	96.7/79.2	98.3/78.6
10	97.3/74.7	98.7/72.6	99.3/77.7	99.3/87.4

$$\sigma = \sqrt{\frac{\sum_{i=1}^{n} (x_i - \mu)^2}{N}} \tag{1}$$

where σ is the standard deviation, μ is the mean, N is the number of subjects, xi current sensor output. Similar procedure is conducted for all words from each of the four datasets both flex sensor and accelerometer. Prior to all, sensors are calibrated at divergent positions. Flex sensors

are tested at no bend, half bend and full bend. ACC are tested at hand shapes which are inclined at up, down, tilting right and left to calculate the x, y, z axes measure. The flex sensor output is converted into electrical signal by voltage divide using a 10 k ohm resistor. In the 3-axis accelerometer the chip itself produces voltage output of X, Y and Z axes. These analog voltages values would be transformed into digital values. The process of digitization is done by analog to digital convertor (ADC) within the microprocessor. Hence, the digital output can be applied to observe variations in ISL word's gestures. Including the difference taken from samples either from a single-user or a multi-user, as the selection of features is based on these factors. This process begins at the press of calibration button on the Arduino lily pad, indicated by blueLED.

4.1 Feature Selection

Words in the dataset, were selected on the frequency of usage by the speech and hearing impaired people on the day to day life. The words are categorized prescribing emotions, public communication, workplace, services, offerings, etc. To recognize these words, a unique differentiation among sensor outputs is required. Flexion degree after calibration, is measured for each word in the dataset. The voltage ranges of no bend (), half bend () and full bend (). Similarly, the ACC axis ranges from X-axis (), Y-axis () and Z-axis (). Flex sensor bends are indicated as no bend-FB0. Halfbend-FB1, full bend-FB2. ACC measures are represented as X-axis (XA), Y-axis (YA) and Z-axis (ZA).

These regions are exclusively listed for each word in the dataset as shown in Table 2. It was noticed that flex sensor exhibits similar outputs for words 'Question', 'Month', 'Year', 'Family', 'Gift', 'Help' and 'Teacher'. To avoid this misclassification, ACC have been integrated into the SS glove.

Problems of same finger bending are overcome by estimating the inclination of the hand shape of the gesture by ACC. ACC yields three axes measurement wrt gesture hand positioning, palm parallel to ground indicates X-axis, perpendicular to ground indicates Y-axis and at an inclination to the ground indicates Z-axis. The words 'Month' and 'Year' mostly match in the finger bending, so to distinguish among them the X-axis of 'Month' fed an output of 3.45V and Y-axis of 'Year' fed an output of 4.01 V. The same pattern is observed to differentiate words like 'Family' and 'Teacher'. Finally, some words 'Gift', 'Help' and 'Question' are yet to be differentiated by the estimated of two other parameters Mean absolute deviation (MAD) and Root Mean square (RMS). ACC exhibit X-axis for both words 'Gift' and 'Help', so these parameters are employed for further classification. The MAD and RMS of 'Help' were 3.57 V and 3.11 V and for 'Gift' were 2.99 V and 2.05 V, respectively. Hence MAD and RMS serve as support to complete the classification with high accuracy.

4.2 Gesture Classification

In this glove, the gestures are classified into 18 classes using Support Vector Machine (SVM). An SVM is a supervised machine learning for multiple data classification, since it is theoretical and computational efficient. With the labeled support vectors (among the samples) and optimal hyperplanes, the decision of classes are taken. Raw data are converted into 1D support vectors using kernels and 2D using transforms. The decision boundary should consider all the points in the dataset as stated in Eq. (2):

$$y_i\left(w^T x_i + b\right) > 1 \text{ for } i = 1, 2 \ldots . N \tag{2}$$

where x is the sample in dataset, y is the label assigned to dataset, w is the width between hyperplanes and support vectors, b is the proportionality constant. The optimal decision boundaries are selected by satisfying the condition as in Eq. (3).

$$\text{Minimize} 1/2||w||^2 \tag{3}$$

The smallest distance between the support vectors is calculated for the entire sample size and minimized for optimization purpose. For each correct classified word label y yields +1 and incorrectly classified word yields −1 known as neutral class.

In this SLR, n-classes of SVM classifier are required to distinguish one class from the other. These classifiers average is estimated to a parameter called confidence value. Higher the confidence value (greater than 0.5) indicates the higher probability of selection of the corresponding class.

4.3 Feature Extraction

For the ISL words classification, a feature vector X has been considered which is comprised of 16 built in features. Features were flex sensors over the ten fingers, 3 readings from each ACC over two hands. This feature set is unique for 18 words in the dataset. On collective basis, the total amount of sample size is given as per Eq. 4.

$$\text{No. of samples size} = (\text{No of subjects}$$

$$\begin{aligned} &\times \text{sampling rate} \times \text{no. of signs} \\ &\times \text{time duration} \times \text{iteration}) \\ &= (24 \times 100\,\text{Hz} \times 18 \times 10\,\text{sec} \times 6) \\ &= 25,92,000 \end{aligned} \quad (4)$$

Hence, 25,92,000 sample dataset are trained using SVM in a similar procedure for all words and calculate the accuracy, which is illustrated using a confusion matrix as in Fig. 5. A confusion matrix is a diagrammatic representation of the performance of the classifier and computes performance metrics as mentioned.

(1) Accuracy = TP + TN/(Total)
(2) Misclassification Rate = (FP + FN)/total
(3) Precision (P) = TP/(TP + FP)
(4) Recall (R) = TP/(FN + TP)
(5) F-Score = 2[(P × R)/(P + R).

5 Results Anddiscussion

5.1 Experimental Results

Words were classified into three groups: Home, Public and Work as in Table 1. For the purpose of observing the notable variation, for instance two words 'Children' and 'Gift' are considered. The gesture for the word 'Children' is that both hands are half bend and with both palms facing toward ground side as each finger is bent to form a triangular shape.

The 'Gift' word gesture was indicated with both hand fully bent and placed over each other in the horizontal direction. Fig. 6a depicted a typical example of the flex sensor value plotting for the words 'Children' (blue) and 'Gift'(orange). The regions which are analyzed are similar to those mentioned in the Table 2. Large and unique variations could not be observed from the flex sensor output which leads to misclassification of words. To solve this, sensor fusion technique has been employed by the inclusion of ACC as shown in Fig. 6b, which yields clear distinction as increase in the Y-axis of the ACC for the word 'Gift'. By similar ways the misclassification is reduced and the accuracy rate has been increased by 30.2% from the first version to the second version for words 'Question', 'Gift', 'Help' and 'Year' in Table 2.

Still there were minor misclassifications present in the second version. This was due to the smaller difference in flex sensor and ACC voltage outputs for the most subjects. Thus, half bend was interpreted as no bend and X-axis was combined with Y-axis reading. For instance, while considering words 'Answers' and 'Teacher' both the similar regions for flexion vector of index and middle fingers and in the same X-axis which produce false classification. To invariant these rates two additional parameters were trained in SVM.

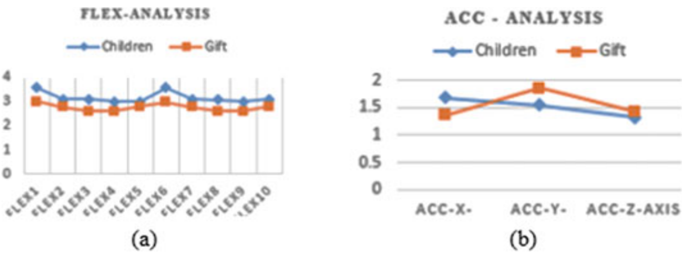


Fig. 6 Sensor plot for 'Children' and 'Gift' **a** Flex sensor variation **b** ACC variation over both hands

Sensor outputs have heterogeneous features based on time domain, frequency domain and time-frequency domain. From these time-frequency domain characteristics are more complex and time consuming than time-domain characteristics. Therefore, time-domain features have been preferred as they are more advantageous. The first parameter determined was Mean Absolute Deviation (MAD) is a method of calculating average distance from each output to mean. MAD tells how the values in the dataset have been spread which have been analyzed by the Eq. (5).

The second parameter computed based on sensor output was

$$\sigma = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \text{mean})^2}{N}} \tag{5}$$

Root Mean Square (RMS) is the square root of the mean or average value of the squared function of instantaneous value of any AC sinusoidal and non-sinusoidal signals. RMS value can be calculated by Eq. (6).

$$r_{MS} = \sqrt{\frac{1}{n}\sum_{i=1}^{n} x_i^2} \tag{6}$$

From the Table 2 it is observed that, sensor output modifies as per the ISL gestures. These outputs are presented along with their standard deviation values. On examining, the gestures can be judged and varied. This was done by the variation in the assessment of the Mean Absolute Deviation (MAD) and Root Mean Square (RMS). Similar approach can be done for all other word's ISL symbol and gesture can be recognized to their corresponding words.

6 Conclusion

In this study, the specialized SS Glove has been designed and implemented successfully as a smart device to recognize the ISL words using SVM. A voice module with speaker translates the recognized gesture into voice in a time and portable efficient manner. The device was tested personally with the subjects and collected feedback in terms of accuracy, comfort and cost. Depicted in Fig. 6. This glove would serve as an aid to communication from speech and hearing impaired people of age ranging from 15 to 50 years. Kinesics of ISL is conquered by both the right and the left hands. Sensor fusion of Flex sensor and ACC are used to improve accuracy from 74.12% to 97.2 %. Some of the demerits of glove-based system would be to make the gesture movement cumbersome and weigh high due to sensors, which can be rectified in future versions. The possible extension of this proposed glove would be miniaturization of the entire device, inclusion of sentence structure of ISL and experiment gestures of other SL as ASL, JSL, etc.

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Chapter 9
Simulation and Analysis of Rural Energy Systems Based on Multi-criteria Decision-Making Methods

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Abstract The aim of this study is to analyze and simulate the rural energy systems using multi-criteria decision-making approaches. Firstly, study identifies the all the criteria such as; cost, sustainability, reliability, durability, social acceptance, efficiency, and safety factor from various literature and reports. Then all the alternatives are highlighted likely; wind, solar, biogas, firewood, and micro-hydro, etc. Thereafter, a hierarchy is developed keeping in mind the goal is at the top layer, criteria at the second layer and alternatives at the final one, respectively. In this study WSM and WPM two multi-criteria decision-making approaches are utilized to select and evaluate the optimum energy system. Result shows that wind energy is the optimum system followed by others.

Keywords Renewable energy sources · WSM · WPM · Multi-criteria decision-making

1 Introduction

Energy is considered one of the crucial elements in the development of sustainable economy for any region. Urban region is quite often using resources of energy compared to rural one. In rural areas it's difficult to cultivate energy from different resources because of various constraints. From plenty of abandoned resources, solar energy is one of useful renewable energy sources; and is the energy from the sun transformed into thermal and electrical energy for utilization purposes. Almost all the states in India have installed solar photovoltaic (PV) residential lighting systems, making solar energy the most electrified renewable energy source overall. Another

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critical source, wind energy, plays an important role in rural economic development horizon. It is the world's fastest-growing energy source, and rural areas can benefit a lot from it. Wind energy is an emission-free resource. It is generated using a wind turbine. Wind turbines create significantly less effect on farming and ranching in rural areas. Turbines footing occupies considerably less space; thus, crops can be planted beside the ground, and it can't affect the crops. Projects on wind energy create jobs, provide resources for farming and ranching, and increase the local tax base in rural areas. Wind energy generated in rural areas can be transmitted to other sites by connecting it to the regional utility grid system. The solar cell design of Russell Ohl, which is utilized in many contemporary solar panels, was initially employed by BELL labs in 1954 to produce the first silicon solar cell that was economically feasible. India receives 200 MW/km^2 of solar radiation on a daily average. The rural area is home to about 60% of the population, giving the solar business a huge opportunity to investigate. India's rural areas still don't have consistent access to energy [1, 2].

In rural locations, using solar electricity is an obvious, less expensive choice. The significant advantage of solar energy in rural locations is, its improved accessibility. The nation's electrical grid does not extend to them. Even worse, expanding the power grid is very expensive. Natural degradation of organic materials leads to the formation of biogas by bacteria under anaerobic conditions. Anaerobic digestion converts raw materials into biogas, a sustainable fuel that can be used to run, heat, or fuel cars. Anaerobic digestion (AD) of waste and deposits from agriculture and industry, city natural waste, sewage overflow, and other sources is now one of the most enticing sustainable energy options. The use of biogas for producing energy, such as power, heat, and fuel, with additional financial, natural, and environmental benefits, is made possible via anaerobic processing. The majority of modern anaerobic digesters provide heat and electricity in combined heat and power (CHP) plants, heat-only power plants, and power plants [3, 4]. Wood is utilized as a fuel in the form of firewood. It takes the shape of branches or logs. Softwood and hardwood are the two categories. It can be replenished locally or regionally as a renewable resource. It was the first source of energy used by mankind and is still used today for residential and commercial needs. It is frequently utilized all around the world. It is widely used all around the world since it is plentiful and renewable. The use of firewood as fuel is much older than civilization. Before the use of coal, firewood is man's hydrocarbon fuel. In a remote area that doesn't yet have any electricity-generating machinery, a self-producing facility is being created. Micro-hydro-based power plants are being researched as sustainable energy sources since they can provide electricity at a low cost. For this project, a model grid-connected power-producing system of hydro energy use and hydro energy potential from irrigation canals with a low head but a continuous water flow is being investigated [5, 6]. In this study an integrated model is presented for the optimum selection of rural energy systems for sustainability.

2 Literature Review

Wind energy is the last energy source to be stored. Installation of wind turbines-Installation requires a good wind site. Wind energy helps to reduce pollution and provide energy supply during uncertain times. Conserves water resources. It can displace natural gas, reducing the pressure on natural gas prices and demand. Wind energy is better than conventional power plants since the latter uses a large amount of water to generate power from fossil fuels. So, wind energy can be used in drought-stricken areas. It is cost-efficient, sustainable, creates jobs, and is a clean, domestic fuel source. It can be built on existing farms. Electrochemical batteries or the grid can be used to store the electrical energy generated by solar energy. Thermal mass and water tanks are used to maintain solar heating. In several countries, there is an increase in biogas production facilities for treating wet-waste biomass, landfill gas recovery, and wastewater treatment plants. Infusion into the flammable gas framework or use as a car fuel for biogas that has increased biomethane content is expanding [3]. In contrast to developed nations, where biogas advancements concentrated on large-scale, ranch-based, and commercial, power, and hotness biogas plants, biogas is given in developing nations in small, domestically-produced scale digesters to supply fuel for cooking or, in any event, lighting. To promote family biogas systems that may give people biogas to cook with as a substitute energy source, reduce the need for firewood and stop deforestation, lessen indoor air pollution, and improve soil fertility, a variety of biogas support programs have been put in place. The collection of firewood and its harvesting varies from region to region. In some regions, it is collected from random areas, and in other parts, it is collected from only some particular places by following the methods like crop rotation, etc. The process of harvesting firewood is also diverse. Different tools and techniques are used for the harvesting of firewood [4].

The firewood is delivered to the location where it will be processed or utilized as fuel. The procedure of preparing firewood. When splitting and seasoning (dry) firewood, a maul or a wedge and hammer are typically used. Seasoning is done using a variety of machinery, including a robust electric pipe-threading machine that is safer than the other power sources, a hydraulic splitting machine, and a dedicated internal combustion engine. Hydropower is a cheap and generally abundant energy source because it uses kinetic energy, which is stored in the motion of the water. Both electrical and mechanical energy can be produced using water-flowing energy, often known as hydropower. The entire energy from a hydroelectric reservoir is known as the hydro-potential energy, and it can be represented as follows [5];

$$E = m\,g\,h$$

Low water flows can produce hydropower; the available kinetic energy is:

$$E = 1/2\,mv^2$$

The potential hydropower can be expressed by the following:

$$P = 1/2\,\rho \mathrm{AV}^3$$

The potential power capacity of micro-hydropower facilities can be calculated using the characteristics of the hydropower that is now available. Micro-hydropower plants are regarded as environmentally friendly and sustainable energy sources. Because it employs natural resources like river flow or already-existing irrigation canals, this power generator doesn't need fuel. Micro-hydropower plants are widespread in potential areas because they are simple to construct and maintain. Water's kinetic energy flow through a shaft connected to the generator causes it to automatically revolve, providing electrical energy. In micro-hydropower plants, turbines are turned by an adequate discharge to generate mechanical energy. To gather data about 10,000 households from 371 villages scattered over 41 districts in India, the NCAER conducted a household survey. The following table displays the typical daily hours worked by luminaries by season (percent responses) [6].

To produce natural fertilizer and cooking fuel, the National Biogas and Manure Management Program (NBMMP) in India encourages the construction of family-sized biogas facilities. There were about 4.75 million homestead-sized biogas plants in operation in 2014, compared to the possibility of operating 12 million biogas plants, which could generate over 10 billion m^3 of biogas yearly (or roughly 30 million m^3/day). India aims to construct 110,000 biogas plants between 2014 and 2019. The biogas plants' previously implemented power restrictions were 179 MW in 2015 and 187 MW in 2016. Updates on the biogas and biomethane markets. A shift away from the production of electricity and heat toward the redesigning of biogas into biomethane has been brought about by several factors, including the development of biogas redesigning technology, and unfavorable financial aspects of power biogas plants, as well as new opportunities for use in the vehicle sector. This has raised competition between different biogas sources and opened up new prospects [7, 8].

Natural gas-powered vehicles (NGVs) can run on biomethane that has been converted from biogas, which is similar to gaseous gasoline in terms of methane content, subsequent gas content, and other factors. Biomethane can also be infused into petroleum gas matrix to replace flammable gas and supply conventional end clients (power plants, enterprises, and families). By using lattice infusion, it is possible to store biomethane for less money and make it available to users as needed. Lattice infusion can only function if the biogas office is situated close to a low-pressure petroleum gas network. An assessment of the provided biogas revealed that a modest but increasing proportion of biomethane is being used to fuel automobiles. The biomethane injected into the lattice must adhere to public quality standards. The rate of burning and the amount of heat produced are determined by the moisture level of the firewood. Usually, firewood is sold per volume. Normally, firewood is sold by the cubic meter, or.276 cords, which is the unit of measurement used in stores (In the metric system) [9] (Figs. 1 and 2).

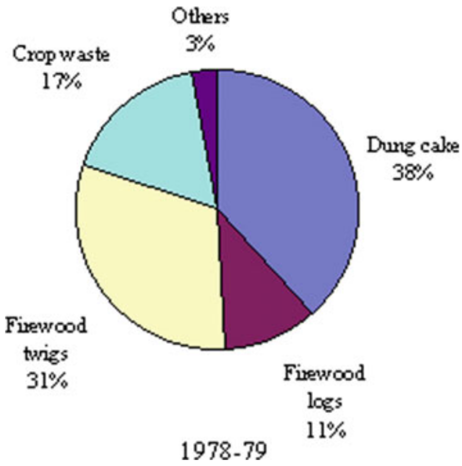

Fig. 1 Distribution of energy sources [9]

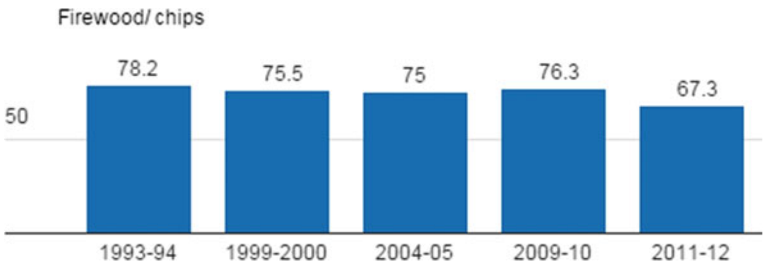

Fig. 2 Firewood/chips ratios for different years [9]

3 Methodology

In this study two-simplified methods of multi-criteria decision-making approaches are presented. Firstly, a hierarchy is developed based on the selected parameters. Thereafter, the methods are applied as per their steps.

The MCDM methods weighted sum model (WSM) and weighted product model WPM are simple methods based on the weight of importance. This method gives us the best rural energy system and also ranks the strategies accordingly [10]. The following criteria are considered in this study;

- SUSTAINABILITY-It is the ability to maintain at a specific rate. This criterion talks about the future availability of energy resources.
- DURABILITY-It is the ability to withstand wear, pressure, or damage. This criterion defines how long the resource can be usable.
- EFFICIENCY-The ability to achieve an end goal with little to no waste, effort, or energy. This criterion describes how efficient the rural energy resource is.
- COST-This is an essential non-beneficial criterion in this study.

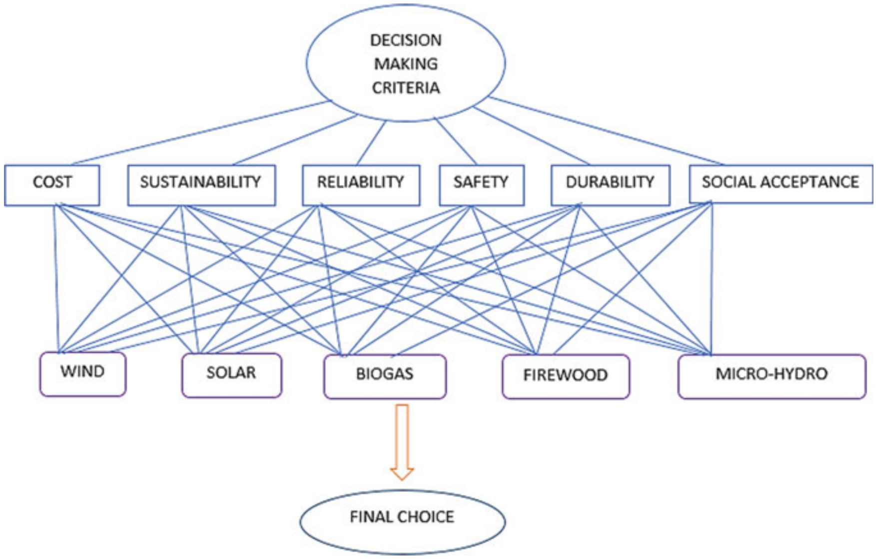

Fig. 3 The hierarchical structure of the problem [11]

- RELIABILITY-It is the ability to perform consistently well. This criterion describes how trustworthy the given rural energy resource is.
- SOCIAL ACCEPTANCE-The literature on the social acceptance of new technology focuses on industrialized civilizations; in developing nations, reservations about new technologies are frequently more profound and pervasive.
- SAFETY-This criterion ensures how safe it is to use the energy resource (Fig. 3).

4 Results

It is all about methods, including the software used to make decisions when multiple criteria are considered to choose between alternatives. Table 1 shows the decision matrix of the selected problem.

Based on the criteria considered, the optimization is done based on beneficial and non-beneficial criteria, and key conclusions are drawn and shown in Table 2. The results indicate that wind energy is mainly used in rural energy resources.

Table 1 Decision matrix and weightage

Type of renewable energy	Cost	Sustainability	Reliability	Safety	Durability	Social acceptance
Solar	9	10	5	9	8	8
Wind	7	9	7	8	7	8
Biogas	4	6	6	9	4	6
Firewood	3	4	3	2	3	3
Micro-hydro	8	7	7	5	5	5
Weightage	20	20	20	15	15	10

Table 2 Weighted sum model and weighted product model

Type of renewable energy	WSM	WPM
Solar	74.70238095	1.89E−17
Wind	76.7797619	6.74E−15
Biogas	71.64285714	1.58E−16
Firewood	55.5297619	3.12E−32
Micro-hydro	65.20833333	1.88E−21

5 Discussion and Conclusions

From the results obtained by WSM and WPM model in MATLAB, wind energy is considered the most desirable of all the alternatives when different criteria are considered such as: cost, sustainability, reliability, safety, durability, and social acceptance. WSM and WPM models were used to make the best decision in MATLAB. The results showed that wind energy is the most desirable of all the alternatives. The WPM and WSM values of wind energy are 76.7797619047619, and 6.73690027764774e-15. Solar energy was considered the 2nd most desirable among all the alternatives with a WPM value of 1.88506734112208e-17 and a WSM value of 74.7023809523810. Biogas is the 3rd desirable of all the alternatives. The WSM and WPM value of biogas are 71.6428571428571, and 1.58330502932916e-16. The micro-hydro is considered the 4th most desirable of all the alternatives; the WSM and WPM values are 65.2083333333333, and 1.87590716544301e-21. The firewood is considered the least desirable of all the alternatives; the WSM and WPM values are 55.5297619047619, and 3.11849771344879e-32.

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Chapter 10
Assessment of Sessional Solar Energy Using PVsyst and SAM

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Abstract The purpose of this paper is to present an assessment of energy production from a photovoltaic system over its first year of operation, along with a financial model for the system. In order to meet the modern era's needs, they are on the verge of exhausting our fossil fuels, natural gas, and coal resources. The use of solar energy is one of the vast renewable energy resources. Solar energy is one of the most abundant sources of renewable energy Photovoltaic systems (PVsyst) software has gained much popularity in this era due to its high accuracy and sustainability. Simulation software called system advisory model (SAM) is widely used to estimate the economic value of solar energy. Data set generated by HB-2, VNIT Nagpur, under different climatic and operating conditions is considered a PV system-generated data set. They have used a long-term data set taken from Meteonorm 8.0 source. SAM software was used to analyze the cost, savings, and economic data from the PVsyst system model. PVsyst simulation results showed specific energy production of 1535 kWh/kW/year. Simulated results show that without the system, the usage cost was $104,614, and with it, it was $62,512, with a simple payback period of 10.6 years. Solar energy assessment has become more accessible and robust through software such as PVsyst and SAM, which are proven reliable for estimation and valuable for case studies in developing countries.

Keywords Photovoltaic · Performance ratio · PVsyst · SAM

1 Introduction

Around the world, fossil fuels are scarce, coal. Global energy consumption has shown an increment of 2% since 2000 and it shows that by 2035 analysts predict that there

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will be an increment of 25%. The increase in power requirement will increase the emission of greenhouse gasses, making life on earth very problematic. To compensate for this growing need for energy and save the environment, there is a need to develop reliable renewable energy, both financially stable and a good energy source. Solar, wind, and hydropower are the most used renewable energy forms [1]. Solar energy is generated through an array of Photovoltaic cells containing various elements, mainly silicon which absorbs solar radiation and converts it into electricity through the PV phenomenon. Photovoltaic cells have shown rapid production growth, creating interest among various global investors. This paper portrays the simulation of PVsyst and its economic data which is done through SAM software [2, 3].

Financial efficiency is a critical entry point for a high-performance photovoltaic (PV) system. Your evaluation depends on whether the trustee predicts the outpouring of the system's life force. Input in one place, life force predictions are based on a range of parameters, including system configuration, system technology, and existing weather conditions. Considering how system losses vary over time with any system damage components is essential. The use of photovoltaic systems for power generation is most prominent in recent times. Therefore, reliable and Sustainable switch resources such as photovoltaic systems are needed. It hits the endless thing energy from the sun and converts it into electrical energy.

It is expensive as it has only purchase and installation costs. PV systems are environmentally friendly as they do not emit any haze-strong gases. Rising fuel prices are also one reason PV systems have gained popularity. As India is tropical, it is warm all year round and has abundant solar solid energy. Therefore, the use of solar panels has increased significantly in the country, trying as an India. The government also encouraged the use of PV systems by providing benefits and exemptions to the tax. In addition to these benefits, PV systems are also guaranteed to be evil. The efficiency of the PV system is based primarily on local climates. Not all regions near the globe have a tropical climate. Therefore, installing solar panels in these regions may not be possible. Also, cyclic variation seasons are an essential factor to consider. The overall efficiency of the PV system is influenced by various factors such as the material for a photovoltaic cell, installation method, tendency or position of the system, and planning.

One may think that the initial cost for the total equipment is too high, so they expect the appropriate returns from the system. To make this happen, a proper simulation should be carried out. They use system advisor model (SAM) to evaluate and to find the payback period and the amount generated from the system [4].

2 Literature Review

The observation from the papers is that designing work for the photovoltaic systems is mainly done in PVsyst software, and the economic data simulations are done in SAM software. The annual performance of the system is around 80% [5], and the improvements done in lead-acid battery technology increase the efficiency up to 70% over its working period [6]. Various studies during the last decade indicate solar energy added more capacity worldwide than any form of energy. The "Global trends in renewable energy investment 2019", commissioned by the United Nations Environment's economy division, paints a bright picture for the future of renewables. It reveals that from 2010 to 2019, the world has invested 2.6 trillion dollars into clean energy and boosted capacity from 414 to 1650 gigawatts. In 2019, renewables accounted for 12.9% of the world's electricity. This saved around 2 billion of carbon emissions and reduced environmental pollution.

The report generated by the United States in 2019 indicates that installing new wind and solar equipment was cheaper than maintaining coal plants in 70% of cases around the globe. It also suggests that developed countries like Australia could reach 50% renewables without making any policy changes against the environment. The United Nations Global summit, conducted on 23rd September in New York City, aims that solar energy should be the primary mode of replacing electricity from coal to prevent environmental pollution due to greenhouse gasses released from burning fossil fuels like coal, etc. India considers an essential target of achieving to generate at least 100 GW of solar energy by the year 2020 [7, 8].

2.1 Limitations in Study/Research

The PV systems power production is exponentially decreased in cloudy environments and low irradiance areas; current studies are only limited to ideal conditions for the systems. For these situations, excess power needs to be generated during the high irradiance and accumulated in the other forms of energy. To store the energy, good batteries need to develop which are affordable and efficient enough for a viable option [9]. Current research mainly involves the conversion of energy into mechanical or the production of hydrogen. Not a lot is done to store the point in the batteries. Most storage systems still use lead-acid, Li-ion can be used for better efficiency, but the cost is high. The battery technology needs to be further improved and massively produced. Further new battery technology is to invent.

The system's effectiveness slows down over time due to various degradation methods. The assessment of lifelong energy assumptions is based on mathematical formulas and considers different types of completion. Although this model is standard, it can have specific effects on climate and technology from degradation levels, and the perceived uncertainty can be changed depending on the location and PV system technology. PVsyst as software is magnificent in predicting the generation of a system. Photon.info was a very reliable source to update the component's data; for the time being, they are not operating, and this means most of the new technology components need to be added manually, which increases the possibility of human error.

PVsyst doesn't provide any details for after the side of the inverter. Unlike other software, PVsyst doesn't offer a single-line diagram and all the details that come with it. Sometimes, the simulated results don't make sense according to reality, but generally, excellent software to use and rely on for designing [10, 11]. SAM financial model uses the cash flow technique, i.e., saved money over its period, to analyze the project's financial system. The software is also used to design various renewable systems and assess the power output from different seasons in its working period.

There is a common misconception that SAM tools can completely mitigate your risk of a costly and disruptive audit. Studies show zero correlation between having a SAM tool and whether you will end up paying audit fees or how much you will ultimately pay. Access this helpful guide to understand limitations that can cause compliance gaps, and surprise true-up fees, double-paying for the same licenses, and incorrect SAM reporting [4].

Wind and solar energy conversion systems require an efficient control system for smooth operation of various components. Pitch angle control is crucial to the proper operation of wind turbine blades. Power converter control scheme is developed to generate PWM for IGBT switches. The simulated wind energy conversion system's computational results were acquired, and its performance is examined [12–14]. All control schemes are capable of controlling the system and making it capable of tracking the MPP, keeping all reactive powers below zero as desired. Comparatively to classical conventional systems, ANFIS provides better alternatives; they are faster converging, perform better, and exhibit less oscillation during steady-state conditions [15, 16].

2.2 Aim and Motivation of Study

The study aims to increase the production from the photovoltaic system. This can be achieved by simulating and considering various degradation factors like irradiance, shading, etc. Further research is to store the power generated in batteries and design a financially viable system to attract investors to shift to renewable energy.

3 Result and Discussion

This part of the report represents the result obtained by performing the simulation in PVsyst. PVsyst version 7.2 has been used for the simulation. The tilt angle and azimuth angles were 25° and 0°.

For the designed system, the total available solar energy throughout the year was found to be 544387 kW with a specific production of 1535 kWh/kWp/year, a performance ratio of 60.91%, and solar fraction SF of 96.35%, while the energy used was 425286 kW/year. The number of battery packs required for the storage of solar energy was found to be 1233, along with a capacity of 24660 Ah. The battery lifetime was estimated to be around 5 years, with cycles SOW of 95.8% and Static SOW of 80%.

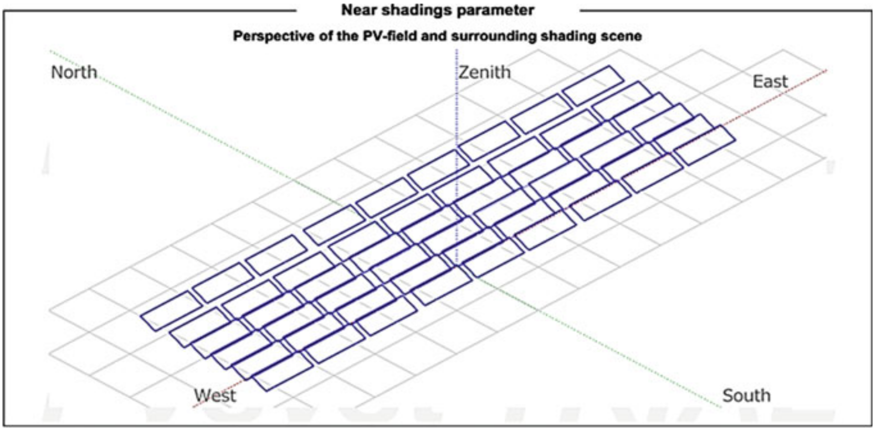

Fig. 1 Net shading parameter

The generated report of PVsyst consists of various details like different parameters of losses considered, sun orientation, placement of solar panels above sunroof with their tilt and Azimuth angles, battery along with PV system and its failures. The figure is shown in this report gives the picture of solar panels along with shading areas and inclinations and a few more critical information.

This section discusses the financial model generated. They show the monthly distribution of energy production of a 350 kW PV system in the first year of its operation, as shown in Fig. 1. The energy production decreased in the monsoon season, which is expected due to low solar radiance because of the clouds. This is the period where energy demand is also low. This type of system can be put to the maximum to save money. Figure 2 shows the normalized energy production, whereas Fig. 3 represents the performance ratio. Figure 4 shows monthly electricity supplied to the grid.

This section discusses the financial model generated. They show the monthly distribution of energy production of a 350 kW PV system in the first year of its operation, as shown in Fig. 1. The energy production decreased in the monsoon season, which is expected due to low solar radiance because of the clouds. This is the period where energy demand is also low. This type of system can be put to the maximum to save money.

The annual energy and various financial parameters, such as the amount saved in the first year and the payback period for the system are referred [4]. Considering the high initial cost of the system, this case study shows that it can pay back itself in the first half of its life with proper maintenance, and it can save more money in its overall life. The solar systems can be more profitable with an increase in the cost of fossil fuels, and the payback can even go down if the scenario happens in a period. Solar energy is a sustainable energy model for power generation and environmental protection. Power utilization in places with higher solar irradiance can be reduced by employing a simple PV system of 5 kW to reduce dependency on the government.

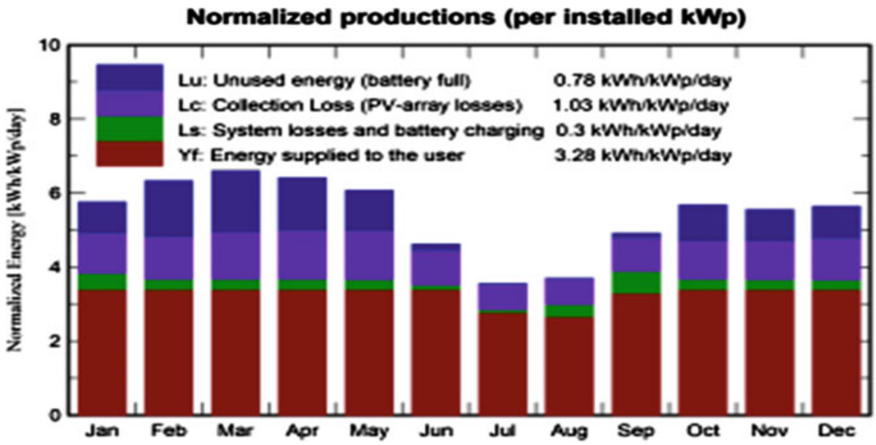

Fig. 2 Normalized productions

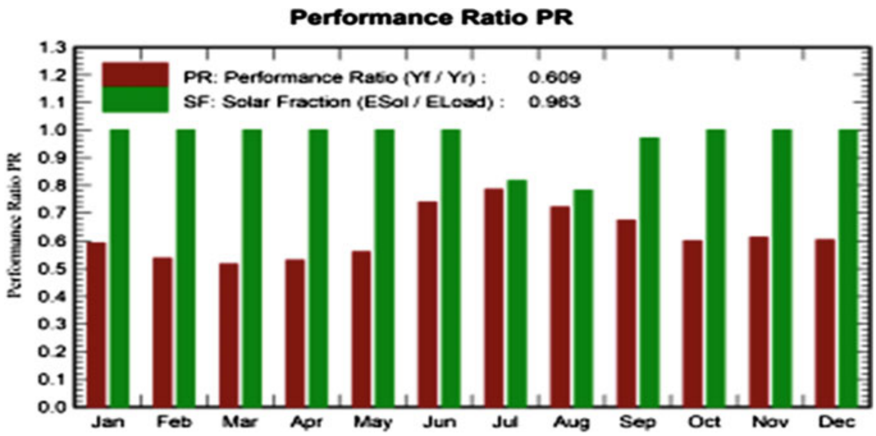

Fig. 3 Performance ratio

These types of studies can further be improved to provide an affordable PV system for residential places in high terrain regions where electricity is quite challenging or sites where fossil fuels cost more than solar energy. The case study shows a high amount of energy production in India compared to other countries in the northern hemisphere, but the solar degradation factor can go up to 2.8%. Thus uncertainties are to be considered in the assessment model; when an investor is interested in setting up a PV system, this can show a difference of 9 to 20%. Hence an investor should be aware of the financial risks for an extended period when sure profit is expected.

A further case needs to be done to improve solar energy production and the cost to use in commercial and automobiles to building a green environment.

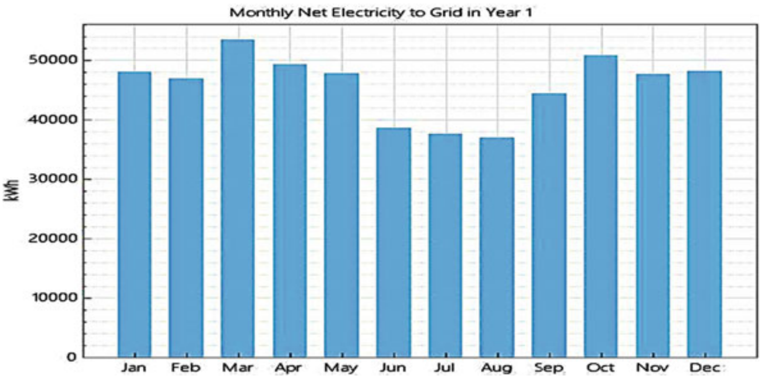

Fig. 4 Monthly net electricity to grid

4 Conclusion

This work focuses its high point on using solar energy by utilizing today's technology such as PVsyst and Sam software. PVsyst shows cases of a system model for the critical area and helps evaluate the total power, performance ratio, etc., by running the simulation. It provides accurate data with reasonable assumptions of degradation rates and uncertainty levels. SAM is software that helps in providing all the in-depth details related to the designed system's economy. For the chosen location HB-2, VNIT Nagpur, the data was acquired from Meteonorm 8.0 source. During different seasons throughout the year, all the required parameters are entered into the system, and the simulation is run. The required results were obtained, which stated the total energy available to be 544.38 MW/year and the performance ratio to be 60.91%, whereas the used energy was found to be 425.28 MW/year and the battery life was found to be 5 years. Later the system was analyzed by SAM software with the same parameters as obtained by the PVsyst results. The simulation was run, and the required results were obtained, which concluded that the design of data without the system costs $104,614, whereas with the system costs around $62,512. A significant difference in initial cost was observed when both the scenarios were compared. Thus, stating the use of SAM software is more helpful and prominent. The simple payback period came out to be around 10.6 years. It states the importance of using solar energy, especially these days due to the lack of availability of coal and petroleum in most countries around the globe. It is essential to use technology to restrict the initial setup cost, which is generally too high. PVsyst and SAM are one such software which was found to be very accurate and sustainable, making them available to the vast majority of the people and enhancing the use of solar energy for future generations.

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Chapter 11
Power Generation Using Municipal Solid Waste: A Review

Amit Atri, Anita Khosla, and Lalit Prakash

Abstract With increasing urbanization and the improvement in lifestyle there is an increase in electricity consumption and to fulfil that higher amount of resources are needed. Much dependence on fossil fuels for electricity generation is affecting the environment and their limited availability is promoting the search for alternative fuels. Increasing urban population is producing higher amount of Municipal Solid Waste (MSW). Due to improper management of MSW, most of the developing countries across the globe are facing huge problems–socially, medically, financially and environmentally. Depending on the type of waste material, different types of techniques are suitable for its treatment. Electric power generation using MSW gives a sustainable solution to both of these issues, i.e. waste management as well as increasing electricity demand. This paper reviews various techniques available both traditional and new for obtaining fuels and generating electric power using MSW with minimized adverse effects on the environment with special consideration in the Indian scenario 250 words.

Keywords MSW · Landfill gas · Steam methane reforming · Waste to energy · Incineration · Gasification · Anaerobic digestion

1 Introduction

With the expansion of economies, increase in industrialization, urbanization and the growing problem, waste generation is also increasing. Municipal solid waste (MSW) consists of garbage (mostly biodegradable organic compounds), common domestic appliances, paper, glass, metal and plastic objects. Mismanagement of MSW contaminates air, land and water. Mismanaged dumpsites become breeding places for pathogens, the collection or logging of water during the rainy season

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becomes breeding places for mosquitoes. With contaminated environment diseases, infections and allergies increase [1]. With the increase in MSW, dumpsites and landfill areas are overburdened. The biodegradable wastes degrade and emit methane (CH_4) and carbon dioxide (CO_2). Both of them are greenhouse gases causing environmental change. Methane is inflammable and so the risk of fire increases at the dumpsite. A sudden fire ignition at such a large feedstock will emit a huge amount of flue gases in the environment and will be very difficult to control. A liquid known as leachate is also produced which on passing through the waste matter absorbs contaminants and is very hazardous. Another issue related to the increase in urbanization and population is the scarcity of land which is more in metro cities.

Industrialization and improving lifestyle is enhancing the energy requirement. As of 31 Jan 2022, India has installed a generation capacity of 395,075 MW out of which 59.7%, i.e. 235,929 MW comes from fossil fuels including coal (51.6%), lignite (1.7%), gas (6.3%), diesel (0.1%) and 6780 MW comes from nuclear fuel. Renewable sources including hydropower constitute 38.5%, i.e. 152,366 MW [2].

As still most of the electricity is generated from coal (thermal power plants) which forms centralized generation. As per an analysis by TERI [3], thermal power plants emits SO2, CO2, NO_x and PM 2.5 in high amounts. In the year 2016, out of the total emissions, about 51% of SO2, 43% of CO2, 20% of NO_x and 7% of PM 2.5 was emitted by thermal power plants.

For transmission of power, a huge transmission network is needed correspondingly causing transmission losses. As per [4] about 22.77% of power is lost in transmission.

Distributed power generation includes the generation of electricity at or near load centres using locally available resources (usually renewable energy resources). These renewable energies are environment friendly and also do not require transmission thereby minimizing the transmission losses. However, most of the renewable resources (like solar and wind) are intermittent. So they are either used in hybrid power generation or they need storage which further increases the cost [5].

A solution for both of these problems (increasing MSW management and electricity requirement) comes out to be as power generation using MSW as fuel/source. The use of MSW as fuel for electricity generation is consistent.

2 Municipal Solid Waste in India

As per [6] India generates 141,064 tonnes of MSW every day out of which 127,531 (90%) tonnes/day is collected and 34,752 (27%) tonnes/day is processed. Garbage consists of organic matter (40–45%), inert matter (20–30%) and remaining are recyclable materials. Major cities are facing the problem of a rapid increase in MSW generation and consequently the trouble in managing that MSW and the land requirement, taking examples of major cities like Mumbai–Mulund dumping yard in 40 acres of land; Ahmedabad–Pirana dumpsite occupying 84 acres; Delhi–Okhla landfill occupying 40 acres; Hyderabad–Jawaharnagar landfill occupying 350 acres [7].

Faridabad is a district in the NCT of Delhi spread in 741 km^2. area and has a population of 1,809,733 [8]. Faridabad expectedly generates 1219 metric tonnes of waste every day [9]. MSW collected by Municipal Corporation Faridabad along with nearing Municipal Corporation Gurugram is dumped at Bandhwari landfill site. This landfill site occupies 30 acres of land and approximately 40 lakh tonnes of MSW is already dumped there. 40% of the total waste generated is wet waste and 30% is recyclable. Ecogreen Ltd. is setting up a waste to energy plant at this location [10, 11]. Forecasted the paper, food and biological waste till year 2025 for the city of Faridabad and the amount of energy obtained from it. It was predicted that in the year 2025 171,897 metric tonnes of paper, food and biological waste will be generated and on collecting 50% of that waste will give 5.29 MW energy. Correspondingly if 70% of the waste is collected then 7.40 MW energy will be available, for 80% collection the energy obtained, the energy obtained increases to 8.4 MW.

As per MNRE, India has a potential of nearly 1247 MW from urban solid waste [12].

Considering the state's coal availability, Jharkhand has the maximum coal availability of 83,152 million tonnes, followed by Odisha (79,295 Million tonnes), Chhattisgarh (57,206 Million tonnes) [13]. Considering the population then Uttar Pradesh has the highest population (237,882,725) followed by Bihar (124,799,926) and Maharashtra (123,144,223) [14]. This shows the lesser availability of coal where the requirement of electricity should be higher. Considering the amount of MSW generated, Maharashtra generates 22,570 TPD, Uttar Pradesh generates 19,180 TPD and Tamil Nadu generates 14,500 TPD per year [6]. So, MSW can be used as a locally available alternative fuel.

Delhi has installed three waste to energy plants totalling a capacity of 52 MW.

3 Methods of Obtaining Energy from Municipal Solid Waste

The best method of dealing with MSW is the reduction in the amount of waste generated and reusing of items at the source level itself. The management of MSW begins with segregation. As MSW consists of organic matter, recyclable matter and construction and demolition (C&D) wastes; all of the matter cannot be treated using the same technology. C&D waste is inert and cannot be used for obtaining energy. But it can be reused in construction work. The collected MSW is segregated and the C&D waste along with sand and mud is separated and is processed and supplied for use in construction work. Segregation of renewable items is done. Different items like paper, cardboard, plastic, PVC and e-waste can be recycled. Organic matter like food waste, kitchen waste, garden and park waste/residue can be used as a source for producing energy. Methods used can be divided under two broad categories:

(i) Thermochemical methods
(ii) Biochemical methods.

3.1 Thermochemical Methods

Thermochemical methods include the MSW subjected to high temperature resulting in production of energy or a fuel.

Incineration in Waste to Energy (WTE) Plants

Electricity can be generated by burning MSW in a similar method as used in a thermal power plant. The schematic diagram of such a power plant is shown in Fig. 1. MSW is segregated and is fed to the boiler and combusted. The superheater converts the steam from the boiler into dry/superheated steam which is sent to the turbine. The turbine is coupled to the generator which produces the electricity. Further, the steam can be used for building heating or can operate the building's cooling system thereby forming a combined heat and power plant (CHP).

On using CHP the system's overall efficiency can reach up to 80% [15]. Another cooling system was proposed by [16] using flue gas which was controlling liquid desiccant cooling system. The ash left at the bottom of the boiler after combustion can be used in cement mortar [17]. To increase efficiency and reduce corrosion, preheater and economizer are used [18]. Considering the CO_2 emissions from combustion of MSW techniques like carbon capture and storage (CCS) and carbon capture and utilization (CCU) can be used for reducing the CO_2 emissions not only from power plants but also in other industrial applications. CCS includes capturing and compressing CO_2 in a supercritical condition and then storing it at a suitable location (could be the depleted region from where fossil fuel is extracted). CCS technology is costly thereby increasing the overall cost of power generation [19]. CCU also captures CO_2 but utilizes it in the manufacturing of useful products as an alternative for conventional petroleum products [20]. CO_2 can be captured using

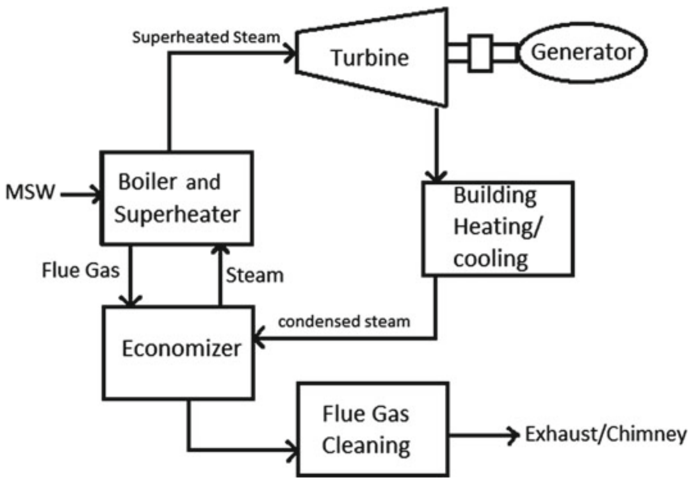

Fig. 1 Schematic diagram of WTE power plant using CHP

adsorption by (i) chemical or physical solvents like Piperazine [21], (ii) inorganic membranes, polymeric membranes and mixed matrix membranes; (iii) chemical looping (iv) directly capturing from air (v) combining two or more methods. The CO_2 captured can be used for (i) increasing the recovery of oil or gas from reservoir [22] (ii) production of fuels like methanol, ethanol, syngas, etc. [23] (iii) production of chemicals like urea, polymer synthesis, pharmaceutical products [24], etc. (iv) manufacturing stable mineral carbonates [25], cleaning of saline water [26].

Pyrolysis and Gasification

Components in MSW like food wastes, paper, rubber and textiles are suitable for thermochemical conversion. Pyrolysis includes heating of MSW (300–600) in the absence of oxygen. Products obtained from pyrolysis are solid biochar, liquid bio oil and syngas. Gasification is a process in which organic matter is treated with high temperature (approx. 700–1000 °C) in limited supply of oxygen and produces syngas/synthetic gas. Syngas is composed of hydrogen, carbon monoxide and small amount of carbondioxide. Constituents of syngas is affected by the type and composition of the feedstock [27], type of gasifier/reactor used and other conditions like temperature, catalysts and gasification agents, etc. [28] selected MSW containing kitchen waste, paper, wood, plastic, cloth and residue for catalytic pyrolysis and the products obtained were having higher amount of syngas (78.87%), lesser bio oil (5.13) and tar (14.92%). He et al. [29] studied the performance of different gasifiers and found that fixed bed downdraft gasifier is comparatively better in handling ash content in the feedstock, tar and char produced during the process, which thereby increased the purity of the gas produced. Moisture content in the feedstock is also decreases the efficiency and needs to be minimized. For increasing the efficiency, the segregated MSW is shredded and dried before fed to the gasifier. The syngas produced is cleaned, i.e. different impurities like ammonia, sulphur, hydrogen sulphite, etc. and can be used for generating electricity if used as a fuel in

(i) Combustion engine
(ii) Integrated gasification combined cycle
(iii) Fuel cell.

(i) Combustion engine

Syngas is much suitable in to be used as a fuel for an internal combustion engine (ICE) as an alternative for natural gas [30]. ICE is less affected by impurities in syngas. However, they are less efficient when compared with CNG. Syngas can be dual fuel in compression ignition engines. Also, it can be used in diesel engines which is also environmentally friendly. Dual fuelling (syngas with diesel) is needed as the ignition temperature of syngas is higher than diesel which avoids ignition by compression. The main components of a combustion engine-based generating system are shown in Fig. 2. Here the speed governing system takes input from the output frequency of the generator which is mechanically coupled with the engine and correspondingly regulates the fuel supply to the engine thereby maintaining the frequency. The output voltage is maintained by the voltage regulator controlling the generator field voltage.

Lieuwen et al. [31] studied the impact of H_2 and CO_2 in syngas on the performance of a four-stroke engine with diesel added to form dual fuel increasing efficiency. Another similar study was done by [32] on direct and spark ignition on different loads and reported better performance on higher loads. These studies preferred supplementing diesel with syngas which decreased the overall fuel cost and also decreased NO_x and particulate matter emissions.

(ii) Integrated gasification combined cycle

In this process, organic matter is gasified and syngas is produced. As the process of gasification takes place at a higher temperature, the heat used in gasification is further utilized to produce steam. This steam is used to run steam turbines and produce electricity. An IGCC system is shown in Fig. 3.

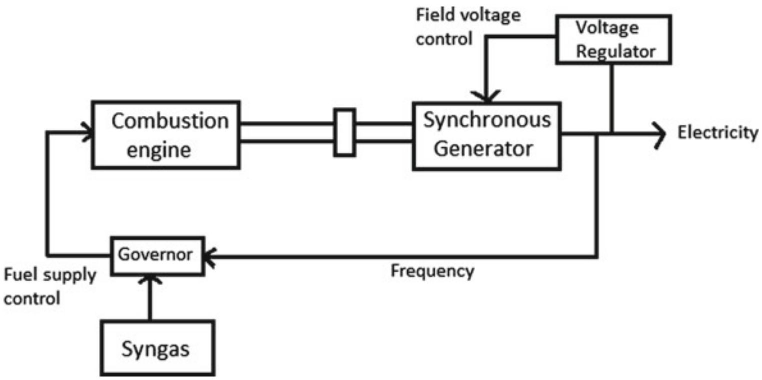

Fig. 2 Typical combustion engine and generator system for power generation

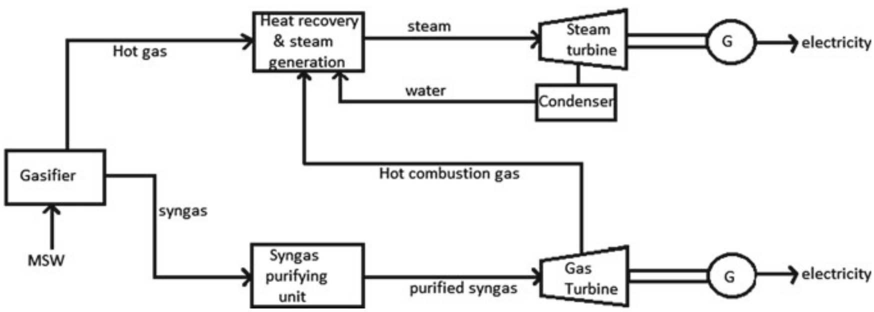

Fig. 3 Integrated gasification combined cycle system

The syngas produced from gasification is conditioned, impurities like CO_2 are removed and hydrogen content is increased using water gas shift reaction. The conditioned syngas is then used to run a gas turbine (GT) which produces electricity. The efficiency of the system is increased. Sahoo et al. [33] proposed an IGCC system with and without CO_2 capture. By CO_2 capturing the power obtained was higher.

(iii) Fuel cell

A fuel cell is an electrochemical energy conversion device that continuously converts a part of free energy change into chemical energy. As long as hydrogen-rich fuel gas is supplied to the fuel cell it produces electricity. Depending on the type of fuel cell, the purity of the supplied fuel is desired. Solid oxide fuel cell (SOFC) which works at a high temperature of 600–1000 °C is most suitable for producing electricity. Asif et al. [34] developed an electrochemical reduced-order model for a SOFC and studied the effect of temperature. With a temperature rise the output of SOFC increased. A typical fuel cell is shown in Fig. 4.

Jin et al. [35] studied the effect of tar on the performance of SOFC. The performance of SOFC was inferior and a high amount of carbon was accumulated at the anode of the fuel cell. Syngas needs pre-processing to be suitable for a fuel cell using techniques like hot/cold gas treatment, scrubbing, etc. [36, 37] Integrated the gasification process with high-temperature fuel cells. The heat required for gasification was used for the fuel cell thereby increasing the efficiency of the system.

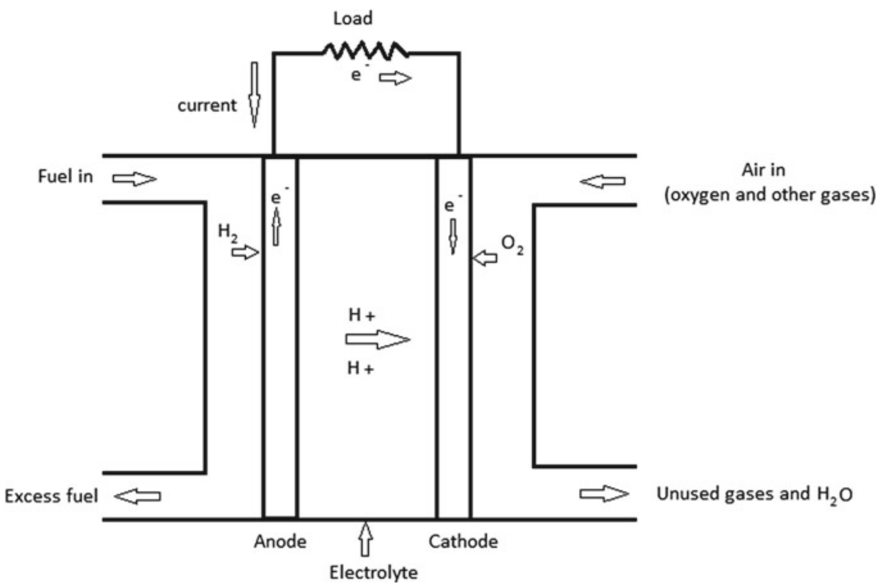

Fig. 4 Schematic diagram of fuel cell

Biochemical Methods

Biochemical methods include the action of microorganisms on MSW in some specific environment resulting in production of a fuel.

(i) *Anaerobic digestion*

Landfill gas (LFG) consists mainly of methane (40–50%) and carbon dioxide (50–60%). Methane and carbon dioxide are greenhouse gases; methane has 25 times higher potential than carbon dioxide for global warming. LFG is produced when MSW is dumped in the landfill sites, in the absence of oxygen, by the process of anaerobic digestion due to the action of bacteria, i.e. Organic components in MSW are broken down by anaerobic bacteria and produce methane-rich LFG [38]. As per [39] about 50–100 m^3 of methane is generated by each tone of MSW. This methane/LFG can be used for electricity generation, combined heat and power (CHP) plants in place of natural gas.

The base/bottom of the landfill site is consists of a lining of sand, clay and plastic to avoid leakage of leachate to the ground. The leachate produced in the landfill is pumped out and stored or can be further processed. LFG accumulates in wells in the MSW and is collected via pipes and supplied further as fuel. Common methods of generating electricity from LFG are via engine generator set or gas turbines as shown in Fig. 5.

In engine generator set; an LFG powered combustion engine is coupled to a generator–similar to syngas engine generator system. This method is suitable for distributed power generation having a power level up to 3 MW [40]. Gas turbines (GT) are commonly used for CHP systems. LFG is used to power a gas turbine which is coupled to a generator. The heat in the exhaust emission of the GT is further utilized for heating purposes which increases the overall efficiency (up to 80%). These GT systems are used for generating up to 5 MW of electric power.

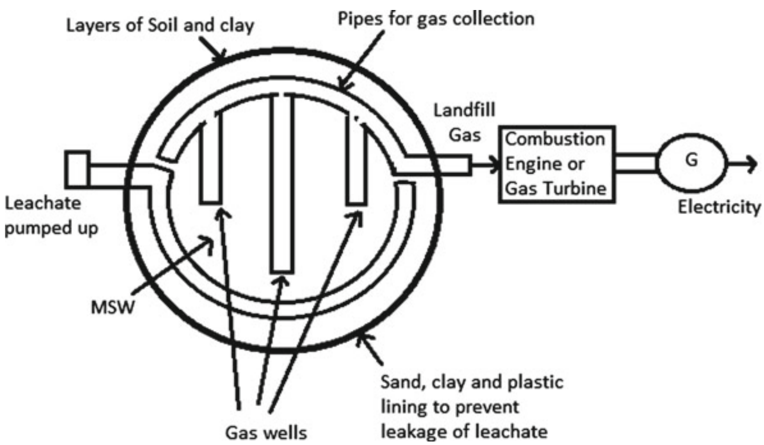

Fig. 5 Landfill gas collection and power generating system

One more approach for generating electricity from LFG was proposed by [41]. Landfill gas was purified and methane was extracted. Hydrogen was produced using the steam methane reforming process. Currently, 48% of hydrogen production is from natural gas. So this approach gives a renewable alternative fuel for hydrogen production. This hydrogen can be used for producing electricity by a fuel cell. This method is also suitable for low-temperature fuel cells like alkaline fuel cells and polymer exchange membrane fuel cells.

Energy from Leachate

Landfill leachate consists of a high amount of pollutants and if it is discharged untreated it may contaminate land and water thereby affecting human beings and other organisms. Leachate can be treated using biological, chemical and electrochemical methods. The electrocoagulation method for leachate treatment is simple easy and efficient. In the process, electricity is applied to the two electrodes placed in leachate. The contaminants present are coagulated and become dense [42]. Asaithambi et al. [43] studied hydrogen production by electrocoagulation of leachate using three different types of electrodes (Aluminium, Nickel and Iron) with changing pH and applied voltage using response surface methodology. On selecting a sample of 800 ml leachate, applying 9 V voltage and pH value of 4; Nickel electrode evolved 809 ppm of hydrogen, Aluminium and Iron electrodes evolved 697 ppm and 554 ppm, respectively. On increasing the pH value, the amount of hydrogen produced by the Nickel electrode reduced but Aluminium and Iron had little change. On reducing the voltage, the hydrogen production was reduced.

Mana et al. [44] studied the process of hydrogen production by fermentation of leachate on varying temperature and pH values. The study was conducted on pH values of 6, 6.5 and 7.2 at 37 °C. Also, hydrogen production on the addition of sewage sludge, sucrose and glucose with the main substrate (leachate) was studied. Further, to maximize hydrogen production, the activities of methanogenic bacteria was reduced and hydrogen forming bacteria on prior heat and pH treatment of the substrate. The maximum output obtained was 5754 ml of hydrogen per litre of the substrate at pH value 6, approximately 37 °C temperature and mixing speed of 100 rpm (with higher speed process became inefficient).

Hydrogen production from supercritical water gasification of leachate was studied under different conditions by [45]. Hydrogen production increased by adding catalysts. Four catalysts used were sodium hydroxide, potassium hydroxide, potassium carbonate and sodium carbonate. The temperature was varied from 380 to 500 °C and the percentage of leachate in the substrate was varied. Output gas obtained from gasification consisted mainly of hydrogen and methane. Maximum hydrogen production was 70.05 mol per kg of the substrate which came on using sodium hydroxide as a catalyst at 450 °C temperature with 15 min retention time.

4 Discussion and Conclusion

Different technologies are available for obtaining electrical energy from MSW. Considering Indian scenario, management of MSW is becoming difficult due to the rapid expansion in urban population more specifically in big cities. Dumpsites are getting loaded beyond their capacity. Search for alternate sites is also becoming difficult due to scarcity of land in big cities. With increase in earnings, the energy consumption is also increasing. Distribution of fossil fuels like coal is not uniform. In this case MSW can be a prominent alternative fuel as–higher the population, higher MSW generated. Further the waste generated needs to be efficiently collected. India is having advantage of cheap and surplus manpower which makes manual waste collection efficient. Considering the composition of MSW, the segregation of MSW becomes important. Identifying the bulk waste generating areas in the city will help in this. Residential societies are one such area. Door to door collection as well as segregation is easy in such societies. Recyclable materials separated can be sold for reuse. The organic matter can be used for electricity generation using suitable technique. This will reduce about 75% of MSW.

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Chapter 12
Solar Power Probabilistic Prediction Using Random Forest Regressor

Jaskaran Singh Sohal, Vasudha Hegde, and B. Smitha

Abstract Variation in the energy from renewable energy resources like wind and solar energy sources have major issues in the way the power grid is handled as the output from the plant varies randomly in the short term. Predicting the energy output can reduce the challenges by proper planning the operation of the grid. In this direction, solar power forecasting by various models is gaining much importance. This paper proposes a solar power probabilistic prediction by using Random Forest Regressor model to generate prediction of the solar plant power output. The model performed satisfactorily with R2_score metric above 96% for the given data for two solar plants.

Keywords Feature engineering · Probabilistic prediction · Random forest regressor · Solar energy prediction

1 Introduction

Rapid boost of variable energy from renewable energy sources has not only quantitatively added value to the power grid but also infused more uncertainty to the grid. For the optimized and economical operation of the grid, the load balancing and scheduling along with generation optimization are necessary. As more penetration of the renewable energy sources results into more impact due to intermittency of the sources, suitable reserve power sources and storage systems are to be added to the system. However, the dependency on these reserve power sources may be reduced and also the highest benefits from the variable and reserve power sources may be achieved if the output from renewable energy source is predicted efficiently [1].

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1.1 Variable Generation Prediction

The practical prediction of variable power generation sources started as early as in 1990s in Europe especially in Denmark and Germany, when national grids with rapidly increasing levels of wind power penetration affected the performance [2]. In recent days, the U.S. is also experiencing a surge of renewable portfolios in California and Texas. This resulted into critical necessity of renewable energy prediction since accurate prediction leads to better management in terms of scheduling and dispatching of the reserve power plants thus improving the performance of the entire electrical system [3]. Power policy reforms like FERC order 764 [4], which requires ISOs/RTOs to offer scheduling in short duration in minutes, helps in increasing the penetration level of renewable resources and also introduces more flexibility for the addition of variable generation predictions into power system operations in trading electricity [5]. The duration of supply and operating mechanism of renewable energy prediction varies from different electric utilities. The time frame of the prediction depends on the scheduling and intervals of market operation, e.g., some utility companies update the entire system every five minutes, reducing the power variation due to the wind resources from one operating interval to the next. Generally day-ahead prediction is used by the utility company in making day-ahead unit commitment decisions and in reliability assessment while the real-time forecasts are used for economic dispatch with real-time security constraint [6].

1.2 Variable Generation Prediction Models

The latest technologies based on artificial intelligence and data science are used to build forecasting models and are continuously improved for a better forecast of variation in solar and wind power generation. The prediction model may be either a physical approach model or a statistical approach model.

(1) The physical approach model: This approach establishes the physical relationships between the various parameters like weather conditions, topography, solar irradiance, and the solar power outputs of the renewable energy source. The input data like numerical weather predictions (NWP), local meteorological sky imagers for tracking the movement of the clouds and demand data (the user) are used for prediction of output power, along with more topographical information about the characteristics of the nearby terrain and hilltop. The satellite systems data were used for tracking the clouds and solar irradiance is predicted up to 3 h in advance, beyond this, NWP method is usually used for the irradiance [7].
(2) The statistical approach model: This model establishes the connection between predicted solar irradiance from the numerical method of weather prediction and power generation by solar source directly by time series statistical analysis from data in the past. This method doesn't consider the physics of the system. This connection can be used for prediction even for the future plant outcomes.

(3) The Artificial Intelligence Learning model: The correlation between predicted irradiance and weather conditions and the power output generated as time series of the past are established by Artificial intelligence (AI)-based methods. Unlike statistical approaches, AI methods use algorithms that are able to relate when nonlinear and highly complex relations between input data and output power are to be related, and AI-based methods are preferred over statistical analysis. However, both the statistical and AI approach require high quality time series of data relating irradiance and power outputs from the past are necessary for training.

(4) The hybrid approach: Modern practical renewable power prediction models are usually a combination of physical and statistical models. The physical approach needs statistics to predict for more accurate forecasts, while the statistical approach needs the physical relations of output power production for accurate forecasts. The combination provides optimal performance by optimal shifting of weights between the physical approach-based forecasts and the statistical forecasts [8, 9].

The objective of probabilistic solar forecasting model is to determine probabilistic solar forecasts in the form of probabilistic distribution in hourly steps through a month of forecast horizon [10, 11].

In this work, solar probabilistic prediction by Random Forest Regressor has been carried out. This method is basically derived from Decision Tree algorithm [12]. Text classification and text extraction, comparing data statistically etc. are the commonly used applications of decision tree algorithm.

The Random Forest Regressor method, has the features that are randomly selected with each decision split. The reduction in correlation between trees is achieved by randomly selecting the features. This method improves the prediction power and results in increased efficiency. Less difficulty with the problem of over fitting, less sensitive to the training data for outlier, and pruning of the trees are the other advantages of Random Forest Regressor algorithm. The data having more missing values and its capacity to handle continuous, categorical and binary data make it best suited algorithm for high-dimensional data modeling. The features like bootstrapping and ensemble scheme makes Random Forest Regressor algorithm strong enough to overcome the problems of over fitting and hence there is no need to prune the trees. Besides high prediction accuracy, Random Forest is efficient, interpretable and non-parametric for various types of datasets [13]. The features of model interpretability and prediction accuracy provided by Random Forest are very unique among popular machine learning methods. Utilization of ensemble strategies and random sampling results into better accurate predictions and better generalizations in this method [14].

2 Solar Prediction Modeling-Methodology

Any machine learning model requires more data to predict the generalized outcome, but the data available may have missing values or unusual value's (outliers) which could ruin the predictions of the model if left untreated.

Thus data visualization is the best way to look at entire data and figure out anomalies or relationships between different features of the datasets. It helps in understanding the data and good understanding of data helps in creating meaningful variables for the model which could improve the performance of the model significantly, and the process of extracting, transforming, creating new features is called feature engineering.

All of the above steps are part of a process called data preprocessing or the essential step for treating the data for modeling or data preparation.

2.1 Forecasting Dataset

The data is collected at two solar power plants over 34 days (source: Solar Power Generation Data | Kaggle). Plant A is near Gandikotta, Andhra Pradesh, India and Plant B is near Nasik, Maharashtra, India. It has two sets of details with each pair having one power generation data and another sensor reading dataset. The power generation datasets are gathered at the inverter level and each inverter has multiple lines of solar panels attached to it. The sensor data is gathered at a plant level with a single array of sensors optimally placed at the plant.

The power generation data has the following features.

1. 'SOURCE_KEY': The source key in this file stands for the inverter id.
2. 'DC_POWER': Amount of DC power generated by the Inverter (source_key') in this 15-min interval (in kW).
3. 'AC_POWER': Amount of DC power generated by the Inverter (source_key') in this 15-min interval (in kW).
4. 'DAILY_YIELD': Daily yield is the cumulative sum of power generated on that day, till that point in time.
5. 'TOTAL_YIELD': This is the total yield for the inverter till that point in time.
6. 'DATE_TIME': Date and time for each observation. Observations recorded at 15-min intervals.
7. 'PLANT_ID': Plant ID—this will be common for the entire file.

The Sensor Readings Datasets Consists of the following feature

1. 'DATE_TIME', 'SOURCE_KEY', 'PLANT_ID' same as it was in the Generation Dataset.
2. 'AMBIENT_TEMPERATURE': This is the ambient temperature at the plant.

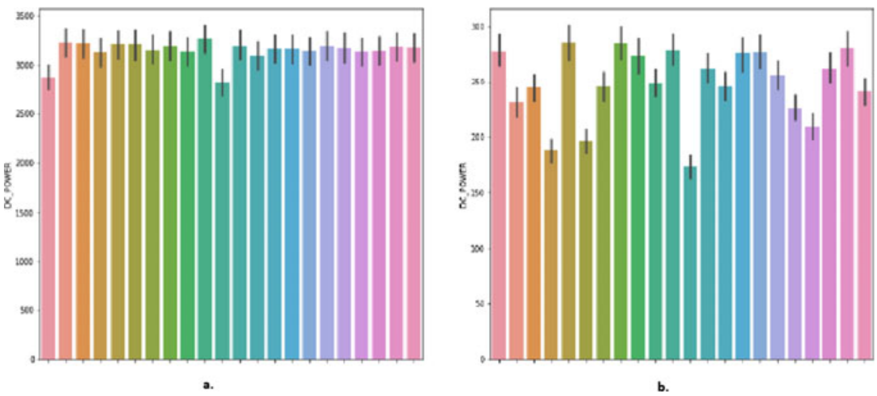


Fig. 1 **a** DC output power of different inverter sets for plant A **b** DC output power of different inverter sets for plant

3. 'MODULE_TEMPERATURE': There's a module (solar panel) attached to the sensor panel. This is the temperature reading for that module.
4. 'IRRADIATION': Amount of irradiation for the 15-min interval.

Now in order to get better insight from the data the different distributions, relationships, and correlations are plotted. Figure 1 shows the plot of SOURCE_KEY against the DC_POWER.

From Fig. 1, it is observed that each Inverter in plant A is having nearly the same DC_POWER output with very little deviation from the mean, whereas plant B has a large variation in the output of each inverter with a huge deviation from the mean, which indicates that that the machine learning model for the plant B may perform badly as compared to the model with Plant A data.

Figure 2 shows the distribution of the DC_POWER output. As we can observe from the histogram that most of the values are zero for both plant A and plant B. To investigate more about the reason for most of the values as zero, the plots of TIME versus DC_POWER in Figs. 3 and 4 are examined.

Since the data is collected for 34 days in the same year and month, prediction for the months and years may not be accurate or it may overfit on the data and whereas if the days versus irradiation are considered, it does not follow any trend and there's no significant difference in the output on the different days of the month. Hence, a specific day prediction is not considered.

TIME variable is extracted from the DATE_TIME and plotted against the DC_POWER as shown in Fig. 3. It indicates the Amount of DC_POWER generated each hour of the day in terms in box plot.

From Figs. 3 and 4, it is clear that there's no irradiation in the interval [0, 5] and [19, 24] and therefore is no DC_POWER and this explains the reason for more zero values of the DC_POWER in the dataset, but there are few inverters in the plant producing zero DC_POWER even when the IRRADIANCE reaches the maximum level, so the reasons for this anomaly may be,

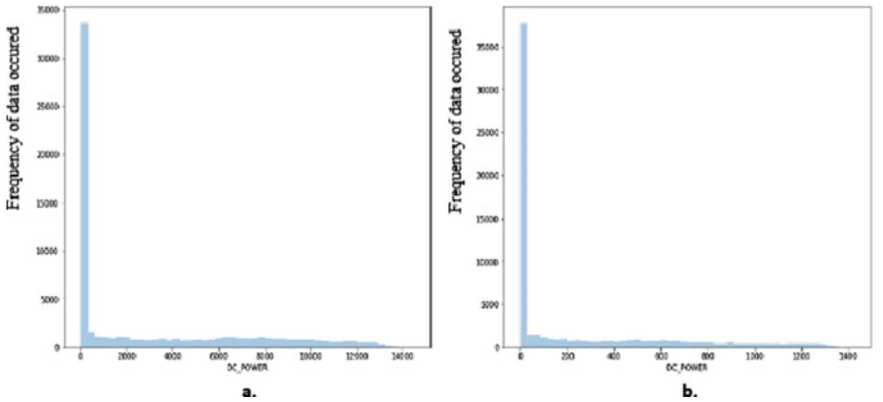


Fig. 2 **a** Histogram of variable DC power output for plant A. **b** Histogram of variable DC power output for plant A

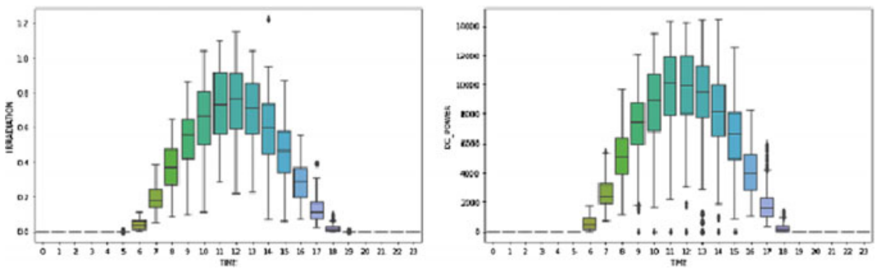


Fig. 3 Time versus irradiation and DC_POWER for plant A

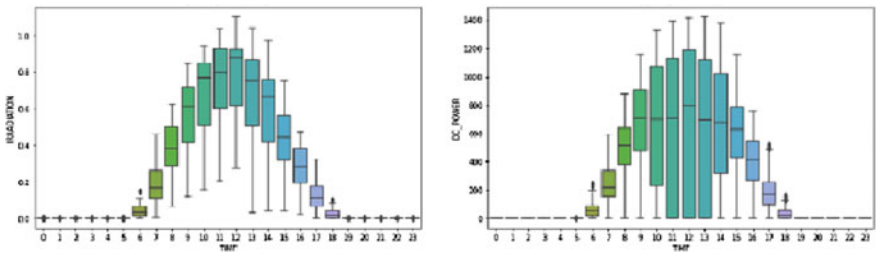


Fig. 4 Time versus irradiation and DC_POWER for plant B

- The inverters shut intentionally to meet the grid requirement.
- There could be a faulty working inverter or having been covered by dust to block the irradiation.

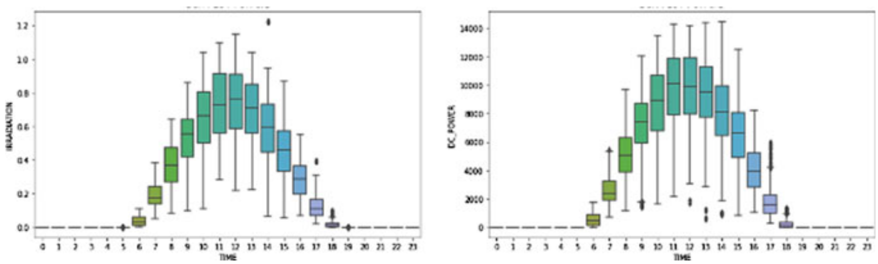


Fig. 5 Time versus irradiation and time versus DC_POWER with zero values removed for plant A

But, none of the anomalies are following any trend so we should remove them from the analysis.

Figure 5 represents the TIME versus IRRADIATION and TIME versus DC_POWER for both the plants, after removing the zero values. From the plots, it is observed that the quartile range of the hours in IRRADIANCE versus DC_POWER for plant 2 between hours [11, 14] has significantly reduced because of which the relationship of IRRADIATION and DC_POWER has improved significantly.

From Figs. 5 and 6, a categorical feature using time-variable called TIME_VAR is created. This indicates that the irradiation is zero between the interval [0, 5] and [19, 24]. So these ranges are assigned as 'ZERO_IRR' category and increasing irradiation between the intervals [6, 12] has been assigned it as 'INC_IRR' category and decreasing irradiation between the intervals [12, 18] we assign it as 'DEC_IRR' category.

The DATE_TIME variable in the predictive model as we have extracted the TIME variable from it, The DATE_TIME variable will be useful while plotting the DATE_TIME versus the predictions.

In the next step, the heatmaps are analyzed to understand the relationship between dependencies of the different variables like DC power output, temperature, time of the day, etc. with respect to each other. Figures 6 and 7 show the relationship between the different features of the dataset for plant A and plant B, respectively.

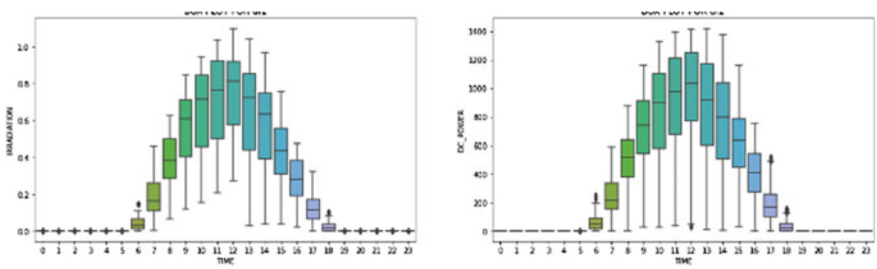
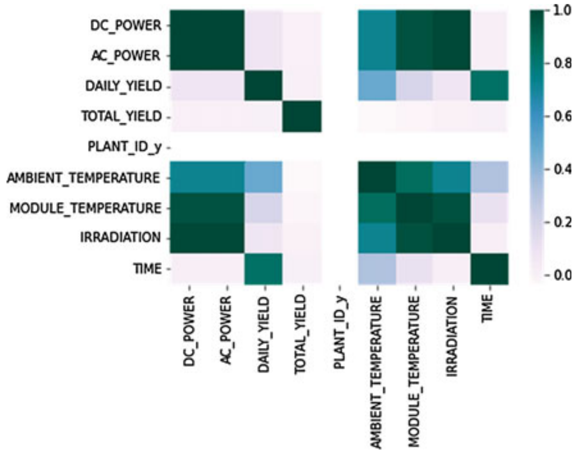


Fig. 6 Time versus irradiation and time versus DC_POWER with zero values removed form plant B

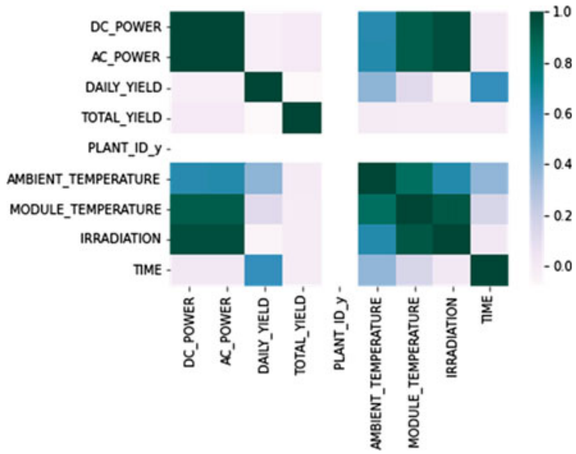
Fig. 7 Correlation heatmap for the plant A dataset



From Figs. 7 and 8 it is observed that,

1. The DC_POWER and AC_POWER are the highly correlated features since DC output from the solar panel is fed to the inverter to get the AC power, so AC_POWER is directly proportional to DC_POWER. It should be noted that there are two possible solutions viz. either predict DC_POWER or AC_POWER for better energy management. Since predicting DC_POWER of the solar panel gives better information, the AC_POWER variable has not been considered.
2. DC_POWER is positively correlated with IRRADIATION, MODULE_TEMPERATURE, AMBIENT_TEMPERATURE.
3. AMBIENT_TEMPERATURE, MODULE_TEMPERATE is positively correlated with IRRADIANCE.

Fig. 8 Correlation heatmap for the plant B dataset



```
<class 'pandas.core.frame.DataFrame'>
Int64Index: 68711 entries, 0 to 68773
Data columns (total 8 columns):
 #   Column               Non Null Count  Dtype
---  ------               --------------  -----
 0   DATE TIME            68711 non null  catctime64[ns]
 1   DC_POWER             68711 non-null  float64
 2   AMBIENT TEMPERATURE  68711 non null  float64
 3   MODIII F_⁻FMPFRATIIRF  68711 non-null  float64
 4   IRRADIA⁻ION          68711 non null  float64
 5   TIMF                 68711 non-null  int64
 6   TIME_VAR_INC_IRR     68711 non null  uint8
 7   TIME_VAR_Zero        68711 non-null  uint8
dtypes: datetime64[ns](1), float64(4), int64(1), uint8(2)
memory usage: 6.3 MB
None
```

FOR PLANT 1

```
<class 'pandas.core.frame.DataFrame'>
Int64Index: 64019 entries, 0 to 67697
Data columns (total 8 columns):
 #   Column               Non-Null Count  Dtype
---  ------               --------------  -----
 0   DATE_TIME            64019 non-null  catetime64[ns]
 1   DC_POWER             64019 non-null  float64
 2   AMBIENT_TEMPERATURE  64019 non-null  float64
 3   MODULE_⁻EMPERATURE   64019 non-null  float64
 4   IRRADIA⁻ION          64019 non-null  float64
 5   TIME                 64019 non-null  int64
 6   TIME_VAR_INC_IRR     64019 non-null  uint8
 7   TIME_VAR_Zero        64019 non-null  uint8
dtypes: datetime64[ns](1), float64(4), int64(1), uint8(2)
memory usage: 6.0 MB
None
```

FOR PLANT 2

Fig. 9 Information on dataset representation for plant A and plant B

Since PLANT_ID_x, TOTAL_YIELD, DAILY_YIELD doesn't seem to follow any relation with DC_OUTPUT variable, it is neglected.

Since the TIME variable is not correlated with the IRRADIANCE or DC_POWER, but this variable makes more sense to the model if created with the variable TIME_VAR as mentioned earlier.

After Observing the heat map, the variable's mentioned earlier like AC_POWER, DAILY_YIELD, TOTAL_YIELD, and PLANT_ID_y are neglected.

For the TIME_VAR variable, one hot encoding method has been used to convert it from categorical feature into numerical feature.

Now the data is represented as shown in Fig. 9.

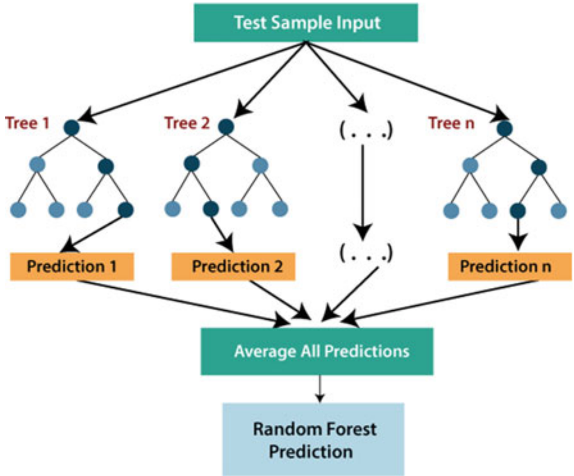
From Fig. 9, it is observed that there are no missing values in the dataset and the data is suited for a modeling process.

3 Modeling

Modeling has been carried out for the right selection of method for a particular data, training and tuning, testing the performance, and choosing the important parameter using feature importance.

The first step in the modeling is to split the data into train and test sets,

Fig. 10 The random forest regressor structure



Training set is used to train the model and testing set is used to test the performance of the model on the unseen data.

The model for this particular data used is Random Forest Regressor. Random Forest Regressor creates several decision trees using subsamples of the dataset and uses averaging to improve the predictive accuracy and control over fitting. Figure 10 shows the basic structure of the Random Forest Regressor.

From Fig. 10, it can be observed that test sample has been taken as input and is subdivided into several samples and if the samples are drawn repeatedly with replacement from the data the subsampling is called bootstrapping. Sampling and aggregating the result of each decision tree made from those samples is called bagging.

After modeling, all the features that are not important to the model can be removed using a feature importance plot as shown in Fig. 11.

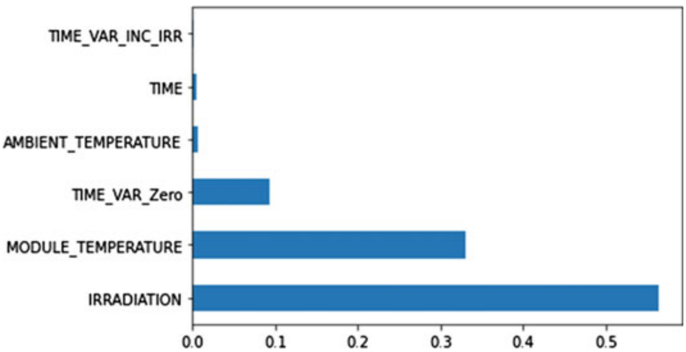


Fig. 11 The feature Importance plot

Removing redundant features from the model will reduce the dimensionality and training time which in turn prevent overwhelming predictions of the model. So after visualizing the feature importance plot, the parameters like TIME_VAR_INC_IRR, TIME, AMBIENT_TEMPERATURE are not considered and this will not affect the performance of the model.

It should be noted that, TIME_VAR_INC_IRR and TIME_VAR_Zero are the dummy variables of the variable TIME_VAR and these are obtained using the method of converting categorical to a numerical feature of one hot encoding method.

The metric called R2_score is used to evaluate this model. R2_score gives details on the percentage increase or decrease of losses in the model concerning the mean regression line, e.g., if the R2 score of a particular model is 96% then it means the model has 96% fewer losses than the losses that mean regression line.

4 Results

After feeding the test data of plant A and plant B to the model, it has been observed that, the R2_score for model of plant A is 99.154% and that for model of plant B is 96.57%. From the result, as it is evident that Plant B is having more variable DC_OUTPUT which explains the irreducible losses of the model for plant B as it can be seen from Fig. 1.

The predicted versus the actual output for plant A on different dates mentioned along *X*-axis is shown in Fig. 12.

Predicted versus the actual for plant A on different hours of the day is shown in Fig. 13.

Similarly, Predicted versus actual DC_OUTPUT on different days for plant B is shown in Fig. 14.

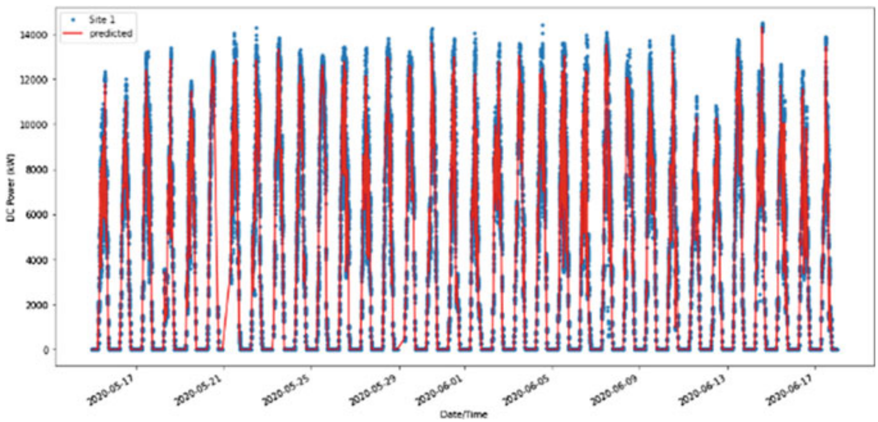


Fig. 12 Predicted versus actual DC_POWER for plant A on different dates

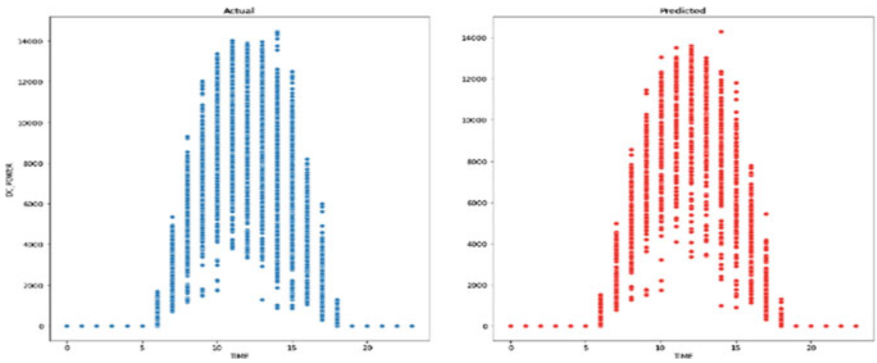


Fig. 13 Predicted DC_POWER versus actual DC_POWER on different hours of the days for plant A

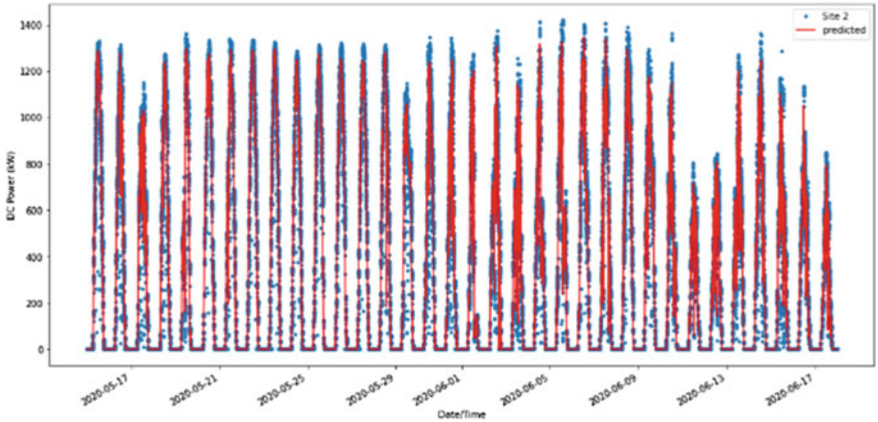


Fig. 14 Predicted versus actual DC_OUTPUT on different days for plant B

Predicted versus the actual for plant B at different hours of the day is shown in Fig. 15.

5 Conclusion

The Random Forest Regressor model performed well on the dataset for both plant A and plant B. The data available for 34 days have been used for training and plant A has the performance metric 99% and plant B has 96%. But in the available data, there are some inverters in both the plants producing very less output DC power though the irradiance is maximum, which the proposed model fails to explain. The reasons for these may be due to delamination, and corrosion, covered by the dust, etc. on

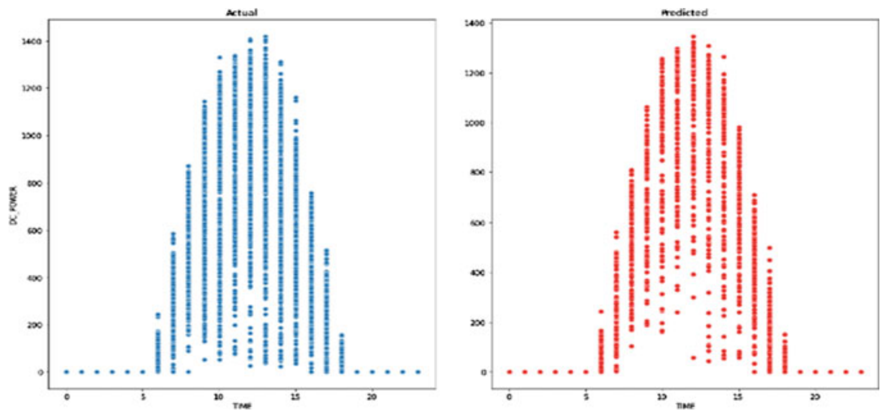


Fig. 15 Predicted DC_POWER versus actual DC_POWER on different hours of the days for plant B

the panel and inverter. The model will perform very well if these anomalies in the historic data are eliminated.

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Chapter 13
Impact of COVID-19 on Renewable Power Generation in India

Pankhuri Kaushik and Harpreet Kaur Channi

Abstract The rapid increases of COVID-19 pandemic have affected India and including many countries. In spite of serious and frightful effects on health, as well as in air quality. COVID-19 has also been detected in air and as well as in samples of sewage across the globe. This Corona virus waves has snatched many lives and also effected industrial sector and energy sector as well. India is a most populated country, because of pandemic government of India has imposed a nation worldwide lockdown in last week of March 2020 due to which there was a huge effect on sustainable resources development and infrastructure of renewable energy. As lockdown started, all industrial and transportation sectors were closed, demand of energy has reduced but there is an energy demand which has a critical effect on generation of energy as well as grid. In this paper the consequences of Corona virus and its challenges on non-conventional energy in India has been discussed.

Keywords COVID-19 · Pandemic · Lockdown · Sustainable · Infrastructure · United nation · Sustainable development · Environment

1 Introduction

Corona virus which is comes out from Wuhan as a most effected and transmitted virus or infection in the month of November 2019. But at the end of the June, this virus spreads in many of the countries worldwide, even it is transmitted all over the continents. United States of America was called epicenter of corona virus, because of having maximum no. of active cases of COVID. Corona virus became a challenge for people in respect of their health worldwide. On Feb 11 2020, corona virus was renamed as COVID-19, and also on Mar' 11th 20 WHO has announced COVID-19 as pandemic. The COVID-19 breakout is a huge shock for economy of India. The World Health Organization has announced social distancing in terms of reducing this virus. Government of India has taken the step of Lockdown in India. Due to

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lockdown, use of transportation systems like roadways, railways, airways have been restricted, which results in a huge reduction in oil worldwide [1]. This pandemic has affected Indian states in terms of industrial sector, sustainable development in renewable energy.

Renewable energy sources are the most important sources of energy generation. India secured rank third in large scale consumer of power generation globally and also secured 3rd rank in largest renewable energy manufacturer with 38% of power capacity at international level in the year of 2020 (136 GW of 373 GW) generating from renewable sources. This pandemic has impacted on demand of electricity in India. Non-conventional energy or renewable energy has impacted because of COVID-19. There was a significant delay in renewable energy supply chains due to huge downturn in economic activities. In this paper a brief impact of COVID-19 on renewable energy in has been discussed [2].

2 Indian Power Sector

Country has a great electricity technology capability however lacks good enough system of transmission and distribution support. Power sector of India is influenced by way of fossil fuels, particularly coal, which can generate approximately two third of India's electricity [3]. Government of country attempts in growing investment in non-conventional energy.

2.1 Installed Generation Capacity Sector Wise

The India's National Electricity Plan of 2018 states that the country does not need greater nonrenewable energy plants in the utility region until 2027, with the commissioning of 50,025.0 MW coal-based electricity plants production and addition of 275,000 MW general renewable strength ability after the retirement of almost 48,000 MW coal-fired plants [4]. Table 1 shows installed generation capacity sector wise.

Table 1 Installed generation capacity sector wise

Sector of India	Generation capacity (MW)	Percentage of total (%)
Central	98,327	24.90
State	105,314	26.70
Private	191,434	48.50
Total generation capacity	395,075	100.00

2.2 Installed Generation Capacity Fuel Wise

India's electricity region is one of the maximum diverse in the global. The source of electricity generation ranges from nonrenewable resources to feasible renewable inclusive of wind, sun, and agricultural and domestic waste. India is most populated country, so the demand of electricity in country increases at a very fast rate, and it is assumed that the demand of electricity in the coming years increases. To fulfill the challenge of power in the country, requires an enormous addition of installed generation capacity. India scored fourth ranked in wind power generation, and fifth ranked in generation of solar power and also fifth ranked in renewable power generation capacity as of 2018. India secured sixth ranked in the index of countries to have efficient investments in clean energy [5]. Among G20 nations, India is the only country which achieve the targets under the Paris Agreement. India's energy sector goes through an efficient modification that has reevaluate the industries outlook. Electricity generation in India is done with the use of non-conventional energy sources as well conventional sources. The installed generation capacity fuel wise is shown in Table 2.

3 Influence of Corona Virus on Energy Sector

The COVID-19 has impacted the demand of electricity generation. This pandemic has an adverse effect on energy sector which curbing the investments and also terrifying to downturn in extension of clean energy. It also caused an exhaustive downturn of economy activity in the whole India, as all industries scale down, working from home by the employees, and all the sector enters in a stage of lockdown. Because of lockdown, there is an adverse effect on energy sector of India. This lockdown has caused both short-term and long-term impacts on Indian economy [6].

3.1 Short-Term Impacts on Energy Sector

During the stage of lockdown, there is a significant impact on energy sector more widely. As the lockdown increases, it is seen that reduction in the usage of fuel, as a consequence of restrictions. Due to reduction in usage of fuel, there is a fall in economy, excluding the residential sector. As in lockdown every individual spends maximum of their time at home, due to which the bills of electricity and gas tends to increased. Transportation sector has been also slowdown in the meantime of lockdown, due to which there has been adverse reduction in the private and public transport usage. As a result, the demand of fuel for transportation purpose has dropped down. As we compared to month of March 2019 to March 2020, the total consumptions of petrol and its products has been dropped down by nearly 20%. The demand

Table 2 Installed generation capacity fuel wise

Category wise	Installation generation capacity in MW	Percentage of share in total (%)
Fossil fuels		
Coal	203,900.0	51.60
Lignite	6620.0	1.70
Gas	24,900.0	6.30
Diesel	510.0	0.10
Total	**235,929.0**	**59.70**
Non-fossil fuel		
Resources (include hydro)	**152,366.0**	38.50
Hydro power	**46,512**	**11.80**
Solar, wind and other resources	105,854	26.80
Wind power	40,101.0	10.20
Solar power	50,304.0	12.70
Bio mass power	10,176.0	2.60
Waste to energy	434.0	0.10
(Small) Hydro power	4840.0	1.20
Nuclear power	6780.0	1.70
Total non-fossil fuel	**159,146.0**	40.30
Total installed capacity	**395,075.0**	**100**

for aviation fuel has also dropped down by 30%, and the fuel used for roadways have also fall down between the range of 20–30%. There has additionally been a big drop-off in commercial and business energy intake, with employees running from domestic or constrained from getting into their standard offices. Since the begin of lockdown, total power demand is around 25% lower than same time in the last year. Electricity generation by the use of coal has impacted. All the sectors which are using nonrenewable also shifted to renewable energy sources for electricity generation. Renewable energy generation has also continued in COVID times. During 25th of march 2020, electricity generation from nonrenewable sources like coal has dropped down approximately 25%. It is shown that coal's energy generation drop down from 73 to 66% consistent with renewable energy and hydropower each growing from 9 to 11% [7].

3.2 Long-Term Impacts on Energy Sector

It will be an enduring monetary impact, instigated by the COVID-19, which may additionally bring about a recession. In the case of a monetary downturn, the demand of fuels will remain decrease than they might were in any other case, as other economic activities are limited. As seen in economic downturn, we might also see poor consequences at the availability of finance to deliver capital intensive projects of energy. Renewables, as an example, depend on efficient levels of capital, paying lower back over some of years. If the government achieve its bold goal of 450 GW of renewables, then measures may additionally must be taken to offer enough capital. Due to lockdown Up to 3 GW of solar projects have been behind schedule from coming out of China due to alternate regulations. As during COVID times the international travel were restricted and potential of economy go slower, there was be bad effects on supply chains which can be essential for the energy industries, again effecting the cost at which energy strength initiatives may be deployed. Many of the modifications we see these days could bring about high-quality impacts for the energy technology and a transition to a greener and cleaner manner of residing. Companies and its employees are accustoming to themselves with far off operating arrangements, which if retained to a point, might lessen the amount of journey and the power utilized in commercial buildings. Moreover, metro regions are witnessing the blessings of reduced fossil gas combustion at the local air quality that have supplied.

4 Pre-COVID Renewable Power Generation in India

The power department performs a very crucial position inside the monetary improvement in India. Country has a numerous energy region source along with conventional sources. The demand of power has improved appreciably and is anticipated to increase within the future time also [8]. The government of country keeps to boost up capability inside the country, with the commitment to carry power to each house inside the country. India secured third rank in the global after China and the United States for primary electricity intake and consumes 162 kW hours of power according to capita. Indians are at the way to multiplied investments and smooth power installations. India has massive non-conventional energy generation aims. The developing India with nearly 1.4 billion people is inside the interior of an electricity conversion, significant for accomplishing the sustainable development [9]. In the year of 2015, the government of India declare a brief-time period objective of 175 GW of non-conventional power potential by current year, targeting energy of 100 GW from solar, 60 GW energy from wind, 10 GW energy from bio waste, and 5 GW energy from hydro. In the long-time period country has set an aspiring renewable energy target of 450 GW by the year 2030. The India has seen a considerable ramp up over the past decade with a purpose of 100 GW of solar energy by means of 2022, with significant and nation huge-scale solar tasks. The authorities had supplied an incentive of INR

220 billion for energy renewable power quarter in the Energy Budget 2020, and it gets a tremendous reaction from the collaborator in energy sector [10].

5 Present Renewable Capacity Trend in India

India secured third rank in renewable energy generation country attractive index in the year of 2021. The country has set an aspiring goal to gain a capacity of a 175 GW really worth of renewable power through the end of 2022, which expands up to 500 GW by means of 2030 [11]. This is the world's biggest growth plan is in renewable energy. India's established renewable energy ability has increased 286% within the ultimate 7.5 years and stands at more than 151.4 GW (including large Hydro), which is around 39% of the country's total generation capacity (as on 31st December 2021). The installed solar electricity capacity has increased by 17 times within the remaining 7 years, and stands at 49.5 GW. India has met its NDC target with a total non-fossil-based energy capacity of 158.17 GW, or 2% of total installed energy capacity [12]. The Government of India has set various goals to lower down India's overall projected carbon emission by 1 billion tons up to 2030, lessen the carbon depth of the country's economy by way of less than 45% by the end of the ten years, to obtain net zero carbon emissions via 2070 and extend Indian renewable electricity installation capacity to 500 GW through 2030 [13].

6 Effects of Pandemic on Renewable Energy in India

6.1 Positive Impact on Renewable Energy

This pandemic has impacted a lot on energy generation not only in India but in the entire world. In the undergoing of such a global disaster against COVID-19, during lockdown the consumption of electricity has been increased due to which the potential use of renewable energy has focused. The use of non-conventional energy resources over conventional sources is one of the positive effects which is observed during the times of pandemic [14]. Year wise renewable energy generation trend of India is shown in Table 3.

All the industrial sector and as well as household have been shifted to solar panels and windmills during pandemic. These steps during COVID-19 period could result in setting up a cleaner environment and leading to a new approach of sustainable development in an energy sector. The utilization of both electrical energy and fossil fuel has been rapidly decreased within the industry, educational sectors, and as well as in private organizations. The worldwide expenditure on energy utilization remained nearly equal to last three years [15]. The international expenses in oil delivery and power end users in the year of 2019 was no longer appreciably same from last few

Table 3 Year wise renewable energy generation

Sources	2016–2017	2017–2018	2018–2019	2019–2020
Large hydro	122.3	126.1	135	156
Small hydro	7.73	5.1	8.7	9.4
Solar	12.1	25.9	39.3	50.1
Wind	46	52.7	62	64.6
Bio mass	14.2	15.3	16.4	13.9
Other	0.2	0.4	0.4	0.4
Total	**204.1**	**228**	**261.8**	**294.3**
Total utility power	1236	1303	1372	1385
% Renewable power	**16.52%**	**17.50%**	**19.10%**	**21.25%**

years (approximately five% decrease). For power sectors and energy end consumers, however, spending decreased moderately (about 15%) from the year 2019 to the year 2020. On the other hand, due to COVID-19-related lockdowns, fuel delivery expenditures dropped by nearly 30% in the year 2020 as compared to the last year. From the above table it is shown that the renewable generation in 2019–2020 is more as compared to 2016–2017. Day by day renewable energy comes into priority for all the sectors in terms of electricity generation. Total percentage of renewable power generation in 2019–2020 is 21.25%, which is more than previous years. Non-conventional energy like solar power, wind power, and hydro power generation is increased after pandemic. So, pandemic as positive impact also on renewable energy generation of electricity [16]. All the sectors are now wants to shift from conventional energy to non-conventional energy. Total generation of power and growth for past 10 years in the country including renewable energy sources is shown in Fig. 1.

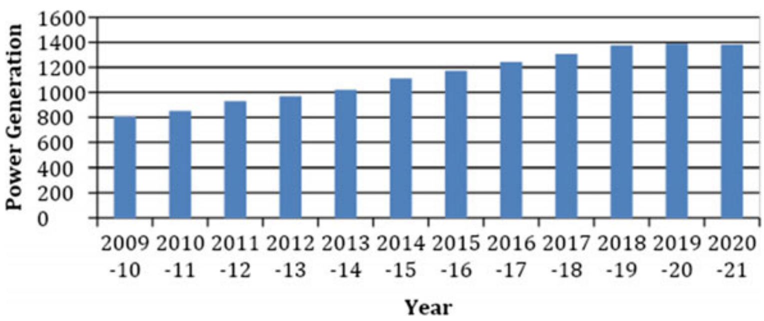

Fig. 1 Total generation of power including renewable energy sources from 2009 to 2020

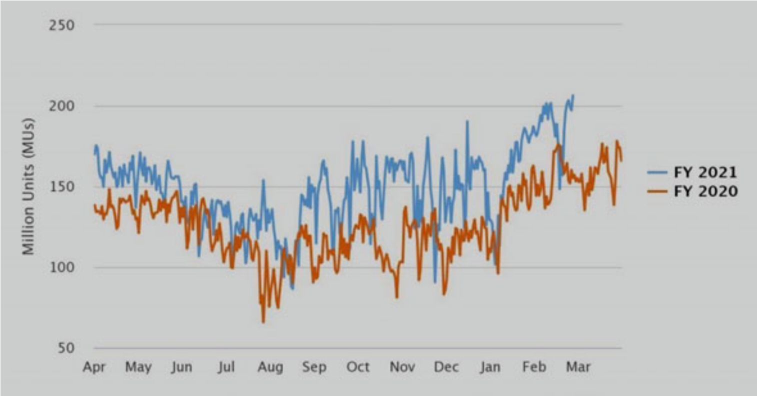

Fig. 2 Solar generation of the year 2020–2021 [17]

6.2 Impact on Solar Power Generation

Solar energy capacity inclusion for the duration of FY21 drop down by 36% as compared to FY203. This may be ascribed in large part to supply chain interruptions, manufacturing delays, and logistical restrictions caused by the lockdown. But due to lockdown, total aggregate of solar capacity in India in month of February 2021 handed its total wind potential. We additionally saw that in between April 2020 and February 2021, solar generation was nearly 8% better shown in Fig. 2 than within the previous financial, and that its proportion in the general supply changed into always better. This signifies that the should-run reputation of renewable energy, reinforced throughout the lockdown, did have an effect. Solar generation of the year of 2020 and 2021 has shown in Fig. 2 [17].

The pandemic has impacted also on solar project which are under construction in India. Solar power considers for over 70% of the cost of a solar mission, while some companies of China provide around 80% of the modules and solar cells. COVID-19 has also coexisted with the true implementation schedule for solar projects, since the majority of implementation happens in India and in the fourth quarter of the fiscal [18].

6.3 Impact on Wind Power Generation

Renewable power generation is increasingly less expensive than any new electricity potential based on fossil fuels, present trend show. More than half of the renewable energy capacity delivered in 2019 carried out lower power charges than the cheapest new coal plant, consistent with a record by means of the International Renewable Energy Agency (IRENA). In India the wind power generation has been impacted from the COVID-19 crisis. The obstructions in supply chains have strained mission improvement timelines. There has been an impact on delivery of assignment additives and unavailability of group of workers because of uncertainty in timely project management and a sequential impact on project economics due to lockdowns. Year of 2020 was not just a pandemic year but also produced a gust of peculiar weather events. This change was now a good information for the wind region. In Fig. 3 wind speed curves indicates a drop down in Jamnagar, Gujarat during the downpour season of the year 2020 [19].

Despite an increase in installed capacity of wind power generation, in comparison to prior years, India has seen a rapid and unexpected 24% reduction in wind electricity output during the peak wind season (June–September). The main motive was changed into a drastic and uncommon drop in wind speeds. The wind generation of western region in peak season of the year 2020 is shown in Fig. 4 [20].

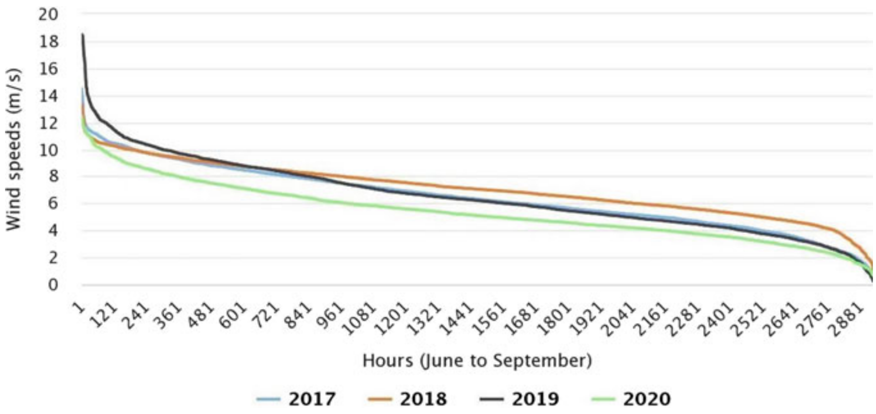

Fig. 3 Wind speed of Jamnagar, Gujarat in the monsoon season [19]

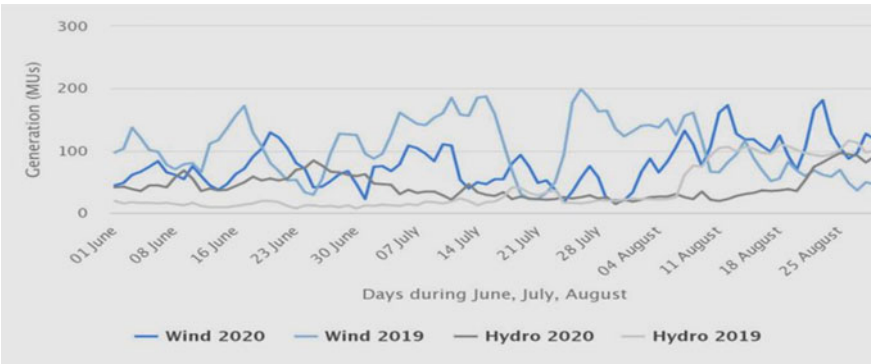

Fig. 4 Western region wind generation containing hydro drops during peak wind season of 2020

In the Western regions, which includes 40% of India's total wind capacity generation, facing a drop down of 12% increase in hydro power generation between the months of June and August 2020 respective to same time as in the last year shown in Fig. 4. The proportion of coal electricity generation also extended by 4% in June and July 2020 relative to the preceding two months. By the month of December 2020, wind speeds partly compensate for the hit. But unfortunately, the accelerated frequency of climate anomalies could make wind resources more unpredictable.

6.4 Impact on Hydro Power Generation

India ranked 5th in globally for installation of hydro power capacity. India has installed power distribution hydro power capacity of around 46,000 MW, or 12.3% of total commercial electricity producing capacity, as of March 31, 2020 [21]. This includes small hydro power capacity of 4683 MW that has been installed. At a 60% load factor, India's hydropower potential is estimated to be 148,700 MW. The total hydro power strength generation in the economic year 2019–2020 was 156 TW with a median capability aspect of 38.71% [22–24]. At a 60% load factor, the hydro power capacity in India l is estimated to be 148,700 MW. But similar to sun and wind energy, hydroelectricity isn't proof against the effects of nature. The contribution of large hydro power plant was 22% more in the month of June and July in the year of 2020. This indicates that hydro energy plant filled in for the decreased wind power era at some stage in these months. Hydro power generation prove as flexible energy generation plant. During lockdown, energy demand decreases due to which it impacts on renewable energy generation as well as nonrenewable energy generation. But hydropower generation is increased in the pandemic times as compared to previous years which can be shown by Fig. 5 [25–28].

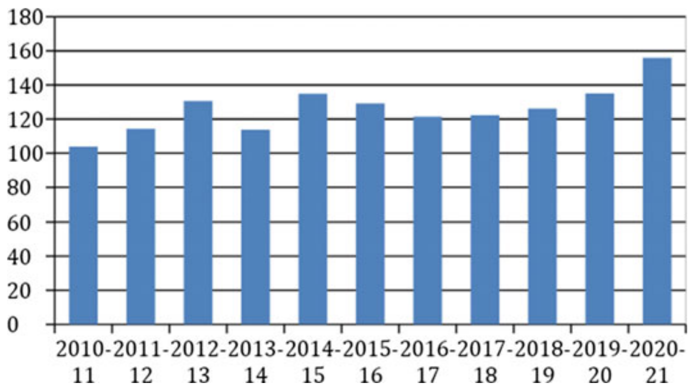

Fig. 5 Hydroelectric generation of past 10 years

7 Impact of COVID-19 on Power Demand

The demand of energy of industries and commercial clients has reduced, due to significant losses of transmission as well as distribution losses and financial obstacles are only some of the issues that the renewable energy sector is dealing with. The fall in demand of power has an effect on all three collaborators: the prosumer, the power distributor, and the financier [29–31]. Due to unreliability in scheme, tariff system flaws, and absence of governing uniformity, the department of energy has also witnessed a moderate loss of economic momentum in the last several years. India has dropped from third to seventh place in EY's 'Renewable Energy Country Attractiveness Index' in the most recent worldwide rankings. As a result, the pandemic has struck the department of energy at an inconvenient time [31–34]. COVID-19 pandemic has brought down the cost of fuel by reducing renewable energy production. Similarly, the shutdown of industries as a result of the rigorous lockdown has resulted in a drop in energy consumption, which has been met primarily by renewable energy output in most countries. The outbreak has also resulted in a significant reduction in electrical usage [35–39].

8 Impact on Energy Generation

The lockdown has delivered approximately a sharp decline within the consumption of power in India. The generation of power in our country India between April and May in the year of 2020 was low as compared to past 5 years [40]. On annual basis, generation of electricity reduced 19% to 201 billion units during April and May of 2020, due to the lockdown which leads in demand and supply of electricity generation. The reduction in generation was due to the thermal energy resources namely Coal-based energy which proves as a 28% reduction in output during pandemic. Power generation for domestic purpose in India is due to thermal power generation sources (72% of total generation in between April–May 2020) in which coal acquires about 64% part in overall power generation as shown in Fig. 6 [41–43].

Renewable energy sources accounts 12% portion in the overall generation and there is an increase in output by 5.2% to 23.5 billion units during the month of Apr–May'20 on annual basis [44–47].

There was an increase in power generation in month of May 2020 over April'20 including both conventional and renewable sources which can also be the characteristic to the easing of the lockdown and the increase in demand scenario. Nevertheless, production of energy from conventional energy resources like thermal power and nuclear energy was 18% less than as compared to May'19 [48–50].

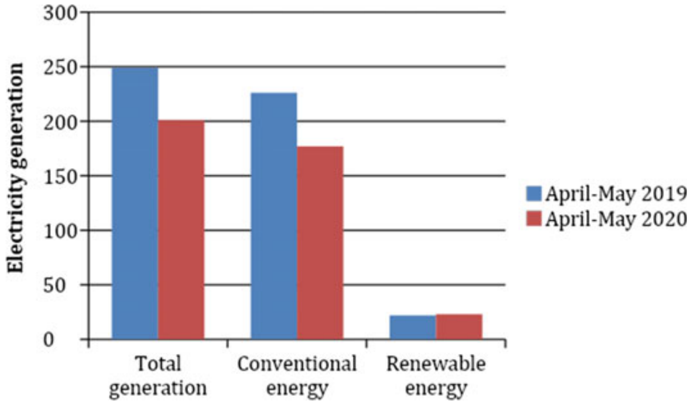

Fig. 6 Comparison of two years of electricity generation of month of April–May

9 Conclusion

In India power sector situation is majorly to have a significant reduction in 2020–2021, due to disruptions caused by Corona virus. The resumption of financial activity would be required for the sector to recover. This pandemic has had an influence on both conventional and non-conventional electricity generation. It has a positive impact on hydropower generation whereas has a negative impact on non-conventional sources of generation. Pandemic has impacted electricity demand in India, due to which it directly effects renewable energy generation. Various sector has shifted to renewable power generation during pandemic time. This pandemic witnessed as a significant impact in reduction in power demand and also hold down various projects. Renewable energy generation in 2019–2020 is more as compared to previous years. Due to pandemic many sectors shifted to renewable energy from conventional sources.

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Chapter 14
Reference Model Design, Control and Reliability Analysis of PV Emulator

Simmi Sharma and Dheeraj Joshi

Abstract Photo-Voltaic Emulator (PVE) is a nonlinear power supply with voltage-current characteristics similar to those of a real PV panel. It provides a simpler and more efficient solution while maintaining output comparable to the considered PV panel in laboratory setup in a less expensive and faster mode. Based on the test bench requirements, this paper provides a framework to use during the design stage. This will be useful when installing solar panels in remote areas where testing is difficult. The closed loop control determines the operation of PVE on three main operating points. The work is original since it utilizes different reference models on the same PVE with conventional and hybrid controllers to improve performance indices.

Keywords PVE · Stability · Reference-diode models · Control strategies · Reliability · MATLAB

1 Introduction

Renewable projects are prioritized over conventional methods due to their positive impact on nature and ecosystems. So, the use of renewable resources cannot be ignored or delayed to save our earth from global warming and increasing energy demands. The research in the field of solar has gained pace globally in the last decade. India is among countries who have highest solar energy-based projects and research setups. India has tread plans to capture the renewable market of the world by 2022 by achieving the target of 175 GW [1]. Automation in power sector has opened doors for software projects due to their ease and safer work environment. Researchers are highly interested in modeling, control and optimization of solar energy [2]. The post pandemic period has changed the research and development environment. So, to cope up with the situation, designing stage is explored by reliable

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software implementations. One such area is simulation of solar panel in the form of PVE (PVE). MPPT confirms that maximum power is extracted from the PV panel due to its nonlinear output [3]. But the testing setup of MPPT is complicated. A large area is also required for the actual solar panel along with high cost of installation in case of far-off areas. A PVE (PVE) is termed as efficient if it continuously tracks VI and PV characteristics of selected PV panel [4]. However, PVE reliability calculation is an important aspect to determine the effectiveness of the designed model, to avoid any premature failures and to estimate the maintenance time. For better understanding of reliability, the system must be kept simple at designing stage. Military handbook MIL-HDBK-217F highlights manifestation on coefficients involved in failure rates of various components. Power Electronics finds a wide range in renewable sector due to advantage of long operating hours in harsh environmental conditions, reduction in cost of power. The objective of the presented work is to cover the PVE that also encompasses PV reference model designing, the control techniques and overall reliability analysis. The following sections describe the overview of the PVE in Sects. 2 and 3 demonstrates the architecture of PVE and designing of the reference PV model, Sect. 4 covers the control strategies based on performance indices and the finally Sect. 5 shows the reliability analysis of designed model followed by results and discussion.

2 Overview of PVE

Solar-based research is swayed by manufacturing costs, area, discontinuous solar irradiation and MPP for validating different configurations [5]. It is critical to model, design, control and eventually imitate photovoltaic panels for optimal utilization. A solar panel consists of solar cells in series or parallel connection [6]. They are primarily made up of silicon, copper indium gallium selenide, or gallium arsenide. A PVE is a nonlinear power supply that can replicate a PV panel's characteristics. In the prototype phase of the solar power generation system, a PVE serves as a power source to allow for iterative testing conditions. For quicker and efficient validation of solar power, the PVE provides a very convenient control compared to complicated irradiance and temperature control [7]. The PVEs generally range from a panel to a PV array. It is concluded from research papers [8–10] that a PVE is necessary because of the following reasons.

(1) The actual PV panels are highly-priced.
(2) It is difficult to obtain and maintain characteristics of panels due to varying environmental conditions.
(3) It provides advantage of carrying out testing during night time and cloudy weather too.
(4) Minor changes in circuitry gives faster emulation of different panels with lesser efforts.

The aim of PVE is:

- To emulate all PV panels that lie within its output limits.
- To emulate panels for different irradiance, temperature and partial shading conditions.
- To have a portable design.
- To obtain a model having good dynamic response.
- To obtain a model for testing solar equipment such as inverters and maximum power point trackers.

Many topologies are described in the literature [11–13] regarding VI curve measurement. PVE reviewed in literature can be grouped as Conventional PVE, Converter-based PVE, Microcontroller or DSP-based PVE and Hardware-based PVE emulator [14]. PV research includes everything from numerical method approximation to authentic controller applications. The diode model approximation is the most traditional method for designing PVE. Because PV panels exemplify nonlinear behavior, a diode approximation approach is used to obtain solar PV characteristics.

3 Architecture of PVE and Designing of Reference Model

The architecture of PVE can be divided into three subsystems:

- Converter in closed loop circuitry
- Reference PV model
- Controller.

In PVEs, switched mode power supplies are a popular and effective power supply. To create a PVE, different converters can be incorporated in closed loop with a fine tune controller and reference model. This paper considers buck converter for PVE modeling as buck converter has its roots on the left half of s plane as shown in Fig. 1.

As a result, a stable converter has been confirmed. Figure 2 depicts a bode plot to further validate the stability of the selected converter. The plot shows a positive phase

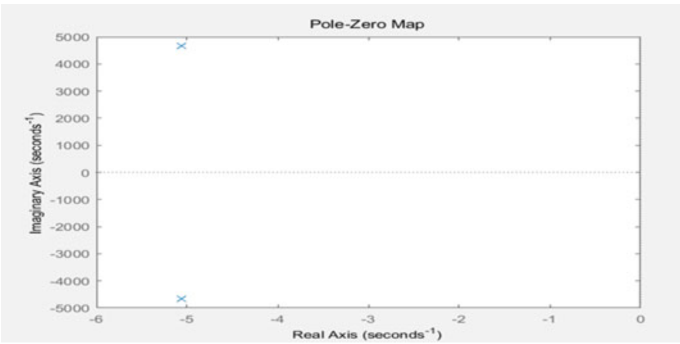


Fig. 1 Pole-zero plot of buck converter

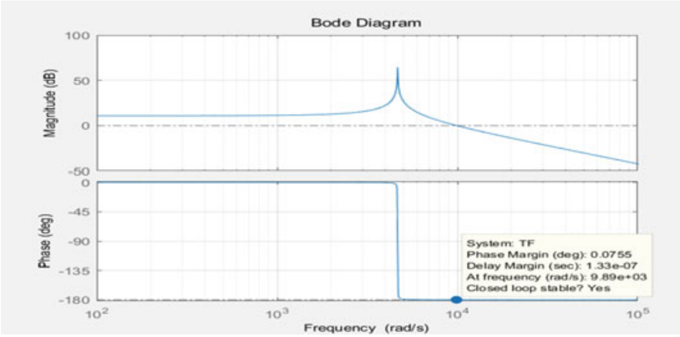


Fig. 2 Bode plot of buck converter

margin and an infinite gain margin (GM) (PM). A positive phase margin indicates that the system is stable. As a result, the converter is chosen based on a simple structure and stable configuration.

The internal resistance of inductor, r_L, and the capacitor's resistance, r_C, are the non-ideals considered in the buck converter.

$$\text{Critical } L \text{ value; } L_c = \frac{(1-d)R_L}{2f} \tag{1}$$

$$\text{Critical } C \text{ value; } C_c = \frac{(1-d)}{16f^2L_c} \tag{2}$$

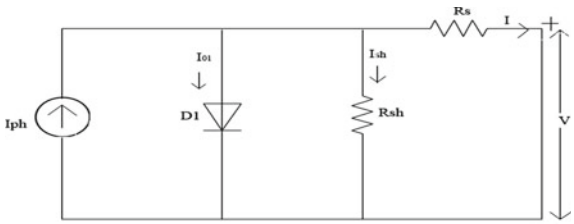
The system configuration for buck converter-based PVE can be classified as either current or voltage controlled. This classification is based on whether the reference model has V_o as input and I_o as output or vice versa.

The reference model can be simplified by implementing a look-up table [15] and piecewise linear method. A variety of solar cell models have been studied by researchers [16, 17]. Figure 3 depicts the 1D2R model as reference model.

Figure 4 demonstrates basic block diagram of PV reference model. The PV module block can be LUT or a diode model. The output of this block is compared with the output of converter to generate error. This error is taken as input of controller.

The output current of 1diode model is:

Fig. 3 1diode model



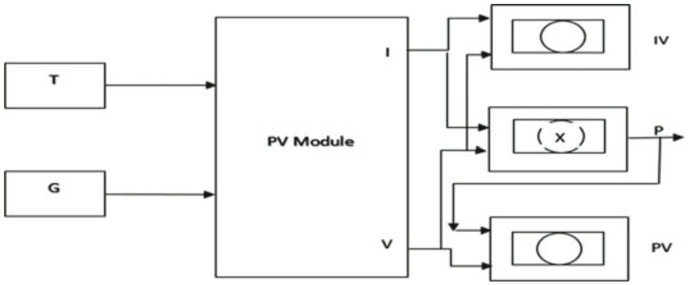


Fig. 4 Basic block diagram of PV reference model

$$\text{Output Current; } I = I_{\text{ph}} - I_o\left[\exp^{\left(\frac{q(V+IR_{\text{s}})}{nN_{\text{s}}kT}\right)-1}\right] - I_{\text{sh}} \tag{3}$$

I_{ph} = Photo current (A)
I_{sh} = Shunt current (A)
T = Operating temperature (k)
q = Electron charge (C)
n = Diode ideality factor
k = Boltzman's constant (J/k)
N_{s} = No. of series-connected cells.
R_{s} = Series resistance (Ω)
V = Diode thermal voltage (V)
I_{o} = Saturation current (A).
Equations representing two diode (2D) model for reference model of PV are:

$$I = I_{\text{ph}} - I_{o1}\text{e}^{\left[\frac{(V+IR_{\text{S}})}{a_1VT_1}-1\right]} - I_{o2}\text{e}^{\left[\frac{(V+IR_{\text{S}})}{a_2VT_2}-1\right]} + \frac{(V+IR_{\text{s}})}{R_{\text{sh}}} \tag{4}$$

Equations representing three diode (3D) model for reference model of PV are:

$$I = I_{\text{ph}} - I_{d1} - I_{d2} - I_{d3} - I_{\text{sh}} \tag{5}$$

$$I_{\text{ph}} = I_{\text{sc}} + k_i(\Delta T) * \frac{G}{1000} \tag{6}$$

$$I_{\text{sh}} = \frac{(V+IR_{\text{s}})}{R_{\text{sh}}} \tag{7}$$

$$I_{d1} = I_{o1}\text{e}^{\left[\frac{(V+IR_{\text{S}})}{a_1VT_1}\right]} \tag{8}$$

$$I_{d2} = I_{o2}\text{e}^{\left[\frac{(V+IR_{\text{S}})}{a_2VT_2}\right]} \tag{9}$$

$$I_{d3} = I_{o3} e^{\left[\frac{(V+IR_S)}{a_3 V T_3}\right]} \quad (10)$$

Above equations [16, 17] will be utilized for reference block modeling to generate current and voltage of actual PV panel.

4 Control Strategies Based on Performance Indices

The proposed control method is accountable for setting the operating point of the PVE. The designed model has integrated a closed loop converter to frame required PVE. A good controller should be able to specifically track the PV model's aspects, produce a stable PVE output, have a low processing burden and must be capable of replicating multiple PV panels instead of completely redeveloping the control strategy. PVE is designed by small signal analysis (SSA) to obtain transfer function of the system. The controller is precisely designed using this transfer function. PVE applications employ the state space averaging by examining states of the circuit during switching conditions. The analysis targets energy storage components. SMPS converters are duty cycle dependent so depending on it the analysis of the various states is averaged. Further, this obtained equation is rearranged as per the state space to obtain final transfer function.

Thus, the General expression for Transfer function of Buck converter is given as:

$$G(s) = \frac{\frac{V_{\text{in}}}{LC}}{s^2 + \frac{1}{RC}s + \frac{1}{LC} + \frac{V_{\text{in}}}{LC}} \quad (11)$$

Ziegler Nichol's continuous cycle method and Cohen Coon's process reaction curve method are two widely used conventional tuning methods reported for controller tuning [18–20]. It is observed and noted that employing *Z–N* formula to estimate optimized solution is difficult. As a result, it is critical to improve PID controller performance by introducing new attributes such as performance indices, error indices.

It is also observed that using hybrid-mode controlled methods [21, 22] improves issues related to PVE dynamic performance and transient loading. As a result, PSOPID controller is designed to minimize rise and settling time, as well as the system's error component. With the above parameters, an objective function is formed to obtain tuned values of gains, resulting in a faster and easier process for PVE controller tuning action.

5 Reliability Analysis of Designed PVE

Reliability is an important performance index in PVE as it provides the information regarding time taken by the compiled system to maintain its efficient functioning and estimate the repair and maintenance time of the components. Mean time to failure (MTTF) is calculated to find reliability of complete non-repairable systems. It refers to the time elapsed between start and first failure point. As per bath tub curve, the failure rates can be divided into three zones: Infant Mortality, Constant and Wear out zone. Out of these zones, reliability calculations can be done in constant zone using MTTF.

Figure 5 shows that the maximum failure rate occurs at post manufacturing state and the debugging and aging of components lower this failure rates. In case of semiconductor devices, the consumer assembles, adjusts and calculates the aging of devices. Upon installation for a particular application, the stress level is reduced and failure rates are reported in a range of low FIT to several hundreds of FIT. This is represented as a constant zone on bath tub failure rate plot (as shown in above figure), it is clear that the reliability can be increased by extending the constant zone to the left side and lowering the initial failure rates. An important factor to increase the reliability is the manner in which the components work with other components in the circuit.

$$\mathrm{MTBF} = 1/\lambda(\text{inverse of failure rate})$$

If we consider various blocks to be connected as shown in Fig. 6; the reliability of each component can be calculated by part stress method.

The degree of reliability of semiconductor devices also majorly depends upon its usage and environmental conditions [23]. Thus, the basic failure rate λ is determined by dissipated power and operating temperature. Reliability of device under usage is calculated by multiplying factors defining the design and manufacturing parameters. Failure rates are commonly poor and are articulated as failures per million (10^{-6}), especially for each component [24]. A component's Failure in Time (FIT) represents the number of failures that may occur in one billion (10^{9}) hours of operation. These units are generally used in semiconductor related reliability analysis. In this paper, official failure rate data is taken as reference from MIL-HDBK-217F. A PV system

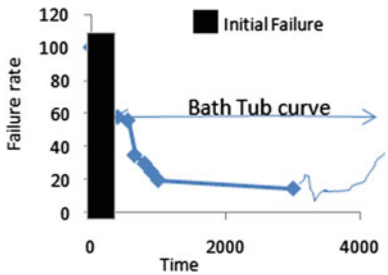


Fig. 5 Failure rate versus time for semiconductor devices (bath tub representation)

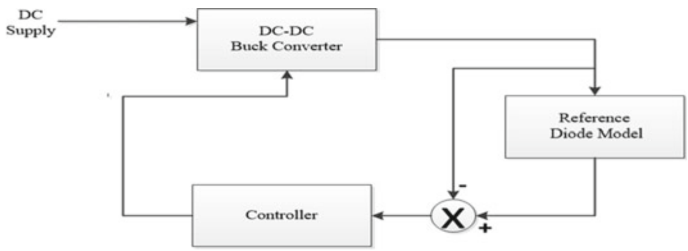


Fig. 6 Block diagram representing PVE

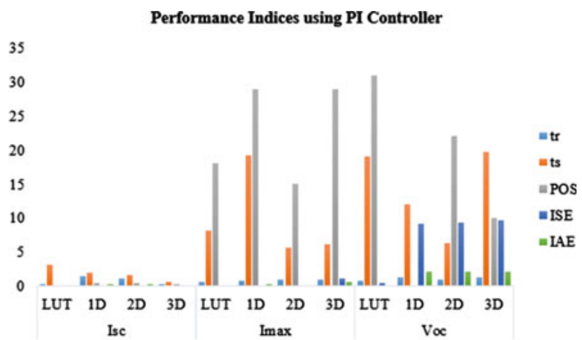
is estimated to operate for 25–30 years. During this tenure, however the components like MOSFET [25], diode, capacitor, inductor experience stress due to switching circuitry, temperature and irradiance factors. Reliability techniques namely analytical and simulation evaluate reliability indices by mathematical modeling and simulation of real panel along with its random behavior, respectively. Many research papers are available for calculation of components [26] and PV system reliability but very little research is done on complete PVE reliability. The author here intends to calculate the reliability of overall systems. The PVE system taken for the study is first implemented on MATLAB simulink for its accuracy and efficiency.

6 Results and Discussion

Figure 7 concludes that 3D models perform better with PI in the I_{sc} and Imax regions, whereas 1D performs better near V_{oc}.

Figure 8 shows that performance with 3D models is better with PID in the I_{sc} and I_{max} regions, whereas LUT performs better near V_{oc}. The results show that traditional controllers produce a lot of overshoots. However, because of their simple structure, they are widely used. Unfortunately, it has been discovered that properly tuning the

Fig. 7 PVE model with PI controller



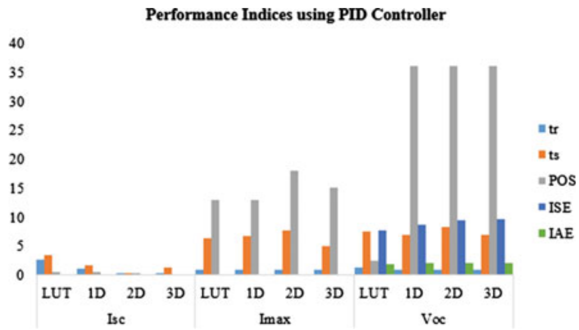


Fig. 8 PVE model with PID controller

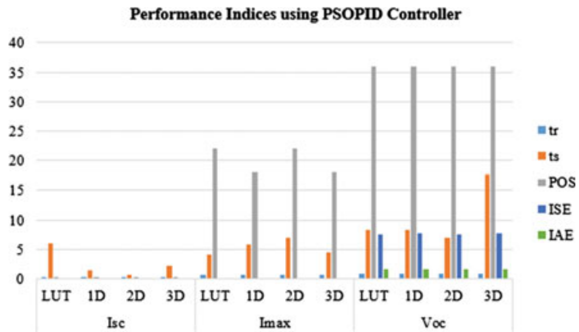


Fig. 9 PVE model with PSOPID controller

gains of PI and PID controllers is quite difficult because PVE are frequently burdened with problems such as load variation, partial shading and operation other than STC.

Figure 9 summarizes the comparative analysis of PSO tuned PID performance indices based on different reference models. With all diode models, the histogram shows good results in the I_{sc} region. MPP region has good results with LUT, but near V_{oc} there is a problem with overshoot because the selection criteria is based on settling time.

Reliability Analysis of various components:

a. **Power switch reliability Analysis**:

Power losses in MOSFET are calculated by following equation:

$$P_{\text{static}} = I_{\text{rms}}^2 * R_{ds(\text{on})} \tag{12}$$

MOSFET switching losses are calculated using following equation:

$$P_{\text{sw(CCM)}} = P_{(ton)} + P_{(toff)} = \frac{1}{2} V_{\text{off}} * I_{\text{on}} * (t_{\text{on}} + t_{\text{off}}) * f_s \tag{13}$$

$$P_{\text{Total}} = P_{\text{static}} + P_{\text{sw(CCM)}} \tag{14}$$

$$T_J = T_C + \theta_{JC} * P_{\text{Total Loss}} \tag{15}$$

$$\text{Therefore}: T_J = 35 + (0.3) * 3.74 \tag{16}$$

$$\text{Temperature factor, } \Pi_T = \mathrm{e}^{-1925\left(\frac{1}{Tj+273} - \frac{1}{298}\right)} \tag{17}$$

$$\text{Part failure rate, } \lambda_p = \lambda_b * \Pi_T * \Pi_A * \Pi_Q * \Pi_E \text{ failure/}10^6 \text{ h} \tag{18}$$

$$\lambda_{\text{MOSFET}} = 0.0192 \text{ failure}/10^6 \text{ h} \tag{19}$$

b. **Diode Reliability Analysis:**

Static Loss of diode is calculated using following equation:

$$P_{\text{reverse}} = V_r * I_r(1D) \tag{20}$$

Switching Diode loss is calculated using following equation:

$$P_f = V_f * I_f + I_f^2 * r_d \tag{21}$$

Lower value of V_f results in low power losses and thereby lesser failure rate.

$$P_{\text{Total}} = P_{\text{reverse}} + P_f \tag{22}$$

$$\text{Temperature factor, } \Pi_T = \mathrm{e}^{-3091\left(\frac{1}{Tj+273} - \frac{1}{298}\right)} \tag{23}$$

$$\text{Part failure rate, } \lambda_p = \lambda_b * \Pi_T * \Pi_S * \Pi_C * \Pi_Q * \Pi_E \text{ failure/}10^6 \text{ h} \tag{24}$$

$$\lambda_{\text{Diode}} = 0.01 \text{ failure}/10^6 \text{ h} \tag{25}$$

c. **Capacitor Reliability Factor:**

$$\text{Part failure rate, } \lambda_p = \lambda_b * \Pi_T * \Pi_C * \Pi_V * \Pi_{SR} * \Pi_Q * \Pi_E \text{ failure/}10^6 \text{ h} \tag{26}$$

$$\lambda_P = 0.0054 \text{ failure}/10^6 \text{ h} \tag{27}$$

d. **Inductor failure rate:**

$$\text{Part failure rate, } \lambda_p = \lambda_b * \Pi_C * \Pi_Q * \Pi_E \text{ failure/}10^6 \text{ h} \tag{28}$$

$$\lambda_b = 0.000335 * \frac{(T_{HS} + 273)}{329} * 15.6 \tag{29}$$

$$T_{\text{HS}} = T_A + \frac{1.1 * 11.5 * P_{\text{Loss}}}{W_L^{0.6766}} \tag{30}$$

$$\text{For THS} = 70,\ \lambda_p = 1.59 \times 10^{-4}\ \text{failures}/10^6\ \text{h} \tag{31}$$

which shows affordable behavior. Inductor failure rate is least among all other components and thus can be ignored.

e. **Reliability of Microcontroller**

Although microcontrollers such as Arduino are said to be extremely reliable, external circuitry protection is required when using a microcontroller. Given the foregoing, the failure rate of the microcontroller is estimated to be 0.01 failures/10^6 h.

f. **Diode Model Reliability Analysis**

$$\lambda_p = \lambda_b * \Pi_T * \Pi_C * \Pi_S * \Pi_Q * \Pi_E \tag{32}$$

$$\lambda_p = 0.000172\ \text{failure}/10^6\ \text{h} \tag{33}$$

g. **Load Resistance failure rate**

Is calculated as 0.00004 failure/ 10^6 h

Because all components are interconnected forming a series system, thus λ_T, equals the sum of the failure rates of all series-connected components.

$\lambda_T = \sum_{n=1}^{m} \lambda_m$, where m is the number of components connected in PVE.

$$\text{As a result, } \lambda_T = 0.06\ \text{failure}/10^6\ \text{h} \tag{34}$$

$$\text{Reliability, } R(t) = \mathrm{e}^{-\lambda t} = \mathrm{e}^{-0.06t} \tag{35}$$

Figure 10 shows how the reliability of the system varies with time in years. In initial stage the reliability is high and over the years it decreases due to physical and internal factors.

7 Conclusion

PVE is required during the design phase of PV panel applications. The work presented in this paper demonstrates the effectiveness of the designed PVE in regards to performance indices, as illustrated in Figs. 7, 8 and 9. The research performed with different

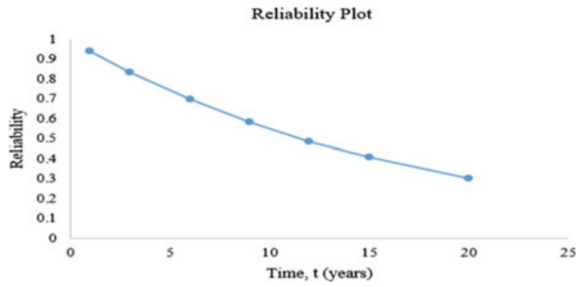


Fig. 10 Reliability plot of designed PVE

diode models for the same PVE is unique and demonstrates that the results obtained with the hybrid controller and diode models are the best. PVE reliability analysis is performed to demonstrate the model's effectiveness in the coming years. Figure 10 depicts the reliability plot, which shows that the reliability is highest at $t = 1$ and decreases over time to a value = 0.3 @ $t = 20$ years. Thus, the research work goal is achieved by designing a PVE that replicates PV panel characteristics in a laboratory setup prior to installation to avoid delays and reduce installation costs. All designed PVEs have characteristics similar to the reference panel, but the diode reference model PVE has the best performance indices.

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Chapter 15
Smart Technologies in Indian Environment—A Critical Review

Akash Mohi Uddin and Harpreet Kaur Channi

Abstract India tries to satisfy the electricity needs of its rapidly expanding economy. The power industry's restructuring has only exacerbated several issues for electrical engineers. The advanced perception for implementing a feasible smart grid (SG) at different stage in India's electricity systems suggests that a modified automation technology can be used. Smart grids are being implemented to build operation of grid as more sophisticated and modish. When properly implemented, smart grid operations can reveal new channels and chances with major monetary repercussions. In the context of India's evolving electricity market, this article discusses numerous smart grid efforts and their ramifications. Many instances of present technology of automatic mechanisms in country are used to illustrate many of the points made in the paper.

Keywords Technologies · Environment · Renewable energy · Globalization · Smart cities · Smart grid · Advance database management

1 Introduction

The economic growth of developing countries like India is heavily dependent on the reliability of power system. The Indian economy is expected to develop at a rate of 8–9% in the 2010–2011 fiscal year, with double-digit growth (10 percent +) expected in the coming years [1]. However, India is experiencing a severe electricity crisis that is expected to increase in next many years. The electrical system in India is plagued by low generation and large distribution losses. Furthermore, heinous geological and environmental elements have aided carbon footprints since the country's grassroots range of carbon dioxide emissions, greenhouse effect, and negative effects of globalization [2]. This could lead to power system instability and problems such as brownouts and blackouts [3].

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Smart grid (SG), one such emerging technology, plays a critical role in attaining major technical benefits such as reduction in power loss, supply quality refinement, maximum reduction, and cost-effective load dispatch, among others. In many developing and developed countries, the advance research technology and development is the high priority of smart grid system [4]. This advancement is playing a pivotal responsibility in reshaping the global power landscape. Policies, legislation, market efficiency, costs and benefits, and services all play a role in the smart grid advancement marketing strategy. Stable connectivity, modified database administration, and systematic structure with ethical data exchange are all important considerations. Other technologies, such as flexible air conditioning, could benefit from such technology [5].

2 Summary of Indian Energy Sector Market and Its Approach

The Electricity Act 2003 was enacted as a result of the monitoring of the supply act of electricity 1948 of India and the Electricity Act of 1910, allowing the government and various non-governmental departments to participate and ease the electricity demand. The statute redefines the authority of the economy of the market, consumer protection, and provision of services [6].

While the concept of a smart city is constantly evolving, it is uncertain what form it will eventually take. In practice, number of smart cities are focusing on projects that employ technology to improve output, helping cities to become more reliable and competitive. A major difficulty is the failure to address urban concerns holistically through technological revolution in administration, planning, and infrastructure investment as shown in Fig. 1. Smart cities are made up of various networked components that constantly exchange data and make life easier for a country's citizens. Smart city framework is shown below [7].

3 Smart and Modern Cities

3.1 Research of Modern Cities in a General Perspective

The field of smart cities research can be tackled from a transdisciplinary and multidisciplinary perspective. Solutions to diverse difficulties in smart city applications include several components that span various areas such as repercussions, benefits, possibilities, trends, global developments, and practices. Smart and intelligent cities encompass a wide spectrum of research, and it comprises fundamental, analytical, practical, discursive, socio-technical, and other types of knowledge. The great range

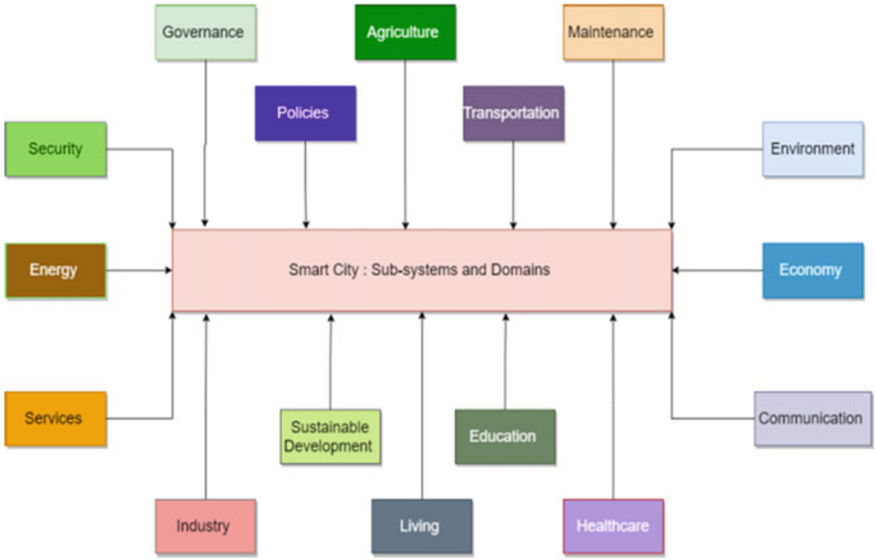

Fig. 1 Smart city framework [8]

of research in this topic reflects many diverse perspectives and methodologies [9, 10]. A smart city can look at the physical universe in real time.

3.2 *Structure of Modern Cities*

For investments in human and social capital, as well as existing and new communications infrastructure, a smart city is a source of long-term economic growth. Building architecture benefits from telecommunications infrastructure in the absence of a wired electricity network. In regions with restricted access or without cable installations, wireless technologies such as Wi-Fi, Bluetooth, and radio-frequency identification are used. For a good communication, proper analysis of data and optimization of resources including all equipment is necessary, which will be enabled by a good selection of outer and inner infrastructure. As descript in Fig. 2, the creation of a successful modern city ecosystem is dependent on several factors.

3.2.1 Outer Infrastructure

In order to understand what is going on the smart city, several sensors must be installed, allowing data to be used in taking decisions throughout the environment. Different sensors provide the city with diverse architectures, the most common of which is the star architecture or network mesh [12].

Fig. 2 Problems in the development of smart cities [11]

3.2.2 Inner Infrastructure

Building's geometric shape is highly dependent on the placement of various sensors in a smart building, if the building is considered a heritage asset, how the building is used, who owns the building (public or private), and whether the building is new or old. Another milestone in the design phase is the architectural and sensor configuration of new buildings [13]. However, the building which is already there, the criteria must be examined, and sensor devices must be installed for IoT systems to function properly as shown in Fig. 3. Many sensors are used in smart cities such as proximity and humidity sensors, etc.

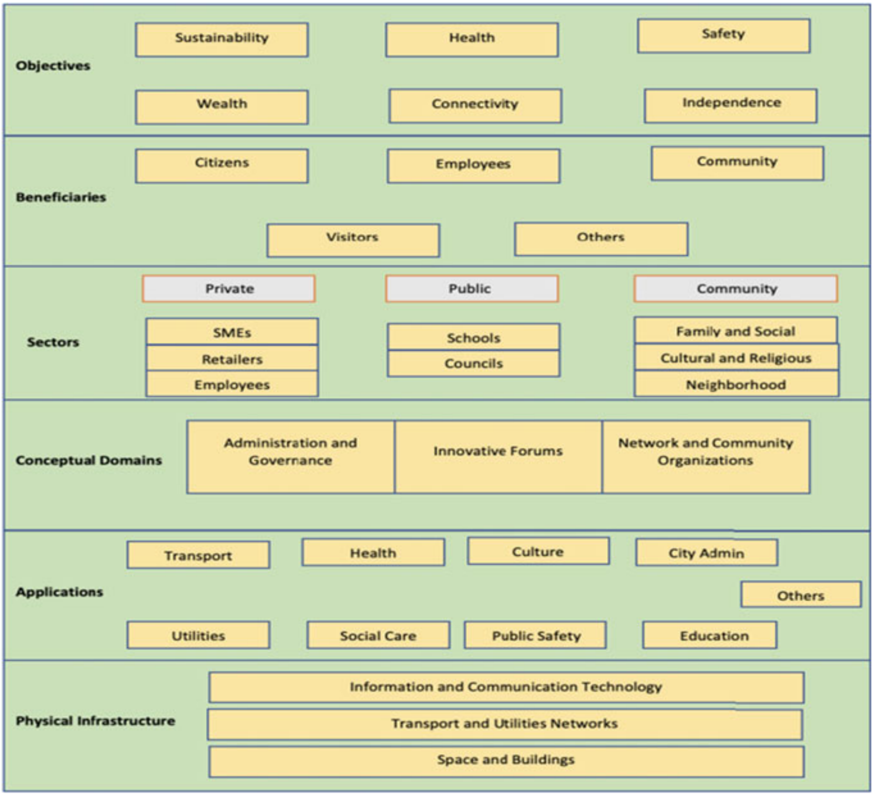

Fig. 3 Structure of modern cities [14]

4 Future of Smart Grid Advancement in India

In India, generation of electricity in increasing at a major level due to various reasons like different technologies are used for production, due to increase in population and also our country is working on energy conservation at different levels. With the effect of latest technology, terms like energy preservation, discharge depletion, clean energy, protection features, T&D losses, etc., plus utilization of beneficial components have resulted in forming the center of conversation [15–17].

As India struggles to satisfy the demand in electricity related to energy and maximum loads, smart grids can assist in better managing the power shortage and optimizing the country's power grid condition [18]. A "smart grid" recognizes of changing the situation of the India's power generation grid by combining information and different operations technology and applying it to the grid, permit customers to have more sustainable options and utilities to have improved security, dependability, and efficiency [19]. Smart grid (SG) technology's exceptional vision enables for more effective and efficient energy generation, transmission, distribution, and utilization.

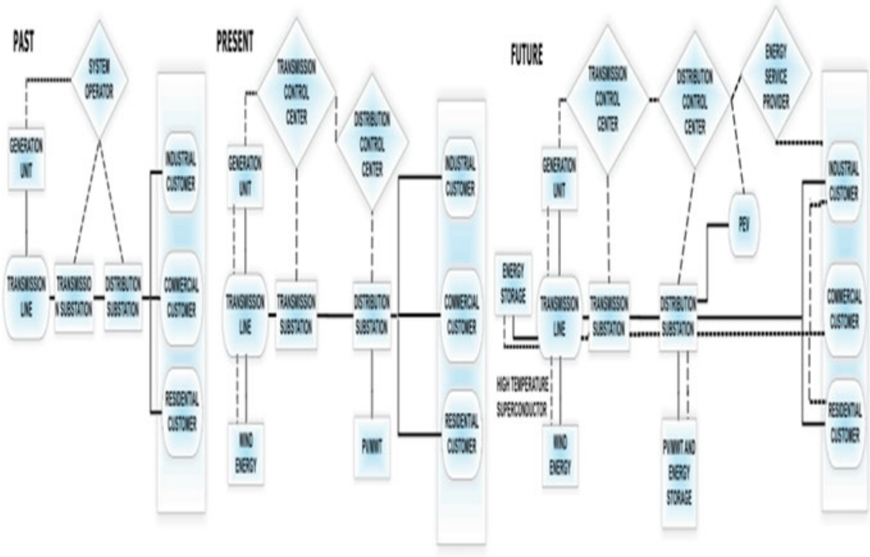

Fig. 4 Smarter electricity system [22]

The most economical and effective way to utilise electricity is via demand-side management (DSM), particularly in emerging countries like India where demand outpaces supply [20].

Demand side management (DSM) is a critical method for making the most efficient and effective use of power, especially in developing nations such as India, where demand exceeds available output. The grid remains stable. The electricity system landscape in India, being a developing country, changes on an exponential basis. Furthermore, the system is likely to be more dependable and versatile as data transfer and data analysis capabilities improve. Figure 4 depicts the advancement and the direct results of its adoption in the future. As demonstrated in Fig. 2 [21], the definitive strategy for the Indian smart grid will be depicted accordingly, with the newest technology advancements and vast characteristics.

5 Initiatives of Modern Cities in India

As previously said, smart grid technology has a broad scope for converting India's electricity grid from advancement deploy standard to a performance-based one. In October 2008, the Ministry of Power (MoP) joined "The Climate Group" [23] and "The Global e-Sustainability Initiative (GeSI)" at the SMART 2020 event that is used to point out the studies pertinent to production management in India [13]. Meanwhile, the government's probable "path forward" has yet to be dug out and remains

Table 1 Installation capacity of non-conventional energy in India

Non-conventional sources	2007–2012 year (In GW)	In 2012 year (In GW)	Till 2022 year (In GW)
Wind power	10.50	17.00	40.00
Hydropower	1.40	3.50	6.50
Biomass energy	2.10	3.00	7.50
Solar power	1.00	1.50	20.00
Total power	15.00 GW	25.00 GW	74.00 GW

a question mark. However, in order to support the management of demand networks, production and distribution networks have been substantially supplemented and modernized for IT industry, resulting in improved grid network and customer service. Table 1 summarizes some of the initiatives that have been implemented. Smart grid technology, as previously said, provides a broad scope for converting the power grid of India from a technology-based standard to a performance-based standard. In October 2008, the Ministry of Power (MoP) joined "The Climate Group" [24] and "The Global e-Sustainability Initiative (GeSI)" for the SMART 2020 event, which aimed to highlight studies pertinent to India's major stakeholders [25]. Regrettably, the possible "path ahead" has yet to be dug out, and the Government's position remains uncertain. However, in order to support demand side management, networks distribution have been substantially supplemented and modernized for IT enabling, resulting in improved grid network service. Table 1 summarizes a few of the initiatives that have been implemented.

Smart grid technology is likely to evolve into a more superior and advanced form as a result of the advancement of advanced data and technology of communication as well as the expansion of sustainable energy. It will include some of the most recently developed opportunities, such as non-conventional collaboration, villages' electrification, and micro-grids [26, 27].

6 Renewable Energy Generation

Environmental consciousness has heightened attentiveness in the modification of current smart grid advancement and also collaboration with clean nature and as well as sustainable environment. Table 1 presents a concise overview of India's renewable energy generation, as projected by the Indian government and its Ministry [28]. Figure 5 highlights the depiction of non-conventional power in India by 2022.

With the identification of non-conventional energy, the power converges to; lower carbon footprints, a clean nature, plug-in electric vehicles, and decentralized electricity, all of which improve the quality of power system such as reliability and security of the system and load management [30]. Some problems occur in using renewable energy sources such as wind and solar power. Conventional energy, such

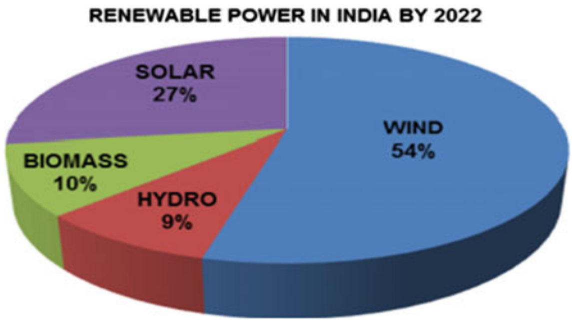

Fig. 5 Depiction of non-conventional power in India by 2022 [29]

as biomass, hydropower, and geothermal energy, consists no similar issues with grid integration.

Collaboration of non-conventional with smart grids improves the electrical sector's reliability and flexibility in terms of economic across a large area, also between countries [31]. Many research analysis teams are developing forecasting methodologies, design algorithms, and other models, which will be implemented in many places around the country. Figure 4 depicts a brief examination of renewable energy solicitation in smart grid advancement across its entire network of electrical network engineering [32].

Because of the unpredictability of oils, alternative and renewable energy sources have emerged. Wind and photovoltaic cells need be supplemented by emerging technologies such as micro-grid and ICT because of their inherent volatility. Emerging technologies like this will play a critical role in maintaining a high level of living while reducing costs.

Renewable energy implementation on a large scale requires inspiring countries schemes and maintained standards [33].

7 Conclusion

The article discusses the Indian power strategy, as well as its flaws in many areas, with an orderly identification to evolving the smart grid concept. An outline of the India's energy sector market is provided, as well as a quick examination of the units of electrical system. In India, the power market is characterized by less demand authority and response due to improper architecture and knowledge. Smart grid advancement has the ability to naturally solve these problems. It can also acknowledge down turn in losses of line to alleviate current shortage of electricity, increase supply dependability, improve power quality and management, preserve revenues, and prevent theft, among other things. Model architecture, as well as the government's and several private sector's smart grid efforts in India the paper presents the bodies. In this paper, it is highlighting the importance and fortification of smart grid idea, as well as implanting it in the Indian subcontinent on the behalf of existing technology.

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Chapter 16
Socio-Economic Analysis—Solar and Wind Energy in Indian Scenario

Minakshi Katoch and Vineet Dahiya

Abstract The second most populated country India strives to fulfill the nation's requirement. The densely populated country had given birth to pollution because of the rapidly growing urbanization and industrialization. The anthropocentric happening for the need has raised the greenhouse gas (GHG) emission and resulted in the global warming challenge to society. The rise in unpredictable natured wind and solar energy generation is a challenge for grid management make RE forecasting mandatory energy sector. The exorbitant high prices of RE installation make it necessary to study the site before the deployment and know the energy predictions based on wind and solar availability. The paper gives an insight into RE status and various challenges in the RE sector. The paper also provides the information gathered from the open-source platform.

Keywords Wind energy · Solar energy · Grid parity

1 Introduction

India is the third largest after the United States of America and China in energy production and consumption. India has the third position for overall generation, fourth in wind generation, and fifth in the solar generation on the globe. Figure 1 shows the exponential increase of RE installation capacity in India's northern, western, eastern, southern, and northeastern zone. For the study, a data set of 264 readings was taken. The data indicates that southern zone is having maximum RE installation capacity, second largest RE generator is western zone. The northeastern and eastern zones are having less RE installation capacity.

The data indicates that the RE installation of southern is double the northern zone and 20–50 times from the eastern and northeastern zone. However, from 44 months, data including the COVID pandemic shows that the southern zone has increased the capacity by 15.9 GW, western zone by 12.1 GW, northern zone by 8.95, eastern zone

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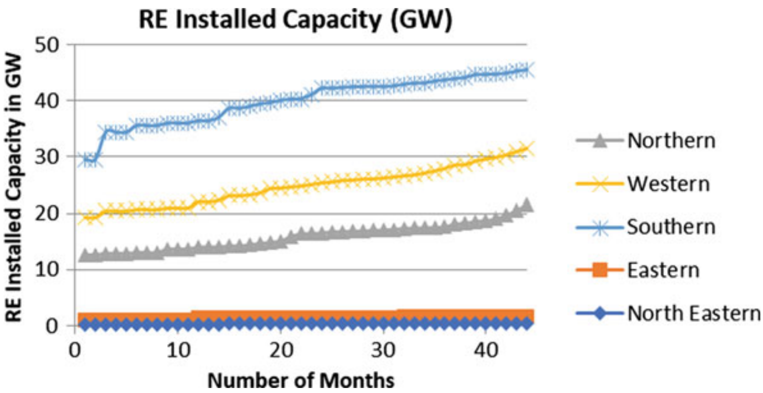

Fig. 1 India installed capacity in giga watt (MNRE report) [1]

by 0.64 GW, and northeastern zone by 0.14 GW. The data indicates that the slope of solar energy installation capacity was 23% during the COVID pandemic, whereas, after one year of the pandemic in 2021, the slope was 97%. The RE installation got a halt because of the pandemic and lock-down conditions in India, but after the new normal, RE sectors jumped to achieve the set targets.

2 Potential of Solar and Wind in India

India has got an estimated renewable potential of 1096 GW, wind-302 GW (at 100 m mast height), solar power-750 GW, small hydro-21 GW, and bio-enrgy-25 GW. India, on an average, receives about 5000 trillion kWh per year solar radiations incident on the land area exposed to about 300 clear sunny days in a year over most parts of the country. The peninsular India receives 7200 kWh^{-2} in a year over significant portions, while the annual highest dosage is over the Leh Ladakh which receives yearly average of 6.36 $kWh/m^2/day$ where temperature various between − 40 °C and + 35 °C [2] and in Run of Kutch 5.23 $kWh/m^2/day$ with temperature variation of 17–34 °C [3]. An example of the impact of changing climate can be seen on in Fig. 2 which shows the monthly average solar irradiation data for Srinagar, Jaipur, Shillong, Kolkata, and Chennai [4]. The country receives an average of global solar irradiation of 4–7 kWh m^{-2} per day. Rajasthan is having highest and Jammu and Kashmir second most top solar potential states as shown in Fig. 3 [5]. Geographical location of India on the globe is between the equator and tropic of cancer with an average annual temperature of 25–27.5 °C which makes India a strong solar potential country. Solar PV is the cleanest way to produce the energy geographical and climatological conditions. Bridge to India 2017 report says that cost of PV module price index is reduced by 29% in last two years and as on March 2017 it was 22 Rupee/Wp [6].

Solar inverter price index has decreased to 21% over last two years as of March 2017 it was 1.9 Rupee/Wp.

In India climatological conditions changes within two to three months, from the previous records of Indian Meteorological Department, it has been observed that under spatial conditions the wind speed keep on changing. As per National Institute of Wind Energy, India has a potential of 302 GW (100 m above the ground). India has a vast peninsula of 7600 km long coastal line NIWE with ministry is working on offshore wind power generation. India's wind power capacity majorly concentrated in the seven states of the peninsula so while transferring the wind power from one state to other the tariff policies wave off interstate transmission losses and charges for the sale of wind power between states. Table 1 gives the data for the topmost windy states, which are significant contributors to wind power generation [7]. India has got an extended transmission network of 5283 ckm for transferring energy interstate and to the neighboring country [8]. The green energy corridor project is an interstate

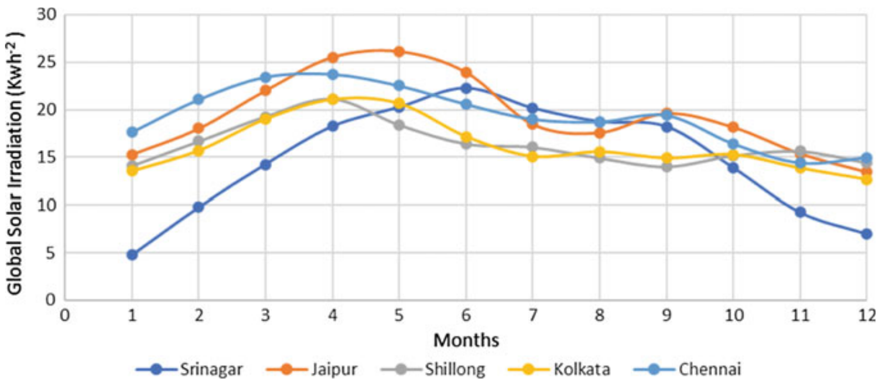

Fig. 2 Monthly average solar radiation exposure (kW h^{-2})

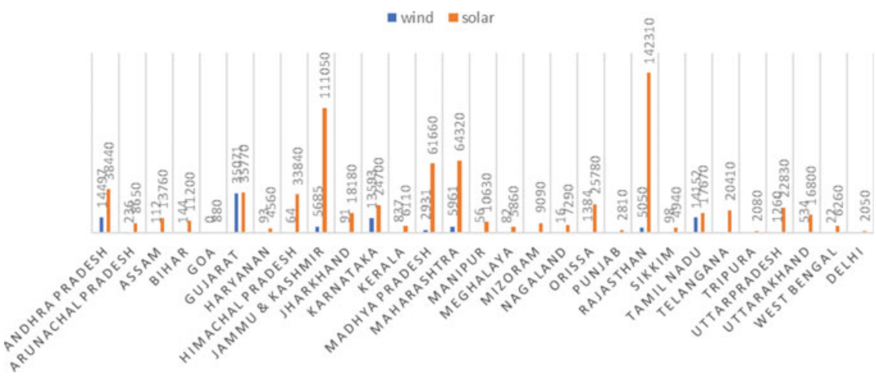

Fig. 3 Potential of solar and wind energy in the different states of India (MW)

transmission system which involves eight states to strengthen the intrastate transmission. This project includes approximately 9400 ckm transmission network with 19,000 MVA capacity, is targeted for 2020. The cost of project infrastructure and transmission network will be Rs.10,000 Crores. At the end of the year 2017, solar and wind tariff rates were lowest Rs.2.44/unit and Rs.2.64/unit, respectively. Indian Government dream of 175 GW by 2022 of the deployment of RE is getting fulfilled by the revolutionary and attractive policies of the government. India is aiming for 100 GW by 2022 from solar power generation under the National Solar Mission, for achieving the set target 35 solar parks with 20.514 GW capacity have been approved in 21 states [9]. India has got first operational Kurnool Solar Park with 1 GW capacity in Andhra Pradesh which positioned as a largest solar park in the world. In the year 2017, solar park Bhadla Phase-II in Rajasthan of 650 MW and Neemuch Mandausr Phase-I in Madhya Pradesh of 250 MW capacity have commissioned. New solar parks in Rajasthan with 1000 MW capacity, Gujrat 500 MW capacity, and in Mizoram 23 MW have approved for achieving the target of 2022. For ramping the ability of solar, lighting systems, solar pumps, and power pack, 181.52 MWeq has installed. The Jawaharlal Nehru National Solar Mission is the national solar mission and inaugurated in 2010. JNNSM phase-I was from 2010 to 2013 and completed 1000 MW. In 2013, under the JNNSM phase-II, India has achieved 21.65 GW installed capacity and GOI dreams for 100 GW. India has attained the sixth position on global in solar PV capacity after China, United States, Japan, Germany, and Italy.

Table 1 Wind installed capacity

State	Wind installed capacity (in MW)
Andhra Pradesh	3618.85
Gujarat	5340.62
Karnataka	3751.40
Kerala	51.5
Madhya Pradesh	2497.79
Maharashtra	4771.33
Rajasthan	4281.72
Tamil Nādu	7861.46
Telangana	100.8
Others	4.3

3 Challenges in the Accomplishment of Solar and Wind Energy

3.1 Social and Political Challenges

- Solar and wind-based generation varies from state to state so this variability of energy balance among the states is a challenge, and it is not being utilized at nation level [10].
- PV sites face the challenge of theft and defacement of panels.
- Renewable energy is intermittent, and as the generation is not getting balanced at the national level, different states are paying a huge penalty when they are not meeting the deviation settlement mechanism targets set by Central Electricity Regulation Commission.
- India is planning to hit 100 GW by 2022 out of 60 GW are ground-based solar park projects. The issues in the solar park are the difficulty in identifying and acquiring suitable land acquisition for the solar parks. Different states are participating in solar park plans but the difficulty in determining and then buying land and then its implementation due to land acquisition problems, so projects are facing great hurdle and delay in meeting the target 2022.
- The lengthy and slow procedure to get land acquisition permits, environmental and other statutory clearance are the significant challenges in deploying infrastructure for energy [11].
- In the absence of regulatory guidelines for interstate transmission, with the increased capacity of renewable energy states are the challenges for the Green corridor implementation in India.
- The policy and regulatory framework needs to improve for overall incentives offered in different states to RE [12].
- Renewable purchase obligations (RPO) is a significant driving component to the RE sector, but State Electricity Regulation Commissions (SERCs) may have off putting effect in the growth of RE sector. Analysis of state-wise RPO regulation across India shows that different states have different favorable conditions for the RE sector [13].
- Adequate technology and expertise upgradation required to be encouraged in the forecasting and scheduling of solar and wind. For solar and wind energy, the regulatory framework is not available to manage the intermittency.
- The emote and hilly areas of north and northeast have low RE potential, the land is also limited to install the RE projects. In these areas, people have less awareness RE. Rooftop solar generation can be emphasized, but lack of incentives, harsh geographical conditions, and limited private players in this sector is a problem in these areas.
- The power generator of solar and wind has to combat for selling their high-priced power. The RE face challenges in selling electricity to distribution companies and delayed payments [14]. The direct seller of solar and wind energy struggles to

pay taxes and cross-subsidy surcharges while offering domestic and agricultural users low prices. These issues are an obstacle to the growth of RE.

3.2 Environmental Challenges

- The birds and bats killing due to change in air pressure while turbines rotate impacts the wildlife near the wind plant.
- Sizeable rotating turbine blades rotating in the sun blocks the sunlight, and these moving shadows of the blades can be felt with even closed eyes. It effects the illumination inside the buildings also if the windows are closed. This shadow flickering is a big issue for the persons living nearby the wind farm.
- The noise produced by the aerodynamic movement of the turbine is a problem for societies near to the wind farm.
- If the wind farm site is in the green area with vegetation and trees; while installing the large turbines, huge area according to that is required, and it is not allowed to clear the green vegetation filled space. It becomes a challenge to assemble the lengthy and burdensome parts without destroying the environmental conditions.
- For the deployment of solar parks to achieve target, the land is a big issue, and agricultural land may get affected due to this. The land acquisition social impact also includes resettlement and rehabilitation.
- For the 1 MW solar park, from 4.5 to 7.5 acres and wind require from 25 to 96 acres of land depending on the size and arrangement of turbines, while this land can be used for agriculture and farming. In the case of offshore wind plants fishing, sea mammals and aquaculture majorly get affected.
- International Renewable Energy Agency report gives the estimate of the waste volume from the solar PV due to early, and full-term end of life in India is 3500 t in 2016 and will be 11,900,000 t in 2050[15]. This waste is a threat to the environment and recycling of panels is a global challenge.

In 2010, India Biennel update report was prepared according to the guidelines of Intergovernmental Panel for Climate Change states that India has emitted 2136.84 million tons of CO_2 equivalent greenhouse gases. 71% of emission is due to the energy sector, and per capita, GHG emission was 1.56 tCO_2 equivalent [16]. In 2017, GHG emission from electricity reached to 2066.04 $MtCO_2$. In developing country like India, power demand is increasing day by day which further leads to increase in GHG, to mitigate these problems: energy generation is shifted from conventional to renewable sector and under Kyoto protocol Clean Development Mechanism (CMD) is designed [17]. Proper site location and forecasting of sun irradiation level and wind speed for renewable are influencing aspect which is dependent on the demographic area. States Himachal Pradesh, Uttarakhand, Jammu Kashmir, and north-eastern have hydropower potential, but solar and wind are not much exploited in these states. Southern coastal states are producing surplus energy with wind energy and solar. Renewable energy is variable, but variable RE is smaller in capacity than in conventional generation and is deployed in a dispersed manner. A grid connected RE should have flexibility and ability to respond to rapid changes in load demand. RE sources provide energy security by diversifying the energy supply options and reduces the dependency on conventional energy. For achieving the green corridor mission reliable operation of interstate transmission, high penetration level of RE into the grid and better infrastructure is required.

4 Conclusion

The paper presents India's potential for generating solar and wind energy. India, a hugely populated country, needs to generate energy to serve the nations need. The deployment of solar and wind is a challenge. The challenging terrains with different seasons and geographical locations make some of the locations like Rajasthan and Leh best suitable for solar sites and coastal areas best suitable site of wind energy. Social, political, and environmental challenges hinder exploiting the solar and wind potential. The country is providing incentive schemes for promoting the RE installations, but the forecasting of RE generation based on site, season and weather condition is a great challenge. Many technological advancements brought parity between RE and fossil fuel. With technological advancement, the awareness among people has made RE a major energy contributor. The never give up approach of RE installation made India achieve the fifth rank globally.

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Chapter 17
An Overview of Blockchain Technology in Smart Grid

Saurabh Singh Laledia and Harpreet Kaur Channi

Abstract The increase in the use of renewable energy has opened up gates for new ideas and technologies to emerge. One such fresh concept to knock on the door for a while is blockchain technology. This technology is playing a significant role in changing the ethics of conventional transactions with its key features. Blockchain focuses on connecting information and data in such a way that any task or process performed on it becomes transparent as well as secure. With the implementation of blockchain in our conventional gird, consumers can buy and sell green energy directly from each other. This allows forming peer-to-peer network that results in the decentralization of electricity. Although the power of this technology is already known yet one of its crucial impacts is assumed to take place in the field of smart grid technology. This paper discusses the fundamental concepts and functionalities of a blockchain-based microgrid and provides information on peer-to-peer network for energy trade.

Keywords Blockchain · Microgird · Peer-to-peer · Consumers · Prosumers · Energy · Technology · Decentralization

1 Introduction

As energy consumption is rising with the evolution in technology, renewable energy production is in heavy demand. The conventional energy resources are continuously depleting at an alarming rate, therefore renewable energy is the definite future to generate electricity. So, to meet the forthcoming challenges, conventional and renewable sources need to function in parallel. This is only possible with the smart grid, where rapid action can take place to supply the load without interruption, making the system more reliable. So to make these advancements blockchain-based grid is the go to option because it offers peer-to-peer trading where every individual can have the opportunity to act like a provider or consumer according to his/her need. With

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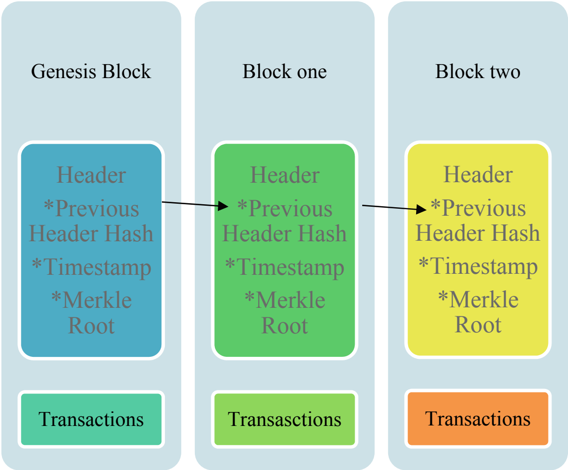
the increase in installation of small-scale renewable energy sources in commercial and residential areas, the reliability and quality of power system is being improved. Distributed energy resources are installed in many areas, which are supervised by the microgrid [1–3]. Distributed ledger technology and local energy market are essential parts of a decentralized system. So blockchain is a distributed ledger in demand which is applicable to large scale [4, 5]. The major implementation of blockchain has only taken place in the last decade, yet still, it has experienced constant evolution. As of now, it is classified into three types based on its advancements. The first generation that is Blockchain 1.0 provides access to paperless or digital transactions. The second generation enables smart agreements and advanced applications, and finally, the third generation introduced the concept of decentralization in different fields where-ever data is exchanged or transferred on a network [6, 7].

Normally, the blockchain shows the connected information formation of rising blocks which have transactions data [8]. The lump of data is reproduced for duplication and is transferred throughout the network to evade predation and removal of data. This makes the data more secure by comparing the information with each server to maintain transparency and ownership. Fresh data insertion in the chain is acceptable from mass consensus in between different users in the chain. All these features combined helps in maintaining the permanency and expandability. This is possible because of its compatibility with various object-oriented programming languages, which makes it flexible for developers [9]. Ballooning in the amount of distributed energy resources paired with the grid combined with rising microgrid creates a problem in prime trans-active network where trading or exchanging of energy takes place. So to achieve the up-gradation in the existing grid, blockchain technology arose as a boon for the modern power system. Via employing blockchain, the instantaneous trans-active energy control can be attained that is very difficult for a standard system. Apex security is demanded for microgrids that are functioning as a power supplier. The power delivery and monitoring system requires imminent transactions with proper authority. Different users inside the chain have access to multiple options where dispense ledger of energy trade can happen with decentralized smart contracts that can be authenticated by cross checking the data with different users. The discussed ledger may acquire important data, transaction information, energy transmission information, etc. [10].

2 Basıc Structure of a Blockchaın

N number of blocks, when linked together inside a network forming a chain that contains data information, forms the base of a blockchain. Figure 1 shows every single chain has a genesis block that forms the bedrock of a blockchain network [11, 12]. Every block that is created links the previous one to form a network. The safety of the data is maintained as every header embeds the header hash of the last block. Distinctive characterization of individual blocks is formed by cryptographic algorithms, as a result portion of each block makes a fresh hash. This process repeats

Fig. 1 Fundamental structure of blockchain



with each modification that occurs inside a block. If any type of tempering starts to take place, the entire block becomes invalid. This isolates the other blocks from the tempered one, that's why hash has a key role in maintaining reliability and security [13]. Basic structure of blockchain is shown in Fig. 1 [14].

The formation of a block is shown with the representation of a timestamp where different node consists of various confirmation intervals for every single block. The structure of a chain is rooted in the constant assistance of timestamp. For authentication and transferring data, Merkle root is employed, which is a hash of its own tree. This hash of the previous node is used to form hash of the next node until the root is acquired, which means the action is pursued till the end. Complete transaction status with every record is represented, as every block saves a transaction counter. Individual data transaction attaches information and address of shipper and collector. And to validate the given data, it is circulated around the network for confirmation.

3 Introductıon of Smart Contracts Inside the Blockchaın Base Network

Smart contract is one of the most important features that have originated with the rise of blockchain technology. As it is already known that its application inside the grid can change the entire processing of the power transmission. These contracts revolve around the idea of removing the middle man like any government or private organization while transferring power into the network. Ultimately, all this helps in lowering the electricity charges and making the system more efficient. This will encourage people to generate renewable energy, which will reduce the overall emission of greenhouse gases in our environment.

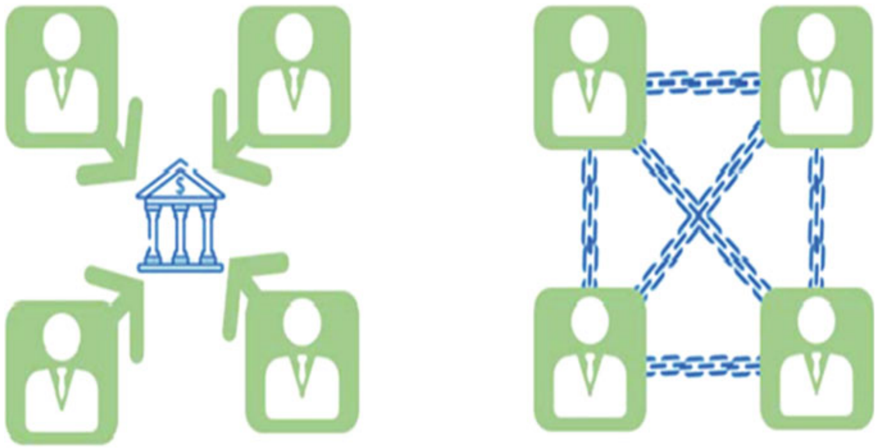


Fig. 2 Conventional versus blockchain-based trade

Descend on the dependability of fossil fuels is likely to be experienced as smart contracts become common. This contract technology permits the transfer of power in peer-to-peer form, excluding the distribution system which is executed on different levels [15]. For occurrence in U.S.A., the earliest implementation of this application was done in 2016, where people exchanged electricity showcasing the power of blockchain to the entire world. No third parties were involved in this exchange, therefore, cost reduction got possible. The smart contract waste no time in planning the entire procedure because the instructions are already embedded in the contract, saving precious time. Unlike conventional grid, where the consumers rely on a single provider, blockchain-based gird has an interlinked system between multiple users showcased in Fig. 2

Multifactor verification is on display as its key feature, which is a technique of certification that involves a client to offer multiple confirmation credentials in return for access to an asset, like a program or an account. Various strategies that could be used to ensure security, like as autonomous information storage come with it [16]. The entire process begins with the production of electricity that is subsequently purchased by clients. Then, for the purpose of updating the entire blockchain, specific gages that are dependent on blockchain offer a special block that is essential for the authentication phase. The previously outlined operating concept results in less information need and a quicker delivery processing time [17, 18].

Smart metering methods that are enabled for the chain network make smart contract deployment and trade tracking more convenient. It thus provides the transfer of surplus levels of produced electricity with ample storage to distribution systems by avoiding the mass effect repercussions [19]. Decentralized information locks the smart contract, so it is feasible to exclude the meter operator, which is an arduous task within the conventional network. Nevertheless, fresh opportunities are generally accompanied by new challenges [20–27]. To begin, there is a requirement to submit scheduling forecasts to the network management to make everyone aware of the contract.

4 Advantages of Blockchaın in Smart Grıd Technology

Blockchain has proven to be a boon for power grid applications because, in the ongoing scenario, grid administration is dealing with the deficiency of security in the cyber world of distributed energy resources. Although this technology can figure out any malfunctioning that occurs by hacking or external tampering with the information block yet it has ample of opportunities and advantages over any conventional system. Additionally, establishing smart contracts between the users will showcase other merits for this technology [28–34].

(1) Reliable agreement in between the energy merchants.
(2) Dispensed records capable of holding variant validation for process.
(3) Certainty in information storage.
(4) Removal of middle man in energy exchange due to which valuable prince drop can be experienced.
(5) On board trans-active domain to boost the demand in need.
(6) Establishes habitat so that microgrids can take part in energy exchange. Extra produced energy in the microgrids will support the feature of exchange that will ultimately reduce the tension on the grid.
(7) Information inspection of the secured data, which can be attached to the purchase of customer.
(8) It can also be used to power EV charging station which will encourage the suppliers to produce more energy.
(9) Extra power produced will assist the conventional supply during the peak load hours to accomplish uninterrupted running of electric appliances and will result in the reduced bill.
(10) In emergency conditions, blockchain-based microgrids will play a crucial role in providing needed power at important places like government offices, hospitals, etc., making the network self-dependent.
(11) This can also be appointed in EV charging stations to gain proof of authority.

4.1 Demerıts and Exıstıng Lımıtatıons

In spite of the many benefits of blockchain technology, still there are a number of drawbacks to consider, including highly pricey nodes that seek higher returns for completing trade in a firm that uses the demand–supply protocol. A compact ledger could compromise the network's protection and authenticity, as well as the files contained on the system [35–41]. Most of the blockchain used today, take more time than other Internet processes to complete the transaction, so the transaction per second count has to be reduced in the near future. Although the peer-to-peer network is a very reliable platform, but there is always a chance of human error when the physical interaction of the machine and the user is involved [42–48]. Each and every user has to have some access to an electronic device to accomplish any type of trade in the network. Implementation of this technology in rural areas is difficult due to a lack of infrastructure.

5 Brooklyn's Blockchaın Technology in Smart Grıd Applıcatıon

Brooklyn's microgrid test system is a real-world illustration of decentralized microgrid technology, which is being deployed as a new initiative in New York by LO3 Energy [49]. Consumers who own solar panels have the power to sell their excess electricity to other homeowners and users. Energy exchanges among members of the blockchain employ a peer-to-peer capitalistic market system. Ordinary meters cannot judge the bidirectional flow of energy therefore, in this system, customers and providers monitor the energy by using smart meters [50]. They record and authenticate energy exchange in a peer-to-peer setting with the help of a (distributed ledger technology) blockchain-based network. The characteristics of Brooklyn microgrid are represented in Table 1 with seven coverings of its topology.

The starting three layers have been accomplished and, to strengthen group engagement, members of layer 1 are made up of purchasers and prosumers. Rural suppliers are also urged to engage in microgrid system so that the peer group is more diverse. This microgrid is utilizing the pre-existing underground electrical network, so layer

Table 1 Multiple layers of blockchain-based Brooklyn mircogrid

Layers	Comment
Layer 1	The goal of this mircogrid is to improve regional supply security usage. Here, this layer has two different kinds of customers that are termed as consumers and prosumers
Layer 2	This blockchain-based microgrid is a grid-connected MG-TES that operates on UG electrical network
Layer 3	Users choose their price ranges for nearby NETWORK as well as their personal requirements
Layer 4	After a given interval of time a double auction procedure is employed to identify regional price
Layer 5	For power trade among the members in this microgrid, a blockchain-based distributed ledger technology framework is deployed
Layer 6	Real-time monitoring, cloud computing, and exchange validation are all possible with a stable and safe communication system
Layer 7	Brooklyn MG is collaborating alongside regional electricity organization to develop legislative standards for MG-TES adoption

2 establishes a supply demand balance. Layer 3 is being used in part to figure out how to get the general public to actively engage in this network.

It does not include the learning of the effects of high power production or utilization on network losses at a specific section. Furthermore, by analyzing consolidated energy generation and consumed data, it is realized that other critical elements, such as dependability, supply security, and durability, must be enhanced. The double auction process is used in the layer 4 where n number of users has the potential to buy or sell electricity. Furthermore, only a tiny fraction of prosumers and consumers are fully engaged due to lack of implementation. As a result, the practical success of local energy market is still a work in progress. The network of distributed ledger technology layer 5 is a closed chain network and is completely operational for documenting and authenticating energy transactions in the network. It is expected that the layer 6 is centered on the Internet or the facility's native communication system. Yet, further analysis and effective execution are required to choose a transmission system that meets the system requirements. The policy of control in layer 7 is still in the early phase as a result there is not a single foreign entity overseeing peer-to-peer energy exchange between two members. To administer peer-to-peer local energy market mechanisms, the distribution system operator can function as a separate network administrator.

6 Conclusion

The implementation of blockchain inside the smart grid has enabled the users to sell and purchase electricity without any external involvement. This has uplifted the use of renewable resources inside a blockchain network, which reduces electricity demand from the convention supply. Now, the consumers have the choice to select the source of energy they want to use in their network. The lucidity and security have secured the prices in the network where data can be stored without any discrepancy. Brooklyn microgrid that is based on this technology has showcased the actual implementation of a peer-to-peer network which has become a standard for future smart grid projects.

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Chapter 18
Design and Laboratory Implementation of Real-Time Optical Tachometer for High Speed Motor's: A Simplified Approach

Rakesh Goswami, Dheeraj Joshi, Anita Khosla, and Layba

Abstract A new simplified design of digital tachometer has been proposed wherein a photo diode takes place of shaft encoder. For the computation stage, new method has been proposed for extraction of shaft rotation from output signal of sensing element. The computation circuit has been further simplified by eliminating counter operation. Unlike conventional tachometer, the proposed design do not require sensing element to derive power by pressing against the motor shaft. It has been experimentally verified that use of proposed hardware structure could result in instantaneous availability of shaft rotation which is fastest among the computation time reported by various researchers. Instantaneous availability of motor speed can effectively increase the computation efficiency and transient analysis capability in feedback control of motor control scheme.

Keywords Tachometer · Photo sensor · BLDC motor · Photo diode · Counting error · Relative error

1 Introduction

At one hand sensing element in conventional analog tachometer and speed counters presented by various researchers[1–4] such as analog [5], AC drag cup induction generator [6], drag-magnet eddy current disk [7, 8], magnetic drag cup [9], reluctance pickup [10], diode type [6], incremental encoder (shaft angle digitizer) or proximity

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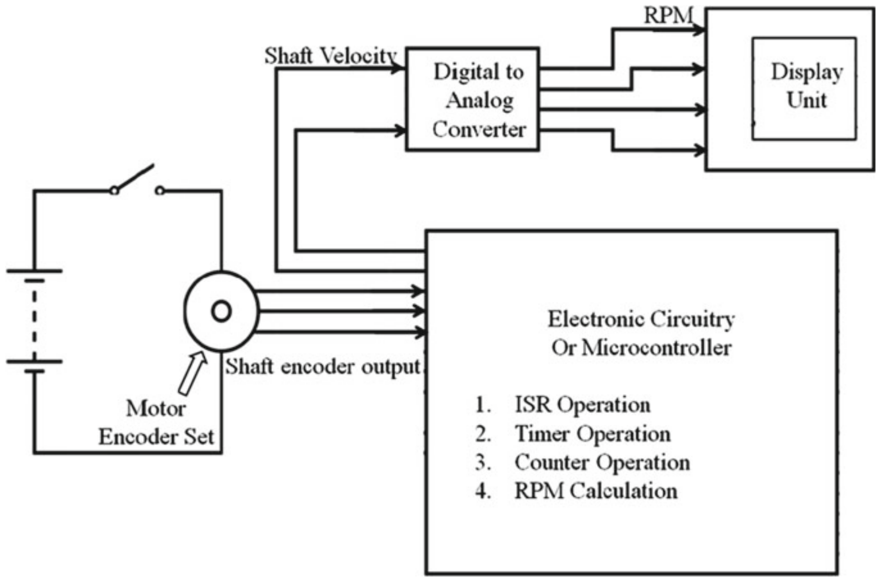

Fig. 1 Tachometer configuration

detector [10] are made to derive some power by pressing sufficiently hard against motor shaft which is highly undesirable and requires frequent calibration for accuracy of result. These are not suitable for very small motors of fractional horse power capacity. On the other hand, a digital tachometers or speed counter registers the number of revolutions of the machine in a given time and computation is based on shaft encoders input which makes it suffers from counting error and relative error [11]. Both speed counters and tachometers are subjected to sleep errors [1] and cannot provide real-time data. Speed counter consists of basic elements as shown in Fig. 1.

İt contains a shaft encoder as sensing element, a microprocessor/digital circuitry for computation, digital to analog converter and display unit. The output of the shaft encoder is a pulse train proportional to the rotational speed which requires processing in electronic circuitry for extraction of speed signal. The electronic circuitry performs three operations namely interrupt handling, time measuring operation and counter operation. Digital to analog converter converts digital speed data into analog form for final display. This configuration is widely being used for precise measurement of shaft rotation. Several methods have been proposed in several literatures to extract the speed signal from the output pulse train of shaft encoder. Out of the various proposed methods, following known methods [3, 11, 12] are widely being used.

(a) Direct pulse counting (DPC).
(b) Single pulse time measurement (CPTM).
(c) Constant elapsed time (CET).
(d) Pulse time measurement using a variable number of counted pulses (PTM).

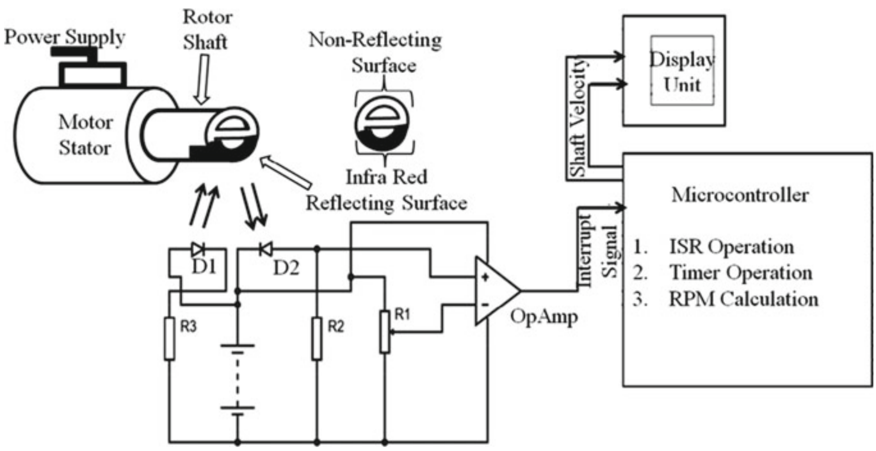

Fig. 2 Proposed tachometer configuration

First two methods (a) and (b) are similar to the one used in timer/counter instrumentation [3] and both were found to be suitable only for low RPM [12]. The last two method (c) and (d) are combination of encoder pulse counting and time measurement [3]. The third method (c) in particular was successfully applied for measuring medium and high RPM [12]. This paper proposes a digital tachometer design with simplified computation method as depicted in Fig. 2.

The proposed design does not require sensing element to be attached to the motor shaft like its analog counterpart, combination of an Infrared light emitting diode (D1) and a photo diode (D2) as sensing element has eliminated the requirement of shaft encoder. To process the output from photo diode, only timer operation followed by data processing is required which simplifies the computation method. This experimental setup was successfully realized using ARM Cortex M3 RISC processor. Pulse period time measurement (PPTM)-based method has been proposed and effectively verified for instantaneous angular velocity ranging from medium to high RPM.

2 Experimental Setup

2.1 Basic Theory

In proposed experimental setup as shown in Fig. 2, small area of peripheral motor shaft surface is painted with infrared sensitive coating capable to reflect infrared light. Infrared light emitting diode (D1) acts as light source and a photo diode (D2) placed at a suitable distance from the motor shaft is used as sensing element. D1 is permanently connected to 5 V power supply through resistance R3 so that infrared light is continuously radiated toward the motor shaft. Whenever the infrared sensitive layer at motor shaft/blade comes in front of D1, infrared light is reflected toward photo diode (D2). Whenever D2 receives the infrared reflection from motor shaft, it completes the circuit from resistance R2 to power source and a voltage pulse is generated across the resistance R2. Duration of voltage pulse is dependent on the span of infrared sensitive coating of rotating shaft/blade which falls in front of D1. This voltage pulse is fed to non-inverting input of operational amplifier. Inverting input of Op Amp is fed by voltage through potential divider R1. The Op Amp is configurated to operate as comparator, and it generates an interrupt signal for ARM Cortex M3 RISC processor. For one revolution of motor shaft, the microprocessor generates a pair of one high pulse and one low pulse. Time taken to complete the one successive high pulse (TH) and low pulse (TL) constitute one pulse period (TP) which is actual time taken to complete the one revolution. The schematic diagram is shown in Fig. 3.

Actual time taken to complete the one revolution is then used to calculate the angular velocity RPM. Even time of high pulse (i.e., 'TH') or low pulse (i.e., 'TL') may also be used for instantaneous calculation of angular velocity and RPM. The duration of TH pulse from microprocessor is actual the time taken to travel the part of motor shaft periphery with infrared reflective coating. As peripheral distance with infrared sensitive coating is known and time taken to travel this distance has also been recorded by the microprocessor, instant angular velocity and RPM can be made available by simple computation. Similarly, the instant angular velocity and RPM can also be obtained from time recorded in traveling the peripheral distance without infrared sensitive coating and time taken to travel this distance, i.e., TL.

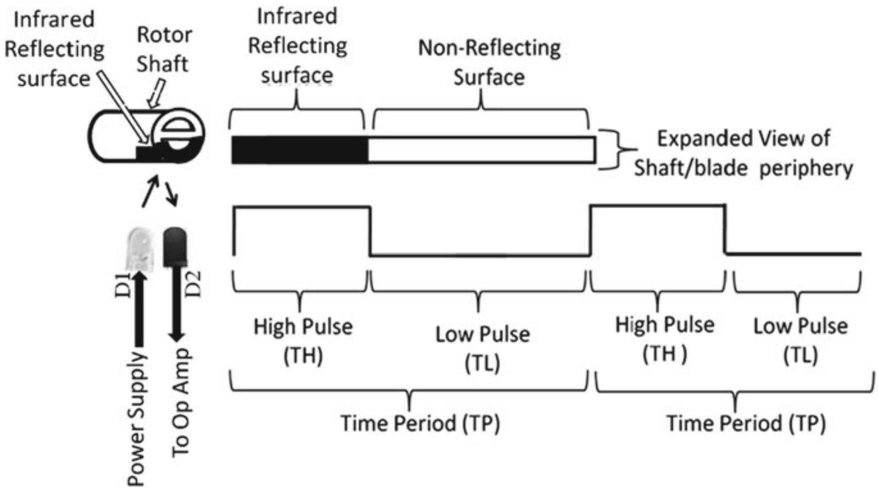

Fig. 3 Pulse train from Op Amp to microcontroller

2.2 Simplified Computation

As described in earlier section, whenever infrared light is reflected from the motor shaft and is received by the D2, an interrupt signal is generated from the operational amplifier for microcontroller. On receipt of the interrupt signal, the microcontroller records the time duration of interrupt signal. For this duration, microprocessor generates TH signal. Till the time next interrupt signal is not received, the microprocessor records the non-interrupt time duration and generates the TL signal for this duration. Time taken to complete the one successive TH pulse duration and TL pulse duration constitute one pulse period TP which is actual time taken to complete the one revolution (i.e., 360°) of motor shaft.

Let,

$$\text{Peripheral distance of motor shaft with infrared coating} = \theta \tag{1}$$

$$\text{Peripheral distance of motor shaft without infrared coating} = \varphi \tag{2}$$

$$\text{Time taken to complete } \theta = \text{TH} \tag{3}$$

$$\text{Time taken to complete } \varphi = \text{TL} \tag{4}$$

$$\text{Time taken to complete } \varphi + \theta = \text{TP} \tag{5}$$

$$\begin{array}{l}\text{Peripheral distance of motor shaft}\\ \text{without infrared coating} = \varphi\end{array} \tag{6}$$

$$\varphi + \theta = 360^\circ \tag{7}$$

$$\text{Time period} = \text{TP} = \text{TH} + \text{TL} \tag{8}$$

$$\text{Angular velocity} = \omega = \frac{\varphi + \theta}{\text{TP}} = \frac{360}{\text{TP}} \tag{9}$$

The duration of TH pulse from microprocessor is actually the time taken to travel the angular distance θ of motor shaft periphery, therefore instant angular velocity and RPM is computed using the following relation.

$$\text{Angular velocity } = \omega = \frac{\theta}{\text{TH}} \tag{10}$$

Similarly, the time duration of TL pulse from microprocessor which is actual time taken to travel the angular distance φ of motor shaft periphery is used to compute instant angular velocity by following relation.

$$\text{Angular velocity} = \omega = \frac{\varphi}{\text{TL}} \tag{11}$$

2.3 *Operating Sequence of Experimental Setup*

Flow chart of instruction to compute the RPM and angular velocity using TH is shown in Fig. 4. The operation of experimental setup (Fig. 5) starts from receipt of interrupt signal followed by information processing. At the start of the program, an interrupt service routine (ISR) is initialized to pick up the signal coming from D2. Two in no timer T1 and T2 are initialized and T1 is configured to record the duration of interrupt period TH and T2 is configured to record the duration of non-interrupt period TL. Both the time counters are reset to initial value (i.e., 0), and it goes to wait state till the time it gets instruction to start time counting operation. The microcontroller keeps monitoring input pin for interrupt signal from differential amplifier and whenever D2 falls in front of the infrared reflective coating, it receives reflected infrared light because of which it generates the interrupt pulse. At the rising edge of interrupt signal, time counter T1 gets started and it keeps counting till the time interrupt signal is available. At the falling edge of interrupt signal, T1 is stopped and its data gives time duration of TH. At the falling edge of the interrupt signal, time counter T2 gets started and it keeps counting till the time interrupt signal is not available. At the rising edge of interrupt signal, T2 is stopped and its reading gives time duration TL. Shaft revolution is then calculated by the microprocessor using TH or TL or TP. Thereafter, both the time counters T2 and T2 are reset to initial value and is ready for next revolution. One pair of signal TH and TL basically represents total time taken in completing one revolution of the motor shaft and the microprocessor output is updated during shaft revolution itself. A 32 bit ARM Cortex M3 RISC-based microcontroller board is used in this experimental setup, this circuit operates at a maximum speed of 84 MHz. The experimental setup was tested on a A2212/13 T high speed brushless DC motor by operated it on both acceleration mode and retardation mode to obtain the RPM.

3 Results and Discussion

Motor was operated in both acceleration and retardation mode using instruction and flow chart displayed. The TH was obtained and RPM was calculated for both the case plotted for both acceleration and retardation mode in Figs. 6 and 7, respectively.

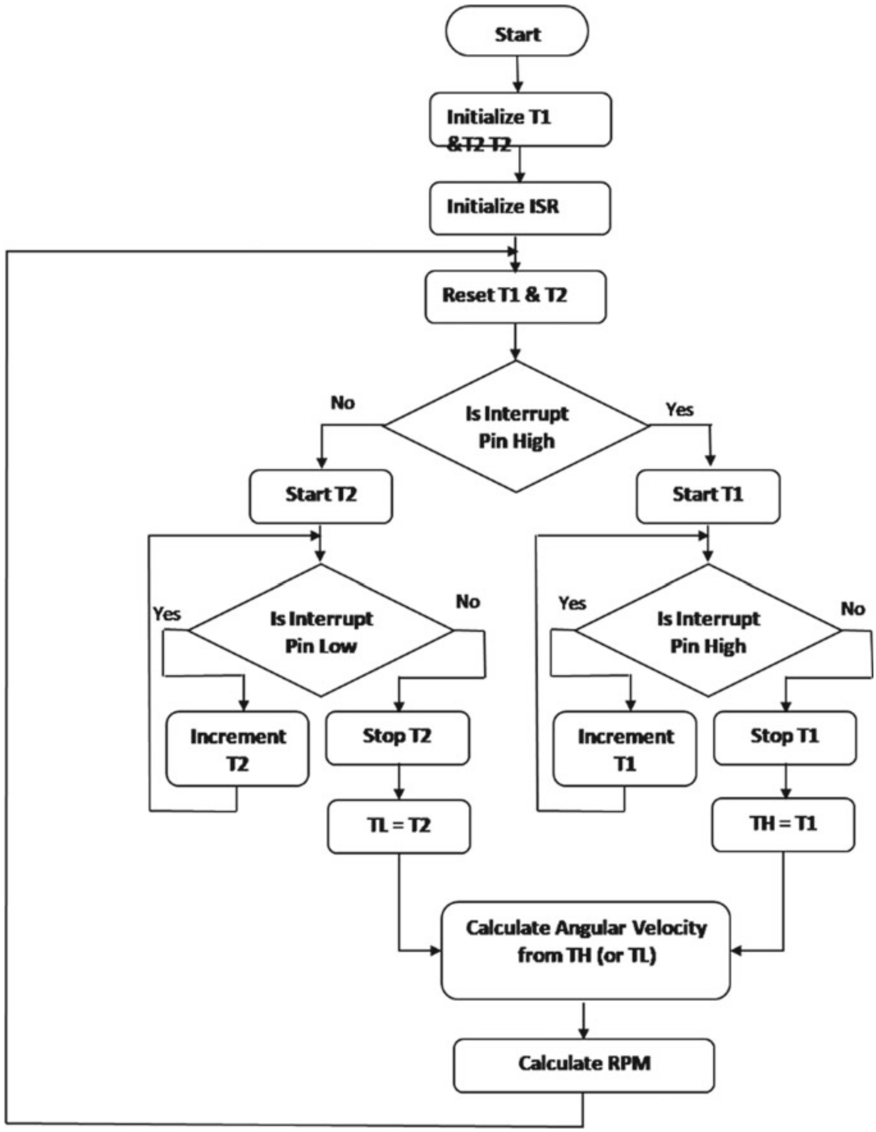

Fig. 4 Flow chart to calculate RPM

It was observed from the plot that the RPM so obtained contains noise and it needs smoothing operation before being displayed. The noise in the calculated RPM appears to be due to imperfection in infrared sensitive coating surface, eccentricity of motor shaft and location of sensing element. To remove the noise, Savitzky-Golay filtering (SGF) was applied on the calculated RPM. Calculated RPM, recorded RPM and RPM obtained by SGF was also plotted for both acceleration and retardation mode.

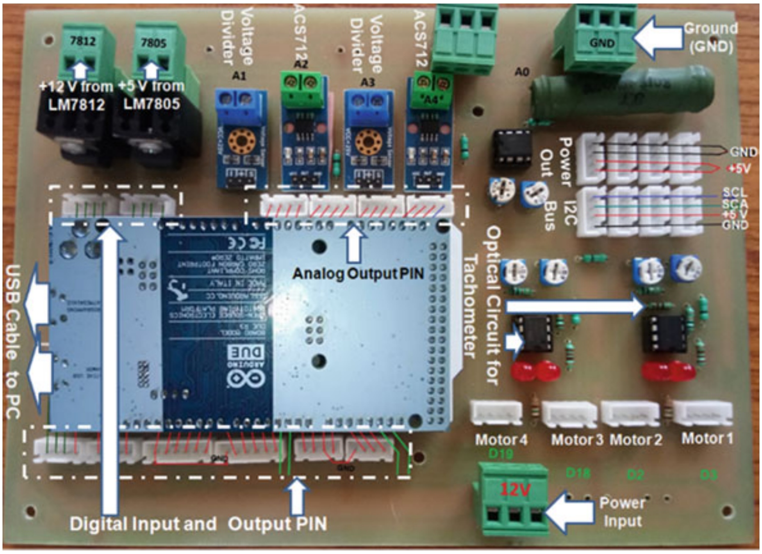

Fig. 5 Experimental setup

The result so obtained was successfully verified in comparison with the industry standard non-contact laser tachometer.

On evaluation, of program structure, it was found that prototype takes 2.03 µs to initialize time counter T1, T2 and interrupt service routine. Thereafter it takes 1.88 µs to reset the T1 and/or T2 to initial zero state. Hence, at the start of microcontroller program, it takes a delay of 3.91 µs (2.03 + 1.88) µs to get ready for recording

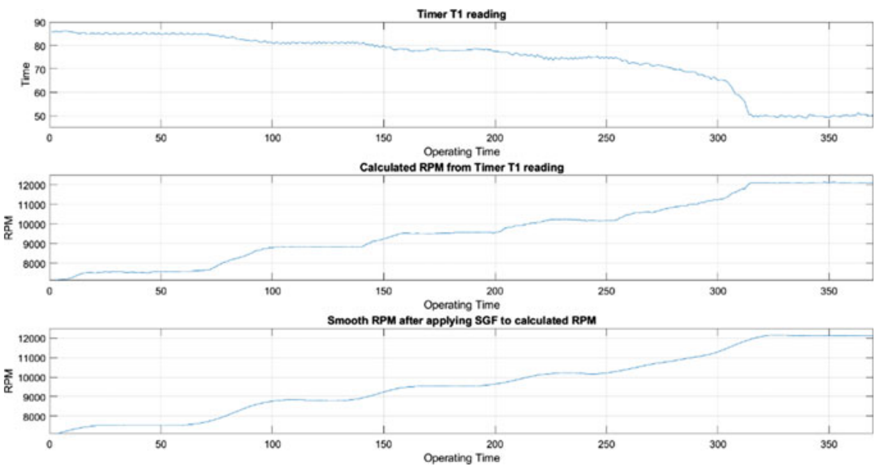

Fig. 6 Experimental setup operating in acceleration mode

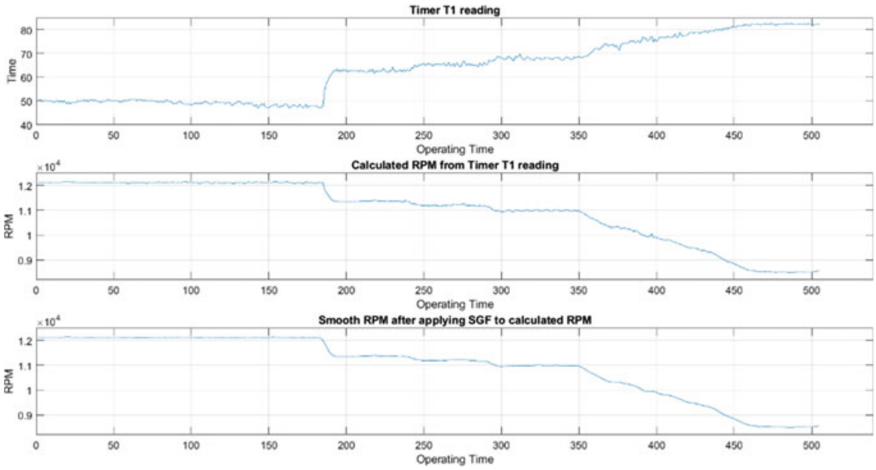

Fig. 7 Experimental setup operating in retardation mode

first shaft rotation. When shaft rotation starts, TH is obtained at the falling edge of the interrupt pulse, and TL is obtained at the rising edge of the interrupt pulse. Microprocessor instruction takes 3.55 μs to process TH (or TL or TP) before giving the result. In present case, the TH value alone is used for the computation, therefore from the rising edge of interrupt pulse, it takes only TH + 3.55 μs before the RPM value is obtained. This scheme works well for hardware configuration where TL < 3.55 μs and this limits the maximum operating range of the experimental tachometer. Since processing time 3.55 is kept less than the TL time, therefore the output is available even before the revolution is completed making it real-time data. This can enable the setup to be suitable for transient analysis and real-time application. On evaluation of Eqs. 9, 10 and 11, it was observed that this scheme does not works for zero or very low RPM. Still this setup was tested successfully within the range of 90–12,500 RPM. The complete hardware structure under trial takes into account only the TH pulse for computation of RPM and is updated only on receipt of next TH pulse, therefore even if any of the TH pulse is lost; it has no effect on the last RPM reading which is based on last TH value. Thus, the sleep error has been eliminated.

4 Conclusion

A new simplified design of real-time digital tachometer based on actual shaft revolution time measurement was successfully developed. This method was able to operate from very wide range starting from very low 90 to very high 12,500 RPM. The design eliminates the requirement of complex mechanical structure such as shaft encoder and direct contact of sensing element with shaft. The computation time has also been reduced to 3.55 μs which is least among the various setup reported in available literature. Even though the setup takes very small time from receive of interrupt to providing the output, still the output is made available to user before the completion of actual revolution. This makes the system real time.

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Chapter 19
Open-Switch Fault Detection in NPC Voltage Source Inverter

Kailash Rana and Dheeraj Joshi

Abstract A simple fault detection method is proposed in this paper for a three-level neutral point clamped (NPC) inverter under the open-switch fault. The proposed fault detection method not only detect the faulty phase of the inverter but also detect the upper and lower-part faulty leg without requiring any additional devices and complex calculation. Simulation verifies the viability of fault detection approach for proposed inverter.

Keywords NPC inverter · Fault detection · Fault diagnosis · Power electronics · Open-circuit fault · Space-vector PWM

1 Introduction

Due to increasing energy demand in today's world, power electronics (PE) technology has been widely used in large scale in the field of power generation, smart grid and industries application, where the voltage source inverter is a key component [1]. Multilevel inverter (MLI) systems have emerged as a viable technology in recent years for high voltage and power applications compared to the conventional two-level voltage source inverter due to its lower voltage stress, better waveform spectrum, reduced filter size, less voltage changes and waveform distortions. [2–4]. Diode clamped, cascaded and flying capacitor inverters are MLI types [5]. The 3-level diode-clamped inverter is considered to be the most widely used inverter topology out of these MLI. It is also called as neutral-point clamped (NPC) and does not need any isolation transformer and clamping capacitor, which enable hardware simplified [6]. Due to its many merits, NPC inverter have been widely used in many applications and its performance has been greatly improved. The PE systems comprise of different

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components. Among all the components, power devices are the most prone to failures. The converter system's failures resulted from failure of semiconductor devices are 21% [7, 8]. Therefore, reliability and safety of PE system is a concern. An inverter system may experience a variety of failures, such as failure of switch due to open circuit (OC) and short-circuit (SC), DC-link SC to ground, line to line SC at machine terminal and DC-link capacitor bank SC [6, 9].

As compared to the conventional two-level inverter, 3-L inverter comprises more number of devices, which make it more prone to failure. In most cases, when a device fails, system functioning must be stopped for safety. However, in case of highly reliable or safety critical operation, the system must continue its operation, even during any failures. In these kinds of instances, designing the system cautiously or providing redundancy to the system is a viable means of boosting dependability, but these practices may rise system cost [10, 11].

Fault-tolerant control techniques have been investigated as an alternative to these methods, allowing uninterrupted functioning of the system in degraded mode during abnormal situations [12, 13]. There are different control techniques and topologies, but each methods share few things same. Fault detection, fault-identification, fault-isolation and system reconfiguration are all performed sequentially in the control scheme. Insulated gate bipolar transistor (IGBTs), the most widely used type of power module, are most affected by temperature changes in terms of wear-out breakdowns [14, 15]. Open-switch (OS) failures can be triggered by the bonding wires lift of owing to thermic cycling, driver failure or IGBT rupture caused by a SC fault. The power devices, which are made of silicon (Si) and bond wires, which are usually made of aluminum (AI), have different temperature coefficients. AI has a coefficient of thermal expansion (CTE) of 23.5 106/K, while Si has a CTE of 2.6 106/K [7]. Due to this mismatch of CTE, bond wire failures in the power module are caused by temperature changes. For semiconductor OS fault diagnosis, several research have been done for the conventional two-level inverter. The majority of earlier methods [16] analyze the distortion of output currents to detect OS faults. The distortions of the output currents varies based on the faulty switch, and the difference can be identified using, current vector method using park's transformation, normalized average current method, the slope method, etc.

In this paper, the OS fault diagnosis of NPC inverter is proposed so that the fault tolerant control can be applied to the NPC inverter for its continuous operation in safety critical conditions. The sections of the paper are structured as follows: Sect. 2 presents the operation of neutral point clamped (NPC) inverter. The behavior of NPC inverter during OS fault is presented in Sect. 3. Section 4 gives the fault detection method for proposed NPC inverter. In Sect. 5, simulation results of detection method, while Sect. 6 gives the conclusion.

2 Neutral Point Clamped (NPC) Inverter

The NPC three-level inverter has six clamping diodes and twelve switches as shown in Fig. 1. It uses four switches in each leg. The neutral point is the midpoint between upper and lower half of dc capacitor. The phase $x \in (A, B, C)$ switching states are defined in Table 1. Three level inverters contain 27 combinations of switching states that generate 19 voltage-vectors.

The voltage-vectors are categorized into large-vector (LV), medium-vector (MV), small-vector (SV) and zero-vector. For NPC inverter, here space-vector PWM modulation technique is applied due to its bigger modulation ratio, low harmonic distortion and switching losses [16].

For three-level space-vector PWM following steps are:

1. 3-phase to 2-phase transformation.
2. Find the sector where the reference vector's tip is located.
3. Identify the region in the respective sector.
4. Determining best switching sequence.
5. Inverter gating signal generation.

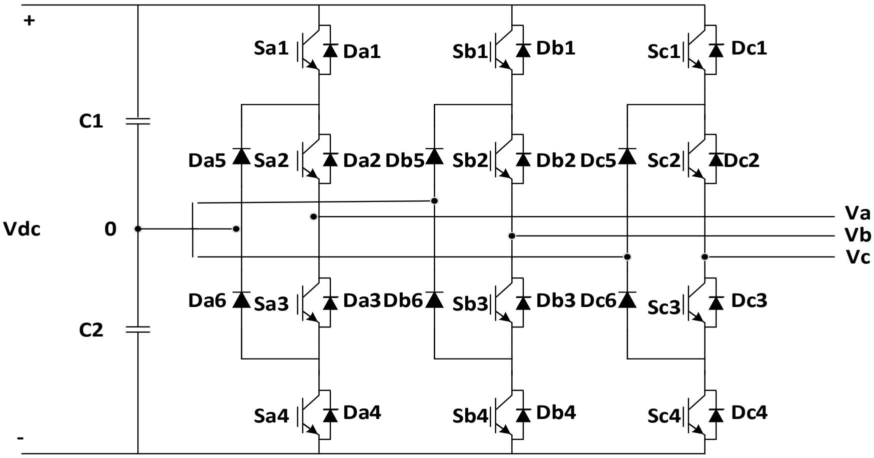

Fig. 1 NPC inverter

Table 1 Switching states of NPC inverter

Switching state	Switching status				Output voltage
	S_{1x}	S_{2x}	S_{3x}	S_{4x}	
P	On	On	Off	Off	Vdc/2
O	Off	On	On	Off	0
N	Off	Off	On	On	− Vdc/2

It is assumed that the 3-phase system is balanced

$$V_{ao} + V_{bo} + V_{co} = 0 \quad (1)$$

The three phase sinusoidal voltage quantities are

$$V_a = V_m \sin\omega t \quad (2)$$

$$V_b = V_m \sin(\omega t - {}^{2\pi}/_3) \quad (3)$$

$$V_c = V_m \sin(\omega t - {}^{4\pi}/_3) \quad (4)$$

The voltage vector V_{ref} in 2-phase stationary coordinate (αβ-plane) can be derived by Eq. (5).

$$V_{\text{ref}} = \frac{2}{3}\left(V_a + e^{j2\pi/3V_b} + e^{-j2\pi/3V_c}\right) \quad (5)$$

$$|V_{\text{ref}}| = \sqrt{V_\alpha{}^2 + V_\beta{}^2} \quad (6)$$

$$\theta = \tan^{-1}\frac{V_\beta}{V_\alpha} \quad (7)$$

SVM algorithm for NPC inverter is based on volt-second balancing principle, which is given in Eq. (8).

$$\overrightarrow{V_{\text{ref}}} \cdot T_s = \vec{V}_1 t_a + \vec{V}_8 t_b + \vec{V}_2 t_c \quad (8)$$

$$t_a + t_b + t_c = T_s \quad (9)$$

The three nearest stationary vectors synthesized reference vector V_{ref}. The equation for the switching times in sector I is given in Table 2.

Table 2 On times in sector I

On time	t_a	t_b	t_c
Region 1	$2k\sin({}^{\pi}/_3 - \theta)$	$T_s - 2k\sin({}^{\pi}/_3 + \theta)$	$2k\sin\theta$
Region 2	$T_s - 2k\sin\theta$	$2k\sin({}^{\pi}/_3 + \theta) - T_s$	$T_s - 2k\sin({}^{\pi}/_3 - \theta)$
Region 3	$2k\sin\theta - T_s$	$2k\sin({}^{\pi}/_3 - \theta)$	$2T_s - 2k\sin({}^{\pi}/_3 + \theta)$
Region 4	$2T_s - 2k\sin({}^{\pi}/_3 + \theta)$	$2k\sin\theta$	$2k\sin({}^{\pi}/_3 - \theta) - T_s$

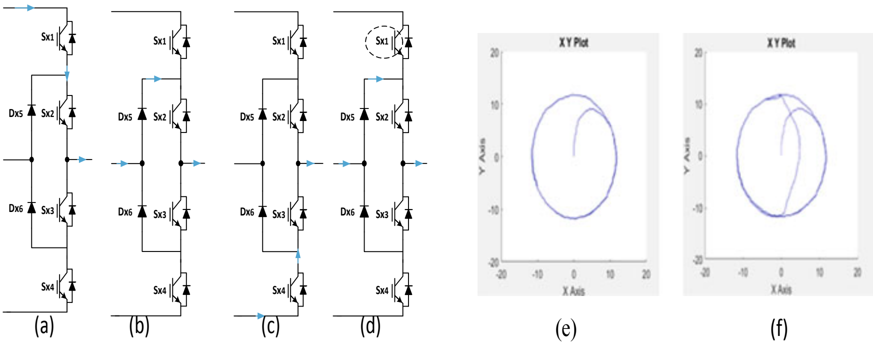

Fig. 3 **a–d** Shows the conduction path and **e**, **f** shows current pattern

3 Three-Level NPC Inverter Under Open-Switch Faults

Inverter semiconductor devices may fail OC or SC. The failure happens due to driver faults, high temperature, lifting of bonding wire, due to CTE mismatch or happens due to avalanche stress [17].

The OS faults distorts and/or eradicate output phase currents in defective leg based on the position of faulty device. It also affects normal phase currents, which degrades the system performance considerably [18].

Under the normal circumstances, if $i_a > 0$ and the pulse control signal of a phase leg is [PPOO] (P represents IGBT on; O represents IGBT off), the output voltage is $V_{dc}/2$, the current passes through switch S_{a1} and S_{a2} and the corresponding voltage vector is P. Figure 3a–c shows the conduction path in P, O and N switching states under normal conditions. When an OS failure occurs in switch S_{a1} the system will not be able to produce the P switching state. Similarly, when the OS failure happens at switch S_{a2} the system will not be able to produce the switching state P and O. In case of the OS failure of switch $S_{a3,}$ the system will not be able to produce O and N state. If the OS failure occurs in switch S_{a4}, the state N is not available for the negative direction of current. Figure 3d shows the switch S_{a1} fault.

When inverter is operating under normal condition the current pattern on output of inverter is shown in Fig. 3e, and for the switch S_{a1}, fault current pattern is shown in Fig. 3f.

4 Three-Level NPC Inverter Open-Switch Fault Detection

Most fault detection approaches use additional devices which have big drawbacks regarding increase in size and cost [19]. The suggested detection method is based on the distortion in current without employing any additional devices. The current sensors are used to monitor the output current and control the system. This data is

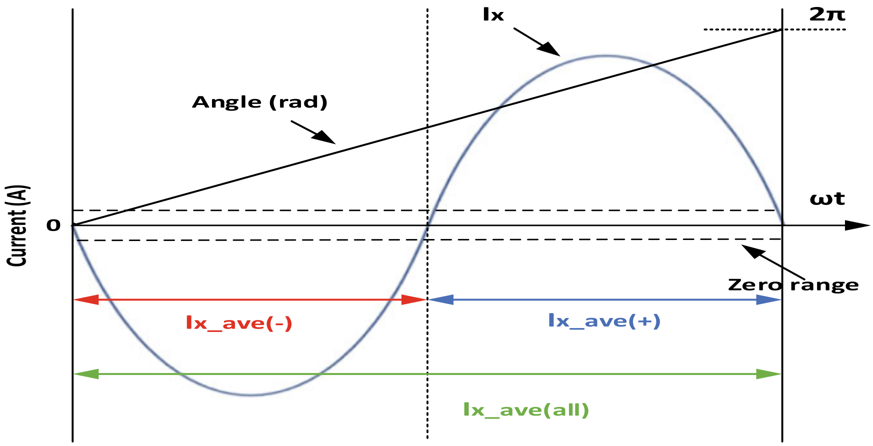

Fig. 4 Fault detection variables

used to identify faults. In this fault detection method, only phase A is considered. $I_{a\_ave}(+)$ defines the average value of positive phase current, while $I_{a\_ave}(-)$ defines the average value of the negative phase current. In case of normal condition, when there is no fault and current waveforms are not distorted, $I_{a\_ave}(+) = I_{a\_ave}(-)$ or $I_{a\_ave}(\text{all}) = 0$. $I_{a\_ave}(+) + I_{a\_ave}(-) = 0$. $I_{a\_ave}(\text{all}) = I_{a\_ave}(+) + I_{a\_ave}(-)$ illustrated in Fig. 4.

When there is fault in any switch by using the average values of the current, we can detect the faulty leg. The leg can be divided in two parts, upper components and lower components. When fault occurs to switch S_{a1} or S_{a2}, the average value of current has a negative value. Thus, it can be used to detect the fault in upper part of leg. Therefore, the defective phase and the group can be detected by the polarity of $I_{a\_ave}(\text{all})$. The threshold value 0.45 is considered for the detection of fault [20].

5 Simulation Results

A three-level inverter simulation model was built and implemented in Simulink. Under normal condition, when there are no faults in the system, the voltage and current waveform are depicted in Fig. 5a, b. In case of the switch S_{a1} fails at time $t =$ 0.15, the current waveform of all three phase and faulty switch detection waveform are shown in Fig. 6a, b. When switch S_{a1} fails, the positive current does not flow after the occurrence of fault which is shown in Fig. 6a.

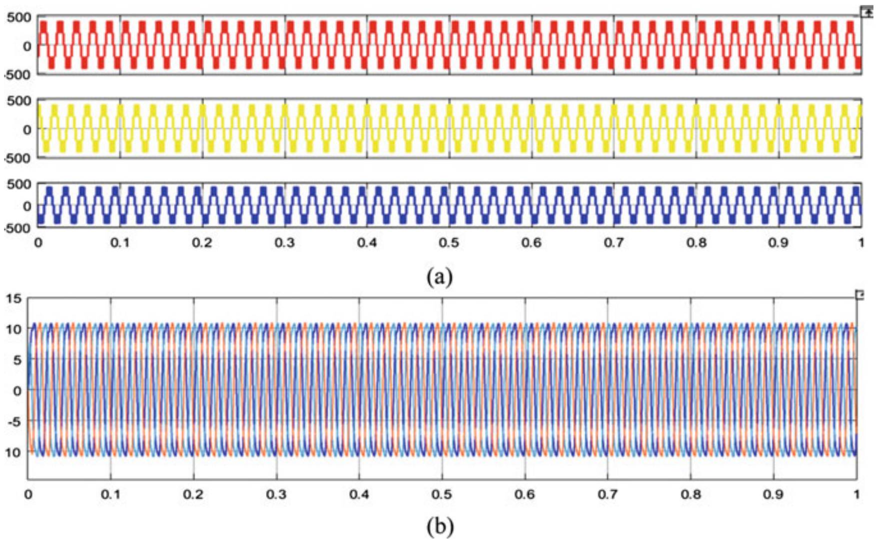

Fig. 5 **a** L-L voltage under R-L load. **b** 3-phase current under R-L load

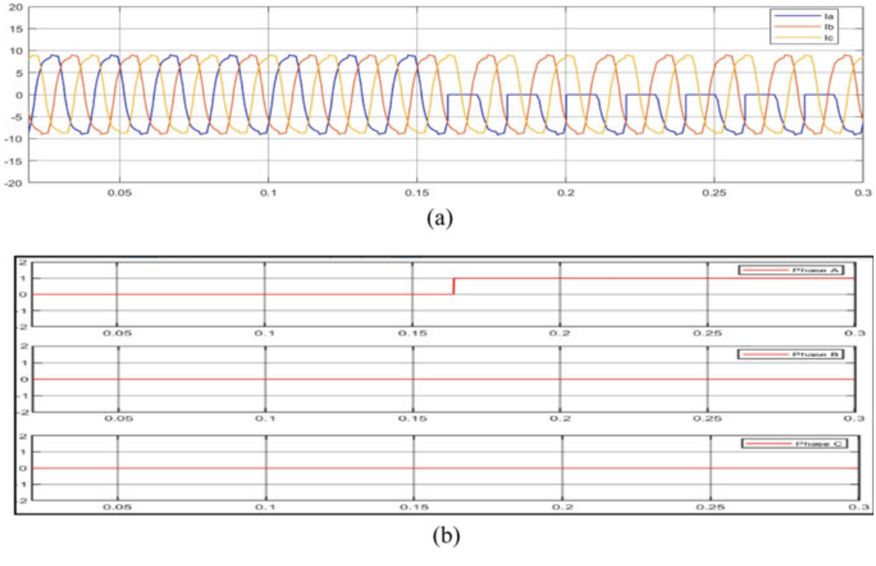

Fig. 6 **a** Iabc when switch Sa1 OC fault occur at $t = 0.15$ s. **b** Fault detection of upper switches of phase A for OC fault at $t = 0.15$ s

6 Conclusion

In this paper, fault detection of three-level NPC inverter is proposed and investigated. The result obtained by simulation using this detection approach, the open circuit of semiconductor switch and faulty leg is detected. This method for fault detection does not requires any additional devices, which is helpful to reduce size and cost.

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Chapter 20
Energy Consumption by Solar LED Streetlights in Domestic Application

Ruchi Gautam and Harpreet Kaur Channi

Abstract In this paper it is proposed the standalone solar LED streetlight for the roads of Harsh Vihar, Delhi. The LED light, poles, sensor, height and space between the poles are kept same only solar panel is used to glow the streetlights so that the use of electrical energy is reduced and renewable sources of generation is used. The cost of PV panel is taken approximately to exact value to estimate the overall cost of the LED streetlight system. Also the irradiance of solar energy and the tilt angle for the solar panel for months in a year 2021 is shown so that further approximation can also be done. Hence, the overall cost of the system is estimated and by estimating we will conclude the result in which overall cost of 25 years will decide the reliability of both the aspects of connecting LED streetlight. This result will show the long term benefit of energy saving by using solar panel in streetlight.

Keywords Solar LED · Streetlight · Renewable energy resource · Solar irradiance · Tilt angle · PV Solar panel · Lead-acid battery

1 Introduction

Energy is the single most significant characteristic to consider when considering the environmental implications of technical systems in today's society. Because of the streetlights, a greater amount of electricity is consumed [1–5]. Solar LED streetlight is popular in providing affordable lightning, and they are also created to produce light 90% more efficiently than any other streetlight. Lightning is also important to provide safety, security and mobility. And when there is renewable energy used such as solar then it also makes this friendly to the environment compared to grid connected lights. Sun provides us solar energy and as we are moving toward renewable energy resources as non-renewable energy resources are depleting fast. Hence, solar lighting is the best way to get light [6–9].

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When available natural light (sunlight) falls below a predetermined level, street lighting is used to artificially illuminate streets and pathways [6, 10, 11]. Solar LED streetlights are popular because they produce light 90% more efficiently than traditional streetlights [4]. Nearly 95% of the energy is converted into light via LED technology. Incandescent streetlight bulbs, on the other hand, convert just 10% of the energy into light and lose 90% as heat [12]. So nowadays LED streetlight is preferable [13]. Figure 1 shows the streetlight LED and electric meter in Harsh Vihar, New Delhi, and Fig. 2 shows electric meter for streetlight power consumption calculation.

Table 1 shows the data of streetlight in Harsh Vihar, Delhi. There are 500 LED streetlights with the each rating of 30 W. Equation 1 is used to calculate the cost [14]. Approximately, we have taken the cost of per LED, i.e., Rs800/- (in rupees).

$$C = (W * H * P * U)/1000 \quad (1)$$

where

- C cost of total energy in one day
- H number of hours light will glow
- P power of each LED bulb
- U charge per unit.

Cost of total energy in one day = 500 * 8 * 30 * 8 = 960 (in rupees)
Cost of energy in a month = 960 * 30 = 28,800.

Fig. 1 Streetlight LED and electric meter in Harsh Vihar, New Delhi

Fig. 2 Electric meter for streetlight power consumption calculation

Table 1 Data of the streetlights in Harsh Vihar, Delhi

Parameters	Values
Number of streetlights	500
Rating per LED	30 W, 12 V, 2.5 A
Total energy required	15 kWh
Cost per LED	800 (in rupees)
Cost of total energy required per day	960 (in rupees)
Total cost of energy per month	28,800 (in rupees)

2 Literature Survey

Sanguk Park et al. investigated challenges with integrating energy storage system (ESS) in a smart grid, including costly setup and inefficient management. This paper examines the design of a micro-distributed ESS in an intelligent LED streetlight system, as well as its inexpensive installation and efficient control in a micro grid, to solve these difficulties. Micro-distributed ESS and IoT-based intelligent energy management allow power monitoring of streetlights and energy-efficient demand resource management in the microgrid while reducing initial installation costs. Another study explained the development and build a microcontroller-based automated single-axis solar tracking system with an automatic water-cooling system. These solutions boost solar panel production and efficiency [15]. Ghodasara et al. designed a solar tracking system. Mechanical device utilizing LDR and DC motor gear-structure. It is controlled with Arduino UNO solar-earth geometry. The automated solar tracking system is more than fixed one [16]. Another article offers the latest research and applications for studying tilt angle's influence on PV performance using optimization approaches. This article analyzes the best tilt angle for optimum energy gain in Malaysia. According to the research, Malaysia's ideal tilt angle is 15°. This evaluation will help designers and researchers estimate the ideal solar PV tilt angle in Malaysia [17]. Tirmikçi et al. examined daily and monthly solar module tilting the module's solar radiation. Both optimal tilt angles MATLAB calculates solar radiation and tilt angle correlations [18]. In another study, a computational LED filament light bulb model was created. The FEM-based ANSYS Icepak software was compared experimental data. With LED technology, lighting studies have gained attention illumination. Studies show the energy savings of LEDs replace HPS. LED technology is increasing energy savings reduces payback time is diminishing [19]. South African Solar Challenge teams construct solar who can go the furthest in 8 days regulations state. Only sun irradiation should power solar cars. Global horizontal irradiance data indicates solar powered solar vehicles' ranges [20].

3 Materials and Methodology

This section shows the steps used to collect data for the analysis in detail.

In Table 2, all-sky clearance insolation clearness index is shown which can help an engineer to examine the solar irradiance in the area where solar panel is installed.

In Fig. 3, the bar graph of clearness index is described which shows the ups and down in the solar radiance so that actually energy can be estimated. The above analysis for all-sky isolation clearness index tells that the area of Harsh Vihar, New Delhi, will fully support the electricity generation by installing solar panels. The area has an average of 0.54 which is a sustainable value for the installation of solar panels as the ideal value lies between 0 and 1 [21–26]. Therefore, solar panels can be installed in the area to generate green energy.

In Table 3, optimum tilt angle of solar panels is shown by which maximum energy that can be generated by tilting the panel by this angle in the area. Today's time tracking of solar panel is introducing by which maximum energy can be produce [27–30]. Hence by tilting the solar panel, max power generation through the solar panels can be done.

One of the most essential criteria for obtaining maximum solar irradiation falling on solar arrays is the surface tilt angle of a photovoltaic (PV) module [31–33]. This angle, however, is site-specific because it is determined by the Sun's position on a daily, monthly and yearly basis. Furthermore, in order to extract the most energy from the solar PV system, the ideal tilt angle for the location must be determined and the ability of the PV system to modify tilt angle is heavily reliant on the fixed and tracking systems [34–36].

Table 4 shows how much solar panel needed and cost of panel and battery has been taken tentatively. Hence, 500 solar panels and battery will be required individually. Total installation cost will be 967,500 (in rupees), and maintenance cost will be 1500/yr.

The higher efficiency will reduce the size of energy storage units which also prolonged the battery operation period [37–41].

Table 2 Solar irradiance from Jan 2021 to Oct 2021

Months	Solar irradiance in Delhi
January	0.42
February	0.61
March	0.62
April	0.65
May	0.54
June	0.54
July	0.41
August	0.44
September	0.45
October	0.60

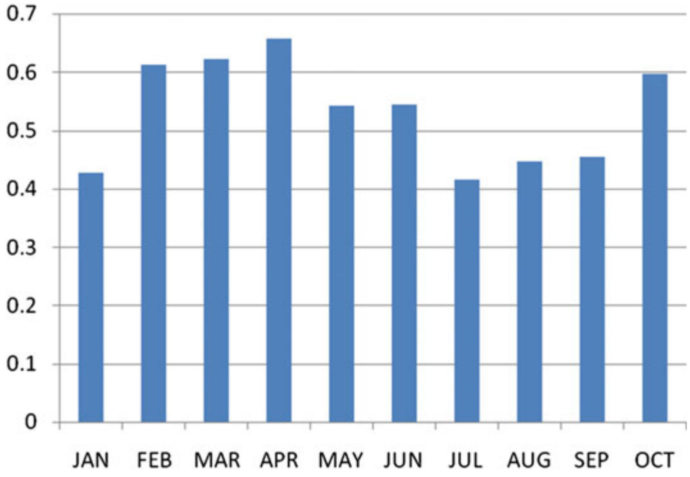

Fig. 3 Variation in average all-sky insolation clearness index (dimensionless) (from Jan 2021 to Oct 2021)

Table 3 Optimum tilt of solar panels by month in Delhi

Month	Tilt angle in Delhi
January	45°
February	37°
March	29°
April	21°
May	13°
June	6°
July	13°
August	21°
September	28°
October	37°
November	45°
December	52°

Table 4 Estimation of solar streetlight in area

Parameters	Values
Number of solar panels required	500
Number of battery required	500
Cost per PV panel	1500 (in rupees)
Cost per battery (lithium-ion battery)	435 (in rupees)
Total cost of PV panel and battery	967,500 (in rupees)
Maintenance cost/yr	1500 (approx.)

Table 5 Comparison of grid connected LED streetlight and solar connected LED streetlight

Parameters	Current grid connected LED streetlight	Solar powered LED streetlight
Number of LED lights	500	500
Number of solar panel	–	500
Number of battery	–	500
Rating of LED	30 W, 12 V	30 W, 12 V
Cost per LED	800 (in rupees)	800 (in rupees)
Cost per solar panel	–	1500 (in rupees)
Cost per battery	–	435 (in rupees)
Energy required	15 kWh	15 kWh
Installation cost	40,000 (in rupees)	1,367,500 (in rupees)
Total cost of 25 years	8,640,000 (in rupees)	50,000 (approx.)
Overall cost	9,040,000 (in rupees)	1,417,500 (in rupees)

By comparing the two batteries lead acid battery and lithium-ion battery, because the lithium-ion battery is three times more expensive than the lead acid battery, it is evident that the lead acid battery is the best alternative for a standalone system [19, 42, 43] (Table 5).

4 Conclusion

In the comparison between both grid connected LED streetlight and solar powered LED streetlight, there is 500 LED light of same rating in both the cases and energy required is also the same but solar panel, battery added to the solar powered LED streetlight by which it is concluded that the installation cost of solar powered streetlight is more than the grid connected streetlights but in the long term of 25 years, solar powered LED streetlights will reduce our electricity consumption in addition it also save lots of money spending on energy. Moreover, it increase cost of maintenance as solar panel will required regular maintenance and battery also requires maintenance time to time. And they both have life of a particular time period so then they should be replaced for the continuity of supply. Hence, overall solar powered LED streetlight has many merits as compared with grid connected LED streetlights.

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Chapter 21
A Circular Graphene Patch MIMO Antenna at THz Range

Nishtha and Rajveer S. Yaduvanshi

Abstract A circular-shaped patch antenna is feed by a proximity couple feed. The antenna uses a very thin graphene layer as the radiating element. The graphene patch-based antenna is designed on a silicon dioxide substrate having constant of relative permittivity 3.8. The antenna operates in a MIMO mode as it is feed by two ports. The MIMO parameters of the graphene antenna such as the envelop correlation coefficient (ECC), diversity gain (DG), and mean effective gain (MEG) are found to be < 0.001, ≈ 10 dB and < -3 dB. respectively which is within the desirable range for the antenna to operate as an MIMO antenna at such high frequencies. The antenna provides a 10 dB impedance bandwidth of 23.52% (1.92–1.49 THz). The isolation between the two ports of the MIMO antenna is found more than 25 dB for the desired range of frequencies. The antenna can be used for future THz communication systems.

Keywords Antenna · Proximity feed · Graphene · MIMO · 5G communication

1 Introduction

Next-generation wireless communication systems require high radiation efficient, wide bandwidth, and loss transmission power antennas. High data rate can be achieved by expanding the bandwidth and signal power which can be done by working in Terahertz frequencies (THz). The signal power and bandwidth are limited parameters. Employing multiple antennas at the transmitter and receiver end or multiple input multiple output (MIMO) systems can enhance the channel capacity and thus give the desired increased data rate[1, 2].

The basic requirement for THz antenna is small size and thus microstrip patch antennas would be best suited for the situation as it is planar and thus can be easily integrated with other on chip technologies [3]. However, it faces the problem of

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narrow bandwidth and low power handling capacity. Implementing nano-or micrometer sized antennas would cause severe attenuation at such high frequencies. Due to metals losing their conductivity at such high frequencies, metal-based antennas become ineffective at THz frequencies [1]. In order to overcome all the drawbacks of metallic patch antennas, graphene-based antennas which supports Surface Plasmon Resonances (SPR) are used to radiate electromagnetic waves at THz range [2–4]. High speed is achieved by the graphene-based devices as the ultra-high mobility of their charge carriers reduces their response time [4]. The metal-based antennas are not efficient at such high THz frequencies and they do not even provide the tunability for frequency response. The most important advantage of graphene over other metallic antennas is its tenability [4, 5]. The conductivity of the graphene can be changed by changing the chemical potential of the graphene layer which can be changed by changing the doping concentration or by applying electrostatic bias [5–8].

To obtain the MIMO performance, the antenna must obtain high isolation between the different ports and low value of envelope correlation coefficient (ECC), and a high value of diversity gain (DG) and mean effective gain (MEG) [2, 2]. The MIMO parameters of the antenna when in the acceptable limit prove that the antenna radiates at the THz frequency. The physical parameters of the proposed circular patch antenna are selected so that they can be fabricated in the near future for various future communication devices.

To the best of authors knowledge the other THz graphene antenna designed uses multi radiators [9] or graphene radiating patch and metamaterial [10]. These designs require individual feeding for each radiator of the antenna structure and hence increases the complexity of the antenna structure. Moreover, different radiating elements in a single antenna increases the size of the antenna as isolation between the ports is needed for a MIMO operation. Hence, it is the need of the hour to design a MIMO antenna that is simple and easy to design. The proposed antenna consists of two ports and a single circular shaped graphene patch and hence uses a single gate voltage source and thus is very easy to design as compared to the other antennas discussed so far.

In this paper, a single circular patch antenna feed by proximity feed is proposed for THz band applications. The proximity feed structure provides a wide impedance bandwidth. The length of the feedline is selected in such a manner that the field applied to one port is attenuated before it reaches the other port and hence a high isolation between the ports is achieved. The response of the antenna can be tuned to different frequencies by exploring the tenability property of the graphene material i.e. an external electrostatic DC bias voltage is used to tune the antenna response at different frequencies. The proposed antenna is based on a single graphene patch radiator and a single-gate source voltage at both the ports and thus can exhibit a simple antenna design at such high frequencies.

2 Antenna Design

Figure 1 depicts the layout of the graphene patch MIMO antenna with two nano feedlines used for feeding the structure so that it works in a multi-mode antenna operation. The antenna structure consists of two substrates of height h_1 and h_2 of relative permittivity $\varepsilon_s = 3.8$ at the optical frequency. A lower substrate, substrate − 1 is made up of silicon dioxide and has $h_1 \times l_s \times w_s$ dimensions. A second substrate with radius $r = 13$ and height h_2 is placed on the substrate-1 and on top of it is placed the circular patch of graphene of the same radius and height t_m. Both the graphene patch antenna and substrate-2 are placed at the center of ground and substrate − 1. Two nanostrip feedline of dimensions $l_f \times w_f$ placed on the opposite sides of the structure and are used to feed the antenna (Table 1).

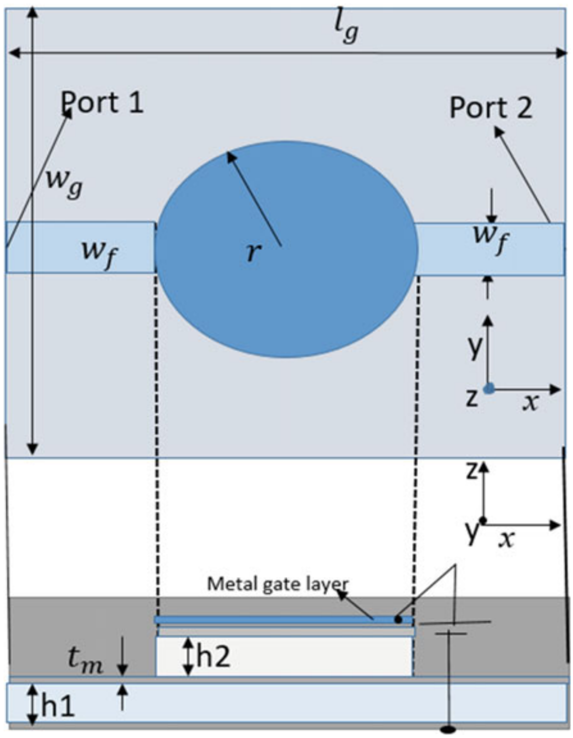

Fig. 1 Proposed antenna structure design in CST

Table 1 *Parameters for antenna design* and graphene patch design

Parameter	l_s	w_f	h_2	w_s	t_m	h_1	r	μ_c	τ	T
Value (µm)	50	2	1.2	35	0.001	3.6	13	0.16 eV	1 s	300 K

The parameters of the graphene patch such as thickness and relaxation time are chosen such that the antenna structure can be experimentally realizable. These parameters are set in a range so that the external DC voltage can change the chemical potential and thus the surface conductivity of the graphene. The DC gate voltage is applied through a gate layer on top of graphene patch. The dimensions of the gate layer and graphene patch are kept equal so as to maintain uniform fermi level when external voltage is applied [11].

3 Result and Discussion

Figure 2 shows the S parameter response of the proposed dual-port MIMO antenna. The antenna provides equal values of reflection coefficients owning to the symmetry of the structure. The value of S_{11} is less than − 10 dB and hence an impedance bandwidth is attained. The isolation between both the ports remains higher than the desired value and hence the antenna works as a good MIMO antenna (Fig. 3).

For ensuring the MIMO behavior of the antenna and the diversity performance of the antenna, parameters like ECC, DG, and MEG have been calculated. Any two-port antenna fulfilling these criterion conditions can be considered as an efficient antenna in wireless communication systems. The ECC defines how the far field radiation pattern is related to the excitation at different ports of antenna. The value of ECC of

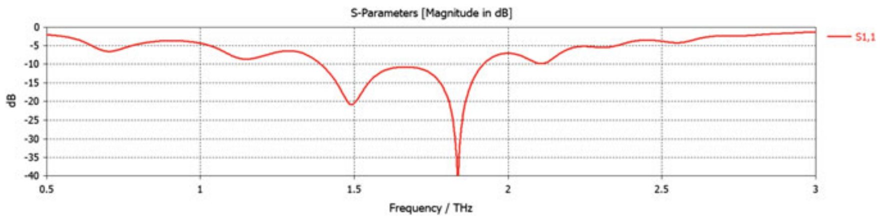

Fig. 2 S11 parameter for proposed antenna

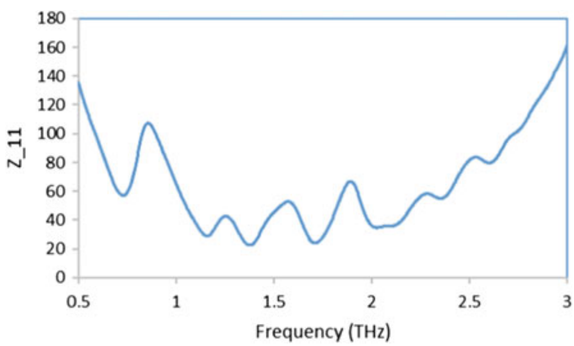

Fig. 3 Z_{11} of the designed antenna

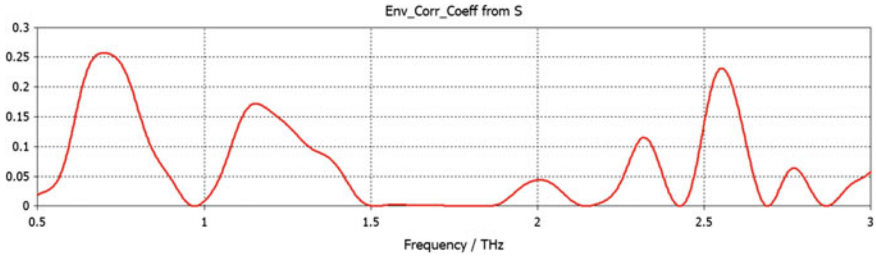

Fig. 4 ECC of proposed antenna

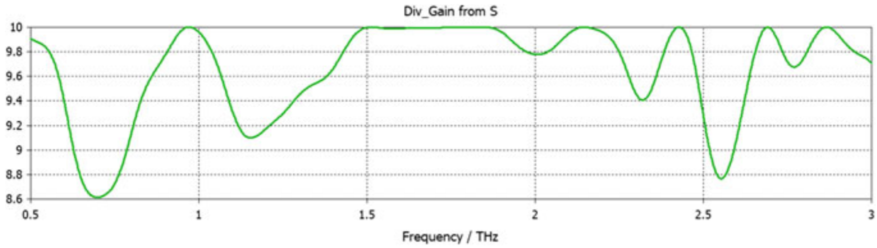

Fig. 5 Diversity gain of proposed antenna

any multiport antenna should be less than 0.5. The ECC can be calculated by either measuring far field parameters or based on S-parameter calculations. The method involving the far field parameters is quite complex. For the antenna designed in this paper, the ECC remains less than 0.01 and is calculated using the S port parameters (Figs. 4 and 5).

The diversity gain (DG) defines the improvement in the antenna structure due to use of multi antennas for transmission and reception rather than a single antenna. This is done by calculating the difference between the signals-to-interference ratio for the multi-antenna system with that of a single-element antenna. The value of DG for a MIMO antenna having good performance characteristics should be greater than 9.95 dB. The MEG gives an account of the power received by multi antenna system in a fading environment relative to a single isotropic antenna. It basically represents the antenna gain while considering the environmental effects on the antenna.

For any antenna to behave as a good MIMO antenna, it should have low coupling between the ports. The coupling effect can be studied by calculating the isolation and ECC. For low coupling between the two signals, the antenna must provide high isolation between the ports and low ECC. The proposed antenna with two ports fulfills the conditions of high isolation and low ECC despite having a single radiator.

4 Conclusion

A circular graphene patch-based MIMO antenna has been proposed in the paper. It can be used in the future 5G communication as it provides a good impedance bandwidth of 23.52% (1.92–1.49 THz). The isolation between the ports is also good. The antenna has a good impedance matching. All the MIMO parameters like envelop correlation coefficient (ECC) < 0.001, diversity gain (DG) ≈ 10 dB and mean effective gain (MEG) < − 3 dB are within the desired range. Since the antenna uses a single radiator and two ports it can be used to design massive systems in the near future for 5G wireless communication.

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Chapter 22
Investigation of a Microgrid Power System for Frequency Regulation by Implementing Ant Colony Optimization Technique Optimized Secondary Controller

D Boopathi, K Jagatheesan, B Anand, J Jaya, and R Satheeshkumar

Abstract In this article, Ant colony optimization (ACO) technique optimized Proportional integral derivative (PID) controller is suggested to implement the Load frequency control (LFC) scheme in a microgrid (MG) power system (PS). The proposed microgrid system is constructed by photovoltaic (PV), wind turbine generator (WTG), photon exchange membrane (PEM) fuel cell (FC), aqua electrolyzer (AE), and battery energy storage system (BESS). The secondary controller (ACO—PID) is employed to stabilize the system frequency within the standard limit during emergency loading conditions. The system performance is investigated by giving one percentage of unexpected load (1% step load). The supremacy of ACO—PID controller is proved by comparing the response of the system with the particle swarm optimization (PSO) technique tuned PID controller for the identical PS.

Keywords Frequency deviation · Secondary controller · Ant colony optimization · Energy storage system · PID controller

1 Introduction

Development of any country is reflected in the utilization of electrical power. The modern world completely depending on the electrical power for the development of industrial and transformation of the domestic life. It increases power demand, making it difficult to balance power generation and demand. In this task, the power quality may be deviated from the standard limit. Load frequency control (LFC) / Automatic generation control (AGC) scheme has been adopted in the stand alone / grid connected power system to maintain power quality under all critical loading in the power system. To implement the LFC / AGC many research peoples are

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developed and implemented secondary controllers and optimization techniques to tune the controller gain parameters. Few of the reputed articles were reviewed as follows to develop and analysis LFC of microgrid.

A renewable energy-based MG system has been and investigated in [1]. Author in [2] has been developed a MG system with renewable sources and electrical vehicle for frequency regulation by implementing PI controller. Equivalent input disturbance Controller developed in [3] to implement the LFC in an isolated MG PS with wind and diesel power plants. A fuzzy-based frequency control scheme is implemented in [4] to analysis the response of a MG power system. A distributed control method is implemented in [5] for PV, fuel cell, and wind form integrated in a MG frequency analysis. The author of [6] designed and implemented an ACO—PID controller for nuclear power plant frequency regulation. An interconnected MG power system constructed with wind form and PV for frequency regulation performance analysis in [7].

PSO—PID controller has been developed for an MGPS which is constructed by wind, PV, fuel cell, and ESS for LFC by [8]. Author in [9] introduced A novel Lyapunov Krasovskii functional (LKF) to analye LFC of the electrolyser based MGPS. (Grey wolf optimization) GWO—PID controller developed in [10] for regulate the frequency oscillation in a MGPS. (Grasshopper—optimization—algorithm) GOA- FPID controller is developed by [11] to study the performance in diesel generator with wind and PV MGPS for LFC. ACO—PID controller designed by the author in [12] for LFC of thermal power plant integrated with hydro aquo electrolyser and FC. A 3DoF—PID controller is tuned by dragonfly algorithm implemented in [13], for LFC of thermal PS with a MG (WTG + AE + FC + BESS). The author in [14] has been introduced a novel hybrid FPID with tilt integral derivative (TID) controller for LFC of a standalone MGPS. In [15], an ACO tuned PIDD controller was implemented for 2- area thermal power network LFC.

From literature review, it is effectively showing that researchers are handled the power quality issues by developing and implementing many of the secondary controllers and optimization techniques to tune the controller. Because of the scarcity of fossil fuels and the rise in pollution, MGPS with renewable energy sources are being developed and interconnected with the power grid. In this work, a MGPS is developed with renewable energy sources wind, PV, and fuel cell with ESS (BESS and electrolyzer) to analysis the performance for LFC.

1.1 Significance of the Article

- To develop a renewable energy-based microgrid power system for investigation.
- Construct a suitable secondary controller (PID) to implement the LFC scheme in microgrid.
- Utilize the proper optimization technique (ACO) to augment the gain parameters of secondary controller.

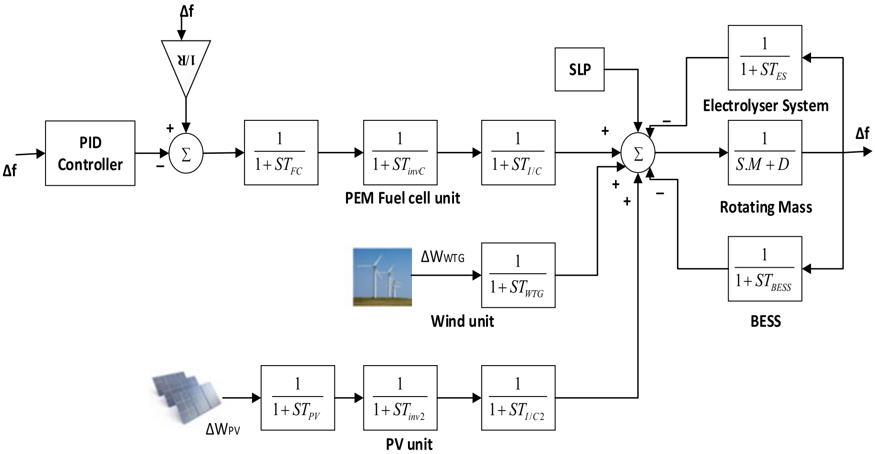


Fig. 1 Block diagram of investigated microgrid

- The response of ACO-PID controller is compared with PSO-PID to show the improvement of the ACO-PID controller.

2 Investigated System Modeling

In this work, a MGPS is developed and examined which is shown in Fig. 1. The proposed microgrid power system consists of renewable energy sources (wind and PV), PEM fuel cell, electrolyzer, and BESS. The nominal values of the system parameters are specified in appendix 1 [1].

3 Structure of Secondary Controller

In the process of implementing the LFC scheme in the power system, the secondary controller is playing a vital role. The secondary controller utilized in this work is PID controller, because it's a most classical controller and economical. This controller is made up of three different controllers (proportional (P), integral (I), and derivative (D)). Each controller has its own significance in the controlling process. Gain values are help to perform the controller to attain the desired output. In PID controller there are three gain values such as (KP-Proportional gain, KI-Integral gain, KD-Derivative gain). The transfer function of the PID controller is in Eq. 1. Fundamental assembly of the controller is shown in Fig. 2 [17, 18].

$$G(s) = K_P + \frac{K_I}{s} + s.K_D \tag{1}$$

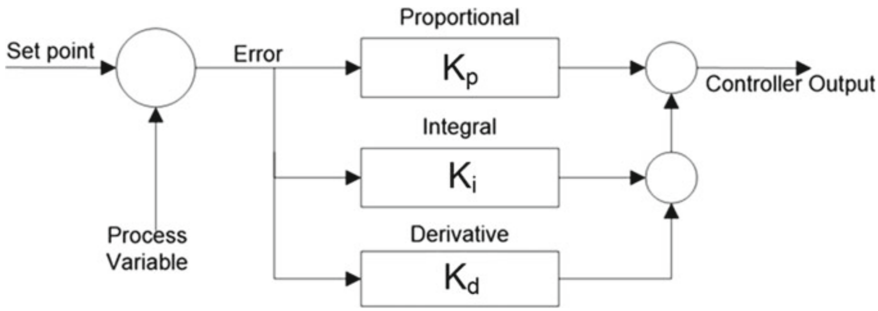


Fig. 2 Fundamental structure of PID controller

4 Ant Colony Optimization Technique

The ACO technique was inspired by the behavior of ant in the colony, the algorithm is developed by Marco Dorigo in the 1990s. Ants in the colony have been start their first tour randomly over the nest to search food. Ants in the colony are communicated through pheromone to share the information about the food. Based on the food quantity and quality the ants are evaporated the pheromone while return back to the nest. From the second tour, all the ants follow the higher concentrated pheromone path. Finally, ants are found the shortest path between nest and food. Similarly, each iteration the algorithm found the minimal fitness values by using objective functions. In this work (Integral time absolute error) ITAE is utilized. Each iteration has a minimal fitness value called local best (best local), at last algorithm provides a minimal value called global best (best global) [16]. The functional flowchart for ACO is shown in Fig. 3

In this work, ACO is utilized to enhance the secondary controller (PID) controller gain parameters, to provide better controlling response in the system frequency during emergency loading conditions. The optimized controller gains are reported in Table 1.

5 System Performance Investigation

The proposed MGPS is investigated in the MATLAB 2014a Simulink working platform with a step load disturbance of 1%. Figure 4 depicts the delF (frequency deviation) response comparison of PSO and ACO technique-based PID controllers. Table 2 displays numerical values such as settling time (TS) and peak shoots.

Frequency comparison shown in Fig. 4 and the numerical values in Table 2 clearly demonstrated the proposed controller (ACO—PID) is provides the better improvement over the PSO—PID controller. The ACO—PID controller performance improved over the PSO—PID in terms of fast settling of frequency oscillation. While

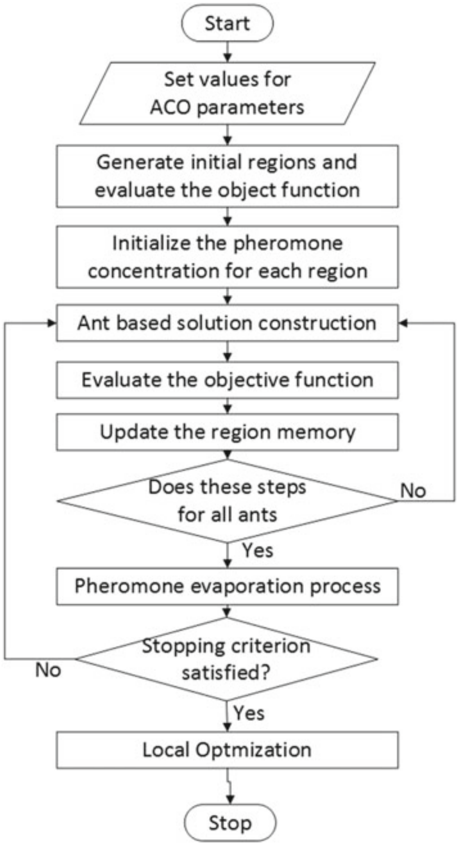


Fig. 3 Functional flow chart of ACO

Table 1 Optimized controller gain parameters of PID controller

Optimization method / Optimized controller gain values	(K_P)	(K_I)	(K_D)
PSO	0.5296	0.7196	0.1287
ACO	0.03	0.99	0.77

settle the frequency oscillation a negatable amount of peak shoot is occurs. To conform the supremacy of the proposed controller a bar chart is shown in Fig. 5 plotted for settling time, it is once again conforming the supremacy of the proposed controller.

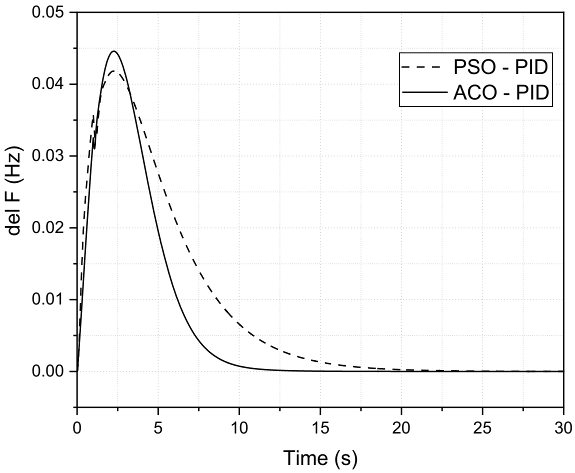
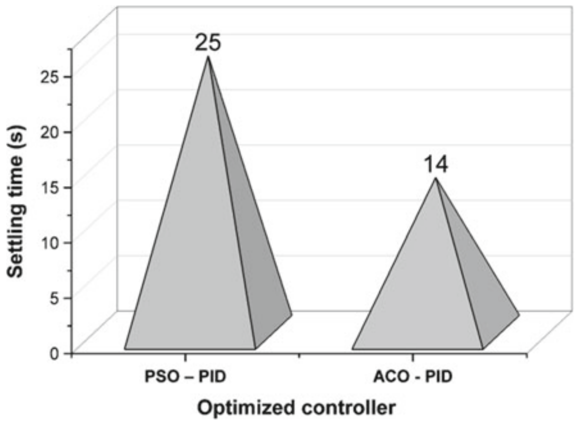


Fig. 4 Performance comparison of frequency deviation

Table 2 Optimized values of system frequency by PSO and ACO – PID controller

Optimized controller/Time domain-specific parameter	TS (s)	Over shoot (HZ)	Under shoot (Hz)
PSO—PID	25	0.042	0
ACO—PID	14	0.044	0

Fig. 5 Bar chart assessment for settling time



6 Conclusion

In this article, a renewable energy-based MGPS (PEM fuel cell + wind + solar + electrolyzer + BESS) has been developed for frequency regulation analysis. The PID controller implemented as a supplementary controller to control the frequency oscillation during unexpected loading conditions in the power system. The ACO—PID controller gain parameters in order to achieve the desired output (zero steady-state error). The response of the projected controller has been compared with the response of the PSO—PID controller, by the comparison the supremacy of the projected controller is clearly demonstrated. The proposed controller provides fast settling in the oscillated frequency over PSO—PID controller (14 s < 25 s) and minimal peak values.

Appendix [1, 19]

TFC = 0.26 s, Tinv = 0.04 s, TI/C = 0.004 s, TPV = 1.8 s, Tinv2 = 0.04 s,TI/C2 = 0.004 s, TWTG = 1.5 s. TBESS = 0.1 s, TES = 0.2 s M = 0.1667, $D = 0.015$.

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Chapter 23
A Comprehensive and Narrative Review of Industry 5.0 Technologies: 2018–2022

Rajat Gera, Priyanka Chadha, Gurbir Singh Khera, and Ruchika Yadav

Abstract The paper aims to classify and synthesize the findings of select articles on Industry 5.0 technologies in literature to provide insights and directions for scholars, practitioners, and policymakers. Forty-three papers were selected for review through systematic process and the technologies were categorized according to the three pillars of I 5.0, human-oriented, resilience-driven, and sustainability based. I 5.0 technologies are emerging across a vast section of industries but primarily automotive, manufacturing, supply chain operations, bio fuel generation, food, and healthcare waste recycling, transportation, power, and agriculture. SDG goals 7 and 9 have recent highest attention. The current technological ecosystem is more oriented towards systems/machines and less towards humans or sustainability. The human-centric aspect of technologies, systems, and services is not yet well developed. Human-centric systems are aimed to minimizing human intervention, enhancing human performance and productivity, and improving safety and comfort of humans engaged in the workplace. Conclusions and implications are drawn and future research directions identified.

Keywords Sustainable development goals · Society 5.0 · Industry 4.0 · Cyber-physical space

1 Introduction

The First Industrial Revolution, originated in the 1780s, with use of mechanical power produced from natural resources such as water, fossil fuels and steam. Assembly line production systems in 1870's powered by electrical energy signaled the beginning of the second industrial revolution (Industry 2.0) followed by Industry 3.0 also known

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as the third industrial revolution in the 1970s, enabled by electronics and Information Technology (IT) for automation and production. Industrial revolution 4.0 (Industry 4.0) was accelerated by the application of digital technologies (for example, Internet of things-IOT, cloud computing, and artificial intelligence) and digitalization of operations and production systems. The "Smart Cyber–Physical Systems (CPS)", which is a real real-time interface of the physical and virtual worlds, is the emerging technological paradigm [1, 2]. Technologies like "big data analytics, digital twins, and AI" can lead to enhanced production efficiency and product and service quality [3]. However, I4.0 is driven by production and manufacturing systems and networks (digitization and digitalization) for better efficiency and flexibility as compared to sustainability and worker well-being [4]. The humanization of factories (see Social Factories) is emerging as the technological trend in major countries like the European Union, Japan, and the USA, which is being known as Industry 5.0. Humanization of technology and societal and organizational sustainability is known as Society 5.0.

The previous review studies for example by Akundi et al. aimed to identify the basic research themes and emerging trends of I5.0 through text mining tools and techniques. Bhandurge and Bhide review study explored the spheres of life that industry 5.0 has the potential to effect and enhance. The review study by Zizic et al. compares the basic concepts of I4.0 with I5.0, from viewpoint of key enablers: people, organization, and technology. The review paper by Moutzis aimed at efficient utilization of Big Data, for process optimization based on the integration of semantics. Hence, none of the previous review papers has evaluated I 5.0 from the emerging technologies viewpoint and the sustainable development goals perspective that these technologies are linked with. This review paper aims to identify the state of the art of Industry 5.0 (I 5.0) technologies applicable to engineering, which have been documented and researched in published literature in recent past and chart the emerging research trends through systematic literature review of the identified technologies and their related SDGs applicable to the field of engineering for the period 2018–2022. This study hence aims to provide direction and insights for research scholars, practitioners, and policymakers regarding the emergent research trends in I 5.0 technologies and their related SDG's to guide future decisions and efforts.

This research comprised of the following objectives:

O1: identify the status of current research on Industry 5.0.
O2: Characterize the existing Industry 5.0 technologies applicable to engineering.
O3: Characterize the SDG's related to the I 5.0 technologies.
O4: Identify the research trends in terms of I 5.0 technologies and SDG's.

2 Literature Review

2.1 Industry 5.0

Industry 5.0 is a system of automated production which leverages human intelligence and I4.0 technologies like AI and social media as a catalyst. Social media users are expected to be (4.59 billion in 2022) 5.85 billion, by 2027.

Breque et al. [5], defined I 5.0 as a system of manufacturing that is human-centered, sustainable, and resilient due to adaptability and flexibility of technologies. "Michael Rada, defined I 5.0 human-based production system based on 6 R principles (Recognize, Reconsider, Realize, Reduce, Reuse, and Recycle) [6]". "Nahavandi [7], defined IR 5.0 as a system in which the factory, the workforce and machines work together to enhance process efficiency by utilizing human creativity and brainpower by the integration of workflows with intelligent systems". According to Friedman and Hendry [8], I 5.0 is likely to force the centricity of human factors in implementation of new technologies. Industry 5.0 would create socially intelligent production system driven by cobots and people interaction and communication between people and CPPS elements [9].

Thus, I 5.0 can be conceptualized as an economic system which is human-centric, resilient, and sustainable. However, most of the definitions of Industry 5.0 have a focus on technological and societal advances, rather than industrial transformation.

2.2 Evolution Toward I 5.0

The transistor and the microprocessor were catalysts of the third industrial revolution (1960) which was later accelerated by computer and communications technologies and process automation. Society is in transition from an industrial society towards a system of production which is knowledge-driven and post-industrial. The 1980s age of digitalization [3], created the global information society with access to Internet and marked by technological innovations in data processing and knowledge creation. 4 IR has transformed society due to advances in AI systems and capabilities of huge amounts of data generated from devices and sensors everywhere. Integration of machines and human activities in cyberspace with the physical world is the emerging trend as society evolves into a social organization engaged in use of technology and information for enhanced productivity and new forms of production systems.

3 Methodology

This literature review aims to summarize and categorize the existing literature on Industry 5.0 in recent years. Select papers are extracted through method of systematic “A Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA)”. The approach followed is of exploratory review. Exploratory reviews are employed for an emerging problem or research domain which is not yet adequately understood and where proper empirical research is not available. The findings of select papers are examined and classified on IR 5.0 into the identified themes using the descriptive review methodology. The four stages of this review article are: initial search, article selection, classification of findings of art, and synthesis.

3.1 Art Search

The keywords “Industry” + “5.0” were used for bibliometric search of Scopus online published by Elsevier and the Web of Science (WoS) online database by “Thomson Reuters Institute of Scientific Information” (ISI). Scopus is the largest interdisciplinary and multi-disciplinary bibliographic since 1996 with over 21,000 scientific journals including 390 commercial publications, 370 books series, 5.5 million papers, 25.5 million patents, and 376 million websites. It has a greater selection of journals and better coverage of Social Sciences (23%) compared to other databases. Web of Science (WoS) by Thomson Reuters Institute of Scientific Information (ISI) was the primary source of bibliographic data prior to 2004 and is capable of Scientometric analysis. The correlation between WoS and Scopus databases is significant and their coverage is extensive (54% in the case of Scopus and 84% for WoS) (Table 1).

3.2 Article Selection

“Filters applied for selection of articles for review were period 2018–2022, Engineering discipline, SDG goals 7 Affordable and Clean Energy or 12 Responsible Consumption and Production or 8 Decent Work and Economic Growth.” Only English-language articles were selected for review. From the 109 articles initially generated from the literature search, 41 articles were selected for the review study after exclusion of conceptual papers, opinion-based articles, duplicate articles, and articles not related irrelevant to this study through a process of evaluation by two academic experts.

3.3 Classification of Findings

The findings of selected articles were classified into the themes of human centricity, resilience, and sustainability similar to the approach adopted by Kamble et al. in their review paper on industry 4.0.

Table 1 Summary of articles selected for this study

Authors	Source title	Title	Industry	I 5.0 technology	SDG
Hassoun et al. [10]	Critical Reviews in Food Science and Nutrition	"The fourth industrial revolution in the food industry-Part I: Industry 4.0 technologies"	Food industry	"Most relevant food Industry 4.0 technologies including, among others, digital technologies (e.g., artificial intelligence, big data analytics, Internet of Things, and blockchain) and other technological advances (e.g., smart sensors, robotics, digital twins, and cyber-physical systems)"	All Sustainable Development Goals
Pattnaik et al. [11]	Sensors	"Future wireless communication technology towards 6G IoT: an application-based analysis of IoT in real-time location monitoring of employees inside underground mines by using BLE"		"Future wireless communication technology towards 6G IoT: industry 4.0/industry 5.0, smart home automation (SHA), smart cities, energy savings and many other areas of wireless communication"	12 Responsible Consumption and Production; 2 Zero Hunger
Mourtzis et al. [12]	Energies	"A literature review of the challenges and opportunities of the transition from Industry 4.0 to Society 5.0"	Manufacturing and production systems	"Digitization and the digitalization of systems, the design and development of the human-centric aspect of technologies, systems, and services"	7 Affordable and Clean Energy

(continued)

Table 1 (continued)

Authors	Source title	Title	Industry	I 5.0 technology	SDG
Fraga-Lamas et al. [13]	IEEE Access	"Next generation auto-identification and traceability technologies for Industry 5.0: a methodology and practical use case for the shipbuilding Industry"	Shipbuilding industry	"Next generation auto-identification and traceability technologies (passive and active UHF RFID tags)"	12 Responsible Consumption and Production
ElFar et al. [14]	Energy Conversion and Management X	"Prospects of Industry 5.0 in algae: customization of production and new advance technology for clean bioenergy generation"	Clean energy	"Algae bioenergy production, customization of the algae-derived bioenergy, algae cultivation and modifications in the cultivating approach. Genetic engineering tools implemented in the algae culture for bioenergy and by-products generation"	8 Decent Work and Economic Growth
Thakur et al. [15]	Computers and Industrial Engineering	"Emerging architecture for heterogeneous smart cyber-physical systems for industry 5.0"	Petroleum, fertilizer, paper, cement, space exploration, and automobile manufacturing"	"Heterogeneous smart cyber-physical systems for industry 5.0"	7 Affordable and Clean Energy

(continued)

Table 1 (continued)

Authors	Source title	Title	Industry	I 5.0 technology	SDG
Wang et al. [16]	International Journal of Mining Science and Technology	"Intelligent and ecological coal mining as well as clean utilization technology in China: review and prospects	Coal mining	"Intelligent coal mining, ecological mining, ultra-low emission and environmental protection"	7 Affordable and Clean Energy
Saniuk et al. [17]	Energies	"Knowledge and skills development in the context of the fourth industrial revolution technologies: interviews of experts from Pennsylvania state of the USA"		"Creation of cyber-physical systems, i.e., digital twins of reality"	7 Affordable and Clean Energy
Onofrejova et al. [18]	MM Science Journal	"Device for monitoring the influence of environmental work conditions on human factor"		"Monitoring of the working environment with reliable miniaturized technology"	7 Affordable and Clean Energy
Świątek [19]	Advances in Intelligent Systems and Computing	"From industry 4.0 to nature 4.0—sustainable infrastructure evolution by design"		"Grey infrastructure (sustainable infrastructure by design "human-nature" systems reintegration), intelligent green–blue infrastructure"	8 Decent Work and Economic Growth

(continued)

Table 1 (continued)

Authors	Source title	Title	Industry	I 5.0 technology	SDG
Bhargava et al. [20]	International Journal of System Assurance Engineering and Management	"Industrial IoT and AI implementation in vehicular logistics and supply chain management for vehicle mediated transportation systems"	Logistics	"IIoT model integrated with intelligent logistics, transportation management structure"	12 Responsible Consumption and Production; 9 Industry, Innovation and Infrastructure
Zambon et al. [21]	Processes	"Revolution 4.0: industry versus agriculture in a future development for SMEs	Small- and medium-sized enterprises (SMEs)		7 Affordable and Clean Energy
Chavez et al. [22]	Advances in Trans disciplinary Engineering	"Exploring data-driven decision-making for enhanced sustainability"	Supply chain operations within the manufacturing industry	"Data-driven decision-making" (DDDM)	8 Decent Work and Economic Growth
Rajad and Mounir [23]		"A review on the HAWCTB performance enhancement methods, numerical Models and AI concept used for the blade composite structure assessment: context of new industry 5.0"	Commercial scale production of electrical power	"Composite materials enhancement of WT blades (using AI techniques to facilitate the exploitation of numerical data from the whole numerical studies of mechanical behavior of composite materials such as elasticity, plasticity, damage initiation and damage tolerance using a well-known commercial software solver"	12 Responsible Consumption and Production; 11 Sustainable Cities and Communities; 9 Industry, Innovation and Infrastructure

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Table 1 (continued)

Authors	Source title	Title	Industry	I 5.0 technology	SDG
Saburo et al.	Journal of Japan Society of Dam Engineers	"Verification of productivity improvement effect by data utilization type site management system"	Concrete dam site	"Promotion of DX in the Infrastructure field", the introduction of cyber-physical systems (CPS), which visualizes and automates data utilization"	7 Affordable and Clean Energy
Wong et al. [24]	Energy Conversion and Management	"Third-generation bioethanol and L-lactic acid production from red macroalgae cellulosic residue: prospects of Industry 5.0 algae"	Biorefinery	"Human–robot interaction(Industry 5.0 algae)innovative integrated biorefinery approach using macroalgae cellulosic residue (MCR)"	8 Decent Work and Economic Growth
Ahmed and Vij [25]	Journal of Mountain Research	"Industry 4.0 and green sustainable manufacturing: a smarter and effective process management"		"Green processes like G-IoT"	7 Affordable and Clean Energy
Yaqot et al. [26]	Computer Aided Chemical Engineering	"Interplaying of industry 4.0 and circular economy in cyber-physical systems towards the mines of the future"	Mining industry's mine-to-mill process	"Cyber-physical system (CPS)"	12 Responsible Consumption and Production
Doyle-Kent and Kopacek [27]	Lecture Notes in Mechanical Engineering	"Collaborative robotics making a difference in the global pandemic"	Manufacturing plants	"Collaborative robotics, or cobots"	8 Decent Work and Economic Growth

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Table 1 (continued)

Authors	Source title	Title	Industry	I 5.0 technology	SDG
Yasufumi et al.	The Proceedings of Mechanical Engineering Congress Japan	"Advances in implementation of smart sensor devices using new FeCo-based magnetostrictive alloys"	Electric motor assisted system of spin-bike	"Sensor application technologies"	8 Decent Work and Economic Growth
Yangin-Gomec et al. [28]	Biomass Conversion and Biorefinery	"Energy recovery during anaerobic treatment of lignocellulose wastewater with dynamic modeling and simulation results"	Biogas generation	"Anaerobic treatment of lignocellulosic wastewater with dynamic modelling and simulation"	7 Affordable and Clean Energy
Torli et al. [29]	Industrial and Engineering Chemistry Research	"Benchmarking of separation methods for bioethanol (<5 wt %) recovery	Biofuel production	"Separation technologies"	7 Affordable and Clean Energy
Vithanage et al. [30]		"A secure corroboration protocol for Internet of Things (IoT) devices using MQTT version 5 and LDAP"		"Internet of Things (IoT)"	7 Affordable and Clean Energy
Dhawan et al. [31]	Frontiers in Built Environment	"Greening construction transport as a sustainability enabler for new Zealand: a research framework"	Construction transport	"ASI (avoid-shift-improve) concept"	7 Affordable and Clean Energy

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Table 1 (continued)

Authors	Source title	Title	Industry	I 5.0 technology	SDG
Lepov et al. [32]	E3S Web of Conferences	"Concept of integrity, reliability and safety of energy and transport systems for cold climate regions"	Energy and transport systems for cold climate regions	"Flexible information monitoring and control systems"	12 Responsible Consumption and Production
Li et al. [33]	Energy	"Fuel economy of Chinese light-duty car manufacturers: an efficiency analysis perspective"	Chinese light-duty car manufacturers	"Energy-saving vehicles (ESVs) and new energy vehicles (NEVs)"	7 Affordable and Clean Energy; 13 Climate Action
Zhang et al. [34]	ArXiv	"Vertically-oriented graphene oxide membranes for high-performance osmotic energy conversion"		"Vertically-oriented graphene oxide membranes for high-performance osmotic energy conversion"	7 Affordable and Clean Energy
Proia et al. [35]	IEEE Transactions on Automation Science and Engineering	"Control techniques for safe, ergonomic, and efficient human–robot collaboration in the digital industry: a survey"		"Human–robot collaboration (HRC) in the industrial setting (robotic controller design)"	7 Affordable and Clean Energy
Priadythama et al. [36]	AIP Conference Proceedings	"Role of rapid manufacturing technology in wearable customized assistive technology for modern industry"		"Rapid manufacturing technology in wearable customized assistive technology"	8 Decent Work and Economic Growth

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Table 1 (continued)

Authors	Source title	Title	Industry	I 5.0 technology	SDG
Islam et al. [37]	Asian-Australasian Journal of Bioscience and Biotechnology	"Anaerobic digestion of kitchen waste generated from atomic energy research establishment (AERE) cafeteria for lactic acid production"	Cafetaria	"Anaerobic digestion of kitchen waste"	8 Decent Work and Economic Growth
Yao and Zang [38]	Energy	"The spatiotemporal characteristics of electrical energy supply–demand and the green economy outlook of Guangdong Province, China"		"Electrical energy supply–demand and the green economy"	12 Responsible Consumption and Production
Ghobadpour et al. [39]	Vehicles	"Off-road electric vehicles and autonomous robots in agricultural sector: trends, challenges, and opportunities"		"Off-road electric vehicles and autonomous robots"	7 Affordable and Clean Energy
Nonoyama et al. [40]	Energies	"Energy-efficient robot configuration and motion planning using genetic algorithm and particle swarm optimization"		"Energy-efficient robot configuration and motion planning using genetic algorithm and particle swarm optimization"	7 Affordable and Clean Energy; 13 Climate Action

(continued)

Table 1 (continued)

Authors	Source title	Title	Industry	I 5.0 technology	SDG
Kumar et al.		"Experimental investigations on thermal properties of copper (II) oxide nanoparticles enhanced inorganic phase change materials for solar thermal energy storage applications"		"Copper (II) oxide nanoparticles enhanced inorganic phase change materials for solar thermal energy storage"	7 Affordable and Clean Energy
Flores-Valdes et al.		"Use of waste from the citrus industry for the production of unicellular biomass"			7 Affordable and Clean Energy; 13 Climate Action
Khan et al. [41]	IEEE Transactions on Intelligent Transportation Systems	"Energy efficiency optimization for backscatter enhanced NOMA cooperative V2X communications under imperfect CSI"	Automotive-industry	"New optimization framework for energy-efficient transmission in AmBC enhanced NOMA cooperative vehicle-to-everything (V2X) networks"	7 Affordable and Clean Energy
Kaklauskas et al. [42]	Energies	"COVID-19 and green housing: a review of relevant literature"	Green housing	Green housing	12 Responsible Consumption and Production

(continued)

Table 1 (continued)

Authors	Source title	Title	Industry	I 5.0 technology	SDG
Ianda et al. [43]	Energies	"Optimizing the cooperated "multi-countries" biodiesel production and consumption in sub-Saharan Africa"	Biodiesel production and consumption	"Multi-countries" cooperated production and consumption of biodiesel"	11 Sustainable Cities and Communities; 7 Affordable and Clean Energy
Abdin and Zio [44]	Springer Optimization and Its Applications	Optimal planning of electric power systems	Electric power sector	"Integrated techno-economic modeling and robust optimization framework for power systems planning"	12 Responsible Consumption and Production
Kasabova et al. [45]	Eastern-European Journal of Enterprise Technologies	"Improvement of a scraper heat exchanger for pre-heating plant-based raw materials before concentration"	Food industry	"Scraper heat exchangers"	7 Affordable and Clean Energy; 13 Climate Action
Afolabi et al. [46]	International Journal of Energy Research	"Thermal energy storage phase change material cement mortar incorporated with clinical waste composites"	Hospitals and other health care institutions	"Silicon catheter waste (SCW) and latex glove waste (LGW) as fillers mix with PCM cement mortar"	7 Affordable and Clean Energy
Liivand et al. [47]	ECS Meeting Abstracts	"Novel way to turn spent Li-Ion battery graphite into valuable and active catalyst for electrochemical oxygen reduction"	Various industries like petroleum, fertilizer, paper, cement, space exploration, and automobile manufacturing	"Vertically-oriented graphene oxide membranes for high-performance osmotic energy conversion"	7 Affordable and Clean Energy

3.4 Analysis of Findings

The findings of the selected studies were categorized into the identified themes of human centricity, resilience and sustainability and critical issues deserving further analysis were discussed to generate insights for scholars and practitioners.

3.5 Discussion of Findings

The SDG goals selected for this study were "SDG 7, affordable and clean energy (24 papers), SDG 12 Responsible Consumption and Production (9 papers), SDG 11 Sustainable Cities and Communities (1 paper), SDG 8 Decent Work and Economic Growth (8 papers), and all SDG (1 paper)". "SDG 7: affordable and clean energy represents the maximum number of articles which points to the primary focus of I 5.0 technologies with SDG 11, sustainable cities and communities (SDG 12) and Decent work and economic growth (SDG 8) receiving relatively less attention". The publications are in journals from the disciplines of food science, Intelligent Systems and Computing, sensors, energies, mechanical engineering, Industrial and Engineering Chemistry, Intelligent Transportation Systems, indicating the multi- and trans-disciplinary character of I 5.0. The articles selected for this review have been published in book series, conference proceedings, lecture notes and abstracts of meetings along with peer reviewed journals indicating the emergent status of this subject. The industries covered are automobile/light duty car manufacturers (2 paper), Biodiesel/bio fuel/bio generation (4 papers), Coal mining/mining process (2), construction transport/logistics (2 papers), various industries (2), manufacturing plants/manufacturing and production systems (2),

The current technological evolution is more oriented toward machines and systems and less toward humans or sustainability. The people-centric aspects of technologies, systems, and services are in evolutionary stage. Human-oriented systems are aiming for minimized human intervention, enhanced human performance and productivity, and higher safety and comfort levels of workers and users. They are also aimed to higher customer satisfaction and customer engagement.

"Internet of things IOT (2 papers), and Industrial IOT (IoT) model integrated with intelligent logistics and transportation management structure" can reduce transportation costs and higher sustainability of business operations.

"Digital technologies (6 papers), (e.g., artificial intelligence, big data analytics, Internet of Things, and Blockchain) and other technological advances (e.g., smart sensors, robotics, digital twins, and cyber-physical systems)" focus is shifting from I 4.0 (operational efficiency of production systems) toward design of human-centric systems, technologies and services, termed as Industry 5.0. Cyber-Physical space, CPS (4 papers), (e.g., work environment monitoring with help of reliable miniaturized technology) technologies can visualize and automate data utilization for sustainable business operations.

Robust data sharing and computational intelligence data sharing between various on board sensors, vehicles, and other devices in automobiles can contribute to society 5.0 by minimizing energy consumption and improved human safety.

Green housing through green building resource-efficient technologies can be used by analyzing a building's lifecycle which takes into account energy, water, consumption, health effects, comfort, and occupant behaviors in real estate and construction.

"Future Wireless Communication Technology toward 6G IoT can contribute to smart home automation (SHA), savings of energy, smart cities, and other wireless communication applications.

Human–robot interaction (3 papers) is emerging as a significant Industry 5.0 technological innovation for enhanced human productivity, safety and comfort, and enhanced industrial efficiency.

The technologies identified from the selected papers are presented and discussed under the themes of "human centric", "Resilience" and "sustainability". Some of the technologies have impact on multiple dimensions of Industry 5.0, for example, their impact can be on human centricity as well as sustainability or sustainability along for example with resilience of business operations.

3.6 Human Centricity

"Heterogeneous smart cyber-physical systems" are making industrial automation I 5.0 compliant with complete autonomy with minimal human intervention in various industries like petroleum, paper, fertilizer, cement, automobile production, and space exploration,"

"Creation of cyber-physical systems, i.e., digital twins of reality" is expected to lead to autonomous cyber-physical systems which include human factors.

Work environment monitoring enabled by reliable miniaturized technology can align working environment with" "EU Strategic Framework on Health and Safety at Work 2014–2020, (EU-OSHA)" which aims to prevent work-related diseases.

Cyber-Physical Systems (CPS) visualization and automation, data utilization, can solve social problems. "T-i Digital Field," a CPS technology which was tested at a concrete dam site established its productivity improvement effect on workers.

"Sustainable Infrastructure by design, "Human-Nature" systems reintegration and transformation through Intelligent Green–Blue Infrastructure" can generate bio-productive lands and biodiversity with regenerative abilities and coexisting ecosystems.

"Industrial internet of Things model (IoT) model of integrated intelligent logistics and transportation management structure" can optimize logistics costs and customer experience and satisfaction, process efficiency, lowers operating costs, and energy efficiency.

Implementing the human–robot interaction (Industry 5.0 algae) as an innovative integrated bio-refinery approach using macro-algae cellulosic residue (MCR) enhances the productivity and efficiency of the bio refinery.

Green processes like green Internet of Things (G-IoT) in manufacturing processes can positively affect health of consumers, climate, and production and operation systems.

Collaborative robotics, or Cobots can facilitate social distancing between workers in manufacturing plant, enhance the flexibility on the factory floor, and enabling production of high-quality medical products.

“Collaborative robots integrate human skills and abilities (e.g., intelligence, creativity, adaptability, etc.) and robots capabilities (e.g., flexibility, pinpoint accuracy, tirelessness, etc.)” for enhanced performance in industrial production and design and address control problems in collaborative robotics by making them more safe, efficient and ergonomic.

Rapid prototyping technologies such as 3D scanning and 3D printing can speed up development of customized prototype with better life cycle performance and affordability which can be combined with new technologies for processing and enabled 3D printing enabled materials development thus speeding up the rapid prototyping to rapid manufacturing process in “wearable customized assistive technology” to enhance individual physical capacity of workers.

3.7 Resilience

“Next Generation Auto-Identification and Traceability Technologies (passive and active UHF RFID tags)” deliver a holistic outcome for complex and harsh industrial scenarios. For example, in shipbuilding, UHF RFID tags can be used “to identify the main components of a ship during its construction and repair even in areas with a very high density of metallic object”.

“Data-driven decision-making (DDDM)” can enable resilient supply chain operations in manufacturing.

“Composite materials enhancement of WT blades (by using AI techniques to facilitate the exploitation of numerical data of mechanical behavior of composite materials)” can contribute to resilience of commercial scale production of electrical power.

Creation of cyber-physical systems: “Autonomous machines or mechatronics (MEC) combined with modeling and solving algorithms (MSA)” can make operations autonomous with minimal or no manpower in hazardous and harsh environments. Information and computing technologies (ICT) create intelligent production systems by integrating advanced I 4.0 technologies with circular economy (CE) ideology in for example a smart networked mining ecosystem.

“Secure Corroboration Protocol for Internet of Things (IoT) Devices Using MQTT Version 5 and LDAP” can enhance the security of automated smart environments by minimizing IoT security issues where human work can be automated through Internet of Things (IoT).

3.8 Sustainability

Algae-based bioenergy production, customized algae-derived bioenergy; modified algae cultivation approach can produce sustainable and economic fuel through genetic engineering tools.

"Intelligent and ecological mining with ultra-low emission and environmental impact" can minimize staff intervention, ecological damage, and emission level in the natural gas and coal mining industry.

"Grey Infrastructure (Sustainable Infrastructure by design "Human-Nature" systems reintegration and transformation from pathogenic to autogenic Intelligent Green-Blue Infrastructure)" can enlarge "bio-productive lands, sustain biodiversity, and reinforce regenerative abilities of coexisting ecosystems".

"Data-driven decision-making (DDDM)" can enhance resilience and circular operations by making supply chain operations resilient and sustainable in manufacturing industry.

"Composite materials enhancement of WT blades (using AI techniques) can enhance "elasticity, plasticity, damage initiation, and damage tolerance" through use of software solver.)

Electrification of agricultural vehicles and renewable energy sources for robotic and smart farming and using fully autonomous robots is the trend for meeting demand for food and minimize environmental damage. "Electric vehicles, alternative green fuels, energy-efficient technologies (for example, hybrid electric, robotic, and autonomous vehicles)" also known as Agriculture 5.0 can improve quality of work and operator comfort.

Sensor application technologies: Combining IoT wireless sensor network of I 4.0 to "electric motor assisted system of spin-bike" can enhance sustainability and efficiency.

Energy recovery technologies: "anaerobic treatment of lignocellulosic wastewater with dynamic modeling and simulation results" leads to sustainability and higher efficiency of paper industry.

"Benchmarking of Separation Methods for Bioethanol (<5 wt %)": optimizes biofuel production which also improves business performance and sustainable green technologies.

Avoid-Shift-Improve (ASI) concept: involving "supply chain (SC) efficiency, transport optimization, data/information sharing, and collaboration for transport decarburization" can provide fundamental optimization framework leading to green and sustainable construction transportation.

"Flexible information monitoring and control systems" which account for the environment, the engineering system, and the operator in hazardous facilities used in "extreme environment energy-saving vehicles (ESVs) and new energy vehicles

(NEVs)" in cold climates can reduce the environmental impact and risk of human fatalities.

Using a "unique database of test-cycle fuel economy parameters of thousands of models and Malmquist decomposition" can be used for benchmarking the fuel reduction targets and the operational efficiency of each firm for best practice identification. This enables policy-level implementation of "energy-saving vehicles (ESVs) and new energy vehicles (NEVs)".

"Vertically-Oriented Graphene Oxide Membranes for High-Performance Osmotic Energy Conversion" facilitates sustainable development by "use of osmotic energy and innovative design strategy for ultrafast transport systems", such as filtration and catalysis.

Anaerobic digestion of kitchen waste reduces quantity of food waste and can facilitate production of value-added products such as "lactic acid via anaerobic fermentation".

The "spatio-temporal configuration of electrical energy supply–demand" enhances the green economy performance of a region.

"Energy-Efficient Robot Configuration and Motion Planning Using Genetic Algorithm and Particle Swarm Optimization" reduces energy consumption and execution time of robot arm configurations for pick-and-place operation at workstations.

"Silicon catheter waste (SCW) and latex glove waste (LGW) as fillers mix with PCM cement mortar in built sector" recycles the clinical waste of hospitals and other health care facilities thus reducing their negative impact on humans and environment.

"Vertically-Oriented Graphene Oxide Membranes for High-Performance Osmotic Energy Conversion" can be used for reusing Li-Ion Battery (LIB) Graphite as catalyst for electrochemical oxygen reduction and sustainable production of LIBs.

4 Methodology

Select papers from Scopus and WoS online databases were accessed using "Industry 5.0" keyword search and filters of engineering, articles, 2018–2022, SDG 7,8, 11, 12, and 13 to classify and synthesize the emerging Industry 5.0 technologies for their impact on society 5.0. The results show that the major industries in which I 5.0 technologies are being researched are automotive, manufacturing, food, agriculture, bio-generation, food and healthcare waste recycling, supply chain operations, agriculture, energy and power, built environment, real estate, construction, transportation, mining, and ship building. Thus, I 5.0 technologies are emerging across the industrial landscape with applications being developed at micro (product and firm operations level), institutional (industry level), and societal (policy and regulation level). The SDG's mostly being impacted by I 5.0 technologies are "clean and affordable energy" (SDG 7) and "responsible consumption and production" which have been the focus of most research on I 5.0 technologies in the selected articles.

IoT 6.0 and AI are the primary drivers of digital technologies and digitalization shift toward I 5.0 technologies with applications in manufacturing, energy electric vehicles, and process optimization. CPS is accelerating the "human centricity, sustainability and resilience dimensions" of I 4.0 technologies by minimizing human interventions and enhancing productivity thus aiming towards the goals of human centricity and sustainability. Reliable miniaturized technology is contributing toward the workplace safety of humans.

Resilience of operations is being enhanced by, for example, "Next Generation Auto-Identification and Traceability Technologies (passive and active UHF RFID tags), data-driven decision-making (DDDM), composite materials enhancement" of for example "WT blades, autonomous machines or mechatronics (MEC) and secure and Secure Corroboration Protocol for Internet of Things (IoT) devices" which are enhancing the security and reliability of production systems and products.

The review paper contributes to development of a theoretical model of Industry 5.0 technologies impact on society by identifying and categorizing the I 5.0 technologies as per the dimensions of human centricity, resilience and sustainability, and SDG goals.

Pathways of specific I 5.0 technologies with SDG goals can be envisaged which will provide directions to practitioners and policy-makers for decision-making. Researchers can identify specific applications and technologies which can be further developed and researched in varied industry and social contexts.

Future research directions:

IoT technologies have been applied in automotive manufacturing and products and production processes. Research on IoT and its applications can be extended to service sectors and other industrial and product contexts.

I 5.0 technologies which have been researched for resilience for example Next Generation Auto-Identification and Traceability Technologies (passive and active UHF RFID tags), data-driven decision-making (DDDM), composite materials enhancement of, for example, WT blades, autonomous machines or mechatronics (MEC) and secure and secure corroboration protocol for Internet of Things (IoT) devices can be extended to other production systems and products, for example, to airport operations, healthcare procedures, tourism and other services which can affect safety of people.

CPS can be extended to other operational and industrial contexts where human intervention can be minimized.

Research on I 5.0 technologies which address other SDG goals, for example, no poverty (SDG 1.0), zero hunger (SDG 2.0), quality education (SDG 4.0), and gender equality (SDG 5.0) can be the focus of scholars future research.

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Chapter 24
IoT-Based Smart Grid Security Challenges

Rasif Bashir and Harpreet Kaur Channi

Abstract The "Internet of Things (IoT)" is just the next phase in the expansion of the internet, in which any physical article/aspect with computation and correspondence skills may want to be flawlessly coordinated, to the Internet on a multitude of levels. "The Smart Grid, which is considered to be perhaps the most fundamental infrastructure, is characterized as the historical trend electrical energy grid accelerated with a huge scope "ICT" and environmentally friendly electricity incorporation, must be regarded as one of the largest IoT companies". Nonetheless, security is viewed as one of the primary challenges impeding the rapid and wide-ranging receipt and transmission of both the IoT vision as well as the Smart Grid. In this article, we look at the security issues and challenges on the "IoT"-based smart grid, as well as the large-scale security benefits that we should consider while regulating smart grid privacy. The electrical companies as of now have records recuperation capacities with understand to their checking and control, yet these are as but restricted. The gathering of "IoT" and Smart Grids opens the way to facts assortment from all marks of the corporation and continuously. The smart grid is an employer for the automobile and appropriation of electricity that is upgraded by way of way of limits as some distance as advanced control, reconnaissance, and telecommunications. Digital trades are strengthening (creation, circulation, and utilization are interconnected) and the utilization of related objects (working with far flung checking, understanding, and control of the whole well well worth chain) builds the degree of weak point of statistics systems industrial. The reason for this work is to introduce a complete outline of difficulties, risks, and a few arrangements of protection in "IoT" principally based smart grid.

Keywords Internet of Things · Smart grid · Security · Cyber-physical systems · Advanced metering infrastructure

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1 Introduction

As of now, the Internet is conscious of an amazing development due to the fact of the advancement of associated objects. Internet is characterized as an notion of correspondence of folks each and every time and anyplace, the actual world can now transmit, whether for personality to individual, personality to object, or object-to-object linkages, with the existence of linked items [1–5]. The "Internet of Things (IoT)" is defined as a global enterprise of interconnected administrations and clever devices of numerous sorts that are designed to assist humans in day-to-day activities with the assistance of way of life owing to their discovery, estimation, and correspondence capacities [6–8]. Their capacity to notice the bodily world and provide information to dynamic will be a crucial piece of the engineering of the Internet of matters to come. These articles need to coordinate into an extra global framework than the computerized world and alter to it [9–13].

The "Internet of Things" is based on the implementation of a large number of new sensors, actuators, and intelligent systems that interact with one another. The power sector is now studying the impacts that may be achieved via the usage of the "internet of things" [14–17]. Network appreciation is something but a without a doubt new peculiarity for this area. The Smart Grid as of now have records healing capacities with admire to their gazing and control, on the different hand these are as but restricted [18].

"Smart grids are electrical grids that change the development of electricity among suppliers and shoppers using information innovation". These organizations provide an equilibrium of creation, circulation, and utilization with the useful resource of get-together information on the situation of the organization. "Smart grids work on the concord among introduction and utilization, the effectiveness and protection of grids, decorate the aggregate of environmentally friendly energy sources all through the organization and, gratitude to better framework the executives, create energy reserve greenbacks and lower costs (for each introduction and utilization") [19, 20].

The rise of the internet of things necessitates a higher level of cyber security. The expansion of aspects of communication with businesses may expose smart grids to current threats centered on data structures [21]. Different elements are straightforwardly ensnared; the absence of notion of properly being for the length of the format stages, the gamble of oldness no count quick present-day turns of events, the shortfall of cloth and found pointers as a ways as safety and secrecy, or the steering, stockpiling and the board of an outstanding measure of statistics [22–25].

In this work, we examine "IoT-based smart grid" security issues. In Part 2, we'll examine "Internet of Things" and "Smart Grid" We examine IoT-based smart grid security in area 3. Part 4 discusses smart grid protection alternatives, and Part 5 concludes the research.

2 Smart Grid

The smart grid ought to be visible, in its easy structure, as the ancient fashion energy grid accelerated with the large utilization of ICT trends (software, equipment, organizations), However, the use of circulating environmentally friendly electricity and feasible capabilities [26–30]. There are two streams in the smart grid, as shown in Fig. 1. Electric movement ("dashed line") as from plant age to the halt client, which would be the usual strength grid's precept movement. In any case, in the resourceful and prescient of the smart grid, the electric-powered motion ought to be bidirectional, the place the end-client will purchase and ought to likewise promote energy. Information flowing ("regular lines"): A wide range of multiple communication exists in between one-of-a-kind investor and smart grid components. The majority of the correspondence circulate is due to the truth of the large utilization of sensors/actuators and special smart articles shut through the transmission and dispersion regions, notwithstanding the utilization of smart meters and specific clever devices (smart apparatuses, electric vehicles, and so on) toward the end-client side [31, 32].

Two crucial components of the smart grid are "smart metres" and "advanced metering infrastructure,". For the purpose of billing or executive decision making, "smart/advanced metres (SMs)" [33] installed in homes, factories,businesses, etc., collect and report data on energy use. They can file records on demand or in response to specific events in the utility, as well as respond to requests from the value (e.g., "software upgrade," "nonstop evaluation," "load variations," "power trim," and so on), on account of their two-way correspondence capacity [34]. They may also however expect the part of nearby power the executives framework, with the aid of controlling/dealing with the energy utilization of the clever gadgets on the house (refrigerator, broiler, forced air system, electric powered vehicles, and so forth). "Advanced Metering Infrastructure (AMI)" [35], as displayed in Fig. 2 is in charge of gathering, dismantling, storing, and delivering the metering data supplied via the SMs to the relevant accredited events (e.g., energy provider, utility, smart grid

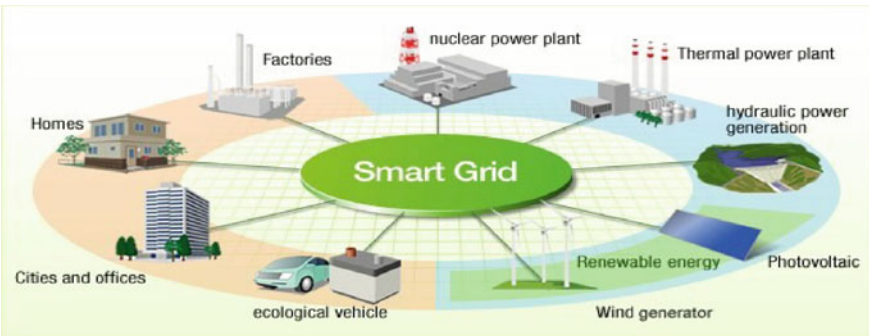

Fig. 1 Smart grid

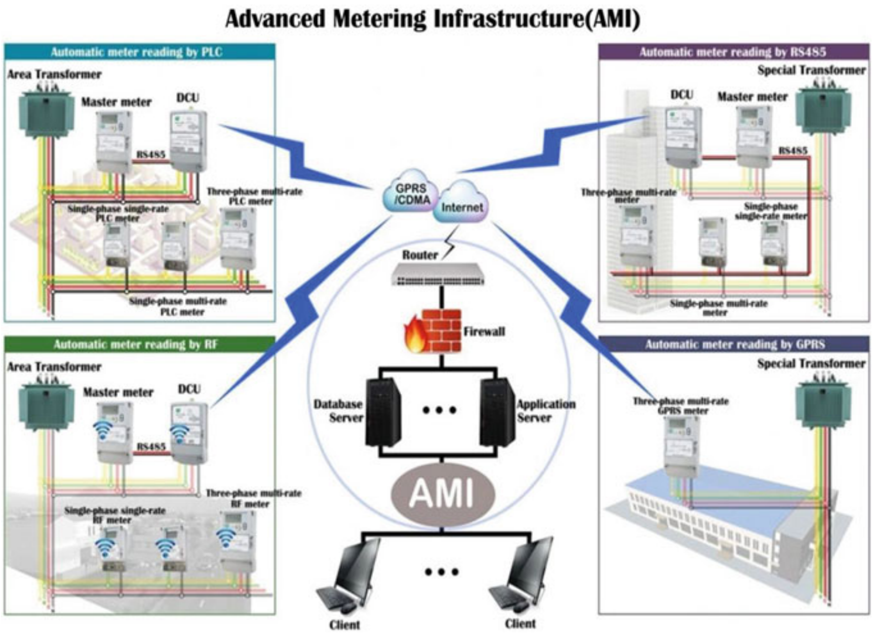

Fig. 2 General view of the advanced metering infrastructure [9]

administrator, etc.). "Meter Data Management Service, and so forth"), so they can continue them (charging, blackout the board, request gauging, and so on) The AMI is moreover dependable for sending demands, orders, evaluating statistics and software program refreshes from the accredited gatherings to the SMs [36–39]. Figure 1 offers an accelerated seen of the AMI as a piece of the complete smart grid.

2.1 Efficiency in Operations

"First, the smart grid coordinates the decentralized deployment of "Distributed Energy Resources (DER)" to increase operational efficiency. Every user may generate power by utilizing renewable energy sources." There is an advancement from the mannequin of one maker and a few customers to a model of a few makers and a few shoppers. Then, it empowers faraway looking at by using making use of the "Supervisory Control and Data Acquisition" (SCADA) framework and diagnostics with the aid of incorporating detectors that are delivered across the whole organization [40]. "These sensors shortly reveal electrical streams and utilization levels. In any case, it works on the dependability of public help power, operational performance, and typically usefulness".

Productivity in Energy. The SG lessens misfortunes on the power transmission and dissemination network by upgrading energy streams. It lets in you to recognize the agency repute continuously, to count on episodes, and to work with navigation.

Environmental Benefits. The SG has a few environmental benefits. In the first place, it approves the coordination of environmentally friendly energy assets. Then, it enacts the huge reception of electric vehicles. These automobiles limit fossil gas byproducts. In any case, it ensures and enhancements unwavering excellent and safety of local weather to oppose to interruptions, assaults, and cataclysmic events, expecting and answering to framework disturbances and strengthening security provide through competencies of similarly developed moves [41].

Security Standards for the SG. A few normalization associations have characterized standards for the sending of the clever grid organization. "A smart grid strategy has been defined by the American organization "National International Standard Technology" (NIST) as shown in Fig. 3. The three tiers of the structure were defined by the "European affiliate Institute of Electrical and Electronics Engineers (IEEE)". He proposed "a single management of ecologically sustainable energy" [9]. IoT-based Smart Grid [42]. "Contrasted with usual power grid, the SG profoundly incorporates ICT all in all power chain (from makers to end-buyers), via the good sized scope organization of a variety of kind of detecting, inciting and other inserted gadgets, however the utilization of smart meters, smart apparatuses and e-vehicles, each and every one of them sharing the limits of processing and correspondence".

What has made Internet all around properly regarded is the utilization of well-known correspondence conventions, mainly the "TCP/IP stack". Any two computers situated everywhere on the globe should have a start-to-end communication, regardless of their enter innovation. "The Internet of Things extends the reachability of the Internet to reach, through normalized correspondence conventions (or a door in the outrageous case), all that may want to impart and be one at a time tended to". "This complies toward the remarkable variety of equipment sent on the SG and the critical need for close regular correspondence with them via brought together criteria

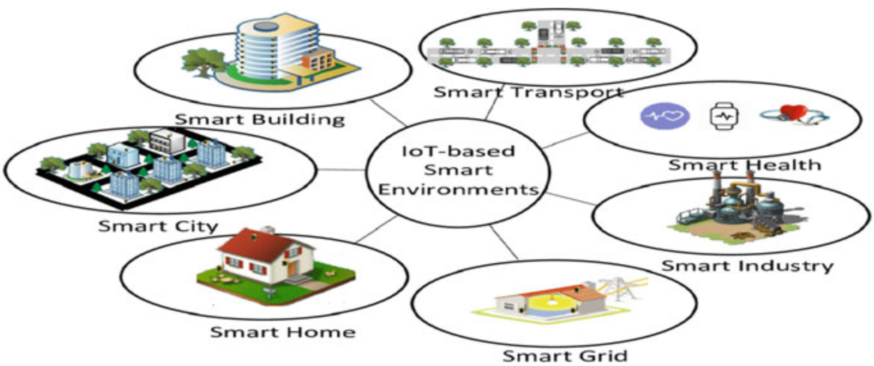

Fig. 3 IoT-based smart environment

correspondence gatherings (in light of the "TCP/IP stack"), rather than different arrangements ("Zigbee v1, (W)HART, Z-Wave," and so on") [43].

Assume a country's SG has 20 million "smart meters," but 30–40 million gadgets are supplied to show the entire energy grid architecture. "It will be fascinating for the SG's administrator to remotely monitor and manage the smart meters and sensors/actuators—however, their producer will acquire information on the remaining mile grid's status". "It will be fascinating for power suppliers to set remotely energy usage from SMs up to precisely charge consumers. However, attempts to tamper with the "SMs" will be made (ex, electricity theft). For the "final," receiving cutting-edge charges (accepting strong evaluating), successfully managing its consumption, and receiving early warnings for impending separation will be exciting. Clearly, this plethora of bidirectional start-to-finish collaborations and exchanges will significantly benefit IP-based entirely correspondence conventions (unless this is not possible or appropriate), as well as, surprisingly, public correspondence infrastructures to make them more adaptable and reduce initiated costs [44].

The "Internet of Things (IoT)" has recently emerged as a key enabler of smart grid technology. Every grid system can be thought of as an article. Using the "IoT" concept, each machine can have a unique "IP address" that can be used to communicate its popularity and download and manipulate orders over the Internet. "IoT enables devices on smart grid infrastructure to be detected and controlled remotely via the potential of an adaptable correspondence organization", "which allows for greater easy aggregate between physical world grid devices and PC-based control structures, resulting in increased efficacy and precision and enabling the grid to meet the energy needs of modern and future people" (Fig. 4) [45].

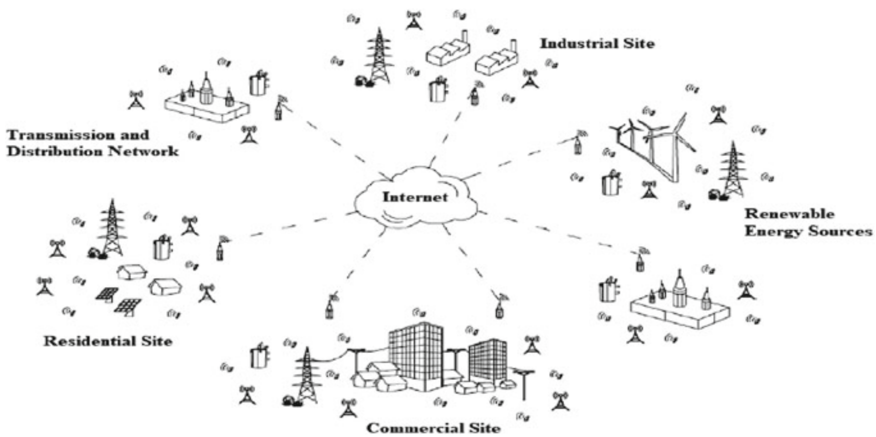

Fig. 4 Smart Grid Architecture based IoT [11]

3 Security Issues and Challenges with IoT-Based Smart Grids

The addition of "ICT" toward the traditional energy grid has created security challenges and difficulties which did not exist (or haven't existed in a long time) on the common energy grid [46]. These security concerns and obstacles should stymie the "IoT-based smart grid's ability to send and receive data quickly via end-clients". From this point forward, we'll briefly outline the most common safety concerns and challenges that have surfaced on the "IoT-based smart grid".

3.1 Security Concerns

The IoT-based smart grid will confront various security challenges as a cyber-physical system:

Spoofing identities: This assault purpose to disseminate information for the advantage of something legitimate in an unauthorized manner by exploiting its identity. Conducting surveillance: Since objects/devices at the "IoT-primarily based totally SG impart", frequently making use of public correspondence infrastructure, an attacker can maximum in all likelihood approach their traded data. "An attacker can genuinely recognize the energy usage of families". Tampering with data: An attacker can manipulate market information, such as vibrant expenses transmitted at previous pinnacle periods, to get the lowest costs [47]. As a result, rather than reducing their usage (for example, charging e-vehicles), families may increase it, causing an oversupply of energy. Issues with Authorization and Control Access: Since some tools, like as smart meters or region-transmitted smart objects in distribution substations, can be found and designed remotely, Unauthorized access to privileges should be attempted by an intruder or even an outraged representative. "manipulate them, and harm physical assets (such as transformers) or cause blackouts".

Privacy issue: In private homes, smart meters and smart devices should be able to indicate more than just how much energy is being used. "Their fine-grained statistics should compromise the privacy of the end-client by providing information about their habits (wake, sleep, and supper times, for example), whether they are at home or away", Even when they're on break, and so on [48].

Malicious and compromising code: SG items are focused on compromising physically or at a distance since they are calculation and correspondence enabled. Furthermore, "because they run specialized software, they may be the target of a variety of software infections or malicious code illnesses designed to influence and control them (ex, focusing on clever meters, or clever apparatuses in families)". Furthermore, widely conveyed goods containing required gadgets (sensors, for example) are often non-alter secure devices, making physical compromise a simple task [49]. Issues with availability and denial of service: It was difficult, even if theoretically conceivable, to focus on the availability of sources (power meters, substations, and so on) in the prior energy grid, especially at a high level. "In the SG, ICT will be coordinated even in the essential energy grid sources, making it possible to target them, making them unavailable to some degree or simply unreachable in the event of a DoS assault". Furthermore, because the vast majority of components is Internet protocol and do not operate special standard stacks, the goal of a natural "Internet attacker" will be considerably more straightforward [50].

Cyber-attack: "The smart grid had to be viewed as the largest Cyber-Physical-System (CPS)6", with physical structures addressing the "SG's" physical sources (transformers, circuit breakers, smart meters, linkages, and so on) and ICT systems controlling/overseeing physical substances [51]. Currently, a cyber-attack should touch physical sources, which was previously difficult in the classic strength grid, as was the case with the "Stuxnet assault 7".

Threats to Security: When dealing with safety procedures, protocols, and rules for the IoT-based smart grid, there are several issues to address.

Extensibility: The smart grid should cover a large area and contain a never-ending supply of inventive gadgets and objects [52]. This will make flexible security solutions like key "management and confirmation" impossible to contemplate".

Flexibility: "With phones/objects like e-vehicles and on-the-ground specialized specialists, there will be a constant need for verification and safe contact with an ever-changing encompassing network (smart meters, electric powered charging stations, and so on)".

Implementation: Because the smart grid should be different across the country, objects/gadgets are shipped in big quantities, work unsupervised, and may need to be placed in remote locations with no physical aspect guarantee, allowing them to be successfully available. Security systems should be able to discern between different types of activities in order to change them [53].

Legacy systems: As they rely on constrained preparations offered on isolated islands with no contact, already delivered systems and gadgets may require near-zero security help, "or through non-public communications infrastructure". Coordinating such historical structures to the "IoT-based completely smart grid is a significant difficulty, given "how difficult it is to replace them with new systems or upgrade them so they can maintain the best security precautions".

Constrained Resources: A few of the smart grid's gadgets/objects, particularly those that are widely disseminated, are asset confined. When designing security arrangements, special care should be made to ensure that their limited resources will comply with the provisions. This puts the usage of old-style safety solutions to the test, notably those based on public-key cryptography [54].

Heterogeneity: Due to errors in the resources of smart grid gadgets/objects ("memory, calculation, transmission capacity, energy independence, time-awareness, and so on"), and their carried out gatherings and correspondence stacks (for non Internet protocol appliances), it is a difficult task to conduct secure start-to-end interchanges. This requires the most frequently transformation of current arrangements or, at the very least, the utilisation of doors [55].

Rearchitecting: How can the essential starting keying materials ("cryptographic keys, cryptographic capacities/calculations and bounds, and so on") be used to successfully bootstrap the vast number of SG gadgets/objects.

Trust Management: The smart grid's objects/gadgets should be monitored by a variety of components (end-clients for smart machines, smart grid's administrator for smart meters and sensors, and so on). Objects/gadgets will not function if a low degree of trust is not established [56]. "While objects/gadgets claimed/oversaw by the same aspect should undoubtedly establish a trust connection, establishing trust between objects/gadgets claimed/oversaw by a variety of factors is a challenge, especially in such a large-scale organization".

Schedule Limitation/Latency: Some parts of the smart grid wish to respond to events and communications on a regular basis." For instance, an electric "SCADA (Supervisory Control and Data Acquisition) system8", which is used on substations for transmission and distribution, must respond constantly to any minor deviation from flow", voltage, or recurrence upsides of the power, as well as different meteorological boundaries impacting hardware's working, all provided by various types of smart articles (sensors, actuators, and so on), to keep the resources safe and prevent the emergence of irreguence. Time-consuming tasks (such as public-key activities) are no longer feasible [57].

4 Smart Grid Security Services Based on IoT

Following is a quick rundown of the most important safety services to consider for the "IoT-based smart grid":

Authorization: The capacity to confirm the identification of any "smart grid" transmitting device or item. A "power retailer," for example, must validate each smart meter before billing a customer [58].

Data Integrity: Ensures that (uploaded) information has not been tampered with in any way. "Regardless of the source," smart meters, for example, "must assure the integrity of a software update".

Classification: Informs that only the intended recipients have access to information ("whether stored or supplied"). End-user consumption, as example, "should be recognised by the smart grids' operator and, as it were, the energy dealer".

Client's Privacy: Any data on the user ("energy client end-client"), whether raw, assumed, or processed, "will not be accessed without its express agreement, and will be used strictly for the purposes intended," according to the policy. For example, data on power usage obtained for charging purposes could not be utilized for unexpected purposes [59].

Access Control and Authorization: Informs that a verified "article/individual has been approved to obtain a few tasks or has been granted the needed credentials to gain access to a few assets". For example, a field technician may want authorization and access to control freedoms in order to do manually installation on a "smart meter".

5 Conclusion

Internet of Things is the subsequent stage toward an around the world and inescapable affiliation with any correspondence and calculation-empowered objects/gadgets, notwithstanding their get right of entry to innovation, handy belongings, and area. The Smart Grid can relatively earnings with the aid of the IoT vision, the place smart items/gadgets are conveyed close through the power way, from the age plant to the end-client. Nonetheless, safety is the principle fear for the IoT, and the massive scope reception and sending of the smart grid. In this paper, we momentarily surveyed the quintessential safety problems and difficulties for the smart grid, and dressed the predominant required security administrations. In the following future, we will listen on profundity the safety of a key component of the smart grid, which is the AMI, the place we core round how we can safely coordinate energy-mindful clever home, outfitted with smart meters and smart machines, in the smart grid, so that end-client ought to efficaciously and safely partake in the electricity utilization/creation harmony. We introduced a thorough overview of the important security issues and difficulties for the IoT primarily based smart grid infrastructure. In this setting, the utilization of the IoT gives a most beneficial manipulate and observing of the electricity grid in clever grid organization, so it is important to focus on the safety challenges to create to execution and reconciliation of the "Internet of Things devices in the smart grid".

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Chapter 25
A Review of Water Electrolysis, Fuel Cells and Its Use in Energy Storage

Amit Atri and Anita Khosla

Abstract The abstract is a mandatory element that should summarize the contents of the hydrogen is a carbon neutral fuel which combines with oxygen to produce energy and leaves water as by-product. Technique used producing hydrogen should also be environment friendly. Water electrolysis is one such technique for producing hydrogen without emitting any pollutants. Hydrogen can be used for generating electricity using fuel cell. Hydrogen and oxygen are supplied to fuel cell to produce electricity and the process leaves water as by-product. Renewable sources of energy like solar and wind are intermittent in nature and need energy storage. Hydrogen energy storage is useful in such cases. This paper reviews different types of water electrolysis techniques, methods for maximizing hydrogen production, different types of fuel cells, their working and the power systems producing hydrogen from water electrolysis using surplus electricity generated from renewable resources, storing the hydrogen and using it as fuel for generating electricity during unavailability or lesser availability of renewable resources.

Keywords Water electrolysis · Fuel cell · Hydrogen storage · Anode · Cathode · Catalyst

1 Introduction

As on April 2022, out of India's total installed capacity, 59.2% is from fossil fuels, i.e., coal, lignite, gas and diesel [1]. Use of fossil fuels for electricity generation releases various toxins which pollute the environment and adversely effects health. Also the stocks of fossil fuels are limited and on extensive consumption, it will get exhausted. These issues have shifted the focus towards clean renewable sources for

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fulfilling the energy needs. Currently, renewable sources constitute 38.5% of India's total power generation, which is expected to increase in future. So as to replace fossil fuels with renewable sources, the cost of power generation by both of them should be competitive. In the recent years, technology has improved and the cost of generation using renewable sources has decreased due to high decrease in installation costs thereby increase in use of these resources.

One major limitation with renewable sources especially solar and wind is its intermittent nature. Considering the case of solar energy, during sunny days, the temperature increases correspondingly increasing the power consumption in refrigeration and air conditioning. After sunset, lighting is the major load. This necessitates the use of storage [2]. Different types of storage systems are used like pumped hydroelectric storage, compressed air energy storage, batteries and hydrogen energy storage. Many of the storage systems are not suitable for long time and are limited to suitable locations.

Hydrogen is a clean fuel and has high calorific value of 119.93 MJ/kg, which is higher than methane (50.02 MJ/kg), gasoline (44.5 MJ/kg), diesel (42.5 MJ/kg) and ethanol (27 MJ/kg) [3]. Along with electricity generation, hydrogen is used in other industrial applications like petroleum refining, methanol production, fertilizers, metal processing, etc. [4]. Different types of methods are available for producing hydrogen, most common being steam methane reforming (SMR) of natural gas. About 50% of hydrogen is produced by this method [5]. SMR produces hydrogen in two stages as in Eqs. (1) and (2):

$$CH_4 + H_2O \rightarrow CO + 3H_2 \tag{1}$$

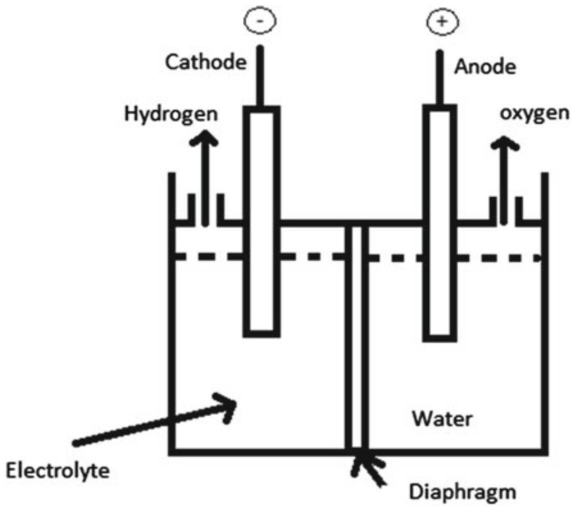
$$CO + H_2O \rightarrow CO_2 + H_2 \tag{2}$$

This process is economical but on the other hand, it produces carbon dioxide which is greenhouse gas. Another method of producing hydrogen is from water electrolysis which does not emits any pollutants is explained in Sect. 2. Use of fuel cell for generating electricity when on supplying hydrogen is covered in Sects. 3 and 4 covers hydrogen energy storage systems.

2 Water Electrolysis

In the process of water electrolysis, electricity is applied and water splits into hydrogen and oxygen. A typical water electrolyser consists of two electrodes (cathode and anode) placed in electrolyte. DC supply is given whose negative terminal is connected to the cathode and positive terminal to anode. Hydrogen is evolved at the cathode (Hydrogen Evolution Reaction or HER) and oxygen evolves at the anode (Oxygen Evolution Reaction, OER). Cathode and anode are separated by a diaphragm. This process uses water as feedstock for hydrogen production which

Fig. 1 Typical electrolyser



is widely available. The process is environment friendly when the electricity used is generated from green energy/renewable resources. The potential required to overcome the energy barriers during electrolysis can be lowered by using a catalyst. A typical electrolyser is shown in Fig. 1.

The reduction reaction taking place at cathode is HER as:

$$2H_2O + 2e^- \rightarrow H_2 + 2OH^- \quad (3)$$

And the oxidation reaction at anode is OER as

$$2OH^- \rightarrow \frac{1}{2}O_2 + H_2O + 2e^- \quad (4)$$

Water electrolysis can be classified according to the electrolyte as explained in Sects. 2.1–2.3:

2.1 Alkaline Water Electrolysis

A conventional alkaline electrolyser is similar to the one shown in Fig. 1. It consists of cathode and anode placed in an electrolyte. Conventional electrolytes are mostly KOH or NAOH. In some cases, H_2SO_4 is also used as electrolyte. It is needed due to the low conductivity of pure water which gets improved on adding base (like KOH or NAOH) or acid (like H_2SO_4).

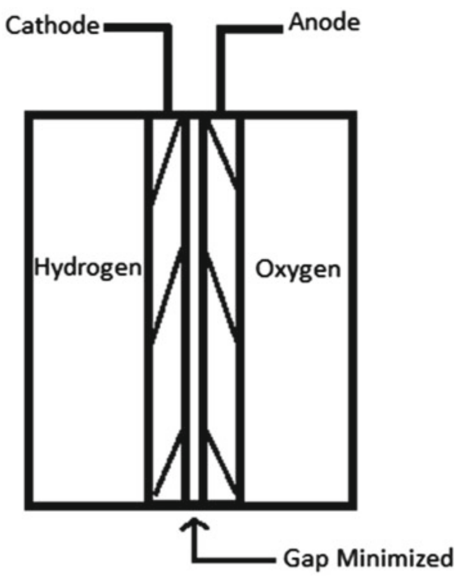


Fig. 2 Modified electrolyser minimizing the gap between anode and cathode

Cathode and anode are separated by a membrane/diaphragm. Initially, asbestos was used for diaphragm but due to health issues its usage is terminated. Ceramic-based composite materials are commonly used now. The OH^- ion produced due to the reduction of water at the cathode crosses the electrolyte and the diaphragm and then reaches the anode where the oxidation occurs and oxygen is evolved. AWE is the oldest and most economical technology for hydrogen production and has good efficiency of approximately 70% [6]. The use of acidic or basic/alkalic medium causes corrosion in the electrodes. Metal used for electrodes should be having low resistance as well. Some of the metals suitable for cathode are Cd, Hg, Pb, Zn, Sn, Fe, Co, Ni, Cu, Au, etc. [7]. Noble metals are least prone to corrosion but are expansive making the electrolysis process uneconomical. Ni and its alloys are suitable for anode and cathode.

Alkaline electrolyser operates at low temperature approximately 80 °C and has high stack efficiency of nearly 70%. Modified electrolyser design was used which minimizes the distance between anode and cathode as shown in Fig. 2, thereby reducing the losses. Ni electrodes are immersed in KOH electrolyte with Fe as catalyst [8].

2.1.1 Role of Catalysts

In a study on the effect of catalysts done by [9], the catalyst should be economical and stable. Catalysts are designed according to the type of electrolysis technique. Alkaline electrolysis has comparatively wider range of catalysts. Use of catalyst lowers the kinetic barrier thereby increasing the hydrogen production. Xie et al.

[10] developed PtNi-based electrocatalyst for KOH electrolyte which increased the hydrogen evolution and provided stability of 90 h. Zhao et al. [11] developed PtNi–O catalyst for KOH electrolyte which increased the hydrogen production with stability of 10 h. Another PtNi-based catalyst was developed by [12] for KOH electrolyte which gave stability of 10 h. $NiCo_2Px$-based catalyst for KOH was developed by [13] which gave stability of 5000 cycles. Gao et al. [14] developed Mo_2C-based catalyst for both NaOH and H_2SO_4 electrolytes which gave stability of 3000 cycles. Ni_2P-based catalyst was developed by [15] for H_2SO_4 which gave stability of 500 cycles. CoS_2 catalyst for H_2SO_4 was given by [16] gave stability of 41 h. For enhancing the oxygen evolution at anode, [17] gave Cu-doped RuO_2 catalyst for H_2SO_4 electrolyte which gave stability of 10,000 cycles. IrNi-based catalyst was developed by [18] for H_2SO_4 and gave stability of 200 min. Park et al. [19] gave IrNiCu-based catalyst for $HClO_4$ with 2500 cycles stability. IrO_2-based catalyst for H_2SO_4 was given by [20] and stability of 200 h. Au40Co60 catalyst for KOH was given by [21] with stability of 1 h. G-FeCoW-based catalyst for KOH was given by [22] and stability was 500 h. Plasma engraved Co_3O_4 catalyst for KOH was given by [23] and stability was 2000 cycles. For HER noble metal-based (Pt, Pd, Ru, Ir, Rh) and non-metal-based catalyst (Mo_2C, WC–carbides, MoS_2-sulphides) and for OER, NiFe-based electrocatalysts are commonly used.

2.1.2 Anion Exchange Membrane

Considering the high cost of noble metals-based electrodes (like platinum group), Ni-based gas diffusion electrodes were used by [24]. On applying high pressure on electrolyte, efficiency was increased. Anion exchange membranes were developed which uses cheaper metals as catalysts and current collectors. Stability of such solid alkaline water electrolysis using anion exchange membrane needs further development. Leng et al. [25] used A201 membrane which stabilized the system for 535 h. A modified trimethyl ammonium added fluorine-alt-tetrafluoro phenylene gave better performance [26]. Another modified poly(fluorine-alt-tetrafluoro phenylene) membrane was proposed by [27] with increased $OH-$ permeability. To improve the performance of electrolysis FAA-3-50 and FAA-3-Br anion membrane was used [28] which reduced the resistance and increased the charge transfer and hydrogen production. An approach of ion solvating membrane was proposed by [29] for KOH electrolyte and Ni electrodes AWE. These membranes are having a higher density as compared with the conventional porous membranes has better voltage efficiency and avoids the permeability of the product gases.

2.2 Polymer Electrolyte Membrane (PEM) Electrolysis

A PEM electrolyser consists of solid membrane surrounded by cathode and anode collectively called as membrane electrode assembly (MEA) which is the main part of the electrolyser [30]. MEA is surrounded by two compartments fed by water. This is different from AWE which uses a liquid electrolyte. Also PEM electrolysis consumes less power, is compact, has better stability for fluctuations in the electric supply as compared with AWE [31]. The disadvantage comes from the economic point of view the electrodes and membranes are costly. Nafion is commonly used for membranes. Electrodes used are made of noble metals (like Platinum group). The hydrogen obtained is of high purity (up to 99.9%). To enhance the performance, noble metal-based electrocatalyst are used; commonly Pt/Pd for HER and Ir or Ru for OER. Like AWE, PEM electrolysis works on low temperature ranging from 50 to 80 °C and pressure less than 30 bar. A study by [32] found PEM suitable for using hydrogen as a storage medium for solar and wind generating systems. A modified model for PEM was proposed by [33], which used two steps—one each for O_2 and H_2 by using $H_3PMo_{12}O_{40}$ as buffer for reduction/oxidation. This arrangement made H_2 and O_2 easy to handle, reduced the burden on the membrane and was cost efficient. Yan et al. [34] proposed an advanced membrane free flow electrolyser. This electrolyser was having two compartments with a porous layer of width 130 μm between them. The distance between the electrodes was minimized which also minimized the resistance. The electrolyser was having a maximum current density of 750 mA/cm^2.

2.3 Solid Oxide Electrolyte Electrolysis (SOE)

The electrolyser consists of cathode, anode, electrolyte and intermediate layer between electrolyte and anode. Ceramic material electrolytes; for cathodes Ni-based metal/alloys and for anode Co or Sr-based materials are suitable. Intermediate layer is needed so as to ensure heat conformity and element mixing, Gd-based ceramic oxide is suitable for this. The intermediate layer may not be needed when using anode which includes electrolyte material.

The solid oxide electrolyser operates at high temperature which is usually between 500 and 850 °C [30] and can go up to 1000 °C [35]. At high temperature, water is available in the form of steam which is used by the electrolyzer. As per [36] with the increase in temperature, the electricity requirement by the electrolyser reduces. Another study of temperature, humidity, current density on the electrolysis was done by Kiros et al. [37] and the performance was much better like 1.25 at current density of 1 A/cm^2 at 800 °C and voltage 1.0 V, current density of 1 A/cm^2 at 900 °C temperature. The high amount of heat required can be obtained from waste heat or in the form of cogeneration. Also renewable resources can be used like solar concentrators. This makes the electrolyser highly efficient (can be near 100%). High efficiency also leads to cost reduction and is suitable for high scale hydrogen production.

3 Fuel Cell

Fuel cell is an electrochemical energy conversion device consisting of two electrodes (anode and cathode) and electrolyte as shown in Fig. 3. Hydrogen is supplied to the anode and oxygen to the cathode, causing charge to flow between the electrodes in the external circuit and leaving water as a by-product. Fuel cell is a static device which does not produces any noise while operating. Electricity generation from fuel cell does not emit any toxins/pollutants and is thereby environment friendly.

Fuel cell can be classified in the following categories on the basis of electrolytes as explained in Sects. 3.1–3.5:

3.1 Alkaline Fuel Cell (AFC)

AFC uses KOH as electrolyte conducting OH^- ions. Hydrogen gas is fed to anode and oxygen to the cathode. Equations at anode and cathode are given by Eqs. (5) and (6), respectively:

$$H_2 + 2OH^- \rightarrow 2H_2O + 2e^- \tag{5}$$

$$O_2 + 2H_2O + 4e^- \rightarrow 4OH^- \tag{6}$$

$$\text{Overall reaction is } O_2 + 2H_2 \rightarrow 2H_2O \tag{7}$$

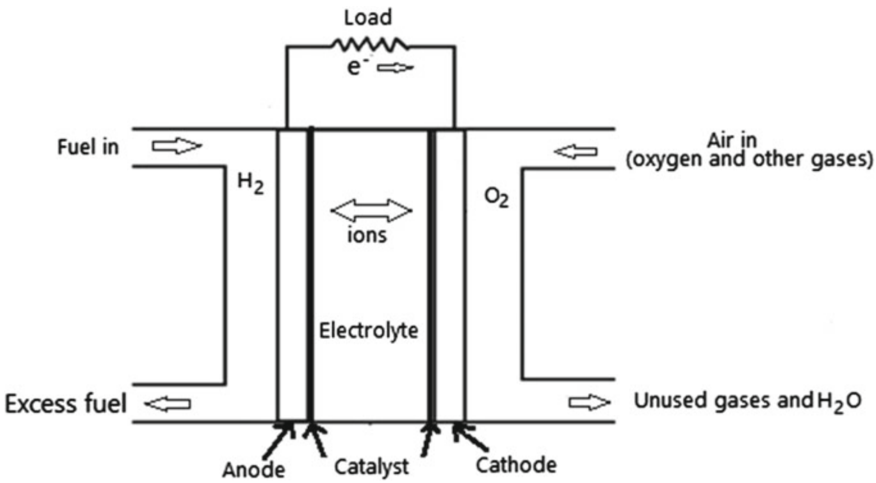


Fig. 3 Schematic diagram of a typical fuel cell

Brisse et al. [38] used Pt–Co alloys on carbon for cathode catalyst and Pt–Pd bimetallic combination for anode catalysts for increased stability. AFC operates at a temperature of 40–75 °C. AFC has a peak power density ranging between 50 and 300 mW/cm^2 and a lifetime greater than 5000 h [39]. AFC suffers from a drawback of CO2 poisoning; the air supplied to the electrode needs to filtered for CO_2. Sato et al. [40] prepared three types of electrodes—hydrophilic activated carbon, hydrophobic acetylene black and furnace type black. Out of these three-furnace type, black isolated the electrolyte form CO2 present in the air supplied. An approach used by [41] was to increase the current density, increase the temperature, lowering the airflow rate to the electrode and by increasing the water level in the cell.

To enhance the performance of AFCs, the liquid electrolyte was replaced by quaternary ammonia/piperidinium-based polymers electrolytes forming Anion Exchange Membrane Fuel Cell (AEMFC). AEMFSs operate at temperature between 50 and 90 °C, having peak power density of 100–3500 mW/cm^2 with lifetime approximately the same as AFC [39]. Use of Pt group catalyst enhances the performance but increases the cost. To reduce the cost and make AEMFCs commercially successful, emphasis is given on search for alternate materials for catalysts and cheap metal components [42]. Poly tetrablock copolymer ionomers were developed which enhanced the peak power and current density [43].

3.2 *Polymer Electrolyte Membrane Fuel Cell (PEMFC)*

PEMFC uses Nafion-like polymer membranes between the electrodes which conducts H^+ ions. Hydrogen or methanol can be supplied to anode [44].

Hydrogen at anode undergoes oxidation as

$$H_2 \rightarrow 2H^+ + 2e^- \tag{8}$$

The positive ions produced travels through the electrolyte to the cathode and the electrons produced flows through the external circuit. At cathode these ions combine with electrons and oxygen to form water as

$$2H^+ + 2e^- + \frac{1}{2}O_2 \rightarrow H_2O \tag{9}$$

Pt catalyst is used to improve the performance. Power density of PEMFC is between 0.5 and 0.7 W/cm^2 and efficiency nearly 68% and operates at a temperature of 90 °C [45].

3.3 Phosphoric Acid Fuel Cell (PAFC)

PAFC uses Phosphoric Acid (H_3PO_4) as electrolyte conducting H^+ ions and Pt catalyst. PAFC works on temperature of 200 °C. Liquid electrolyte is stored in a silicon carbide (SiC) matrix [46]. Hydrogen, natural gas, propane methanol, ethanol and biogas are suitable as fuel for PAFC. Anode and cathode equations are as:

$$\text{At anode}: 2H_2 \rightarrow 4H^+ + 4e^- \quad (10)$$

$$\text{At cathode}: O_2 + 4H^+ + 4e^- \rightarrow 2H_2O \quad (11)$$

Low pH value of phosphoric acid makes the cell corrosive and the electrodes need to be withstand it. PAFC is not poisoned by CO2. The high operating temperature makes PAFC suitable for cogeneration plants which increases the efficiency from 50% (electricity generation) to 80% (combined electricity and heat) [47].

3.4 Molten Carbonate Fuel Cell (MCFC)

MCFC uses molten carbonate like Li–Na and Li–K carbonate conducting CO_3^{2-} ions [48] placed in a ceramic medium like LiAlO2 [49]. Fuel supplied to the anode can be hydrogen or hydrogen-rich gas like natural gas [50] biofuels [51] and syngas [52].

$$\text{Reaction at anode}: H_2 + CO_3^{2-} \rightarrow H_2O + CO_2 + 2e^- \quad (12)$$

$$\text{Reaction at cathode}: \frac{1}{2}O_2 + CO_2 + 2e^- \rightarrow CO_3^{2-} \quad (13)$$

MCFC is free from the ill effects of CO2 contamination; even the reaction at anode produces CO2 which is used in reforming of the fuel gas in producing hydrogen [53] and so MCFC finds an application as CO2 collectors [54]. MCFCs can be used for stationary power generation giving an efficiency of nearly 60%. It operates on a high temperature of 650–700 °C and this high temperature avoids the use of an external fuel reformer. High working temperature makes MCFC suitable for cogeneration applications or in integrated power plants, thereby increasing the overall thermal and electric efficiency to 85% [55]. The high operating temperature range of MCFCs reduces the durability [56]. Another issue with these cells is the corrosive nature of electrolytes which decreases the cell's life [57].

3.5 Solid Oxide Fuel Cell (SOFC)

SOFC mostly uses Ni catalyst and Yttria-stabilized Zirconia (YSZ) as electrolyte conducting O^{2-} ions. Oxidation at anode and reduction at cathode is given by Eqs. (14) and (15):

$$\text{At anode}: H_2 + O^{2-} \rightarrow H_2O + e^- \quad (14)$$

$$\text{At cathode}: \frac{1}{2}O_2 + 2e^- \rightarrow O^{2-} \quad (15)$$

SOFC operates at a high temperature of 600–1200 °C using non-precious metals [58]. Hydrocarbons like purified coal gas, natural gas, methane, etc. can be used as fuel AL, Mn, Zn alloys can be used for electrodes [59].

4 Hydrogen Storage Systems

The use of intermittent renewable sources causes issues like combining of hydrogen and oxygen which also lowers the efficiency. To overcome these issues, redox mediator was proposed. Ni(OH)2 was used as the mediator [60] which gets oxidized at the anode to form NiOOH. The process further continues by using another Zn anode which on combining with the NiOOH mediator electrode functions like a battery giving emf and Ni(OH)2. Hydrogen powered fuel cells are replacing batteries in electric vehicles and diesel engine powered generators used for backup power. Figure 4 shows the hydrogen energy storage system.

An approach for solving the issues due to the intermittency of renewable resources (solar or wind) was proposed by [8]. Wind turbine system is comparatively cheaper than solar PV but variations in wind system are higher. An issue with AWE is the tracking of maximum power point due to which the electrolyser and solar panels were connected via DC-DC converter. Similarly, a AC-DC converter was used for connecting wind turbine. Baldi et al. [61] used a hybrid system consisting of SOFC, PEMFC, battery and hydrogen storage. SOFC was used to supply the base load. The exhaust gases from the SOFC was purified to obtain hydrogen. This hydrogen was stored and fed to PEMFC which supplies the peak load. The surplus electricity produced by SOFC was stored in the battery.

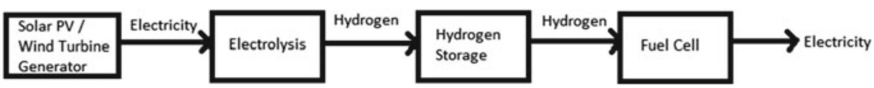


Fig. 4 Energy storage system for overcoming the intermittency in the renewable energy-based power generating system

5 Conclusion

Production of hydrogen from water electrolysis does not produces any toxins. AWE is the oldest and cheapest technology and is widely installed. It has low current density and operates on low pressure. PEM is costly but has high current density and provides pure hydrogen as compared with AWE. SOE takes place at high pressure and temperature which reduces its durability but the energy consumption is reduced and efficiency is high if heat is obtained efficiently. Power generation using fuel cells is also environment friendly. Different types of fuel cell are having different advantages and disadvantages. PEMFC is efficient but uses costly metals, and AEMFC gives similar output without requiring precious metals. High temperature fuel cells like SOFC, MCFC and PAFC are best suitable when used in cogeneration plants giving high overall efficiency, wide range of hydrocarbons can be used as fuel and are least affected by CO2. Electricity obtained by renewable resources is becoming economical and the surplus energy can be converted into hydrogen and stored. This stored energy can be converted to electric energy by a fuel cell. This entire process is environment friendly which can replace conventional power plants as well as power backup systems.

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Chapter 26
Wind Potential and Wind Economics in Türkiye

Gökhan Dündar and Özcan Atlam

Abstract Wind power has been widely used by humans throughout history for varied purposes. With the beginning of the industrial age, energy demand increased greatly and fossil fuels increased in usage. In the twenty-first century, due to environmental concerns, all the countries started to increase their renewable energy portfolio. Türkiye, sitting the world's major energy transfer routes, is highly dependent on imported fossil fuel resources. However, Türkiye has various and abundant renewable energy resources; hydropower in the mountainous eastern region, solar power in the southern, western and Marmara coastal regions and wind power mostly in the Aegean and Marmara region. This paper focuses on the wind potential in Türkiye, the biggest technical potential in Europe, green jobs created by wind, steps to be taken to adapt wind energy and contingencies associated with the policies.

Keywords Turkish wind potential · Wind energy · Wind power · Green jobs

1 Introduction

Energy plays a key role in development of the countries; there is a high correlation between economic growth and energy consumption [1]. Worldwide energy consumption is increasing; according to [2], 2009 was the only year evidencing a decrease in consumption (by an amount of 1.1%) in the last 30 years, a result of the 2008 global crisis. Since the effects of the COVID-19 pandemic have not been reported in detail at the time this article is being prepared, it is not possible to discuss the outcomes of the global crisis. However, a drop on energy consumption is expected due to the diminished supply and demand. In order to sustain economic growth and satisfy demand, different energy resources are being used, the primary being coal, oil, natural gas (NG), hydroelectric, nuclear and a small portion of renewables. At the beginning of the industrial age in eighteenth century, coal consumption increased greatly; with the invention of internal combustion engines oil took the crown from coal. Oil prices

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jumped from \$5/barrel to \$45/barrel in the oil crisis in the 1970s and have recently been fluctuating at the \$90-\$110/barrel level [3]. Türkiye, importing almost all of its fossil fuel resources including oil, has been highly affected by fluctuations in the energy market and volatile oil prices.

Türkiye has a wealth of renewable resources which can help increase its energy independence and drive economic growth. Biomass, in its primitive form, has been the major heating source in the Asia Minor for ages. Hydropower has been and is still being extracted from the rivers throughout the country. Two major rivers, the Firat and Dicle, feed the \$36 billion Southeastern Anatolia Project, a set of dams and irrigation facilities which nourishes the dry Southeast Anatolian fields and plays a major role in supplying water to SE Anatolia, as well as Syria and Iraq. Even though solar power is mostly used in solar thermal form for water heating purposes in the Mediterranean region, investments in photovoltaics gained momentum in the past 10 years surpassing the solar thermal installations. In addition to aforementioned energy, sources electricity generation and ground heating in some parts of the geothermal rich west Aegean region are conducted via the warm geothermal generosity of mother earth.

Many articles have been investigated to best picture the current status of the wind market in Türkiye however most of them either lacked up to date information or do not have detailed data. Most of the data used in this article have been extracted from Turkish State Meteorological Service and European Wind Energy Association. Furthermore, current legislation has been investigated through Turkish Republic Ministry of Energy and Natural Resources website. During the literature survey, we realized that most of the scientific research has been conducted by Turkish State Meteorological Service and very little has been performed by the universities. Most of the studies published by academia use the analysis results of the state research.

This paper will focus on the current role of wind power, potential for increasing its employment and energy independence implications in Türkiye. Both wind turbine economics and the green jobs created from wind will be discussed in the economics section of the paper, with consideration given to the political aspects of wind energy installations.

2 General View of the Energy Market in Türkiye

Türkiye, having the 18th highest economic growth rate in the world and the 1st in Europe, 8.2% in 2010 [4], currently has the 20th biggest economy due to the economic impacts of pandemic [5]. This rate correlates linearly with energy consumption. Türkiye imported 41.2B\$ worth energy in 2019. This amounts about 5% of GDP. When compared to previous terms, approximately 1% decrease in external dependency has been observed. Energy balance of Türkiye in 2018 is presented in Table 1 [6]. When we evaluate the data, it can be seen that despite a 3% drop in oil imports, there is a 40% increase in coal imports. Decrease in budget deficit is targeted by allowing more renewable penetration in the market. If sustainable economic growth

Table 1 Energy resources of Türkiye

Energy source	Production [×1015 btu]	Import [×1015 btu]	Consumption [×1015 btu]	Import rate (%)
Coal	0.739	1.018	1.757	56
Natural gas	0.016	1.775	1.791	99
Petroleum and products	0.12	1.822	1.942	94
Renewable resources	0.887	–	0.887	0

while ensuring energy security and decreasing carbon footprint is aimed, then Türkiye should seek to increase domestic energy resource utilization, mainly renewables.

Historical energy consumption for Türkiye is shown in Fig. 1. It can be seen that energy consumption in 2008 is almost four times bigger than it was in 1980s and is still increasing. The minor decreases in consumption relates to the global and domestic economic crises. However, the trend is almost linearly increasing. Since the last 2 years, data are not clearly reported they are not included in the graph but a drop is expected for 2020 due to the pandemic.

Despite the fact that Türkiye sits on the major energy transfer lines in the world, which connect the petrol rich Middle East and the NG-rich Russian/Caucasian region to Europe and the rest of the world, it has very limited economically feasible extractable fossil fuel resources [7]. Volatility of the oil prices and anthropogenic emissions associated with fossil fuels force Türkiye, like the rest of the world, to increase renewable energy share in its energy portfolio.

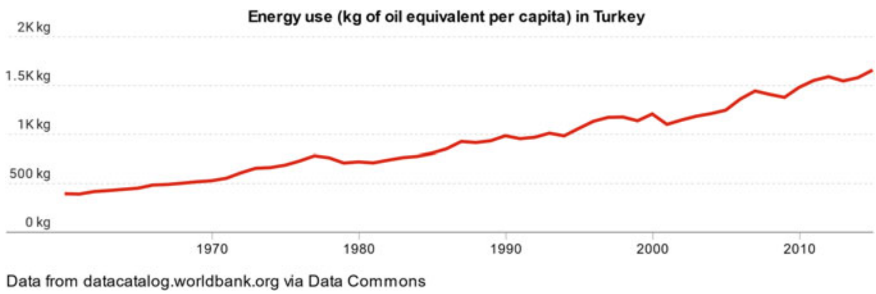

Fig. 1 Energy consumption of Türkiye

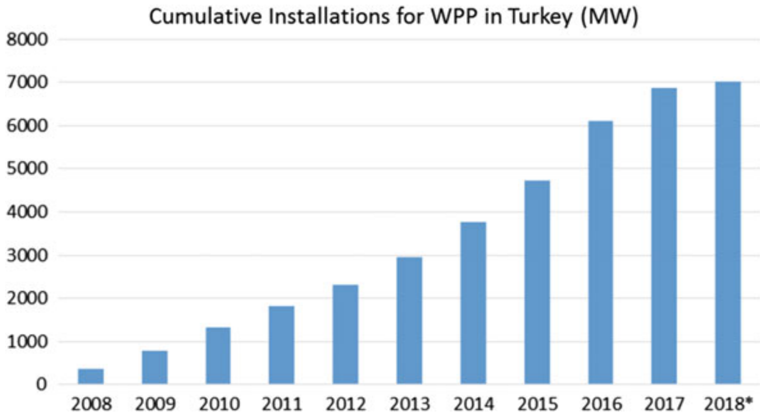

Fig. 2 Cumulative wind power installations in Türkiye

3 Wind Power in Türkiye

3.1 History and Evolution of Wind Power

Use of wind power in Anatolia goes back to ancient Troy. There are historical maps and pictures showing wind mills being used in the fourteenth century in Asia Minor. In the nineteenth century, according to a survey executed by Turkish Ministry of Agriculture, there were 749 wind mills, 718 of which were used for pumping water and 41 were used to generate electricity [8]. The first relatively large-scale implementation of wind power for electricity production was in 1986, in İzmir [9], with a 55 kW name plate capacity wind turbine. It was built for supplying energy to Altınyunus touristic facilities. Yet research into wind power did not turn to industrial/commercial applications until after 1996. The first commercial wind power plant, which has a 1.5 MW nominal capacity, was established in 1998 in Çeşme/İzmir [7]. Since then, there has been an increase in the wind power installations, both in terms of capacity and in terms of number of projects. An exponential increase in the cumulative wind capacity installation is shown in Fig. 2.

3.2 Current Wind Market

Wind power started to regain its value in late 1990s and the new wind market started to attract the attention of investors after the first commercial electricity producing wind plant was erected. Realizing there is a big potential to mitigate energy dependence, the Turkish Parliament enacted the "Electricity Market Law-4628" on February 2, 2001 to encourage more investment [10]. According to this legislation, the Turkish electrical grid changed to become a free electricity market, with grid operation passed

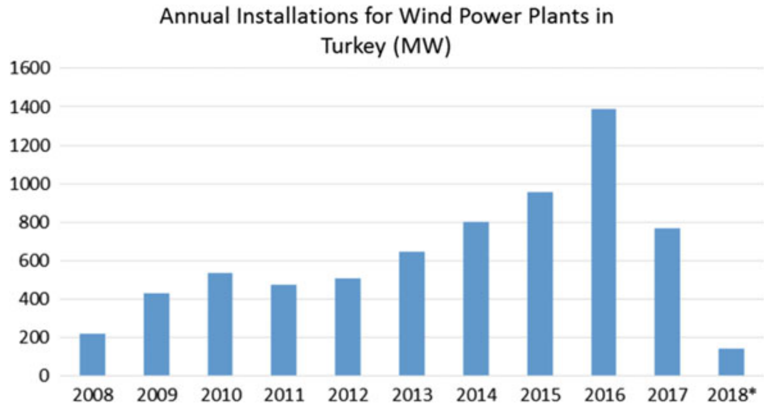

Fig. 3 Annual installation of wind power plants in Turkey

on to private companies, which made the sector attractive for private investments. With the aid of incentives, wind plant investments increased rapidly until 2017. Subsequently, a decrease in new installation is observed due to economic stress. Annual installations for wind plants are shown in Fig. 3.

The installed and proposed capacity numbers demonstrate the competitiveness of this new sector. However, the Turkish government is now faced with the challenge of separating proper proposals from those that are lacking in practicality. Only 1.5 MW of nameplate capacity out of a proposed 85 MW capacity was accepted by the government. By the end of 2018, total installed capacity in Türkiye reached up to 7369 MW. This increase amounts to 390 MW annual installation since 2008 and 730 MW since 2010. A comparison of installed capacity per country is given in Table 2.

4 Turkish Wind Potential Evaluation

A Turkish wind atlas was created using the Wind Atlas Analysis and Application Program (WASP), which is the main software to create the European Wind Atlas. All the calculations and the studies were executed by the Turkish State Meteorological Service. Based on the data derived from the field, measurements and calculations, the Turkish wind potential was estimated at 88,000 MW [13]. This places Türkiye's overall technical wind potential ahead of that of all European countries. Technical potential refers to the amount of wind power that can be extracted out of the gross potential. Gross potential estimates all the wind power over a region regardless of land use, land characteristics and economics while technical potential accounts for land use and applicability of the wind installation. According to wind energy prediction system (RETS–Rüzgar Enerjisi Tahmin Sistemi Tur.), the Turkish regional average wind speed and wind power density are shown in Figs. 4 and 5, respectively.

Table 2 Worldwide installed capacity

#	Country	2018 (MW) [11]	2019 (MW) [12]
1	China	211,392	236,402
2	European Union	178,826	192,020
3	USA	96,665	105,466
4	Germany	59,311	61,357
5	India	35,129	37,506
6	Spain	23,494	25,808
7	England	20,970	23,515
8	France	15,309	16,643
9	Brazil	14,707	15,452
10	Canada	12,816	13,413
11	Italy	9958	10,512
12	Sweden	7407	8804
13	Türkiye	7369	8056

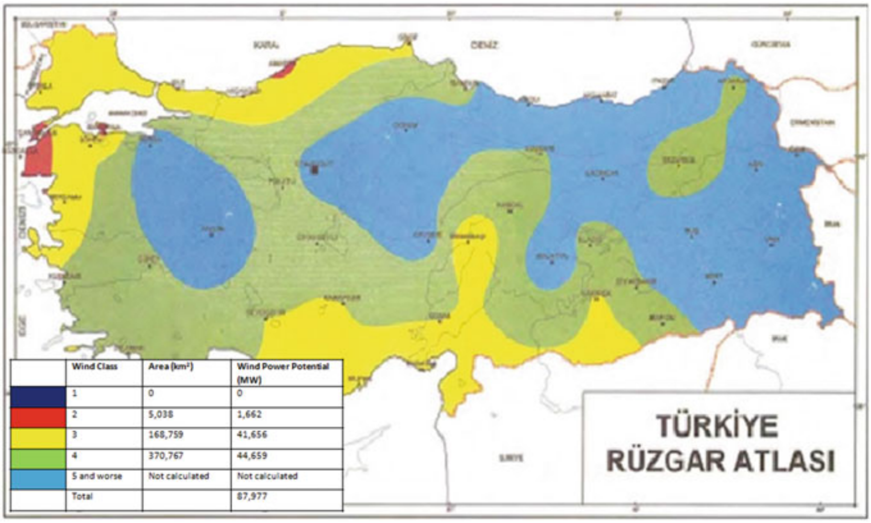

Fig. 4 Turkish Wind Atlas (wind class lower than 5 is not economically feasible so not calculated)

Wind power is stronger in the coastal regions, particularly in the western and northwestern coastal Marmara region. Average wind speed and wind potential in the mountainous inner regions are less than that are in the western regions, hence, most of the current installation proposals target the high wind west coast.

2020 energy consumption of Türkiye was 6.4 quadrillion BTU, an equivalent of 161MMtoe. If all the onshore wind energy in Türkiye were utilized with a capacity factor of 30%, 13% of total energy consumption would be satisfied. Given that oil

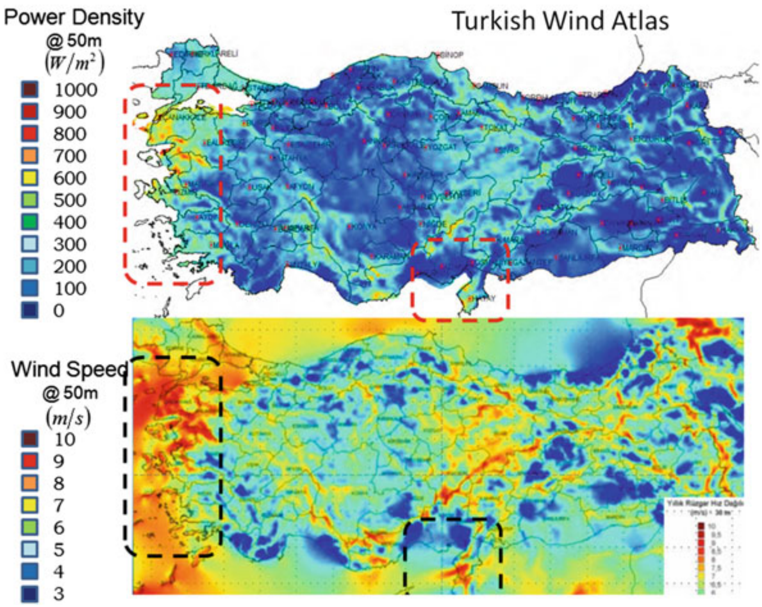

Fig. 5 Turkish Wind Atlas, power density and average wind speed

price is $100.5/barrel the economic value of the energy itself is $11.05 billion [14]. In addition to its sole economic value, new jobs created would significantly increase the prosperity of the local community.

5 Wind Power Economics

5.1 Wind Plant Economics

Wind energy worldwide, the fastest growing energy technology in terms of installed capacity since 2002, reached up to 651GW in 2019 yet still supplies only 1% of total global electricity [15]. The main reason for this is the highly matured conventional power plants, namely coal, nuclear and NG plants. Economics for diverse energy technologies differ in parameters that affect the cost, but converge in the same governing parameters, high installation costs and fuel costs. In fossil fuel power plants, the driving force for the levelized cost of energy (LCE) is fuel cost. For nuclear reactors, fixed and variable operation and maintenance (O&M) cost governs the LCE. It can be seen from Table 3 that variable O&M cost for renewable energy (excluding geothermal and biomass) is insignificant compared to other costs. The capital cost for wind is competitive with advanced coal plants and nuclear plants. The capital costs of photovoltaic and solar thermal are much bigger than those of other technologies. This makes wind power favorable among its alternatives. One challenge with wind power, however, is the almost perfect negative correlation between high-demand periods and high wind generation capability periods, namely the strongest winds usually blow at night, when the demand is the lowest while during the day wind usually stops or blows weakly. Therefore, the real value of wind, with a competitive LCE compared to conventional systems, is actually less than its cost. If wind power was to be delivered during the high demand, it would be more valuable pragmatically; there remains a solid need for conventional power plants (nuclear, coal, gas turbines) and/or backup systems. In order to provide grid-level energy storage to utilize more wind power, there are some mature technologies such as pumped hydrostorage or compressed air energy storage and some innovative technologies such as ocean renewable energy storage and energy storage in balloons [16].

Development in the wind turbine technologies has decreased the cost of electricity generation from 4 to 6 ¢/kWh to 2 ¢/kWh in the past 20 years [17]. However, even with technological advancement, wind still depends highly on financial incentives and/or subsidies. Since, onshore wind is a mature industry, the borders of which are well defined by the Betz Limit and current turbine aerodynamics, the cost associated with the technology itself is not expected to drop significantly. Therefore, it is not hard to conclude that the future of wind power is political in nature. In Türkiye, as in most countries, government subsidy policies are decided either annually or for a given period. This leads to long-term uncertainty since Türkiye still lacks a long-term energy strategy. Although, recent political and bureaucratic enhancements and modernizations in Turkish legislature are projected to make the wind market more stable.

In addition, despite not signing the Kyoto Protocol, there is popular public support toward securing a greener future, which eventually will result in more strict CO2 regulations. Measures to be taken to reduce CO2 emissions will make wind even more attractive than it is now.

In most part of the world, utilities buy wind power produced by individuals or private companies, this is called feed-in tariff (FIT). FIT for Türkiye and some EU countries is given in Table 4.

European officials claim that FIT prices in Türkiye are low thus not competitive compared to other EU countries. However, energy legislature is being adapted to EU legislature so that the entire infrastructure is becoming better organized and mature.

5.2 Role of Wind Nature on Wind Economics

The natural characteristics of the wind engender certain problems: Unlike other technologies, wind power is not concentrated at one point; instead, it is distributed over a region. Additionally, regions where there is high wind potential are not necessarily located close to the population centers and large population centers make the installation of wind turbines difficult for aesthetic and logistic reasons. Furthermore, large population areas usually have higher buildings which has a negative effect on onsite

Table 3 US levelized cost of electricity of various technologies

Plant type	Capacity factor (%)	US average levelized costs (2009 $/mega watt hour) for plants entering service in 2016				
		Levelized capital cost	Fixed O&M	Variable O&M (including fuel)	Transmission investment	Total system levelized cost
Conventional coal	85	65.3	3.9	24.3	1.2	94.8
Advanced coal	85	74.6	7.9	25.7	1.2	109.4
Advanced coal with CCS	85	92.7	9.2	33.1	1.2	136.2
Natural gas-fired						
Conventional combined cycle	87	17.5	1.9	45.6	1.2	66.1
Advanced combined cycle	87	17.9	1.9	42	1.2	63.1
Advanced CC with CCS	87	34.6	3.9	49.6	1.2	89.3
Conventional combustion turbine	30	45.8	3.7	71.5	3.5	124.5
Advanced combustion turbine	30	31.6	5.5	62.9	3.5	103.5
Advanced nuclear	90	90.1	11.1	11.7	1	113.9
Wind	34	83.9	9.6	0	3.5	97
Wind–Offshore	34	209.3	28.1	0	5.9	243.2
Solar PV[1]	25	194.6	12.1	0	4	210.7
Solar thermal	18	259.4	46.6	0	5.8	311.8
Geothermal	92	79.3	11.9	9.5	1	101.7
Biomass	83	55.3	13.7	42.3	1.3	112.5
Hydro	52	74.5	3.8	6.3	1.9	86.4

[1]Costs are expressed in terms of net AC power available to the grid for the installed capacity

Table 4 Feed-in tariff prices for EU countries [18]

Country	Feed-in tariff price c/kWh (USD)
Türkiye	7.3
Germany	9.6
France	11.3
UK	42.7
Denmark	4.82
Spain	9.65

wind profile. This characteristic of wind yields to long transmission lines which means both higher cost and bigger transmission losses.

The intermittent nature of the wind makes it impossible to act as a baseload or intermediate plant without the addition of a storage capability, which adds significantly enough to the capital cost to make it uncompetitive. There is no proven commercial large-scale energy storage device, other than pumped hydro storage and compressed air energy storage, which are both dependent on geological location.

Another problem associated with wind is dispatchability. You cannot turn on and off your wind plants to satisfy the demand. Both the intermittency and the non-dispatchable characteristics of wind make it hard to allow a smooth grid penetration. When wind stops unexpectedly, in a very short time compared to coal plants, low ramping time power plants, namely gas turbines should be turned on immediately. A solution to this can be increasing spinning reserve capacity so that in the case of intermittency, these reserves can act in a very short tie and maintain the system stability. However, this also adds up to the cost of electricity for the end user. Since installed wind power must be coupled with an appropriate back up power system, the target economic benefits of wind power are hard to achieve.

5.3 Employment Economics

Efforts to reduce global warming and CO^2 emissions and rising environmental concerns have opened a new market for employment—green jobs. Basically, green jobs refer to any kind of jobs related to the renewable energy sector as well specifically to reduce CO^2 emissions. When any kind of wind project is built, three kinds of jobs are created: direct, indirect and induced jobs. Direct jobs refer to people directly working in the production and installation of wind turbines. Indirect jobs include the suppliers who are already there, but increase their production volume or change their products due to demand in this field. For instance, wind turbine installation is a direct job, whereas cable manufacturing is an indirect job. Induced jobs are those related to the jobs created by the economic welfare distributed by the new wind installations. When first installing wind turbines employment peaks, because there is a temporary labor demand for installation, however, after finishing the installations, this first group of jobs leaves, to be replaced with a lesser number of O&M jobs.

Direct employment can be calculated according to McKinsey-2006 [19]. A peak 228 MW wind farm creates 500 jobs distributed over 5 years for installing the required equipment and 40 O&M jobs distributed over a 20-year operational lifespan. Starting from an estimated 5-year installation period until the end of a 20-year operational lifetime of a 228 MW Vestas wind farm, 2500 job-years for installation plus 800 job-years for O&M are created. All the job-years created by 228 MW wind farm running with 30% capacity factor installation divided a 25-year lifespan of the project yields 1.93 jobs/MW. The case that was mentioned above is assuming only the direct installation jobs. However, building a factory to manufacture wind turbines or adapting and boosting cable factories will create permanent jobs, where the 88,000 MW wind power capacity of Türkiye fully utilized, without any environmental concerns and regardless of whether it is applicable or not, 169,824 jobs for a 25-year period would be provided. Of course, this is an unrealistic, impractical scenario but it provides a useful description of the wind market in Türkiye.

Since there is no possible analytical way to learn and calculate the indirect employment, a few models were designed to predict indirect job generation. Renewable energy study in Germany [20] for general renewable energy and the European Wind Report [18] is highly used to analytically model the indirect jobs created associated with wind. According to these two reports, a multiplier of 0.9 is used to estimate indirect jobs created. In this case, 1.93 jobs/MW multiplied by 0.9 yields to 1.74 indirect jobs/MW. One should not forget that this is a rough ballpark figure. When this estimation is applied to Turkish total wind potential, it results in 152,856 indirect jobs. Leveraging this potential with the proper strategy and investment Türkiye can be one of the manufacturers of wind turbines.

6 Conclusions

Blessed with abundant wind potential, there is a big market for wind energy in Türkiye. However, as in the rest of the world, wind energy relies highly on governmental policies, both in terms of economics and in terms of applicability. Türkiye has showed a great deal of improvement in adapting its legislature to the fast growing and developing wind market. The future of wind will be decided by policy measures to be taken for CO^2 reduction, government subsidies and financial incentives. We have inadequate knowledge and experience to predict the long-term effects of wind penetration on grids. Hopefully, lessons learned from the Danish and German examples will make the future of wind brighter. Even with the existing uncertainties and predictable contingencies, the wind market in the world and particularly in Türkiye is developing rapidly. Türkiye has the biggest technical capacity in Europe and increasing the implementation of wind power has the potential to result in more economic power, energy security and jobs created.

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Chapter 27
A Machine Learning Approach for Predicting Price of Used Cars and Power Demand Forecasting to Conserve Non-renewable Energy Sources

Swati Gupta, Meenu Vijarania, and Milind Udbhav

Abstract In today's era, renewable energy sources such as sun, wind, and water are becoming popular alternative for building smart cities which thereby increasing the usage of cars on road. Thereby, predicting the car price is one of the high research interest areas, as it requires considerable effort and knowledge. Such system can effectively determine the value of the car by considering several features. In the existing scenario, the price of a used car is decided randomly by the seller leaving buyer with no about the correct value of the car. To overcome the existing problem, we have proposed a model which will be highly effective in determining the price of a used car. We have examined the attributes to automate the process of determining the second-hand car price. The model aims at reducing car price fraud by applying the machine learning technique. Our model is helpful in predicting the price of a used car that are dependent on previous consumer data and a given set of features. It comprises 4000 tuples of test data which are obtained by the pre-processing technique. In our paper, we have used machine learning algorithms with the help of which we are able to obtain the accuracy of 92.38%.

Keywords Renewable energy · Non-renewable energy · Prediction · Machine learning algorithm · Accuracy · Data pre-processing

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1 Introduction

Machine leaning technique has invaded new opportunities in forecasting power load [1]. With the rapid increase in number of cars usage, energy conservation plays a vital role. The main aim of conserving energy is to provide users with safe and reliable power supply. Hence, due to increase in demand of fuel for car and other transport services, energy demand forecasting is important for conserving non-renewable sources that are depleting at a faster rate.

In a car manufacturing system, the price of a new car is kept fixed additional superfluous costs. When a new car is purchased by the customers, they are certain that the amount of money they have invested is worth. But with an increase in fuel prices and lack of funds, the customers are inclined toward the purchase of old cars. The used car price prediction is a significant and interesting problem that needs to be considered. As per the data in [1, 2], there is a decline in sales of new cars by 8% in 2020.

In today's world, reselling used cars has become essential. The primary reasons are increase in car pricing and the traveling behavior of people to explore new places. The used cars can be purchased on a lease basis, by establishing a contract between the two parties who are involved in selling and buying. Once the agreement is completed, the cars are resold to the interested buyer.

The value of the used cars is dependent on several factors. Some of them include the age of the car, its manufacturer (and model), the origin of the car (the original country of the manufacturer), mileage in terms of the number of kilometers it has run, and its horsepower. The type of fuel used in the car along with its consumption per mile highly affects the price of a car due to frequent changes in the price of fuel. Discriminate features that include exterior color, number of doors, transmission type, dimensions, safety, air condition, interior, and navigation enabled also influence the car price. We can conclude that the car price depends on a large number of factors. But unfortunately, information about all these factors is not always available and the buyer decides to purchase only at a certain price based on a few given factors.

In this work, we have created a model that works on different machine learning techniques that solve the issue related to car purchasing and make the sale and purchase of cars easier. Our model is trained over a dataset of 4000 tuples which are obtained after applying the cleaning process on over 4600 tuples. Our proposed model asks the user to input their car's credentials. The credentials include company name, model name, fuel type, kilometers are driven, and year of make. We then set up a relationship of price with all these attributes and create a linear graph. We predict the value of the car's price from the linear graph which eradicates the buyer and seller discrepancy. Thus, our model not only reduces disputes and solves conflicts but also provides an efficient and faster way of determining the second-hand car price. Our proposed model automates the process of price determining and saves manpower and energy.

The road map of the paper is as follows. In Sect. 2, we discussed research work carried out in this field. Section 3 covers the research methodology that covers dataset collection, pre-processing, and data analysis. In Sect. 4, data analysis is performed on the dataset. Section 5 covers the conclusion of our paper.

2 Literature Review

The dataset is taken from Kaggle that comprises various features which are taken into consideration to perform prediction and classification of the prices of used cars. The literature review discusses the work of different researchers that have worked on the car price prediction.

Zhang et al. [3] perform the used car price prediction using the dataset from the Kaggle. The paper discussed different classification techniques like decision tree, SVM, logistic regression, random forest, AdaBoost, and random forest to assess the performance. The prediction task carried out by the random forest classifier provides the best performance. The irrelevant features are removed and several features, namely kilometer covered, associated brand, age time associated with vehicle selling, and vehicle age were taken into account to perform the classification task that provides the accuracy of 83.08%.

Listiani et al. [4] discussed the model that is dependent on support vector machines (SVM) which are used for estimating residual prices associated with cars that are leased providing higher accuracy as compared to techniques like the multivariate regression model. SVM handles dimensional data and prevents over-fitting and under-fitting of the dataset. The genetic algorithm was used in discovering the optimal parameters for SVM in reduced time.

Noor et al. [5] is based on a multiple regression model that is useful in classification. It comprises different variables which include both dependent and independent variables. The model evaluates the prediction obtained from pakwheels.com. The major drawback of the paper is that the dataset comprises different features like color of the car, date of advertisement, etc., for performing prediction and provides less accuracy than are based on using the random forest.

In Kuiper et al. [6], car price prediction is being carried out by using a multivariate regression model that comprises approximately 2005 General Motors (GM) cars dataset. Variable selection techniques are used for determining relevant features for carrying out prediction tasks. However, paper does not proposed any generalized model for the existing variety of brands to predict prices using several relevant features.

Du et al. [7] proposed a technique known as Optimal Distribution of Auction Vehicles (ODAV) system that estimates the best price for reselling the cars. It provides the opinion on the location where a used car can be sold. In this paper, the challenges of the distribution process were handled through Power Information Network (PIN), which is based on automating the decision optimization system to provide maximum profits through auction vehicles. The three models, namely, linear regression model, genetic algorithm, and time series analysis model were considered that are responsible for daily distribution of the vehicles used for price forecasting.

Gonggi et al. [8] proposed a novel model for forecasting the value of used cars. The characteristics that were considered are manufacturer, mileage, and estimated useful life. The model is used for providing optimized nonlinear relationships that cannot be performed by using simple linear regression methods. In the paper, BP neural network (NN) was formulated to extract the feature of the distribution curves under different conditions. To train the neural network, schemed data was used. Finally, schemed input data and outputs from neural network are ordered for nonlinear curve fit.

Nitis Monburinon and Eric et al. [9], [10] proposed a regression model for predicting the prices of the used car where the data was gathered from the German e-commerce site. The Mean Absolute Error (MAE) as the metric was calculated such that the gradient boosted regression technique gives a lower MAE error of 0.28, while random forest provides the MAE value of 0.35.

3 Research Methodology

The dataset of used cars was taken from Kaggle such that data processing is being performed to remove inconsistency in the data. Further training of the data model is being performed using a machine learning algorithm that predicts the price of used cars with higher accuracy. Figure 1 illustrates block diagram for our proposed methodology.

Fig. 1 Block diagram for proposed methodology

Name	Location	Year	Kilometers	Fuel_Type	Transmissi	Owner_Ty	Mileage	Engine	Power	Seats	New_Price	Price
Maruti Wa	Mumbai	2010	72000	CNG	Manual	First	26.6 km/kş	998 CC	58.16 bhp	5		1.75
Hyundai C	Pune	2015	41000	Diesel	Manual	First	19.67 kmp	1582 CC	126.2 bhp	5		12.5
Honda Jaz	Chennai	2011	46000	Petrol	Manual	First	18.2 kmpl	1199 CC	88.7 bhp	5	8.61 Lakh	4.5
Maruti Erti	Chennai	2012	87000	Diesel	Manual	First	20.77 kmp	1248 CC	88.76 bhp	7		6
Audi A4 Ne	Coimbator	2013	40670	Diesel	Automatic	Second	15.2 kmpl	1968 CC	140.8 bhp	5		17.74
Hyundai E(	Hyderabac	2012	75000	LPG	Manual	First	21.1 km/kş	814 CC	55.2 bhp	5		2.35
Nissan Mic	Jaipur	2013	86999	Diesel	Manual	First	23.08 kmp	1461 CC	63.1 bhp	5		3.5
Toyota Inr	Mumbai	2016	36000	Diesel	Automatic	First	11.36 kmp	2755 CC	171.5 bhp	8	21 Lakh	17.5
Volkswage	Pune	2013	64430	Diesel	Manual	First	20.54 kmp	1598 CC	103.6 bhp	5		5.2
Tata Indica	Chennai	2012	65932	Diesel	Manual	Second	22.3 kmpl	1248 CC	74 bhp	5		1.95
Maruti Cia	Kochi	2018	25692	Petrol	Manual	First	21.56 kmp	1462 CC	103.25 bhp	5	10.65 Lakh	9.95
Honda City	Kolkata	2012	60000	Petrol	Automatic	First	16.8 kmpl	1497 CC	116.3 bhp	5		4.49
Maruti Swi	Jaipur	2015	64424	Diesel	Manual	First	25.2 kmpl	1248 CC	74 bhp	5		5.6
Land Rove	Delhi	2014	72000	Diesel	Automatic	First	12.7 kmpl	2179 CC	187.7 bhp	5		27
Land Rove	Pune	2012	85000	Diesel	Automatic	Second	0.0 kmpl	2179 CC	115 bhp	5		17.5
Mitsubishi	Delhi	2014	110000	Diesel	Manual	First	13.5 kmpl	2477 CC	175.56 bhp	7	32.01 Lakh	15
Honda Am	Kochi	2016	58950	Diesel	Manual	First	25.8 kmpl	1498 CC	98.6 bhp	5		5.4
Maruti Swi	Jaipur	2017	25000	Diesel	Manual	First	28.4 kmpl	1248 CC	74 bhp	5		5.99
Renault Du	Kochi	2014	77469	Diesel	Manual	First	20.45 kmp	1461 CC	83.8 bhp	5		6.34
Mercedes-	Bangalore	2014	78500	Diesel	Automatic	First	14.84 kmp	2143 CC	167.62 bhp	5		28
BMW 3 Se	Kochi	2014	32982	Diesel	Automatic	First	22.69 kmp	1995 CC	190 bhp	5	47.87 Lakh	18.55
Maruti S C	Bangalore	2015	55392	Diesel	Manual	Second	23.65 kmp	1248 CC	88.5 bhp	5		8.25
Audi A6 20	Mumbai	2015	55985	Petrol	Automatic	First	13.53 kmp	1984 CC	177.01 bhp	5		23.5
Hyundai i2	Kolkata	2010	45807	Petrol	Manual	First	18.5 kmpl	1197 CC	80 bhp	5		1.87
Volkswage	Kolkata	2010	33000	Petrol	Automatic	First	14.4 kmpl	1598 CC	103.6 bhp	5		2.85
Honda City	Mumbai	2012	51920	Petrol	Manual	First	16.8 kmpl	1497 CC	116.3 bhp	5		4.25

Fig. 2 Data collected for analysis

3.1 Dataset Collection

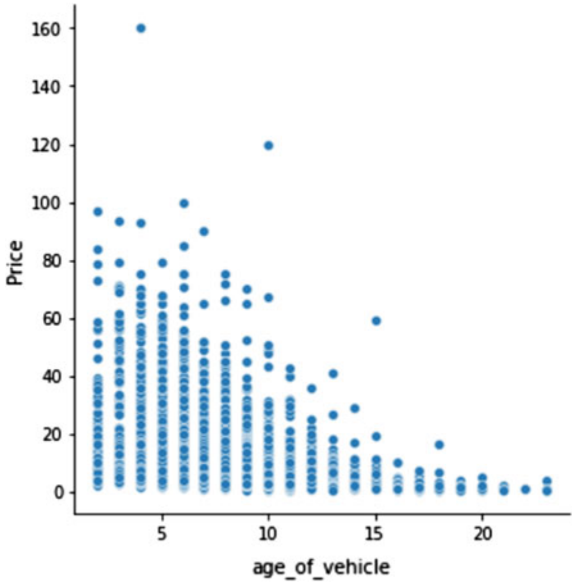
It comprises gathering the data from the Kaggle website which is available in CSV format. The dataset contains 13 variables that include name, location, year, kilometer, fuel type, transmission, owner type, mileage, engine, power, seats, and new_ price. The sample of data collected is shown in Fig. 2.

3.2 Data Preprocessing

Our model is trained over a dataset of 4000 tuples cleaned from a total of 4600 tuples which works to predict the price at which the car should sell. Additionally, the following steps are carried out that helps us to identify the features such as:

1. Maintaining the list of cars that are sold by private owners and filtering those records which are sold by dealerships.
2. Since the data comprises car manufacture years, so we filter out cars manufactured such that we omit any record whose manufacturing is before 1867.
3. Further, we filter out all cars that have unrealistic power values
4. The data comprises certain records where the associated price of the car is missing so we filter out such records.
5. We perform the removal of non-numerical data from numerical features.
6. Data containing Not Available (NA) values are also filtered out.

Fig. 3 Relationship of age of vehicle with price



3.3 Data Analysis

After the preprocessing step, the data is analyzed to perform a visual exploration the data to collect insights for the model which can be applied to the data. The visual representation is being performed by using a box plot, bar chart, distribution graph, etc., to explore each feature that varies. We also derive the relationship with other features including the target feature. The age of the vehicle is calculated using the feature known as year of registration and considering the current year 2021. Speciously, it defines the number of years which is obtained through the year of registration and 2021. Figure 3 depicts the distribution of age of the vehicle.

Figure 4 shows the relationship of price with each fuel type. It is apparent that maximum cars have fuel type as diesel and petrol. The graph also depicts that they have a wide range of price distribution as compared to the other fuel types.

Figure 5 shows the relationship of price with transmission type. It is apparent that maximum cars have a transmission as automatic. The graph also depicts the wide range of price distribution with respect to manual and automatic transmission types.

Figure 6 depicts average price of top brands specifying of Porsche band is much higher, which is around 40,000, while the next highest is around 20,000.

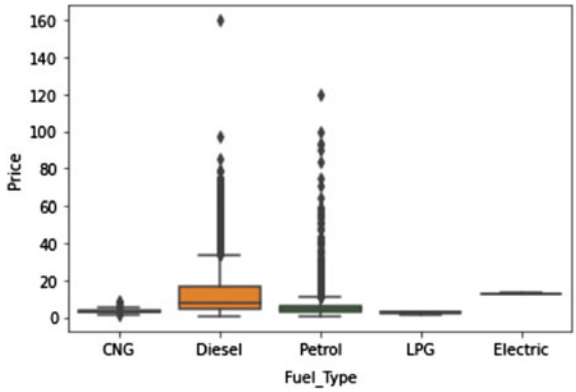


Fig. 4 Relation of fuel type with price

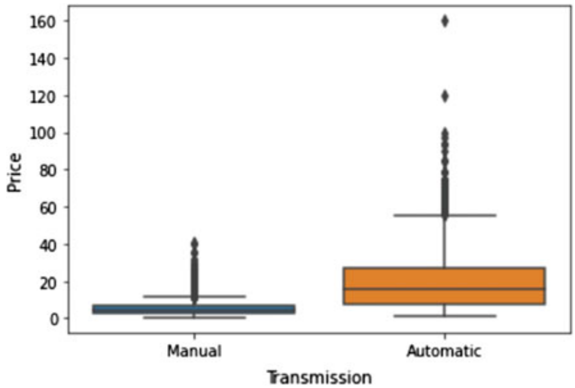


Fig. 5 Relation of transmission with price

4 Model Description

Predicting the car price is a challenging task due to the large number of attributes that are considered for accurate prediction [15]. When a single machine algorithm was applied to the dataset, the accuracy obtained was less than 50%. Therefore, the communal of multiple machine learning algorithms has been proposed and with this combination of ML methods, we gain accuracy of 92.38%. This provides an improvement compared to the single machine learning method approach which is able to avoid over-fitting and enhance the generalization.

With the cleaned dataset and at a train test split with a test size of 0.3, our model produced an R2 score of 55.03 which was very less and hence compromised the accuracy of our model. To overcome this, we tried and tested different test sizes to find the size with the maximum R2 score and landed at a test size of 0.2 for a new R2 score of 67.80 shown in Figs. 7 and 8.

The input data is split into training, testing, and cross-validation into the split ratio of 70:20:10. The model score is calculated which is referred as coefficient of

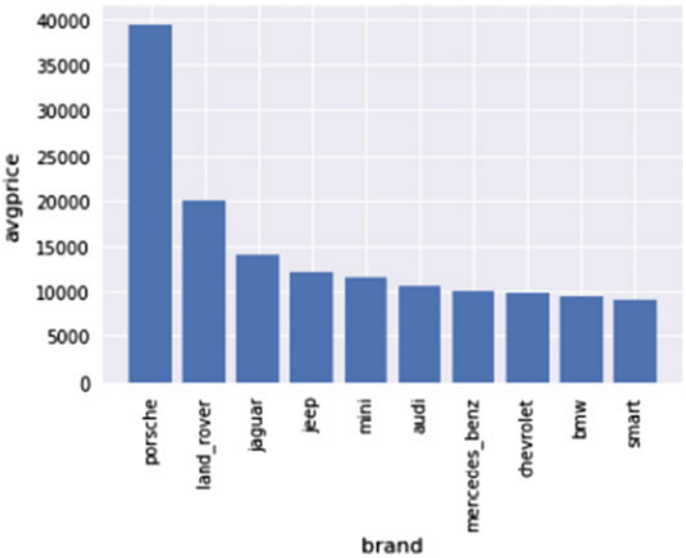


Fig. 6 Vehicle average price for a specific brand

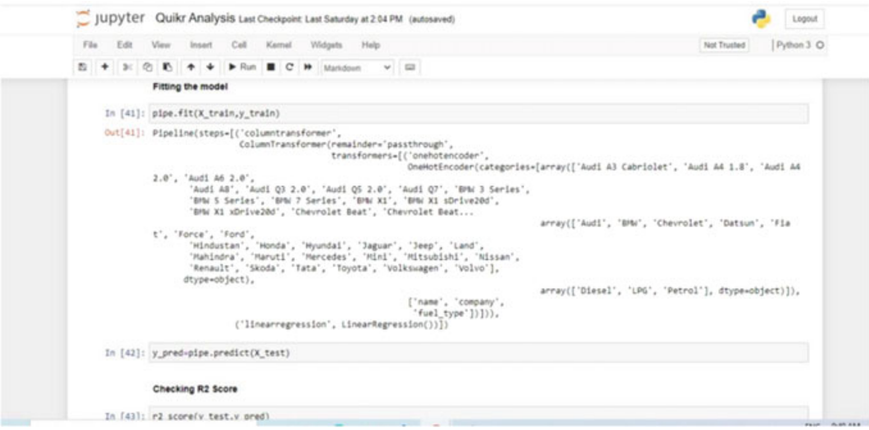


Fig. 7 Fitting the model

Fig. 8 Calculating the R2 score

determination as R2. The score obtained for training was found to be 92.38%, while for testing, 83.63% score was obtained.

5 Machine Learning Approach for Power Demand Forecasting

Machine learning approach is used for predicting demand forecasting [11], [12]. In this technique, past period load is considered as a training sample to build a suitable network structure that uses training algorithm to train the network. In our approach, two power sources are considered, namely renewable and non-renewable energy sources. Further, Exploratory Data Analysis (EDA) [13, 14] is performed to analyze the trends in data. Once the preprocessing step is finished, we split the data into training and test sets. We used support vector regression, CatBoost, and multi-layer perception to train our hybrid model. We obtain the forecasting results and perform the comparative analysis with existing ML models.

6 Conclusion

The presence of a large number of attributes for making accurate used car price predictions makes it a challenging task. The major step involved data collection and then performing the preprocessing of the data. Our model is trained over a dataset of 4000 tuples cleaned from a total of 4600 tuples which works to predict the price at which the car should sell.

We proposed the communal of multiple machine learning algorithms with the help of this we were able to achieve accuracy of 92.38%. This is a significant improvement compared to the single machine learning method approach done which is able to avoid over-fitting and enhance the generalization. Energy sources forecasting uses machine learning techniques that is helpful in solving several challenges related to fuel conservation.

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Chapter 28
Stubble as a Renewable Source of Energy: A Study of Stubble Burning and Crisis of Environmental Degradation in Punjab, India

Hardeep Kaur and Manvendra Singh

Abstract Stubble burning is a major contributor to environmental pollution in north India. It releases massive amounts of toxic pollutants, including particulate matter and gaseous pollutants, which cause serious health risks for humans and substantially impact the environment. Punjab is a prosperous state in India, and agriculture is the foundation of its economy. This study is primarily concerned with the issue of stubble burning, which is a significant cause of environmental degradation in Punjab. It explores the effects of stubble burning, incidents of stubble burning in Punjab, and various governmental policy incentives for crop residue management. The data for this research was collected from newspaper articles, governmental reports, reliable Internet sources, and field visits to the Punjab Remote Sensing Centre, Ludhiana, and the district agriculture department regarding the record of crop fire incidents. The findings revealed a shocking upsurge in stubble burning events in 2022 during the Rabi session despite various environmental legislation and crop residue management techniques. Maximum incidents of stubble burning were reported in the Sangrur district of Punjab since 2016 during the Kharif session (15th September–30th November). Most of the farmers in Punjab are unaware of various crop residue management techniques. Hence, they consider the burning of residue as the best option. Therefore, extensive awareness campaigns are required to educate farmers about the range of financially viable alternatives and the effects of stubble burning. The primary purpose of this study is to provide eco-friendly substitutes for crop residue management. It recommends the effective implementation of regulations as an important prerequisite to preventing environmental degradation in Punjab caused by crop residue burning.

Keywords Environment degradation · Stubble burning · Crop residue management strategies · Air quality index · Punjab

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1 Introduction

Stubble burning is decades old practice in north Indian states. Wheat and paddy are major prevalent crops of Punjab. Most farmers utilize combines for crop harvesting, resulting in a huge amount of crop residue. Stubble burning is the process of the intentional burning of crop residue after harvesting. The short time of 10–15 days between harvesting the paddy crop and sowing the wheat crop is the primary cause of stubble burning. Shortage of labour, lack of financial resources, and low awareness among farmers about biomass management are also responsible for paddy straw burning. It is considered the easiest and most economical method to prepare the fields for the next cultivation [1, 2]. Stubble burning by the farmer in Punjab and Haryana is considered a leading contributor to degradation in the air quality index in Delhi. It emits toxic gases such as carbon dioxide, sulphur dioxide, nitrogen dioxide, and particulate matter, causing serious health issues. Punjab has the highest rate of paddy stubble burning. Around 90% of farmers burned crop residue during the Kharif session [3]. According to Sally [4] Punjab government imposed a penalty of 6 crore on 23,000 farmers for stubble burning during 2019–20. Despite various policies and crop residue management techniques, an increase in events of stubble burning has been reported.

According to Punjab Remote Sensing Centre, "till 15 November 2021, around 12.9 lakh hectares paddy area was burnt, which is approximately 43% of the total rice area of the state" [5]. Punjab recorded 71,304 open field fire incidents between 15th September–30th November 2021 (https://gis-prsc.punjab.gov.in/residue/Index.aspx) [6].

This study deals mainly with the issue of stubble burning in Punjab and its impact on the environment and humans. It investigates the incidents of stubble burning in Punjab since 2016 and provides various crop residue management strategies.

2 Literature Review

Grover et al. (2015), in their study, explored that high cost and scarcity of labour, low awareness level among farmers about alternative measures of crop residue management, lack of financial resources, and less time to prepare fields for the next crop are major reasons for stubble burning. The study reported that paddy stubble burning leads to air and soil quality degradation, resulting in adverse impacts on human health [7].

Singh et al. **(2015)**, conducted their study to monitor the effect of stubble burning on air quality. The study revealed a decline in the air quality of Mandi-Gobindgarh due to an upsurge in PM**10** and PM**2.5** concentrations during stubble burning sessions leading to destructive impacts on the environment and humans [8].

Batra (2017), analysed the status of stubble burning in northwest India and its effects on human health. Stubble burning is more prevalent in Punjab than in other states. Paddy residue burning releases harmful gasses leading to asthma, acute respiratory infection, and eye-related diseases. The use of rotavators, choppers, happy speeders for in situ management techniques, and stubble in power generation, biogas and biofuel production are some measures to control residue burning [9].

Lohan et al. (2018), in their research highlighted the harmful impacts of paddy burning on the environment and humans. It leads to a decline in air quality. The heat generated by Stubble burning kills bacteria and fungi that are beneficial to the soil. It can cause serious health issues in the human-like lung, heart, and respiratory diseases. It described government policies for residue management, such as "Section 144 of the Civil Procedure Code" to ban stubble burning and the "Air Prevention and Control of Pollution Act, 1981" [10].

Saini et al. (2019), in their study, found that stubble burning harms the atmosphere as well as humans and animals. It results in various health issues that lead to premature death. It suggested measures such as decomposition of stubble, bio-compost, and unitization of stubble in bio-thermal power plants to control pollution [11].

Kurinji and Prakash (2021), in their study, explained that mechanical crop harvesting, shortage of labour, lack of time to prepare fields for new crops, lack of feasible markets for residue, low level of consciousness among farmers about crop residue management techniques are some of the reasons for stubble burning. Despite various initiatives for in situ and ex situ crop residue management and judicial rulings, the practice of stubble burning prevails [12].

Singh et al. (2021) revealed that stubble burning leads to the destruction of beneficial microorganisms, resulting in soil fertility loss. It also generates greenhouse gases that have harmful effects on the environment as well as on humans [13].

Kaur and Singh (2022), in their study "An Assessment of Environmental Pollution and Policy Initiatives in Punjab, India: A Review", explored various types and causes of environmental pollution in Punjab. It also revealed that degradation in air quality due to stubble burning led to 41,090 premature deaths in Punjab during the year 2019. It highlighted the government's initiative of ambient air quality monitoring to monitor the impact of stubble burning on air quality at 28 locations consisting of four rural areas of Punjab to curb the issue of pollution [14].

This study is significant because it investigates stubble burning incidents and provides various strategies for crop residue management to prevent harmful impacts of stubble burning, and it can be helpful in the generation of awareness among farmers about these eco-friendly measures.

3 Research Objectives

The leading objectives of this research are as under:

1. To analyse the status of stubble burning in Punjab since 2016.
2. To examine the impacts of crop residue burning on humans and environmental degradation.
3. To investigate various policy initiatives taken by the government.
4. To explore crop residue management strategies in Punjab.

4 Research Methodology

It is exploratory, and to attain the objective of the study, data used in this research was collected from both primary and secondary sources such as newspapers, e-journal articles, reliable internet sources, government reports, and the official website of "Punjab Pollution Control Board" and field visits of the Punjab Remote Sensing Centre, Ludhiana, and the district agriculture departments. Existing literature on stubble burning has been reviewed for framing research objectives.

4.1 Study Area

Punjab is situated between 29 "30′ N to 32 "32′ N latitude and 73 "55′ E to 76 "50′ E longitude in the northwest part of India. The total area of Punjab is 50,362 sq. km. It is one of the developed states of India and agriculture is the foundation of the economy of Punjab due to productive land and abundant water resources.

5 Stubble Burning in Punjab

Stubble burning is the major cause of environmental degradation in Punjab. Rabi and Kharif are two harvesting seasons in Punjab. Paddy residue burning leads to a rise in SO_2, NO_2, and aerosols concentration during the Rabi crop in April–May and the Kharif crop from October to November [15]. According to a study, more than 50% of the total area under paddy cultivation was burnt during the Kharif session in 2020 [12]. Despite many policies, stubble burning rapidly increasing, resulting in environmental degradation. This part of the paper deals with the number of fire incidents in both Rabi and Kharif sessions in Punjab since 2016 and areas under stubble burning since 2017.

Figure 1 shows year-wise events of Crop residue burning during the Rabi session. It revealed that incidents of stubble burning were the least in 2021, and there is a massive upsurge in these incidents during 2022.

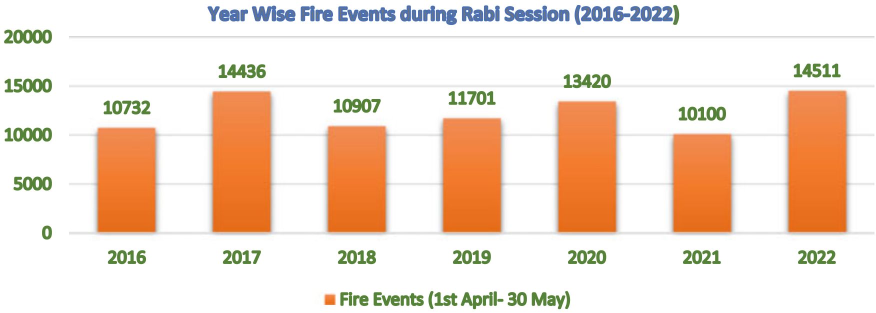

Fig. 1 Year-wise events of stubble burning (1st April–30 May) during the Rabi session since 2016. [6] *Source* Data compiled from Punjab Remote Sensing Centre during the Rabi session (https://gis-prsc.punjab.gov.in/residue/Index.aspx)

Figure 2 depicts year-wise events of crop residue burning during the Kharif session. 71,304 fire incidents have been reported during 2021. It indicated that incidents of stubble burning were maximum in the year 2016.

Figure 3 depicts district-wise events of crop residue burning during the Kharif and Rabi session in 2021. During the Kharif session, "8006 events of stubble burning" were reported in Sangrur. Data from the "Punjab Remote Sensing Centre" indicated maximum cases of stubble burning in Sangrur district during the Kharif session since 2016.

Figure 4 indicated that as per data from Punjab Remote Sensing Centre, the overall area under paddy cultivation was 29.68 lakh hectares, 12.9 of which was brunt till 15 November 2021.The percentage of stubble burning area was around 71.52% in 2017,

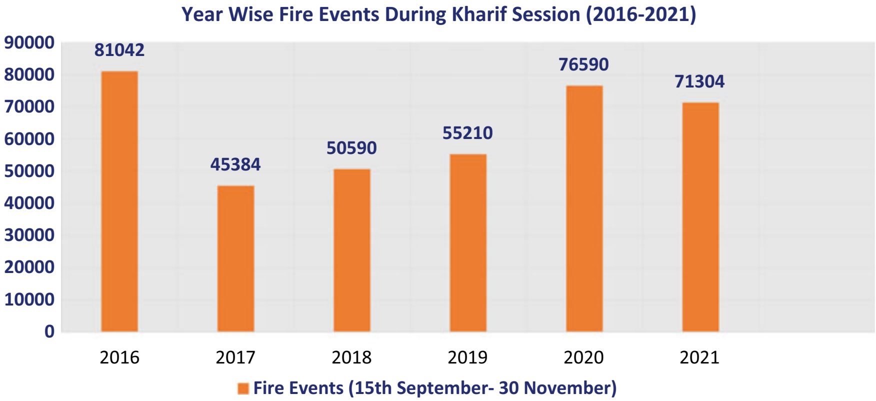

Fig. 2 Year-wise events of stubble burning during the Kharif session (15th September–30 November) since 2016. [6] *Source* Data compiled from Punjab Remote Sensing Centre during the Kharif session (https://gis-prsc.punjab.gov.in/residue/Index.aspx)

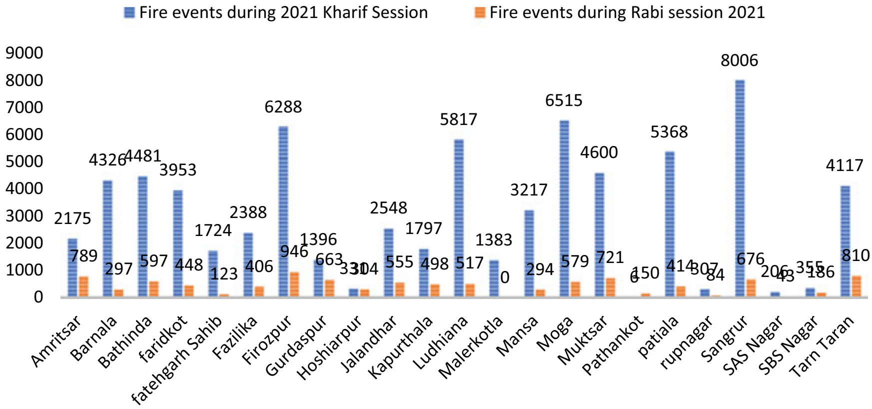

Fig. 3 District-wise fire events during Rabi and Kharif session in the year 2021. [6] *Source* Data compiled from Punjab Remote Sensing Centre District-wise Fire Events during 2021 (https://gis-prsc.punjab.gov.in/residue/Index.aspx)

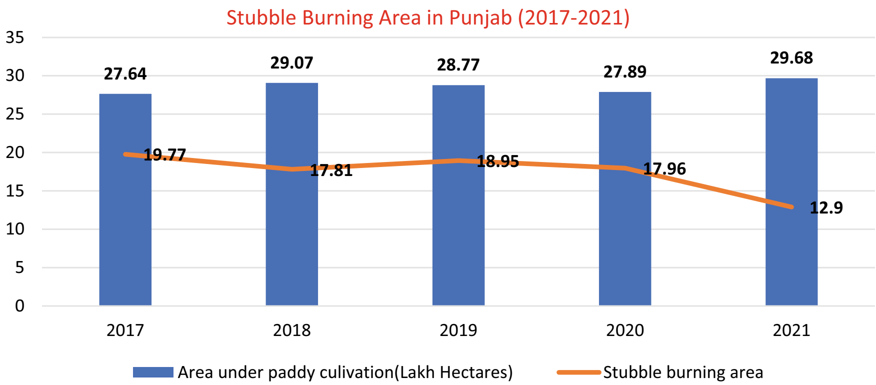

Fig. 4 Year-wise stubble burning area since 2017. [5] *Source* Data compiled from The Indian Express (2021, November 10) and Punjab Remote Sensing Centre

61.26% in 2018, 65.86% in 2019, 64.39% in 2020, and 43% in 2021. It revealed a decline in area under paddy burning but an increase in incidents of stubble burning.

6 Effects of Stubble Burning

Open field burning of crop residue has harmful effects on soil, the environment, and human and animal health.

6.1 Impact on Air Quality Index

Biomass burning is a significant cause of atmospheric pollution and a decline in the air quality index. It releases CO_2, CO, CH_4, N_2O, SO_2, and volatile organics components. An increase in aerosols and the emission of harmful gases contribute to the depletion of the ozone layer. Black carbon emission due to stubble burning leads to global warming. The emission of GHG from wheat crop residue is low compared to paddy crops in Punjab [16]. According to a study, the air quality index of the majority of cities in Punjab was poor during 2021year [17].

6.2 Impacts on Human Health

It releases harmful gases, and fine particulate matter present in the atmosphere leads to degradation in air quality that results in health issues for humans such as skin problems, respiratory diseases, asthma, cough, eye-related diseases, bronchitis, emphysema, cancer, and greater threats for leukaemia (https://www.news18.com/) [18, 19]. Carbon monoxide released during stubble burning reduces the ability of blood to absorb oxygen and causes respiratory problems. Carbon dioxide causes eye irritation, and sulphur dioxide and nitrogen oxides adversely affect the lungs, skin, blood, and respiratory functions, potentially leading to serious disorders such as cancer [20]. Fine particulate matter is the leading cause of premature deaths. Malwa region is regarded as the cancer capital of Punjab [14]. A study conducted by "The Energy Resources Institute" on 3000 persons in 6 villages of Punjab indicated that most people have lung-related diseases [21].

6.3 Impact on Soil Quality

Stubble burning adversely affects soil's physical, chemical, and biological properties. The heat generated by burning paddy residue raises the temperature, leading to the destruction of beneficial microflora and microfauna. It also causes loss of nitrogen, phosphate, potassium, etc. resulting in a decline in soil quality.

6.4 Impacts on the Environment

Residue burning generates particulate matter, that can float in the air for a long time and causes smog. Smog leads to low visibility, a significant cause of road accidents. The inhaling of particulate matter has harmful impacts on animals. It can cause temporary blindness, as well as chronic bronchitis. Stubble burning leads to the death of bacteria, earthworms, snakes, frogs, lizards, etc.

7 Crop Residue Management Strategies

- **In Situ Incorporation**
  In situ incorporation of stubble into the field is one of the best alternatives to stubble burning. Stubble incorporation and stubble mulching are two methods of in situ crop residue management. It is the practice of merging straw into the soil after harvesting manually or with the help of machines, which leads to increased levels of nitrogen and phosphate. It helps to improve soil's physical, chemical, and biological properties. It helps to increase beneficial bacteria and fungi in the soil. The soil's improved zinc, copper, and iron level increases land productivity [11]. "Stubble mulching" is the method of scattering residue on land's surface to prevent soil erosion.
- **Happy Seeder**
  A happy seeder is tractor mounted machine that cuts and removes the residue of a previous crop without burning and sowing a new crop. It is an eco-friendly method for increasing the fertility of the soil. It preserves the moisture of the soil, and it reduces the expenses of labour required to collect and sow the crop.
- **Biochar**
  Stubble can be converted into "biochar", which helps to increase land fertility and reduce environmental pollution. Biochar is utilized in a wide range of applications, including water treatment, construction, food, cosmetics, metallurgy, wastewater treatment, and a variety of other chemical applications [22]. Biochar is a type of charcoal made by burning organic materials such as rice straw with extremely low oxygen. Biochar has been discovered to boost soil fertility but not be an energy source [20].
- **Mushroom cultivation**
  Crop residues can be utilized in mushroom cultivation which reduces the burning of agro-waste. Compost is essential for mushroom growth. Paddy straw is a less expensive resource with a high lignocellulosic content that is widely preferred for mushroom production. The type of compost used for nourishment greatly influences the growth of these mushrooms [20].
- **Composting**
  It is a natural decomposition method of organic matter, such as animal waste, municipal waste, and crop residue by microorganisms under controlled conditions. Organic biomass naturally contains bacteria, fungus, and actinomycetes that aid in decomposition. This natural fertilizer enhances land productivity and improves soil's physio-chemical and biological properties.
- **Paper Production**
  Paddy and wheat straws in a 40:60 ratio can be used in manufacturing paper and pulp boards [23]. The residue from paper production could be used to generate

electricity by bio-methanization. This management strategy could be a viable alternative to deforestation.

7.1 Stubble as a Renewable Source of Energy

Crop stubble is a renewable source of energy. It can be used in the production of biopower and biofuel comprising biogas and bio-oil.

- **Bio-Thermal Power Plants**
  Paddy residue can be used as raw material to generate electricity in bio-thermal plants. Stubble residue can also be utilized to generate energy by extraction, methanation, or gasification. Punjab's first Biomass Power Limited is located in Ghanaur village of Patiala, producing power using paddy straw [24]. It contributes to addressing the problem of stubble burning and the generation of extra income for farmers by selling agriculture waste.
- **Biogas from Paddy Stubble**
  Agriculture waste can be utilized in the production of biogas. Paddy stubble is a significant source of lignocellulose, which is necessary to manufacture biogas. Crop residues are chopped into small chunks with the help of grinders before inserting with other materials for the generation of biogas [20]. Methane-rich biogas generated by an anaerobic process is a substantial source of renewable energy. Methane can be used as a substitute for petroleum-based fuels in the generation of electricity as well as fuel for automobiles that reduce the emission of greenhouse gas [25]. A compressed bio-gas plant established in Sangrur district can produce "33 tonnes of biogas per day" from paddy stubble [26].
- **Bio-oil Production**
  Crop stubble is a useful lignocellulose feedstock that can supply significant raw material for biofuel production. It prevents harmful emissions from stubble burning. A transition from fossil fuel energy to biofuel is economically and eco-friendly [27].
- **Generation of Hydrogen**
  New technology has been developed to generate hydrogen from agricultural residue. This technique produces a nutrient-rich compost that can be used as a fertilizer. This process utilizes a specially formulated microbial community to accelerate the biodegradation of agricultural leftovers. This procedure generates hydrogen as well as methane. It is one of the cost-effective methods that promote eco-friendly hydrogen fuel-cell electric vehicles (https://planet.outlookindia.com) [28].
- **Production of Bioethanol**
  Cereal grains are a viable source of bioethanol. Bioethanol is produced by a consolidated process that combines "enzyme production, saccharification, and fermentation in a single phase in a reactor". In this process, microorganisms produce their own saccharifying enzymes for the lignocellulosic breakdown reducing the processing cost of bioethanol [29].

8 Government Initiatives

The government has taken various initiatives to tackle the issue of stubble burning. There are many laws relating to stubble burning, such as "Environment Protection Act 1986", "Air (prevention and control of pollution) Act 1981", and "National Environment Appellate Authority Act 1997". The National Green Tribunal has implemented strict measures to prohibit crop residue burning in Punjab [24]. This tribunal directed the states to levy a fine of INR 2500–INR 5000 for stubble burning on land from 2 acres to more than 5 acres (https://www.news18.com/) [18]. Crop residue burning is banned under Section 144 of the "Code of Criminal Procedure" and "Section 188 of the Indian Penal Code".

Government has the authority to impose a penalty on farmers who violate laws. In 2021, 56.2 lakh environmental compensation was imposed [30]. National policy for crop residue management was adopted in 2014 to encourage in situ stubble management. To restore soil fertility, farmers are allocated funds for crop diversification programmes. The Punjab government distributes compensation of Rs 2500/acre to farmers to prevent stubble burning [31].

In collaboration with the centre, the Punjab government subsidizes farmers for purchasing technology needed for stubble management. According to data from the Punjab Agriculture department, the government provided a subsidy of Rs 241 crore in 2019–20 and Rs 261 crore in 2020–21 to farmers to purchase the machine. The government provides 50% of the total machine cost as a subsidy to individual farmers for purchasing machines [21].

9 Recommendations

Stubble should be used to produce renewable energy to restore air and soil quality. There should be the provision of collection of crop residue for making compost, bio-oil, and biochar to improve soil quality. In situ technical measures like "straw incorporation" and "straw mulching" should be encouraged. The use of advanced machinery like rotavators and happy seeders should be encouraged. Adequate subsidies should be provided to farmers to purchase machines. Crop diversification should be emphasized to maintain the fertility of the land. There should be a specific market to purchase crop residue from farmers. It recommends comprehensive awareness programmes to enlighten farmers about the harmful impacts of stubble burning. Social media and mass media platforms should generate awareness about various strategies. Kisan camps and workshops should encourage farmers to adopt alternate crop residue management. It recommends proper implementation of laws to prevent stubble burning. Governments should employ coercive and incentive measures to deter farmers from burning crop residue.

10 Conclusion

A huge amount of crop residue is produced every year in Punjab. Crop residue burning by the farmers to prepare fields for the next cultivation is the leading cause of environmental pollution. Some of the main reasons for stubble burning are the insufficient time between two successive crops, low awareness among farmers about stubble management, mechanical harvesters, scarcity of labour, and lack of financial resources to purchase required technology. It has harmful effects on the environment as well as human and animal health. It leads to various human health issues such as skin, respiratory, asthma, cough, eye-related diseases, bronchitis, emphysema, and cancer. Crop residue burning leads to a decline in air quality. It is responsible for the deterioration of land's physical and chemical properties due to the destruction of the beneficial bacteria and fungi in the soil. The findings revealed a decline in area under stubble burning since 2017, but there is a significant increase in stubble burning events in the year 2022 during the Rabi session despite various environmental legislation and crop residue management techniques. This study's main objective was to enlighten farmers on eco-friendly crop residue management techniques such as in situ incorporation, composting, happy seeder machines, and bioenergy use. It recommends a strong need for proper implementation of regulations to prevent environmental degradation in Punjab caused by crop residue burning.

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Chapter 29
Conceptual Study of Latest Trends Used in AI

Parveen Mehta and Shewta Bansal

Abstract Villagers need to access information for central government and state government schemes which are launched for benefit of villagers. Today is the world of computerization and every information is available in digital mode. Citizen can access all information at their location due to artificial intelligence. But still no digital tool available for villagers to get information to access benefit of central and government scheme. A lot of budget lapsed or used by on eligible citizen. In this review, paper in brief describes the artificial intelligent used for information. Brief discussion of chatbot working, AIML format, software used for creating a chatbot. In last, it describes the working of chatbot and reviews the research paper of chatbot.

Keywords Artificial intelligence · Machine learning · Deep learning · AIML · Chatbot · Etc

1 Introduction

A new revolutionist field of computer science which will become core component of all new generation software is artificial intelligence. This tool is a substitute for human intellect in the performance of confident tasks. Machine learning technique used instead of traditional method in AI development to understand the human activity with proper responses.

2 Objective for Choosing the Above Topic

India is a rural development country and 70% population are residing in villages, and most of the people are illiterate and nobody have the knowledge of technology. Government launches so many beneficiary schemes for the development of the village

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persons through Gram Panchayat. But due to lack of information and knowledge, they could not take the benefit of the schemes and benefits used by non-eligible persons. Need a software tool for accessing the information. Artificial intelligence tools are nowadays popular.

3 Background

After World War II, research in artificial intelligence starts [1]. In 1947, English Mathematician gives lecture to give direction to make program for machine. An American Computer Scientist Stanford's John McCarthy is recognized as the father of artificial intelligence. If a human not know how to solve the problem, then machine can be used to solved the problem by programming through searching, pattern recognition, learning planning and induction can be solved by heuristic programming of making computers solve really difficult problems [2]

3.1 Three Stage of Artificial Intelligence Is as Under

Artificial Narrow Intelligence (ANI):

This stage is the stage of smart devices. Examples of artificial narrow intelligence are smart phone, image detection kit, tongue detection kit, self-driving system, Google transform, spam pass through a filter, etc. (Fig. 1).

Artificial General Intelligence (AGI):

In this stage, machine becomes so intelligently trained based on historical as well as input data for getting better prediction.

Artificial Super Intelligence (ASI):

In this stage, machines will become self-aware and powerful to understand human behavior and emotion. This stage is imaginary and there will be no limitation

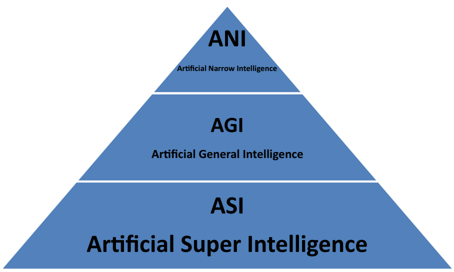


Fig. 1 Three stages of AI

of thinking. If the machine will reach this stage, it might be harmful to human civilization.

We are in a stage of artificial general intelligence which is a machine learning stage. (AI 2.0).

3.2 In 2020, Artificial Intelligence Classify in 4 Distinct Type

Reactive Machine (Fig. 2):

- This is simplest level of AI and performs basic operations.
- Not required learning and storage.
- This machine reacts to some input with some output.

Limited Memory:

To make better predictions, previous and new data are stored in the memory. Memory works in two ways:

1. It continuously trains a model on new data.
2. It automatically renewed and trained a model.

In this AI types, machine learning model should be structured.

Machine learning has six steps which are as under (Fig. 3):

Theory of Mind

We are beginning phase, for example, self-driven cars. AI begins to interact with the thoughts and emotions of humans.

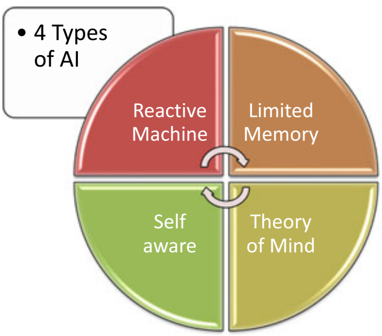


Fig. 2 Four types of AI

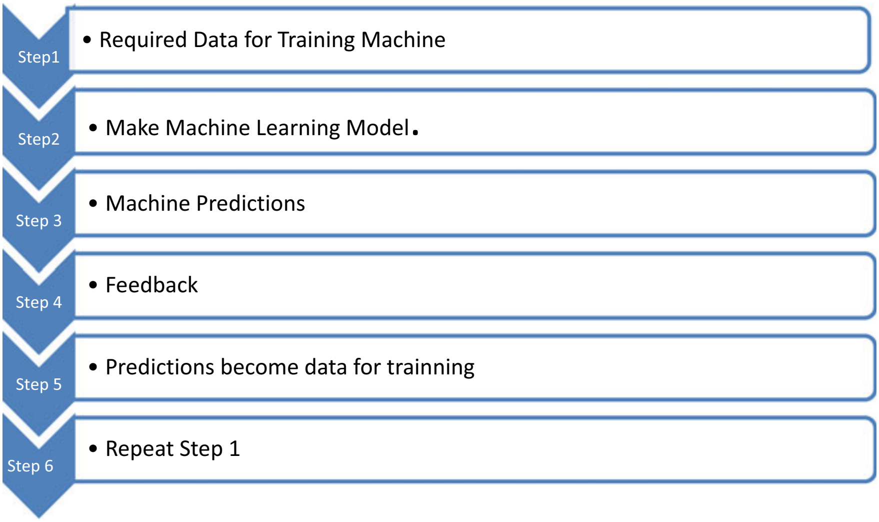


Fig. 3 Process of machine learning

Self-Aware: Future of AI. Perhaps machines become so intelligent that they can take decisions.

Application of Artificial Intelligence

Machine Learning	⟶	Deep Learning	⟶	Neural Network
Vision	⟶	Image and Pattern Recognition	⟶	Facial Recognition
Hearing	⟶	Voice and Speech Recognition		
Natural Language Processing	⟶	Natural Language Understanding(NLU)	⟶	Natural Language Generation
Robotics				
Sentiment Analysis				

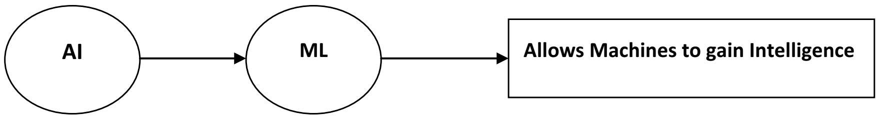


Fig. 4 Relationship between AI and ML

3.3 Relationship Between Artificial Intelligence, Machine Learning and Data Science Is as Under

Artificial Intelligence:- It is an engineering for making intelligent machine and programs.

Machine Learning:- It enables machines to learn without being explicitly programmed (Fig. 4).

Data Science:- Data Science helps in evaluating data for machine learning algorithms**.**

3.4 Machine Learning

Machine learning is a computer program which used historical data for trained the machine to get the best prediction. The various types of machine learning are as under:

- **Supervised machine learning**:- This learning algorithm required supervision. It mean that required "labeled" for trained the machine. Classification and regression are types of supervised learning. The process for identifying the object is called the supervise learning. For example, for identifying the object, image of CAT or DOG needs to undergo new process first store dataset which save the parameter of the image second after training the object asked from machine for prediction.
- **Unsupervised machine learning**:- No historical data is required to trained the machine, clustering and association is type of machine learning**.** These learning techniques are used to identify the hidden pattern**.**
- **Semi-supervised machine learning**:- In this learning both supervised and unsupervised learning technique. for ex is student performance analysis by instructor then it is supervised learning, if student self analysis his performance then it is unsupervised learning.
- **Reinforcement machine learning**:- In this learning, AI agent is automatically explored its surrounding by hitting and trail, taking action, learning from experiences and improving its performance. It is lie human learning process, which used Markov Decision Process (MDP).

3.5 Deep Learning

Deep learning is an algorithm whose function is like a human brain means neural network. Neural network is a human brain like interconnected node.

- **Image Recognition**:- An image into a digital format and performs some operations.
- **Speech Recognition**:- Human used voice to identify the new information from the smart devices.
- **Language Translation**:- Language tools, for example, Google translator used to translated any language to any other language for supporting human.
- **Product Analysis**:- Customer can easily analyze product online and take decision to purchase items. Company can analyze which product rating is best as compared to other company product.
- **A/B Testing**:- A/B testing compares two versions. It is determines the version of a web page that delivers a enhanced performance.
- **Sentiment Analysis**:- With help of this tool with using text, it is easy to identify customer attitude toward the product. It gives response as positive attitude, negative attitude or neutral attitude (Fig. 5).

4 Literature Review

AI way a computer can reflect [3]. The idea of AI was first recognized in 1956. Officially, AI is measured to be an rising interdisciplinary subject involving theory, methodology, technology and system applications that integrates cybernetics, informatics, computer science, mathematical logic, neurophysiology and other disciplines and is used to simulate, extend and stretch human intelligence [4, 5] within a artificial intelligence (AI), and machine learning has emerged as the method of choice for embryonic practical software for computer vision, speech recognition, natural

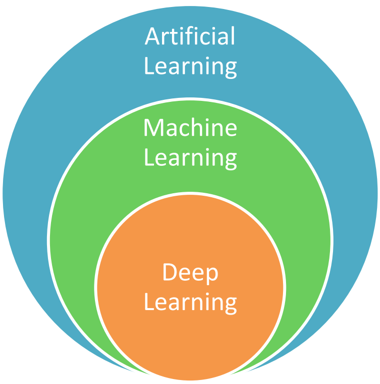


Fig. 5 Relationship b/w AI, ML and DL

language processing, robot control and other applications [6]. Machine learning (ML) is a process which on historical new data trained the machine to get the better result [7]. To improve results and optimize the prediction process, used deep learning which is like human brain model. Natural language processing is a deep learning methods used for image caption generation and handwriting generation [8]. “Natural language processing (NLP) refers to computer systems that analyze, attempt to understand or produce one or more human languages, such as English, Japanese, Italian or Russian. The input might be text, spoken language or keyboard input” [9].

4.1 Architecture of an NLP

Chatbots work as virtual assistants between user and system [10]. Chatbots development start from pattern matching and simple “Q&A” approach to a more human-like approach of delivery result and progressing conversations that highly developed chatbots are ordinary to not only answer questions but also learn and get better themselves with each exchange, and in the end be able to respond properly in various context [11]. Pattern matching (AIML), rule-based and machine learning (NLP) approach used for improvement of chatbot [12] Not any installation packages used to use a chatbot and it is fast with less confusing web and mobile applications. These packages are easy to manage and distribute. “No programming Chatbots (simple easy to code), Conversation-Oriented Chatbots (AIML) and Platforms by tech giants’ Chatbots (Tech giants such as Google develop Api.ai, Facebook develops Wit.ai, Microsoft develops LUIS, Amazon develops Lex and IBM develops Watson)” [13]. Chatbots are more effective than human when need to connect aboard audience. Table 1 summarizes the various chatbot (Fig. 6).

AIML Format:

```
<aiml version= “1.0” >
<topic name=“the topic”>
<Category>
<Pattern>AABBCC</Pattern>
<template>temp</template>
</Catgeory>
</topic>
</aiml>
```

Table 1 Various chatbot

Sr. No.	Chatbot	Year	Description
1	ELIZA	1966	* First chatbot * It checks only for pronouns and verbs * 'we' becomes 'I' and 'I' becomes 'we'
2	Parry	1972	* Virtual a paranoid schizophrenic
3	RActer	1984	It generates English language writing style at random
4	ALICE	1994	* It is artificial linguistic Internet computer entity * It used the artificial intelligence markup language (AIML) to pattern matching * Three times winner of Loebner prize
5	XiaoIce	2014	* It is available in three countries Japan, Indonesia and China * This chatbot established an emotional connection with the human which satisfying need for message, friendliness and social belonging
6	Apple Siri,	2010	* It is virtual assistant associated with Apple IOS * It uses tone of voice queries, gesticulation-based control, focus tracking and natural language user interface
7	Amazon Alexa	2013	Based on technology, a polish speech synthesizer named Ivona
8	Google Assistant	2016	Two conversation is allowed in the Google assistant s
9	Microsoft Cortana	2019	Developed by Microsoft as Bing Search Engine for reminder setting and Question Asking

Fig. 6 NLP process

4.2 Architecture and Work Methods of Chatbot

Chatbot also has an app layer like other normal application.

- A database
- API

Chatbot Trainer:- Trained the chatbot too much faster as compared to the human being.

Chatbot works on 3 classification method

1. Pattern matches
2. Natural language understanding
3. Natural language processing.

Pattern Matches:- Pattern matches used artificial intelligence markup language. Chatbots operate the pattern matches to textual group and it produces an suitable result.

For example.

```
<aiml version="2.0" encoding="UTF-8">
<category>
<pattern> Who is father of AI? < /pattern>
<template>John Mcgrath</template>
</category>
```

Output
Human: Who is father of AI?
Robot: John Mcgrath.

For question for search, a considerable pattern must be available in the database to give a realistic answer.

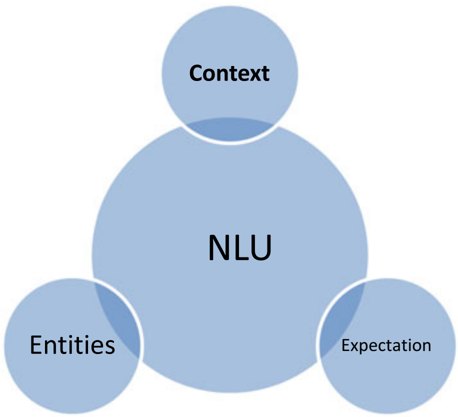
4.3 Natural Language Understanding

Entities:- An idea to your chatbot, for example, e-payment system.

Context:- It means that the machine has not its own data in its memory. Whenever the user puts his query, the machine gives an answer to a specific question because the machine has no previously recalled memory. All the conversations of the users are separately stored.

***Expectation*:-** The purpose of the chatbot fulfills when the user sends an enquiry and the same is different from the other enquiries (Fig. 7).

Fig. 7 Structure of NLU



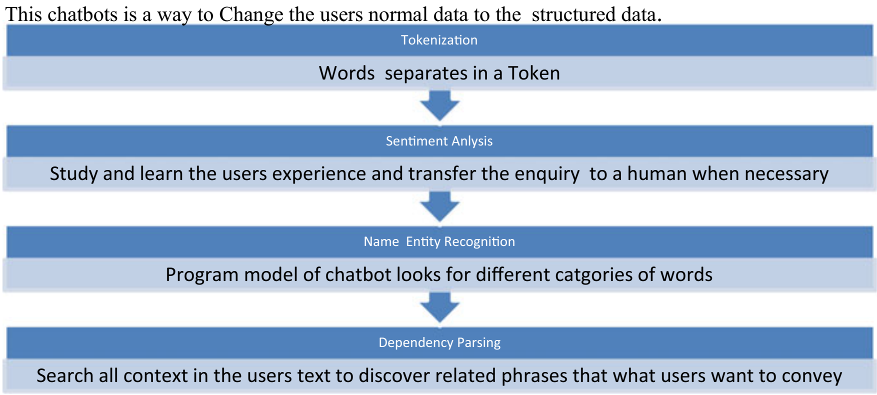


Fig. 8 Step of NLP processing

4.4 *Natural Language Processing*

This chatbots are a way to change the users normal data to the structured data (Fig. 8).

5 Artificial Intelligence and Machine Learning in Renewable Energy

Renewable Energy:- Renewable energy means that energy we get from the environment natural. Environment structure is very complex. Future of humanity depends on the renewable source. So safety of this renewable source required better prediction.

Two types of renewal energy source used.

1. Conventional energy source, for example, fossil fuels, coal, oil and natural gas, timber, etc.
2. Non-conventional energy sources:- Solar energy, wing energy and water energy.

Non-conventional energy source solar, water and wind are directly related to Sun, and geothermal energy is not related to sun.

Artificial intelligence is a predictable-based technology. Machine learning, neural network and deep learning are the subset of AI. Renewable energy is first and foremost dependent on the sun, airflow and water. All these resource are association with weather conditions human cannot manage for the sake of future need to control used of these natural energy sources.

Forecasting: With the help of machine learning on the historical data and current data prediction forecast, power company used AI for forecasting the weather condition.

Grid Management:- AI and machine learning use data analytics to forecast energy utilization in households. The forecast take on the previous year data and specific part of data. It helps to take decision how much energy required for future.

Maintenance:- Power company helps to check which part is damaged or required to maintain.

6 Conclusion and Future Scope

After the re-evaluate of various study paper, I am of the opinion that the chatbot is forthcoming for users and it can be used by all persons who uses mobile phone or computer. Even the users can use them in their own language, in various mobile apps. A GP chatbot responds on the basis of query, which is available upon in its database. The implementation of GP Query System significantly relies on AI algorithms as well as the training data. The implementation of GP Query System further builds awareness of the persons in respect of the government welfare schemes. Moreover, geographical location is not required for using the chatbot. Any person can be used the same any location or area. The only requirement for it is only a simple desktop or smart phone along with Internet connection. The effectiveness of it can be enhanced by accumulating more number of words and escalating the users data store so that of the GP chatbot possibly responds to the all type of question. For making easier, voice conversation can be added in the system. The chatbot is also useful for the renewable energy department to get the information and survey report.

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Chapter 30
Adaptive Clustering—An Optimal Solution to Hotspot Issue in Wireless Sensor Networks

Ab. Wahid Bhat and Abhiruchi Passi

Abstract In wireless sensor networks, maximization of lifetime is an important task. Load balancing with clustering is an energy efficient approach for prolonging the network lifetime. Clustering improves the energy efficiency of the network to a greater extend, but it gives rise to the energy hole or hotspot problem in wireless sensor networks. Hotspot problem is characterized by creation of an energy hole or network deadlock near to the base station. In multi-hop clustering with uniform or fixed cluster size, the cluster heads (CH's) close to the base station gets depleted of energy much quicker than those which are at an appreciable distance, due to the increased load from data forwarding. An alternate approach to mitigate such problem is to employee adaptive or unequal clustering that involves formation of clusters with variable size. The cluster size is a function of multiple factors like remaining energy of sensor node, distance from the base station and location of the node. In adaptive clustering, the cluster size keeps decreasing while moving towards the base station in order to reduce the number of neighbors and increase the number of available cluster heads near to the base station to share the network traffic. The paper provides a detailed literature on various aspects of adaptive clustering. A comparative analysis based on taxonomy of adaptive clustering protocols is carried. The analysis indicates that adaptive clustering improves not only the energy efficiency but also the stability of the network along with other quality of service parameters.

Keywords Wireless sensor networks · Lifetime maximization · Load balancing · Clustering · Hotspot issue · Adaptive clustering

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1 Introduction

Wireless sensor networks are characterized by a limited supply of energy mostly provided by an onboard battery. The replacement of the battery in a sensor node is almost impossible because of there deployment in inaccessible areas. Therefore, measures need to be taken in order to increase the energy efficiency of these networks to enhance their lifetime. Load balancing is one among the various solutions of energy optimization in wireless sensor networks. Load balancing involves uniform distribution of traffic across the network. Single-hop or direct transmission of information to the base station by sensor nodes leads to increase in both the network traffic as well as transmission distance. In either of the cases, the energy consumption is increased leading to premature or early death of the network. Multi-hop communication can decrease the transmission distance but not the network traffic. The network traffic can be reduced by employing clustering technique that involves grouping of sensor nodes with each having a coordinator and several members. The member nodes (MN) are mainly responsible for the sensing of information from the area of interest, while as the coordinator or leader known as cluster head (CH) perform the tasks of data collection, aggregation and transmission of data to the base station. Therefore, a miscegenation of clustering and multi-hop communication is an attractive solution to achieve energy efficiency in wireless sensor networks. However, clustering comprising clusters having uniform or fixed size give rise to a problem known as hotspot or energy hole problem [1] (as shown in Fig. 1), in which the cluster heads closer to the base station suffer from energy exhaustion in comparison with the other cluster heads or member nodes due to increased responsibility of data forwarding from other cluster heads, resulting in the failure of the network.

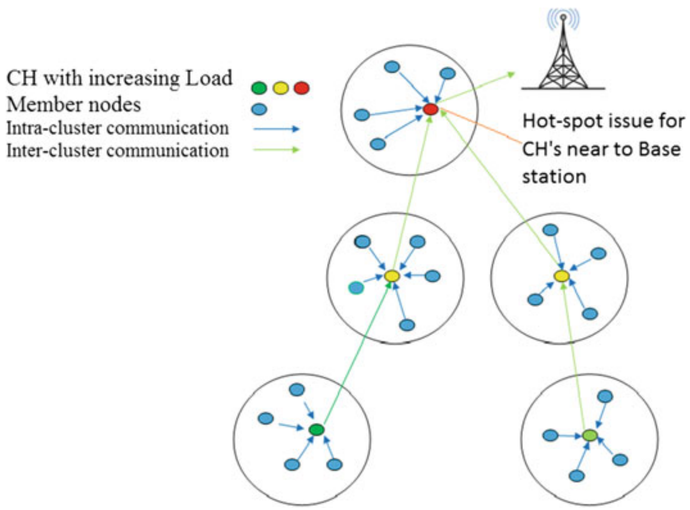

Fig. 1 Hotspot or energy hole problem in WSN

An alternative approach to mitigate such problems is to employee adaptive or unequal clustering. It involves formation of clusters with variable size. In adaptive clustering, the cluster size keeps decreasing while moving toward the base station in order to reduce the number of neighbors and increase the number of available cluster heads near to the base station to share the network traffic [1].

2 Adaptive Clustering

Adaptive or unequal clustering is an energy efficient technique to address the hotspot and other non-uniform traffic distribution problems in wireless sensor networks. In adaptive clustering as shown in Fig. 2, the cluster size decreases as we move toward the base station and vice versa.

Similar to uniform clustering, first step in adaptive clustering is the selection of an optimal cluster head followed by cluster formation. After the selection of cluster head, relative variation in size of the cluster is a function of multiple overlapping factors, some of which are discussed below;

2.1 Distance to the Base Station

Data aggregation and forwarding is one of the important tasks of cluster heads. In multi-hop cluster-based communication, cluster heads distant from the base station,

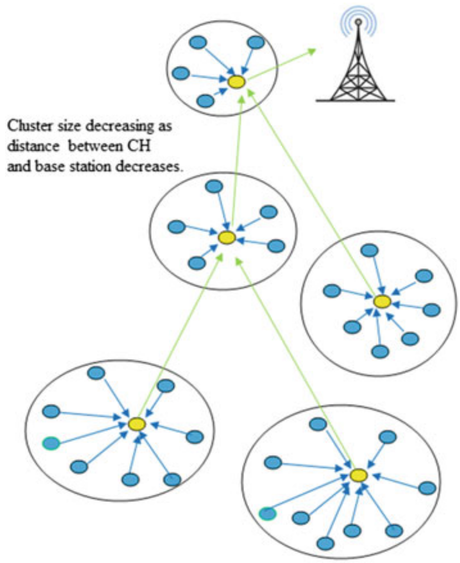

Fig. 2 Adaptive clustering

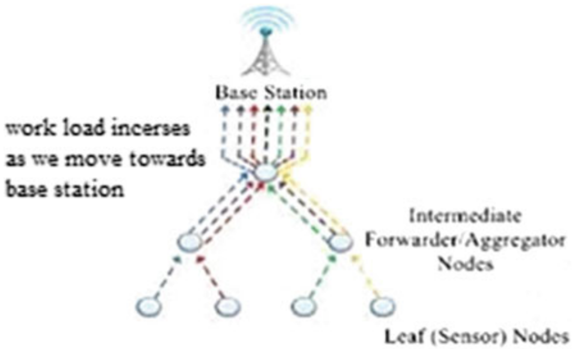

Fig. 3 Increase in traffic on approaching base station [2]

forward their data to the cluster head which is closer to the base station. As a result, the workload on the cluster heads increases as we move toward the base station. Therefore, in order to avoid the premature death of cluster head, the size of the cluster be decreased, to reduce the intra-cluster communication cost (Fig. 3).

2.2 Residual Energy of the Sensor Node

The remaining energy of a sensor node is also known as residual energy. In homogenous wireless sensor networks, all the constituent sensor nodes have equal energy, which goes on decreasing with each round depending on the workload on a particular sensor node. Higher is the residual energy of a cluster head, greater will be the cluster size. Residual energy has more pronounced effect on selection of cluster head rather than on cluster size.

2.3 Neighbor Cost

Neighbor cost refers to the intra-cluster communication cost. For energy efficient transmission, the distance between the cluster head and the member nodes should be minimum, as the energy dissipated in data transmission is directly proportional to the square of the distance between the transmitter and receiver [1]. Therefore, cluster size also varies with the spatial distribution of the member nodes in the cluster.

2.4 Node Centrality

The average distance between cluster head and the member nodes determines the centrality of the cluster head. For energy efficiency, cluster head should be centrally located within the cluster.

2.5 Node Density

Node density refers to the number of nodes in the close vicinity or within a particular area, of a cluster head. Higher the node density, greater will be the reception and aggregation cost on the cluster head. Therefore, decreasing the cluster size results in both the reduction of intra-cluster communication cost as well as the data aggregation cost due to increase in the number of cluster heads near to the base station.

3 Approaches to Adaptive Clustering

There are several ways to organize a network into clusters of variable size, some of which are discussed below.

3.1 Probabilistic Approach

In probabilistic algorithm, the cluster head is selected randomly based on probability similar to that of LEACH protocol. Probabilistic algorithms can be random or hybrid in nature [1]. Random approaches involve random selection of cluster head with minimum overhead and complexity. Examples include LUCA and PRODUCE.

Hybrid approaches are similar to random with inclusion of parameters like distance to base station, remaining energy, RSSI or node density for optimal selection of cluster heads and variation of cluster size across the network. Examples include EEUC and EEDUC.

3.2 Deterministic Approach

In deterministic approaches, the selection of cluster head and cluster size is a function of several network parameters like residual energy of node, distance to based station, inter- and intra-cluster communication costs, number of neighbors, etc. Although deterministic approaches are complex in nature, they provide an optimal solution to cluster head selection in wireless sensor networks. Deterministic approaches may involve constituting a cost function based on above parameters or fuzzy-based approach may be used. Fuzzy-based approach can provide more optimal solution as it combines multiple factors efficiently. Examples include EADUC, DUCF and E-FUCA.

Optimization approaches can also be used for selection cluster head and relay node, cluster formation as well as for energy efficient data transmission. Optimization approaches can be of heuristic or meta-heuristic in nature [3] that includes genetic algorithm, approximation algorithm and swarm intelligence-based algorithms. Hybrid deterministic algorithms are a combination of both fuzzy-based and optimization-based approaches. Examples include EBUC, IFUC and FUCHAR.

4 Comparative Analysis of Various Adaptive Clustering Algorithms

A detailed analysis of various adaptive/unequal clustering protocols is carried out and the summary is mentioned in Table 1. The algorithms are categorized based on approach and nature of selection of cluster head.

Table 1 Comparative analysis of various adaptive clustering algorithms

Algorithm	Approach	Nature	Selection		Data routing	Objective
			Cluster head	Cluster size		
PRODUCE [5]	Probabilistic	Random	Completely probability based	D_BS (function of average one-hop distance)	Multi-hop routing based on stochastic geometry	Hotspot problem to improve network coverage time* and lifetime. Cluster heads close to base station focus more on data forwarding and farther one's on data gathering
LUCA [6]	Probabilistic	Random	Random back-off time	Network density and D_BS	Geographical routing with minimum hop count to sink. Nodes are equipped with GPS-like device	Hotspot problem; Increasing energy efficiency to prolong network lifetime

(continued)

Table 1 (continued)

Algorithm	Approach	Nature	Selection		Data routing	Objective
			Cluster head	Cluster size		
EEUC [7]	Probabilistic	Hybrid	Probability and RE	D_BS	Multi-hop routing with selection of relay nodes based on RE and its distance relative to base station	Load balancing among cluster heads and prolonging network lifetime
EEDUC [8]	Probabilistic	Hybrid	Waiting time, which is a function of only ND at initialization and RE and ND for re-clustering	RE, D_BS and ND	Multi-hop routing with adjacent cluster head as relay node	Uniform distribution of cluster heads, hotspot problem and network lifetime
EADUC [9]	Deterministic	Fitness function	Waiting time based on ratio of average RE of neighbor nodes and the competing node	RE and D_BS	Multi-hop routing with relay nodes with highest residual energy and smallest relay energy that is a factor of hop distance and D_BS	Heterogeneous networks; energy hole problem and improves coverage
EAUCF [10]	Deterministic	Fuzzy Based	Probabilistic selection	RE AND D_BS	Multi-hop routing	Hotspot problem by managing the competition radius of the cluster heads
DUCF [11]	Deterministic	Fuzzy Based	RE, ND and D_BS	RE, ND and D_BS	Multi-hop inter-cluster routing with spread codes to avoid interference between transmitted data	Load balancing and lifetime with proper selection of CH and cluster size

(continued)

Table 1 (continued)

Algorithm	Approach	Nature	Selection		Data routing	Objective
			Cluster head	Cluster size		
E-FUCA [12]	Deterministic	Fuzzy based	RE, Average distance to CH and D_BS	RE, Average distance to CH and D_BS	Fuzzy-based routing to determine optimal relay node	Hotspot problem; extending lifetime by energy efficient clustering and routing
EBUC [13]	Deterministic	Optimization based	Particle swarm optimization (PSO) based with lower bound on energy to qualify as CH	PSO based on Euclidean distance from BS to CH and BS to NC	Multi-hop routing with RE, distance between the relay node and BS and distance been the CH and relay node	Hotspot problem; to select optimum cluster head and relay node for inter-cluster communication
IFUC [14]	Deterministic	Hybrid	RE, D_BS and ND	RE, D_BS and ND	Ant colony optimization (ACO) for inter-cluster routing	Energy efficiency and network lifetime
FUCHAR [15]	Deterministic	Hybrid	RE, ND, D_BS, Neighbor distance and node centrality	RE, ND, D_BS, Neighbor distance and node centrality	ACO for energy efficient routing	To enhance energy efficiency and network lifetime by employing hybrid data transmission

BS is Base Station CH is Cluster Head
D_BS is Distance to base station MN is Member nodes
RE is Residual energy NC is Network center
ND is Node degree or number of neighboring nodes *Time until first cluster head die down

5 Performance Evaluation Parameters of Adaptive Clustering

As sensor nodes are highly energy constrained, performance of any proposed algorithm can be accessed in terms of the energy efficiency and lifetime of the network. Following are the few parameters that are considered while evaluation of an algorithm [1, 4]:

i. Energy consumed during clustering or network setup.
ii. Energy consumed in each round.
iii. Total remaining energy.

iv. Energy consumed by cluster heads and member nodes.
v. Number of alive nodes verses number of rounds.
vi. Stability period measured in terms of time until first nodes dies in the network (FND).
vii. Time until half nodes death (HND).

6 Conclusion

Clustering reduces the energy consumption of the network in comparison to the direct communication, but with multi-hop inter-cluster communication, it gives rise to the hotspot or energy hole problem. Therefore, in order to balance the energy consumption across the network, optimal selection of cluster head and selection of proper cluster size is necessary. The cluster size should be varied in order to reduce the intra-cluster communication burden on the cluster heads close to the base station. The cluster heads close to base station should mainly focus on the data forwarding from other cluster head nodes. However, multiple factors should be considered for both selection of cluster head and determining the cluster size. After going through the simulation results of above algorithms, it is concluded that deterministic algorithms perform better than probabilistic in terms of above parameters. In addition, algorithm performs better with the increase in the number of input parameters in case of fuzzy-based approach. More research needs to done on hybrid approach based on fuzzy logic and swarm intelligence.

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Chapter 31
Proton Exchange Membrane Fuel Cell Power Generation and Loss Analysis

Gökhan Dündar and Özcan Atlam

Abstract A broader view on power and loss relationship of proton exchange membrane fuel cell (PEMFC) to identify the inefficient parameters is presented in this paper. For this purpose, first electrical equivalent circuit of fuel cell is given. Critical operating points and their specifications are discussed. Afterward, the power sharing analogy is presented. Key points and important remarks are explained. Finally, power sharing and loss analogy are evaluated together with the I–V characteristics of the fuel cell. The research shows that a preliminary analysis must be conducted in order to spot the areas where improvements can be performed. The methodology explained in this study can be easily applied to fuel cell systems in order to increase the system efficiency.

Keywords Proton exchange membrane fuel cell · Electrical equivalent circuit · Efficiency · Hydrogen

Abbreviations

E	Energy
F	Faraday's constant, 96,487 C s^{-1}
G	Gibbs free energy, *J*
i	General current term which flows at V_i voltage line, *A*
I	Load current, *A*
I_c	Critical current value where ohmic polarization region starts
I_n	Critical voltage value where ohmic polarization region ends
I_s	Current due to internal leakage
I_{sc}	Short-circuit current, *A*
I_{tot}	Total produced current by FC, *A*
P	Power, *W*

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Q	Volumetric flow rate
Q_{leak}	H_2 Leakage rate
Q_{load}	H_2 Consumption rate due to electrical load
Q_{tot}	Total H_2 consumption rate
R_s	Inner series resistance, ohms
R_p	Inner parallel resistance, ohms
V	System voltage, V
V_{c}	Critical voltage value where ohmic polarization region starts
V_i	Ideal voltage, V
V_n	Voltage value where ohmic polarization region ends
V_{OC}	Open-circuit voltage, V
υ_{mol}	Molar volume

1 Introduction

Energy need of modern world is increasing day by day. Limited life of fossil fuels, increasing environmental awareness and need for energy security lead countries introducing more renewable energy on their portfolio. Low environmental footprint, no fuel costs, low maintenance costs and abundancy make renewables a favorite option. However, you cannot turn them on and off according to you needs. Thus, a backup or storage system is required for deeper market penetration. One method to overcome this problem is producing hydrogen and producing electricity when needed by fuel cells (FCs).

Fuel cells are electrochemical devices that generate electricity by combining two electrochemically diverse elements. The first observations of FC behavior were performed in 1838 by Christian F. Shoenbein [1], followed by Grove inventing the FC in 2839 [2]. However, the first implementation could be conducted 100 years later by Francis T. Bacon. There are numerous FCs which have use different fuels and have different operating temperature and electrolytes [3, 4]. The most common type of FCs is polymer electrolyte membrane (proton exchange membrane). Its low operating temperatures, low or no maintenance requirements and simple structure make proton exchange membrane fuel cell (PEMFC) an optimal solution for daily and specialized use [5]. Space shuttles, cars, submarines, boats and backup systems are some examples of PEMFC applications. Because of their simplicity and the wide range or fields where they are used, PEMFCs are studied by many scholars from distinctive backgrounds. Most of the recent articles focus on increasing the PEMFC efficiency. In order to increase the efficiency, one should know the working principles, operating and performance parameters. In this paper, PEM is considered as a DC power source and is electrically evaluated. In cases where analytical analysis of a system is impossible or hard to perform, then equivalent electrical circuit (EEC) of the system is derived based on empirical data [6]. There are numerous studies in the literature based on electrical equivalent circuit derivation of FCs [7–15]. Due to the difficulties of sensitive hydrogen consumption measurements, nonlinear electrical characteristics of PEMFC and dependency on the operating conditions, EEC modeling appears to be the best method to easily model the PEMFC characteristics. A brief literature survey and background are presented in Sect. 1. PEMFC characteristics are explained in Sect. 2. A unique equivalent electrical circuit of PEMFC based on our previous research and power/loss analogy are explained in Sect. 3. Finally, the results of the proposed analogy are discussed and new research areas stemming from this research is proposed in Sect. 4.

2 PEMFC Characteristics

PEMFCs are electrochemical energy converters that convert chemical energy to directly electricity. Generated electricity is in direct current. It shows nonlinear electrical characteristics in its operating range. Starting from an open-circuit voltage, V_0, it drops logarithmically to a critical operating point where the characteristics show linear features, V_c–I_c. This first zone is called activation polarization region. After this critical point, voltage drops linearly until another critical point, V_n–I_n. This region is called ohmic polarization region. Most of the PEMFCs are designed to operate in this region since this region is where the most electrical work can be achieved. Finally, in the concentration polarization region, voltage drops exponentially until zero where the system is short-circuited. This last region is generally electrically unstable and thus cannot be used for normal operating conditions as a power source. A typical example of working regions and critical points is given in Fig. 1.

The main characteristics of FCs' electrical behavior have been well known for a long time, but there are not many studies on the losses based on the working principles. Some studies discuss losses in a broader perspective [16–18]. However, most of the studies focus mainly on increasing the reaction surface area or heat losses. These studies lack of causality. However, the analogy presented in this paper aims to bring a holistic analysis approach to identify the losses so that each FC can be analyzed individually and solutions can be created on case-by-case basis.

3 Electrical Equivalent Circuit Model and FC Power and Loss Analogy

In order to create the analogy, we first derived an EEC to better analyze the FC operating parameters. Test FCs were connected to a varying load. Voltage and current values were measured and recorded while load is changed between an open voltage and short-circuit condition. Details of the method and study can be found in [19]. After analyzing three different PEMFCs, we created a unique EEC which is presented

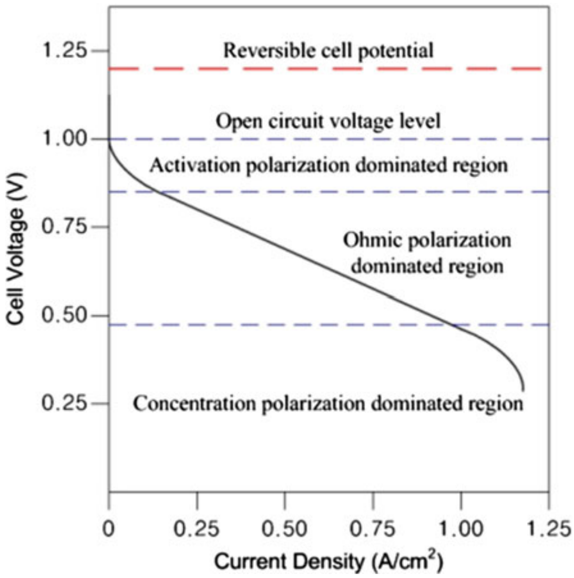

Fig. 1 Polarization curves of FCs [16]

in Fig. 2. V_i represents the ideal cell voltage, V_{oc} represents open-circuit voltage, I_s means current caused by leakages, R_s means internal series resistance and R_p means internal resistance in parallel.

The EEC model in Fig. 2 is based on the following expressions linked to mass–energy and hydrogen consumption rate–power relations in the electrochemical energy conversion process [19].

H_2 consumption rate, Q_{H_2}, due to any current, *i*, is defined by Eq. (1).

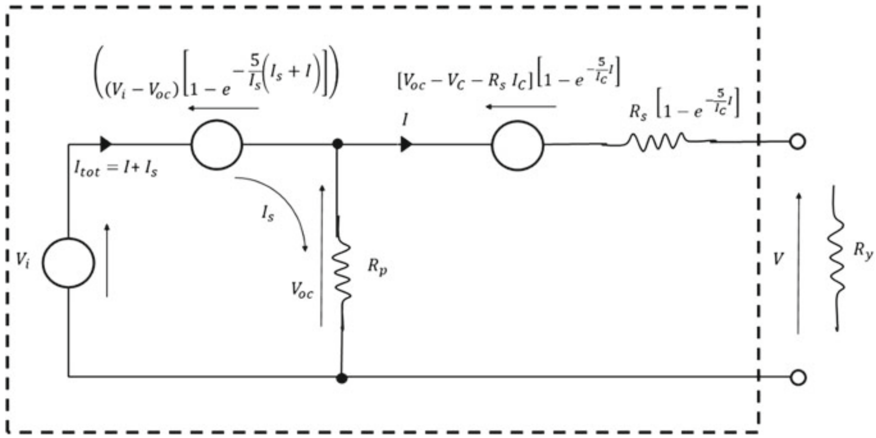

Fig. 2 Practical equivalent electrical circuit of PEMFC [19]

$$Q_{H_2} = \frac{\upsilon_{H_2}}{t} = \frac{\upsilon_{\text{mol}}}{2F} i \tag{1}$$

Change in the Gibbs free energy, ΔG, is defined as the available work which can be extracted from a system. Ideal voltage can be defined by using Gibbs free energy and is stated in Eq. (2).

$$V_i = \frac{\Delta G}{2F} \tag{2}$$

As general expression, electrical power P_{H_2} corresponding to H_2 consumption rate is given as follows:

$$P_{H_2} = \frac{E_{H_2}}{t} = \frac{\Delta G}{\upsilon_{\text{mol}}} \upsilon_{H_2} \frac{1}{t} = Q_{H_2} \frac{\Delta G}{\upsilon_{\text{mol}}} = \left(\frac{\upsilon_{\text{mol}}}{2F} i \right) \frac{2F V_i}{\upsilon_{\text{mol}}} = V_i i \tag{3}$$

By using Eqs. (1–3) and the relation between H_2 consumption rate, Q_{H_2}, and power P_{H_2}, the following flow rate balance in a system can be defined:

$$Q_{H_2(\text{leak})} = Q_{H_2(\text{tot})} - Q_{H_2(\text{load})} \tag{4}$$

$$\begin{aligned} & P_{H_2(\text{leak})} \frac{\Delta G}{\upsilon_{\text{mol}}} = P_{H_2(\text{tot})} \frac{\Delta G}{\upsilon_{\text{mol}}} - P_{H_2(\text{load})} \frac{\Delta G}{\upsilon_{\text{mol}}} \\ & \Rightarrow P_{H_2(\text{leak})} = P_{H_2(\text{tot})} - P_{H_2(\text{load})} = V_i I_{\text{tot}} - V_i I = V_i I_s \end{aligned} \tag{5}$$

Ideal V_i voltage decreases to VOC due to intrasystem H_2 leaks, and when load current I is drawn from the terminal, the voltage drops to V as a result of internal voltage drops (activation polarization, ohmic polarization and concentration polarization) in the I–V characteristic curve. More detailed explanations can be found in [19]. Therefore, overall system efficiency can be defined by Eq. (6).

$$\eta_{\text{sys}} \Rightarrow \frac{P}{P_{H_2(\text{tot})}} = \frac{V I}{V_i I_{\text{tot}}} \tag{6}$$

It can be seen from Fig. 2 that all the critical values are represented by circuit components in the EEC. After deriving the mathematical equations and depicting the EEC, we combined these research outcomes in Fig. 3 in order to create a bridge between theory and practice.

In Fig. 3 on the left side, an overview of I–V characteristics and critical points is presented. Power generation and losses corresponding the points in the I–V characteristics curve are identified on the right side. Region under a given point in an I–V curve gives us power/loss. This can be achieved by simply multiplying the corresponding I and V values for a given point. The figure on the right is a linearized visual demonstration of a nonlinear graph in terms of power. Power generation and losses can easily be identified and focus can be cast afterward for a given region. The

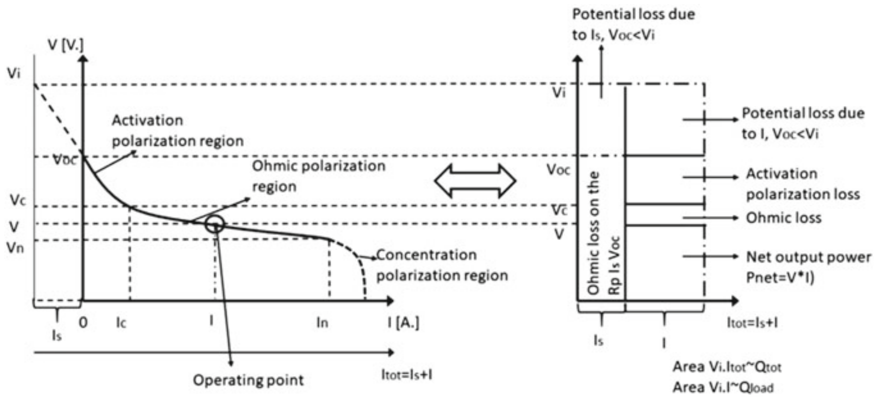

Fig. 3 Power generation and loss analogy [19]

bigger the region, the higher the value, either power generation or losses. After initial analysis, scholars from any background can concentrate their researches accordingly.

It would be beneficial for the academicians to elaborate the data given in Fig. 3. V_i is the ideal reversible voltage but cannot be achieved due to many reasons such as thermal, mechanical and electrical losses. Thus, voltage drops to V_{oc} where we can measure directly from the FC. On the right side, this drop can be observed as potential power loss. For the same region, one can see Is, less than 0. This cannot be achieved since current cannot be a negative value. However, this demonstration implies that there is an internal loss which is caused by leak current, Is. If there were no internal leaks, then Is would be 0, which means an ideal FC. Due to the manufacturing processes and chemical properties of the membrane, there is an inevitable difference between ideal voltage and open-circuit voltage. Depending on the fuel cell, mostly this area is where the highest power loss is observed. If the values are compared with the values of Fig. 2, then role of *Rp*, parallel resistance, representing internal leakages, would be clearly understood. By decreasing losses, which also means increasing membrane efficiency, FC efficiency can be increased.

If we further evaluate the power and loss analogy figures, we can see that activation, ohmic and concentration polarization losses are relatively small compared to the losses caused by non-ideal conditions. Although, one must not forget that numeric data for each FC to be evaluated should be obtained before a design optimization of that particular FC is performed. Another important loss region is defined as the losses caused by operating current in case where V_{oc} is less than V_i. This loss is also caused by non-ideal conditions but is slightly different from the situation explained before. In this case, internal leakages have no effects on this power loss.

4 Discussion and Conclusion

I–V characteristics' curve is the main dataset for an electrical device. Thus, one must derive the I–V curve for a FC in order to examine and analyze that system thoroughly. In order to increase the efficiency of any system, the biggest share for losses should be identified. Afterward, efforts must be concentrated on this particular area. Each academic discipline naturally tries to improve their own interest areas. However, this approach is also controversial with the intention of the research. First, greater losses should be targeted; then, minor improvements can be implemented. In order to spot the higher losses, a wider analysis should be performed.

We tried to bring a new perspective to FC operating characteristics in this paper. Even though there are numerous studies on analyzing or increasing fuel cell efficiency, there are not many studies which show a holistic approach. To our best knowledge, there is not any research article specifically based on this topic. We hope that our motivation put forward in this paper to increase the research and optimization efficiency will eventually lead to increasing component efficiency which in turn will lead to increasing fuel cell efficiency.

End of fossil fuel era is approaching, and sustainable solutions should be found soon. We strongly believe that hydrogen is a perfect candidate for green future. Thus, more research should be performed in every field of hydrogen ecosystem. It can be used in vehicles, for electricity generation and in combustions engines. We tried to support existing efforts by concentrating our studies on hydrogen and fuel cells and are looking forward to seeing more research on this field.

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Chapter 32
Control and Estimation of Renewable Energy

Stepan Ozana, Nayan Mahadev Kengar, and Praveen Prakash

Abstract The renewable energy is obtained from the sources like hydro, wind, solar and tidal. The way energy is generated is dependent on certain factors. In hydro, the factors are guide vane angles, head available, velocity of water and type of turbine being used. For wind, the factors are the direction of wind, speed or velocity of wind and profile of turbine blade. For solar, the factors are sunlight intensity, position of solar panel, heat generated and weather conditions. In tidal, the factors are size of barrage required, difference in tidal heights and natural fall and rise of tidal. Few factors are controllable by us. The factors are being controlled by the change in the configuration, shape or profile of the equipment. By the integration of AI system, a flawless control can be achieved. By continuously monitoring the factors and making changes according to it, the power output of the system can be changed. This leads to efficient use of renewable energy. With the help of AI system, the control, estimation and monitoring of this renewable energy are possible.

Keywords AI system · Cross-sectional area · Variable vane angles · Renewable energy · Control · Estimation and monitoring

1 Introduction

The energy which gets replenished constantly is referred to a renewable energy. The sources of this energy are natural and known by the term renewable energy sources. Till now, there are four main sources of renewable energy. Namely, these sources are solar, wind, hydro and tidal. As today, we are using the renewable energy for generation of electricity, but we are using this source for long time. The good example can be using solar power for cooking. The reason behind the discovery

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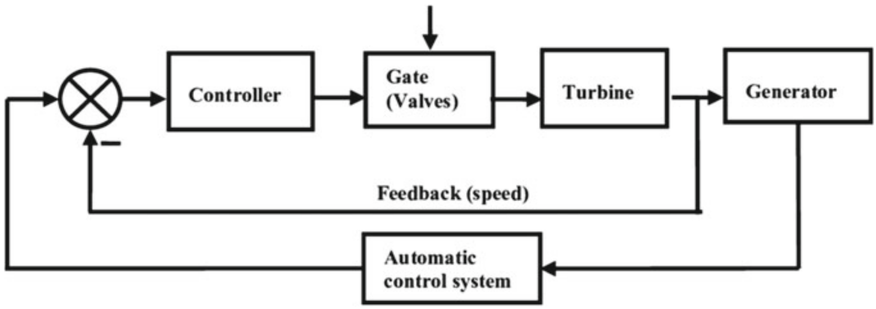


Fig. 1 Block diagram of hydropower system

of these sources is that the fossil fuel is limited in amount. It takes over millions of years to form fossil fuel. The rapid growth in industry required huge amount of power which is continuously creating load on the conventional sources. To overcome this load or to reduce this load, the non-conventional energy sources are the best choice. The detail information of sources is as follows.

1.1 Hydropower System

After the conventional sources, hydropower is the largest renewable energy source for electricity production. In this system, the potential energy of the water is used for the generation of electricity. In the hydropower systems, the water is stored at height. This increases the head as well as the potential energy of the water. This water is then let to flow through a pipe which leads to conversion of potential energy into the kinetic energy. Generally, this kinetic energy is converted into the mechanical energy by means of turbine system. The turbine system is coupled with the generator. This generator leads to conversion of mechanical energy into the electrical energy. On the basis of type flow or the direction of flow, turbines are used and fall under the three types of Pelton, Francis and Kaplan [1] (Fig. 1).

1.2 Wind Power System

The wind power is being used for many years. The traditional windmill is not new for anyone. Today, we use the advance version of these for the generation of electricity. The working of this system is easy as it follows the flow of process as the blades of the turbine turn due to the kinetic energy of the wind. This turbine blades convert kinetic energy into the mechanical energy. The turbine is coupled with the generator which converts the mechanical energy into electrical energy (Fig. 2).

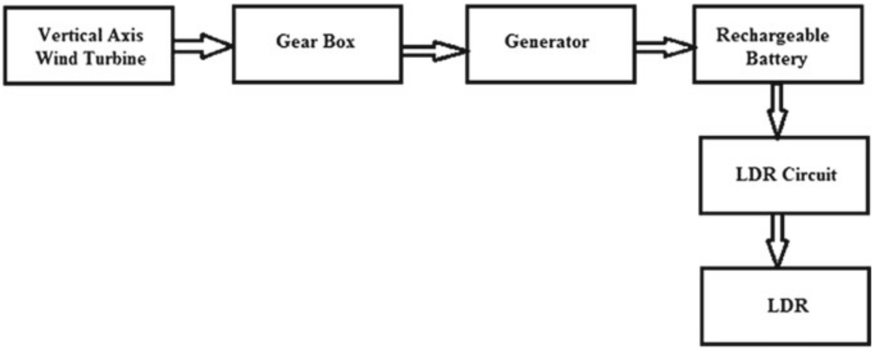
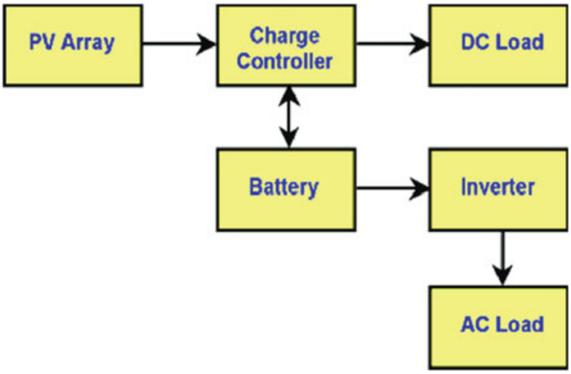


Fig. 2 Block diagram of wind power system

1.3 Solar Power System

The solar system is using photoconductivity property of a silicon. The cells used in the solar system are made up of material silicon. This material converts the solar radiation directly into electricity. The cells are known by the name of solar, or photovoltaic (PV), cells. Distributed solar systems are able to generate enough electricity for local homes and businesses. The solar radiations are available in huge amount. Even if the system is available for around 12 h a day, it is still an effective source of energy. Many methods are used for more efficiency of system. The plus point for this system is that is does not affect the environment around it. There no, any kind of pollution is done because of solar power system (Fig. 3).

Fig. 3 Block diagram of solar power system



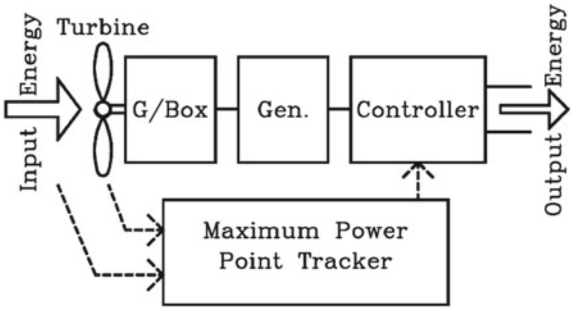


Fig. 4 Block diagram of tidal power system

1.4 *Tidal Power System*

Tidal power is also known by the name of tidal energy. It takes the advantage of actions of tidal to generate electric energy. On the basis how the action is used, there are two ways to generate electric energy from the tidal. One is known by the name tidal barrage power systems and second one is tidal stream power systems. In the first type of power system, the water is being stored during the rise in the barrage, and during the fall, this water is passed through a turbine to generate electrical power. The second type of system uses ocean currents to drive turbines [2] (Fig. 4).

2 Methodology

2.1 *Change in Configuration*

2.1.1 Hydro Power

The Francis Turbine

It is a reaction type of turbine. The pressure of the water changes as it moves in turbine. The guide vanes are used to guide the water flow. By varying the angle between guide vanes and runner vanes, the pressure energy can be controlled [3, 4] (Figs. 5 and 6).

The calculations for the efficiency of turbine are done with help of velocity triangles at the inlet and outlet of a runner vanes. The inlet parameters are directly affected by the guide vane angle [5].

Change in the guide vane angle:

Here,

α Guide vane angle
b Width of passage through which flow takes place
r Radius

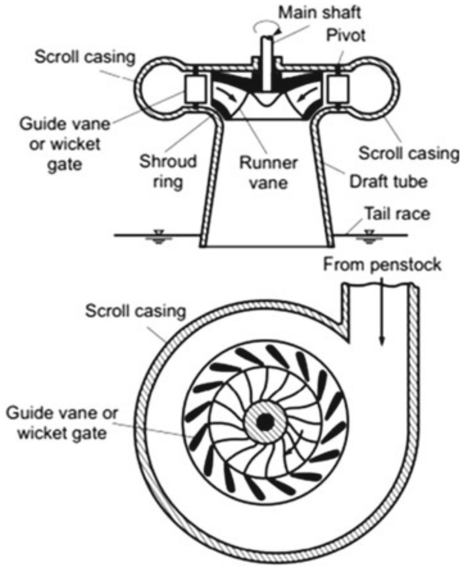


Fig. 5 Francis turbine

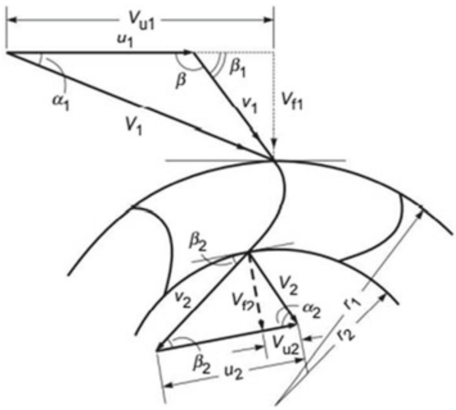


Fig. 6 Velocity triangles at inlet and outlet of Francis turbine

V Fluid's absolute velocity.

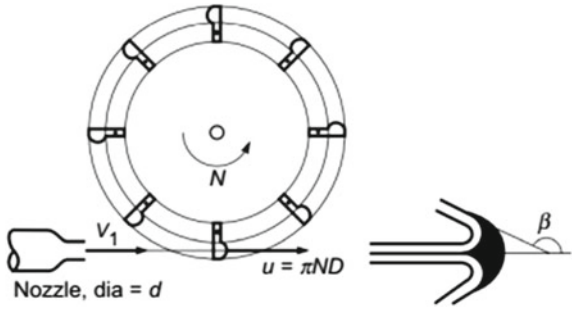
Discharge:

$$Q = 2\pi\, r_1 b_1 V_1 \sin\alpha_1 = 2\pi\, r_2 b_2 V_2 \sin\alpha_2$$

Torque:

$$T = \rho Q (r_1 V_1 \cos\alpha_1 - r_2 V_2 \cos\alpha_2)$$

Fig. 7 Pelton turbine



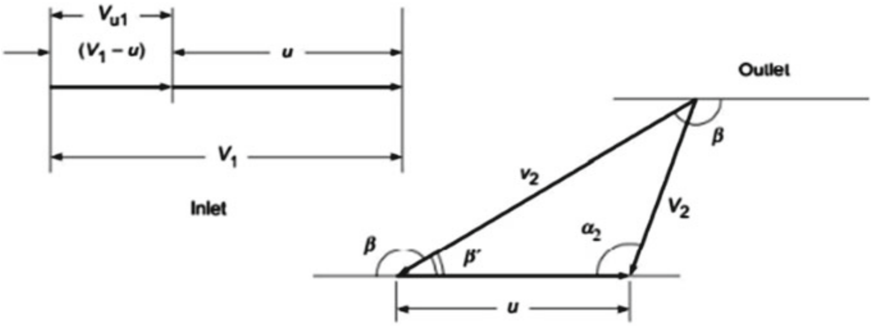


Fig. 8 Velocity triangles at inlet and outlet of Pelton turbine

Power:

$$P = T\omega$$

Pelton Turbine

Pelton turbine is type of impulse turbine. The flow of a fluid is passed through a nozzle which results in an increase the velocity of flow, due to which the kinetic energy of fluid is increased varying the cross-sectional area of the nozzle. As the area increases, the velocity decreases, and as the area decreases, the velocity increases [3] (Figs. 7 and 8).

Discharge:

$$Q = AV$$

Here,

A Cross-sectional area.
V Velocity of fluid.

Power calculations:

$$P = \rho Q u (V_1 - u)\left(1 + k \cos \beta'\right)$$

Here,

Q Discharge
u Peripheral velocity
V Jet velocity
β' 180—bucket angle)

2.1.2 Wind Power System

Wind turbine profile

The wind turbine has the same profile as airplane. Due to its shape, the lift is produced and it turns. Most curved side of the turbine is responsible for generation of low-pressure air, while high-pressure air pushes the other side of the turbine [6–8] (Fig. 9).

Power calculation

$$P = \frac{1}{2} \times \rho \times A \times v3$$

Here,

ρ Density of the air
A Cross-sectional area
v Velocity of the wind.

The efficiency of the wind turbine can be increased by giving the additional degree of freedom to the turbine blade. As the turbine blade is able to adjust angle as per the speed of the wind, this angle is made by the axis of turbine rotation to blade profile plane. As the angle changes, the drag changes resulting in better utilization of a winds kinetic energy [9] (Fig. 10).

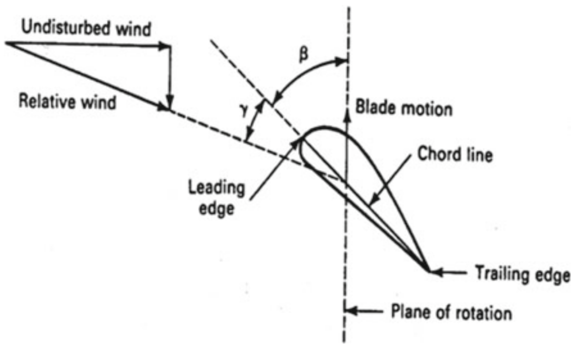
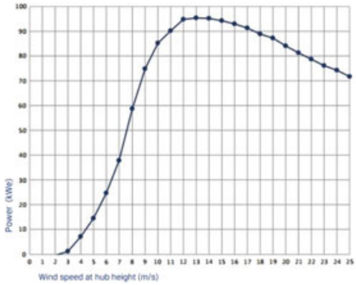


Fig. 9 Wind turbine blade profile



Wind Speed and Corresponding Power Output (kW)

wind speed (m/s)	1	2	3	4	5	6	7	8	9	10	11	12
power output (kW)	-0.5	-0.5	1.2	7.2	14.5	24.7	37.9	58.7	74.8	85.1	90.2	94.7

Wind Speed and Corresponding Power Output (kW)

wind speed (m/s)	13	14	15	16	17	18	19	20	21	22	23	24	25
power output (kW)	95.3	95.1	94.2	92.9	91.2	88.9	87.1	84.1	81.3	78.6	75.1	74.3	71.7

Fig. 10 Wind velocity versus power output graph

2.1.3 Solar Power System

Important factors to consider for solar system are as follows:

- Efficiency of solar panels
- Location
- Orientation of solar panels.

Power:

$$P = \text{Average sunlight} \times \text{solar panel watts} \times \text{efficiency of panels}$$

Solar cell efficiency

$$\%\eta = \frac{P}{E.A} \times 100\%$$

Here,

η Efficiency
P Power output
E Radiation flux
A Area of panel.

Saurenergy [10] by controlling the parameters such as orientation of solar panels and profile shape of the cells, the power output of the system can be increased. As the solar radiation changes, the profile changes from straight line to curve. This transformation leads to the better absorption of solar radiations, which results in the greater electricity generation.

2.1.4 Tidal Power Systems

Nazri et al. [11] a tidal barrage generates the power with the help of potential energy of tides. Tidal basin single action gross energy potential is calculated by

$$E_F = \rho g \int_{z=0}^{z=R} zA dz$$

$$E_F = A\rho g \int_{z=0}^{z=R} z dz$$

$$E_F = A\rho g \frac{R \wedge 2}{2}$$

Here,

A Basin area
ρ Density of sea water
g Gravitational acceleration
R Range difference.

Power potential

One tide average time

$$T_{\text{tide}} = \frac{\text{Time in one month}}{N}$$

Here,

N Number of tides in one month.

Time for one generation of power

$$T_{\text{gen}} = \frac{\text{Ttide}}{2}$$

Gross power potential per tide

$$P_{\text{tide}} = \frac{Ef}{\text{Ttide}}$$

Power potential in month

$$P_{\text{total}} = P_{\text{tide}} \times N \times \eta_{\text{barrage}}$$

Monthly power generated

$$P_{\text{electicity}} = P_{\text{total}} \times \text{N} \times \frac{\text{Tgen}}{3600}$$

2.2 *Use of Artificial Intelligence*

2.2.1 Hydropower System

The AI system integration with hydropower system is used for monitoring the parameters of system. These parameters include the head of the water, level of water, velocity of water in the system, power genearated and configuration of systems. Now in our AI system, the parameters are being monitored, and as per the requirement of power and the head available at the inlet, it changes the configurations as per the following turbine systems [12].

Francis Turbine

The AI system controls the guide vane angle as discussed in above section. This leads to the pressure distribution of the water which turns the turbine.

Pelton Turbine

The AI system controls the cross-sectional area. This varition of area varies the velocity of the water. The kinetic energy of water is being controlled; hence, the convertion of kinetic to mechanical power is controlled. As a result, the power output of system is controlled (Figs. 11 and 12).

2.2.2 Wind Power System

The wind power system is affected by the velocity of wind, density of air, direction of wind and profile of the turbine. By using AI system, all parameters are being monitored, and according to it, it makes changes in the system. Also AI can be used to monitor weather for prediction of wind direction and change the direction of turbine as well as it calculates the velocity of wind and changes the profile of turbine blade and its angle [13].

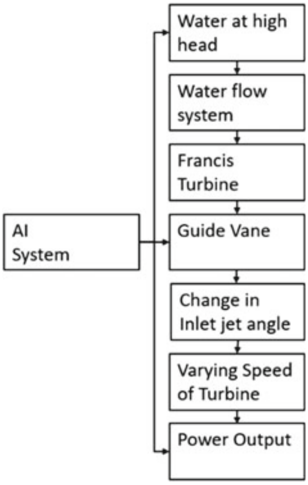


Fig. 11 Block diagram of AI integration for Francis turbine

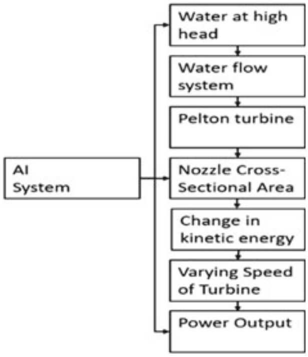


Fig. 12 Block diagram of AI integration for Pelton turbine

2.2.3 Solar Power System

The AI systems monitor the global radiation distribution. As per the date and time, the position of sun changes. The system keeps eye on it. According to the sun's position, it changes the orintation and profile of cell for better absorption of solar radiation. The AI systems monitor the solar radiations [14, 15] (Figs. 13 and 14).

2.2.4 Tidal Power System

The AI system monitors the tidal conditions. It changes the configuration of the system as per the pressure genererated by tides and the velocity of tide in channels [16] (Fig. 15).

Fig. 13 Block diagram of AI integration for wind turbine

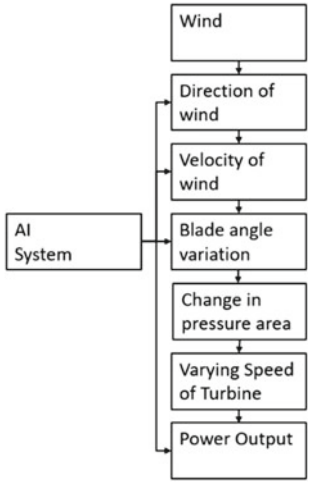


Fig. 14 Block diagram of AI integration for solar power system

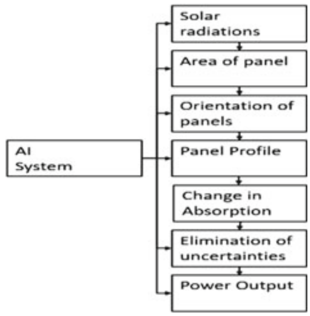
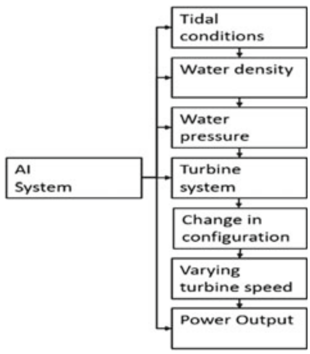


Fig. 15 Block diagram of AI integration for tidal power system



3 Conclusion

The renewable energy sources are better alternatives to reduce the usage of conventional energy sources. The uncertainties in generation of efficient power from the renewable energy sources can be eliminated by the help of AI system. The task AI can perform in the field of energy is that it monitors the parameters necessary for working of power systems, control the parameters and calculations of requirements, change the configuration of systems and find the faults in the system for elimination. For the hydrosystems, the guide vane angles and cross-sectional area are the controllable parameters. For the wind system, the direction of turbine and the profile of the turbine blade are controllable factors. In the solar system, the orientation of the panel and the shape of panels can be controlled and altered. In tidal system, the system configurations like blade angles and area of flow are the factors to be controlled.

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Chapter 33
The Automation of Different Plaque Shapes to Compute Influence of Blood Flow and Wall Shear Stress in Stenosed Artery Using ANSYS

Raman Yadav, Vineet Dahiya, and Sharda Vashisth

Abstract Using Computational Fluid Dynamics (CFD), the blood flow through carotid artery is studied to examine the effect of flow on hemodynamics parameters. Geometrical carotid artery model is designed using ANSYS Fluent, and results of non-Newtonian model are studied. The numerical results are presented in terms of velocity, wall shear stress and velocity vector on carotid artery due to the deposition of different shape and size of arterial stenosis such as plaque shape 1, plaque shape 2, cosine plaque and irregular plaque shapes of stenosis. It is found that area of blockage plays an important role as the stenosis in the artery increases the flow velocity, and wall shear stress also increases in the stenotic region. At the stenosis, velocity is observed maximum compared to pre- and post-stenosis. The highest level of WSS was observed for the plaque shape 2 of stenosis followed by plaque shape 1, irregular plaque shape and then by cosine-shaped stenosis. The flow velocity across stenosis is more for plaque shape 2 followed by plaque shape 1, irregular and cosine plaque shape.

Keywords Carotid stenosis · Atherosclerosis · Wall shear stress · CFD · Non-Newtonian flow

1 Introduction

Human circulatory system is the most essential part of the human body where heart serves as the pump which supplies blood to the various organs of the body through arteries and veins [1]. Carotid artery plays an important role for the transmission of blood from heart to brain and head. There are pair of carotid arteries in human

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body one on the left side and another on the right side of the neck near windpipe. Each carotid arteries is bifurcated among internal and external carotid artery. Internal carotid artery (ICA) transports oxygen-rich blood from heart to the brain, whereas external carotid artery (ECA) provides blood to face, scalp and neck. If adequate amount of blood and oxygen does not reach to the brain, the brain cells will die off and resulting in brain stroke or brain damage. Carotid artery disease like atherosclerosis results in narrowing of artery which further results in reducing the amount of blood through vessels [2]. Atherosclerosis [3] can be attributed to hardening, narrowing and thickening of wall of the artery. The hard substance deposits on the wall of the artery are known as plaque or arterial stenosis which results in narrowing of artery and leads to blockage. Due to the stenosis, adequate amount of oxygen-rich blood does not reach to the organs. The severity of stenosis is a very important factor for anticipating the possibility of stroke. High blood pressure, smoking, low density lipoproteins, obesity, diabetes and a sedentary lifestyle are various factors which result in development of stenosis. Reduction of area of the artery due to the deposition of plaque results in abnormal conduct of blood flow [4]. Detailed study of area reduction of artery will support in realizing the mechanism for this uncommon conduct of flow. Hemodynamics in stenosis will be very helpful for detection and treatment of cardiovascular diseases [5]. Geometry and blood flow constraints are principle factors for affecting hemodynamics of carotid artery. Length and height of stenosis, gradient, shear rate and Reynolds number are various variables for measuring blood flow rate [6]. Experimentally analyzing the hemodynamics are more complex, time consuming and does not yield detailed investigation. Computational simulation methods provide detailed knowledge about hemodynamics and can simulate complex processes easily and accurately [7]. The region which has low wall shear stress (WSS) is the known cause of growth and progression of stenosis.

Computational fluid dynamic ANSYS Fluent [8, 9] is used for the detailed modeling of carotid artery. The shape and size of stenosis may vary from patient to patient [10]. We hypothecate the stenosis of artery into four different shapes for conception of various parameters of hemodynamics. Depending upon the shape and size of stenosis, the present work is directed to check which stenosis shape of carotid artery has much effect on the WSS and flow rate of the artery [11, 12]. Therefore, in this work we consider the effect of surface irregularities, physiological conditions and non-Newtonian model in stenosis artery utilized by computational model. Four different shapes of stenotic models, viz. plaque shape 1, plaque shape 2, cosine plaque and irregular plaque, were used to study various hemodynamic parameters of stenotic region. Thus, this work was simulated to propose the effect of different plaque shapes mentioned above on the blood flow and wall shear stress on carotid artery.

2 Methodology

2.1 Geometrical Model

The carotid arteries are the main blood carrier in the neck which imparts oxygen-rich blood and nutritious to brain, face and neck. There are pair of carotid arteries one on the left and another on the right side of the neck. Each carotid artery can be divided into three segments: common carotid artery (CCA) which is further bifurcated into internal carotid artery (ICA) and external carotid artery (ECA). Figure 1 shows the anatomical model of healthy carotid artery. Internal carotid artery provides blood to brain, and external carotid artery provides blood to face, scalp and neck. The carotid sinus is broadening of a carotid artery at its major bifurcation point.

In our work, ANSYS Fluent Computational Fluid Dynamics (CFD) tool is employed for the designing, analyzing and simulating the carotid artery. Figure 2 shows the geometrical model of healthy carotid artery showing inlet and outlets designed using CFD Fluent. Also, various stenotic models are studied having plaque at different positions, shape and size.

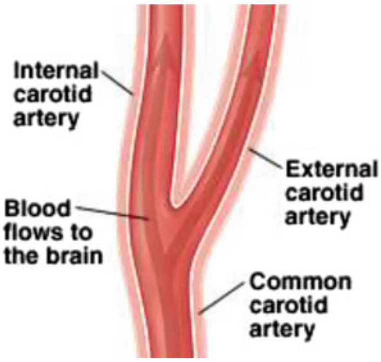

Fig. 1 Anatomical model of healthy carotid artery

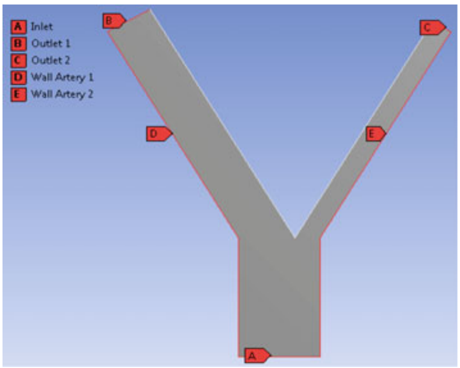

Fig. 2 Geometrical model of healthy carotid artery showing inlet and outlets

2.2 Grid Generation

After designing geometrical model in CFD simulating tool, meshing of arteries is performed in this computer simulation. To obtain accuracy and numerical stability, the analysis of geometry can be divided into large number of cells. Due to the complexities of geometries, these were meshed with unstructured meshing elements in this work.

2.3 Procedure of Carrying Out Research

In our research, outcome of stenosis was deliberated on the hemodynamic parameters of artery. Normal artery is having no stenosis, whereas stenotic artery is having stenosis in the internal carotid artery near carotid bulb. Shape, size and position of stenosis vary depending upon the plaque configurations. In this work, we study plaque shape 1, plaque shape 2, cosine plaque and irregular plaque shapes. Velocity of the flow for all the geometries was studied at three different positions, viz. pre-stenosis, post-stenosis and at stenosis. Vector velocity and WSS for all the cases were studied in this work.

2.4 Materials and Property

Blood properties: In this study, blood is presumed to be incompressible and non-Newtonian. To model the non-Newtonian effect of blood, Carreau model was employed. Blood through the arteries is presumed to be laminar, transient, incompressible and non-Newtonian. Non-Newtonian behavior of blood, where viscosity is expressed as the function of shear rate, is represented by governing Eq. (1).

$$\mu = \mu_{\infty} + (\mu_0 - \mu_{\infty})\left[1 + (\lambda\gamma)^2\right]^{(n-1)/2} \tag{1}$$

where μ_0 (zero shear viscosity or resting viscosity) = 0.056 Pa-s, μ_{∞} (infinite shear viscosity) = 0.00345 Pa-s, λ (time constant) = 3.313 s, n (power law index) = 0.3568 and ρ (density of blood) = 1060 kg/m^3.

Wall properties: Carotid arteries are built up of three surfaces of tissue: intima, the smooth innermost surface directly adjoining to blood flow; media, the muscular middle surface; adventitia, the outermost surface of the artery [13]. In this work, the walls of arteries are assumed to be regular, symmetrical, smooth, cylindrical and rigid. Blood flow through artery is assumed to be steady. Stress–strain relationship curve is nonlinear. The density of wall is considered to be 1057 kg/m^3. The mean thickness of common carotid artery is assumed to be 5 mm, and this value is smaller for internal and external carotid artery due to their smaller diameter as compared to common carotid artery. The thickness for internal and external carotid artery was considered 3 mm and nearly 1 mm, respectively.

2.5 Governing Equations

In our work, we assume blood to be transient, non-Newtonian and incompressible which can be represented by Navier–Stokes Eqs. (2) and (3). Fluid flow through artery can be represented by Navier–Stokes equations which comprise continuity, momentum and energy equations. These can be obtained by applying conservation of fluid flow.

$$\nabla u = 0 \tag{2}$$

$$\rho \frac{\partial u}{\partial t} = -\nabla P + \mu \nabla^2 u \tag{3}$$

where ρ be density, t be time, u is velocity vector, P be the pressure and μ coefficient of viscosity.

3 Boundary Conditions

Boundary conditions may be defined as the set of parameters applied at inlet, outlet and wall of the artery to define various physiological parameters at boundaries [14]. The geometrical model consists of one inlet and two outlets. To analyze the model, physical conditions are applied as velocity inlet and pressure outlet. Value of coefficient of viscosity is 0.001 kg/m-s and blood density presumed to be 1060 kg/m^3.

4 Results

The geometrical representation of carotid artery is developed using ANSYS Fluent CFD. After designing the geometry meshing, numerical calculations and further analysis were performed at ANSYS Workbench. The velocity distribution at three different locations of stenosis, wall shear stress distribution and velocity vectors on carotid artery were obtained for artery having different plaque shapes from Fluent module using computational fluid dynamics (Fig. 3).

From the graphs, we can observe that the highest wall shear stress observed at the bifurcation region and maximum inlet velocity whereas low wall shear stress experienced at carotid sinus and having low velocity. Also, WSS can be affected by

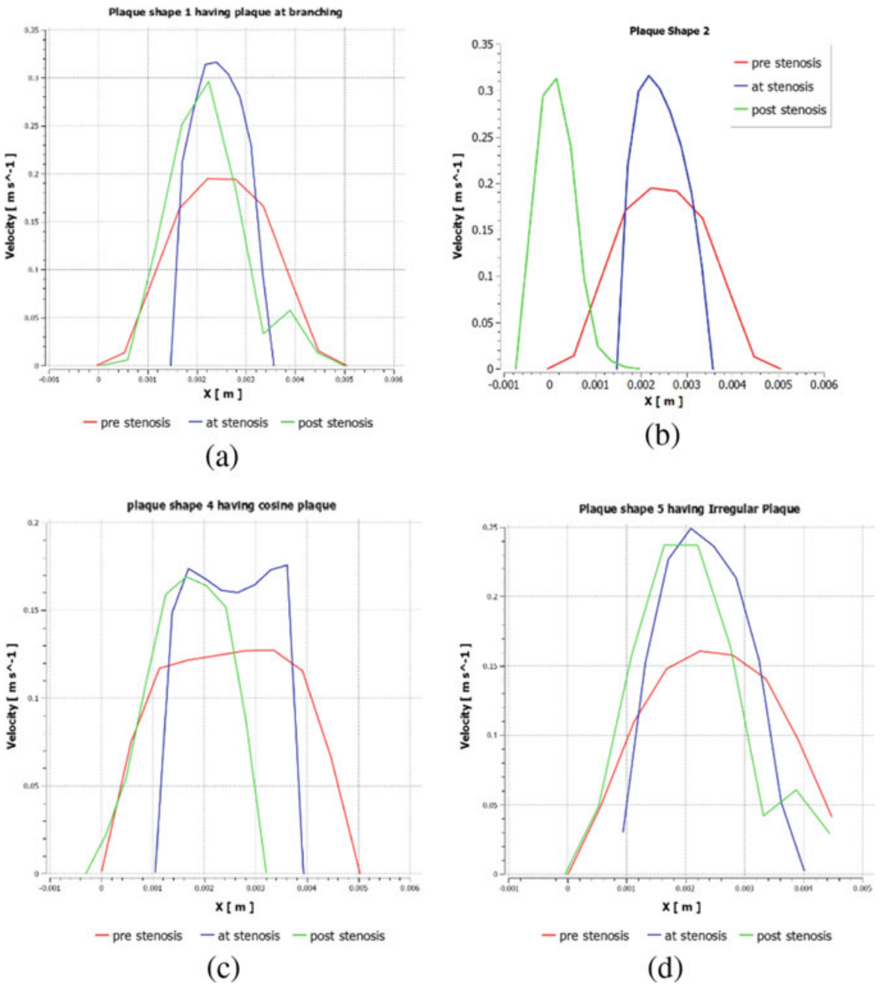

Fig. 3 Velocity of artery having **a** plaque shape 1, **b** plaque shape 2, **c** cosine plaque and **d** irregular plaque

the shape and size of the stenosis; as stenosis increases, WSS also increases [15]. Maximum WSS observed at the neck of the stenosis and at post-stenotic area WSS becomes steady, and it gives nearly constant value for smooth plaque shapes. Firstly, WSS increases sharply and reaches to its peak and then decreases in reverse direction [16].

From the velocity graphs, it is seen that the low velocity is observed at the carotid sinus region. Flow velocity increases with increase in the stenosis region which is clear from the graph that the flow velocity increases significantly at the neck of the stenosis and reduces on both sides of stenosis.

Through velocity vector, excellent visualization of fluid can be seen around the module. Figure shows the velocity vectors emerging out of different planes taken into consideration. It can be seen from Fig. 4a–d at the inlet that the velocity vector seems smooth and flow velocity is also low, but when it passes through stenosis, flow increases and becomes transitional. After passing through the stenosis, it again becomes steady and symmetric.

Figure 3a–d shows flow velocity through the artery having different plaque shapes, viz. plaque shape 1, plaque shape 2, cosine plaque and irregular plaque. These figures depict the flow velocity at three different positions near stenosis that is before stenotic region, after stenosis and at the stenosis. As we know that the velocity increases as the stenosis in the artery increases, maximum velocity is observed at the region where size of the stenosis is maximum and it reduces slightly after stenotic region [17]. From the figures, it can be seen that the plaque shape 2 has maximum flow velocity

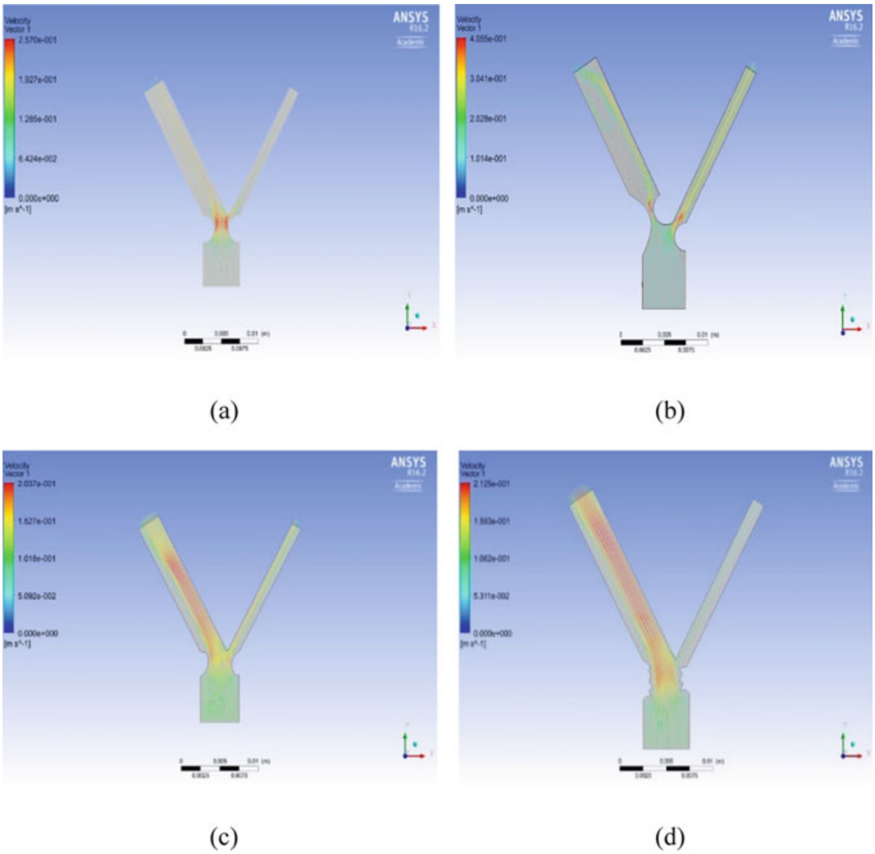

Fig. 4 Velocity vector of artery having **a** plaque shape 1, **b** plaque shape 2, **c** cosine plaque and **d** irregular plaque

near the stenotic region because of low area of flow through artery and maximum geometrical stenosis followed by plaque shape 1, irregular plaque and cosine plaque.

WSS is one of the principal hemodynamic variables for analyzing flow rate as it affected shape and size of stenosis. In this work, we calculate WSS for various models having variable stenotic geometry. WSS for different plaque shape models was calculated and plotted. Figure 5a–d shows the plots of WSS for all the stenotic model. From the figures, it can be seen that WSS distribution for plaque shape 1 and plaque shape 2 was nearly similar, but WSS distribution of cosine and irregular plaque shows sudden peaks. For irregular shape stenosis, these peaks are more irregular as compared to cosine plaque.

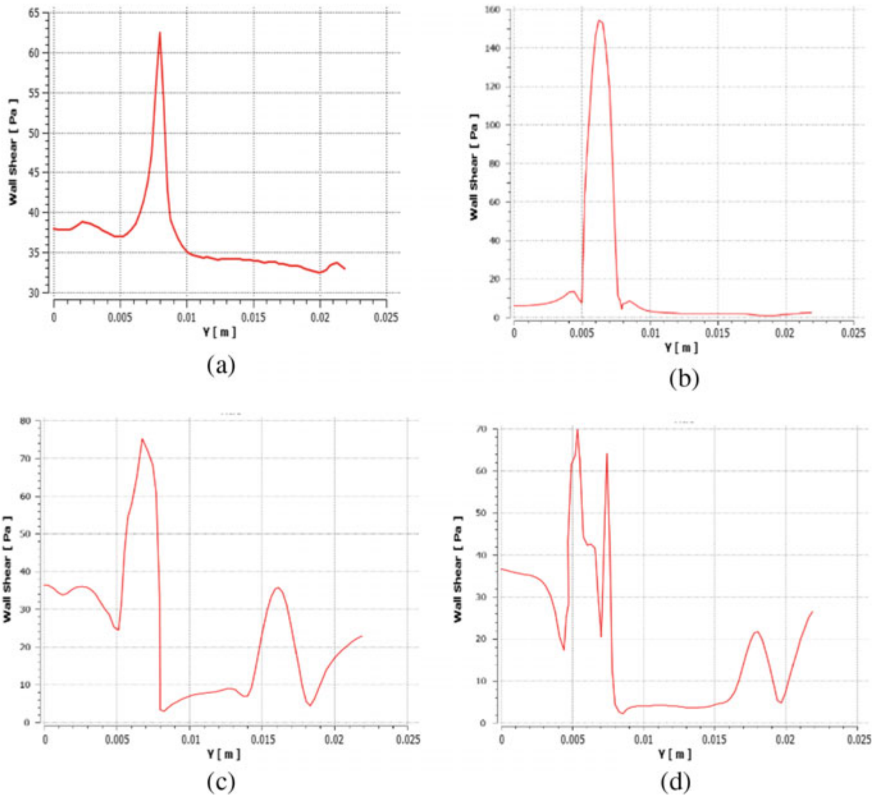

Fig. 5 WSS of artery having **a** plaque shape 1, **b** plaque shape 2, **c** cosine plaque and **d** irregular plaque

5 Conclusion

Hemodynamic parameters such as flow velocity and WSS and the effect of shape and size stenosis on these parameters [6, 10] were studied in our work. As we know that flow within the artery is affected due to its geometry, wall elasticity, shape and size of stenosis and flow signals. WSS, velocity vector and flow velocity through stenosis were observed for all the stenotic models taken into consideration.

The WSS of artery having plaque shape 2 was higher in contrast to other representations. WSS is more in the region before stenosis as compared to the area after stenosis and WSS peaks at the stenosis region. Value of WSS in the stenosis region may depend upon the rupture of plaque on the arterial wall.

This study indicates that the plaque shape 2 has less area for flow, and we know that as the blood flow area reduces velocity of flow and WSS increases, it affects the hemodynamic parameters more as compared to other plaque shapes. WSS and flow velocity were maximum at the neck of stenosis. High WSS increases the risk of atherosclerotic plaque characteristics or atherosclerosis progression [18]. Therefore, the shape and size of stenosis should be observed in predicting wall shear stress and flow velocity in stenosis arterial hemodynamic observation.

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Chapter 34
Design and Analysis of X-Band Metasurface Absorber for Stealth, EMI Reduction, and Energy Harvesting Applications

Gaurav Saxena, Sanjay Chintakindi, Mayank Kumar, Prashant Nigam, Neha Biswas, Y. K. Awasthi, and R. L. Yadava

Abstract In this paper, a relatively very simple structure for an X-band metasurface absorber is designed, along with its analysis. This structure is made with 0.35-mm-thick copper cladding over an abundantly available substrate FR-4 substrate having 3.1 mm thickness. This wideband metasurface absorber also exhibits more than 90% absorption throughout the frequency range of 6.58–14.44 GHz, with a fractional bandwidth of 74.45%. Hence, the designed MS absorber is applicable to the stealth, EMI reduction, and microwave energy harvesting applications.

Keywords Wideband · Metasurface absorber · Electromagnetic interference

1 Introduction

The field of metasurface has advanced tremendously in recent decades. Metasurfaces have the potential to impact practically every field of applied science and technology, including sensing, imaging, communications, defence, and optical communication, because of the unique characteristics and capabilities of the materials. Metasurfaces are the artificial surfaces that are having the exotic properties which cannot achieved by the natural surfaces such as the permittivity, permeability, and the refractive index. Electromagnetic absorbers are one of the used applications in modern technology to

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alleviate the electromagnetic interference. During the World War-II, single layered and multi-layered absorbers were used for the purpose of radar camouflage [1–3].

Metasurface absorbers are of two types, polarization angle (ϕ) sensitive and polarization insensitive based on their behaviour with incident wave angle (θ). This absorber provides improved isolation by preventing mutual coupling between the MIMO elements. The unit cells of metasurfaces are built up of resonators that interact with an external electric field, rather than atoms or molecules. They are typically man-made surfaces. Metallic 'meta-atoms' of a metasurfaces interact with light waves in a specific manner that can influence its electromagnetic properties so as to potentially enter highly unusual regimes; for example, in one where the permeability and the permittivity are negative at the same time (in the same frequency range). The refractive index is a factor that can lower the wavelength and speed of wave when compared to their vacuum values. A natural material does not have all the properties such as negative refractive index that metasurfaces possess [4–6].

Metasurfaces are materials that have characteristics that aren't present in natural materials and can be engineered to have these new features. They have property of manipulating electromagnetic waves which is due to their geometry, orientation, size, precise shape, and arrangement. Research on the electromagnetic properties of metasurfaces increasingly valued for their extraordinary characteristics. The absorber is designed in such an efficient way that the radiating elements have optimum spacing between them. In contrast to conventional absorbers, metamaterial absorbers are designed to efficiently absorb electromagnetic radiation. These absorbers can be further miniaturized, more adaptive and more effective.

Now coming to the classifications of metasurfaces, the properties are described by the defining macroscopic parameters of permittivity and permeability of the materials. The permittivity and permeability of classification of metamaterials the medium with both of them being greater than zero are known as the double positive medium. A medium with permittivity less than zero and permeability greater than zero are called Epsilon negative medium, whereas if the permittivity is greater than zero and permeability less than zero are called Mu-negative medium [7–10].

The proposed structure contains the *L*-shaped metallic structures. This article proposes a structure for the analysis of a wideband metasurface absorber, this structure is made by using a copper cladding of 0.35 mm over 3.1 mm of FR-4 substrate. The wideband metamaterial shows 90% absorption throughout the range of 6.58 to 14.44 GHz with a fractional bandwidth of 74.4%. This designed MS-absorber is applicable to the stealth, EMI reduction, and microwave energy harvesting applications.

2 Design of Metasurface Absorber

The absorber is designed using Computer Simulation Technology (CST) Studios Suite and CNC machine for fabrication of absorber, whereas horn antenna is used for power transmission and reception and Vector Network Analysis (VNA) is used for

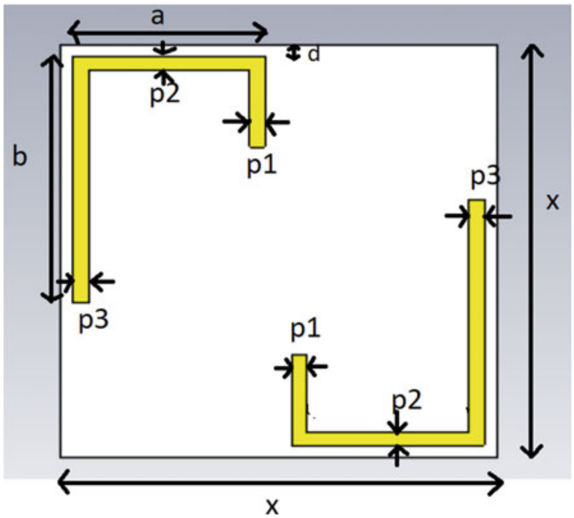

Fig. 1 Geometrical front view of the proposed metasurface unit cell

scattering measurement. The design of the proposed wideband metamaterial absorber is presented in Fig. 1. The top of the layer of the unit cell contains square-based ring in *L*-shaped structure with dimension, $x = 7.95$ mm, $d = 0.225$ mm, $a = 35$ mm, $b = 4.75$ mm, $p1 = 0.27$ mm, $p2 = 0.25$ mm, and $p3 = 0.3$ mm thickness. The top layer metallic patch is etched on FR-4 dielectric substrate of 3.1 mm. The other side of dielectric substrate is complete copper ground (conductivity $= 5.8 \times 10^7$ S/m and thickness = 0.035 mm). The absorptivity A (dB) of the structure where S_{21} (dB) and S_{11} (dB) are the ratios of transmitted and reflected power to the incident power, respectively.

3 Mathematical and Simulated Results Analysis

The unit cell of our structure is simulated by CST software for the results of scattering parameters—*E*-field, *H*-field, and surface currents. We have obtained *s*-parameters which were helpful for us for finding the absorption, reflectance by using Eq. (1) [4].

$$A(\omega) = 1 - |S_{11}(\omega)|^2 - |S_{12}(\omega)|^2 \quad (1)$$

We have used copper as the ground layer so that S_{12} parameter will behave as mirror for preventing of all transmission waves, and it also becomes zero. Now, we get new formula for absorption in terms of scattering parameters and it becomes as

If $S_{12}(\omega) = 0$, then

$$A(\omega) = 1 - |S_{11}(\omega)|^2 \quad (2)$$

Now for getting the results on the basis of above equations, we have obtained the parameters plots that is firstly S_{11} (return loss) versus frequency in Fig. 1 with bandwidth of wideband metamaterial absorber and S_{11} (dB) (return loss) versus frequency. Figure 2a–b will show the graph of absorbance and reflectance with respect to frequency which is calculated by Eq. (1). The graph that is mentioning in Fig. 2a–b will show the absorbance and reflectance of wideband metamaterial absorber with respect to frequency, with the help of this graph we can find the bandwidth of absorber also, the designing of our absorber; we have tried many parameters which was showing results that is showing below. Firstly, we have set our absorber's substrate height, so we have used many values for the setting of height of substrate. The results that we have obtained are shown in Fig. 3a. The graph shows the best results with substrate height of absorber equal to '3.1 mm', so our final absorber's substrate height is '3.1 mm'.

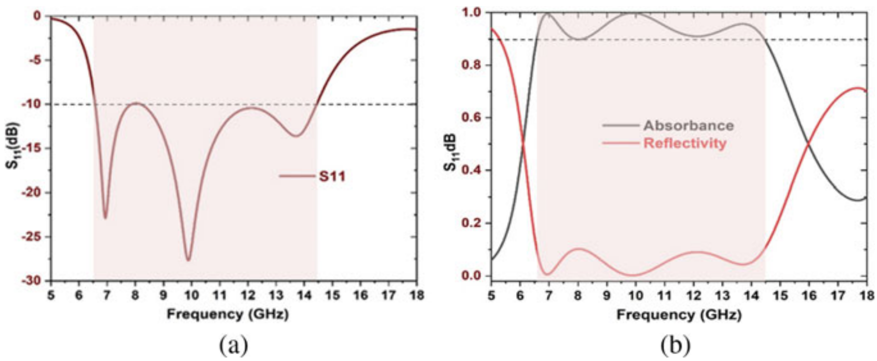

Fig. 2 Simulated results of proposed wideband metasuface (a) reflection coefficient and (b) absorbance

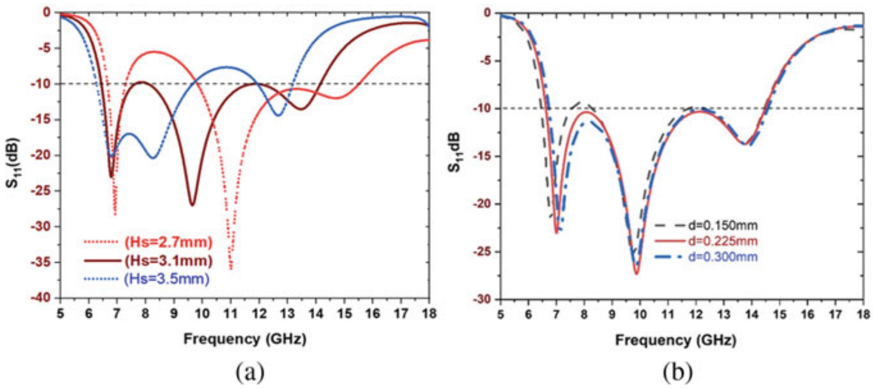

Fig. 3 Parametric calculation of absorber with the **a** variation in height of substrate (H_S) and **b** '*d*' parameter which change in value of from '0.15 mm' to '0.30 mm'

We have also found parametric variation in dimensions of patch design that is d, $p1$, $p2$, $p3$ and other is section wise. Now firstly, we take value 'd' in terms of parameters, and we get the results which is shown in Fig. 3b.

As shown in Fig. 4, the results we seen the best results on value of $d = 0.225$ mm so we have finalized the value of d as same. Then, the value of d is 0.225 mm. We have also worked on other parameters that are length and breadth of L-shapes. The varying values of parameter '$p1$', '$p2$', and '$p3$' we have obtained the results as shown in Fig. 4a–c, respectively (Table 1).

The results that we have obtained on parametric analysis of $p1$, $p2$, $p3$ are shown in Fig. 4a–c. Then according to our requirements, we have set the values of these parameters which show the best results. Similarly during the process of designing, we have designed the unit cell in sections that shows the parametric results, and according to that we have selected the design as shown in Fig. 5.

We have also got the E-field, H-field, and surface current distribution on three frequencies that are '6.7 GHz', '10 GHz', and '13 GHz' that are shown below, respectively, in Figs. 6, 7, and 8.

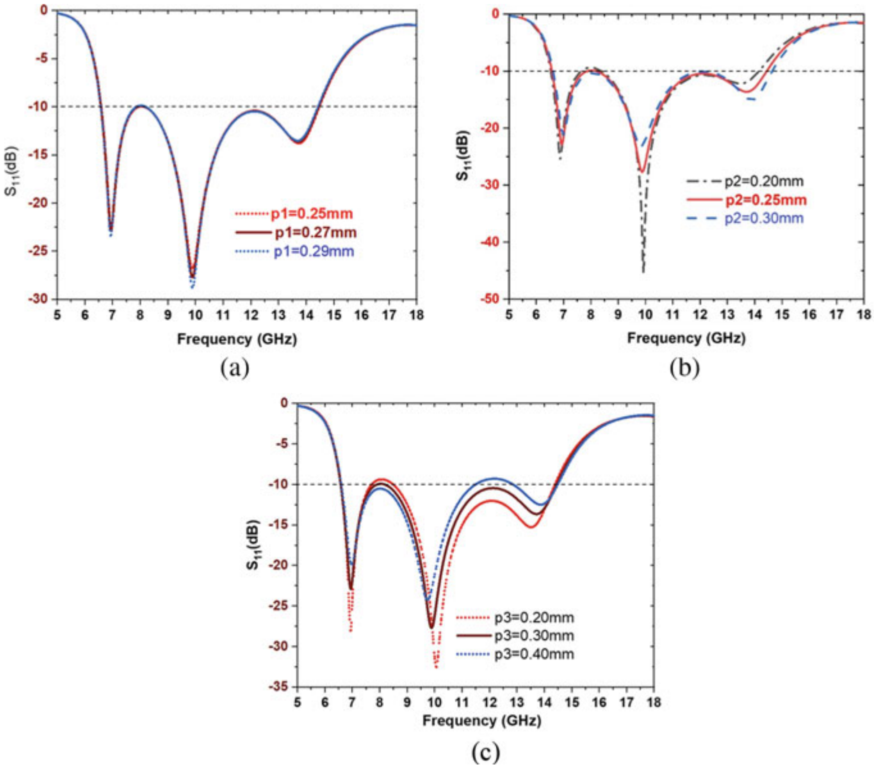

Fig. 4 Parametric calculation **a** '$p1$' parameter which change in value of from '0.25 mm' to '0.29'. **b** '$p2$' Parameter which change in value of from '0.20 mm' to '0.30 mm'. **c** '$p3$' Parameter which change in value of from '0.20 mm' to '0.40 mm'

Table 1 Comparison of the proposed design with various designs available in literature on certain parameters

Unit cell size (mm)	Centre frequency (GHz)	Height of substrate (mm)	Fractional bandwidth (%)
40.0	11.11	0.8	20.0 [1]
8.0	12.2	2.0	60.0 [2]
7.0	12.5	1.6	40.0 [4]
7.95	**13.8**	**3.1**	**74.459***

*Present work
Bold significance represent the superiority of the proposed work over the literature

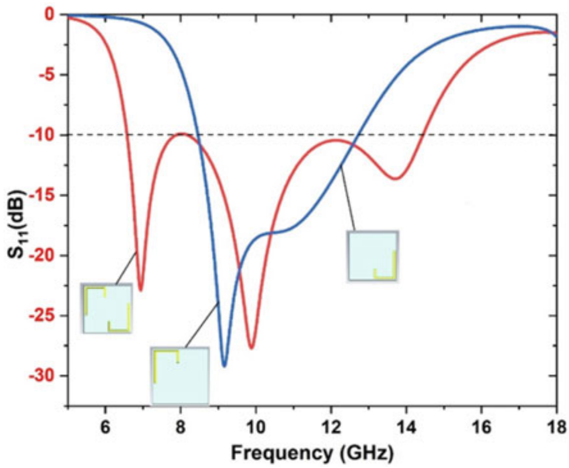

Fig. 5 Parametric results on varying design sections

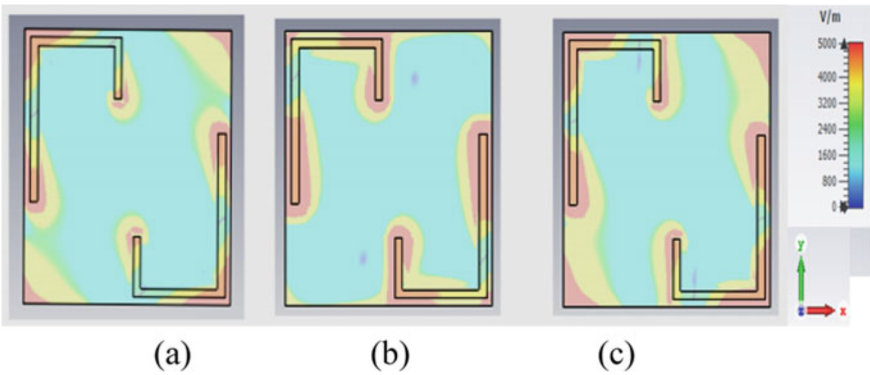

Fig. 6 *E*-field distribution at **a** 6.7 GHz, **b** 10 GHz, and **c** 13 GHz

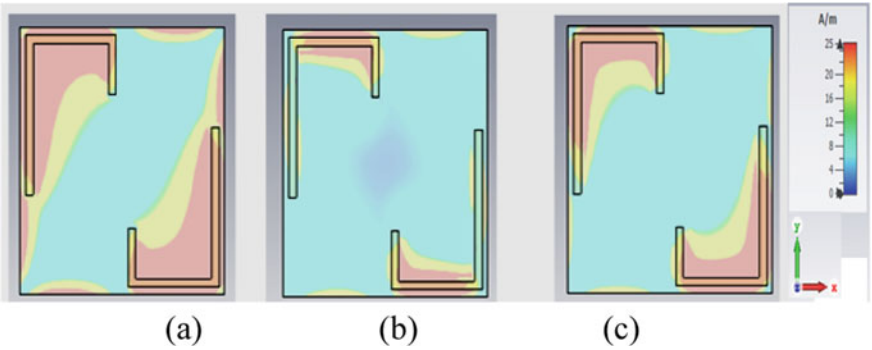

Fig. 7 *H*-field distribution at **a** 6.7 GHz, **b** 10 GHz, and **c** 13 GHz

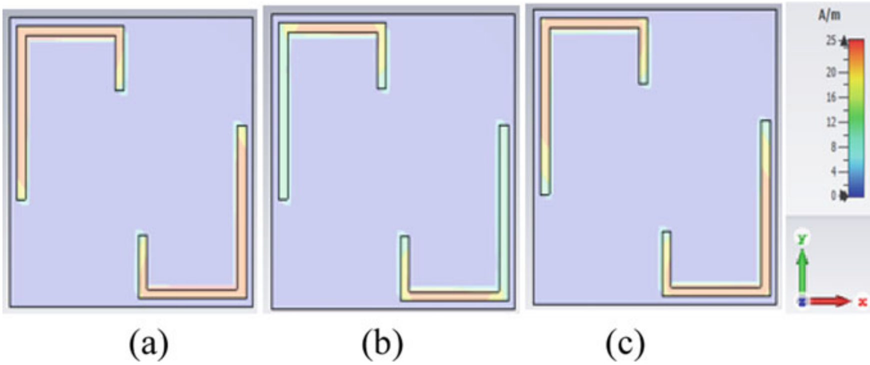

Fig. 8 Surface current distribution at **a** 6.7 GHz, **b** 10 GHz, and **c** 13 GHz

4 Conclusion

In this paper, a wideband metamaterial absorber has been designed which has a shape of square rings in *L*-shaped structure. The principle of metasurface absorber has been discussed. This structure of metasurface absorber is showing more than 90% absorption in the intended band with the approximately bandwidth of 7.86 GHz. This structure comes with more than 74% fractional bandwidth and very thin structure with respect to height of substrate in wideband region. This structure is showing best simulated results and measured results. This metamaterial absorber has many applications in many fields like stealth, aviation technology, and for reduction electromagnetic interference including energy harvesting [10].

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Chapter 35
Smart School Bus Accident Monitoring System and Information Sharing with Authorities

Vanitha Mahadevan, Bindu Puthentharayil Vikraman, and Nusaiba Abdul Aziz Hamood Al-Busaidi

Abstract Every day, the number of automobiles on the road grows. Road accidents are becoming more common as a result of increased car traffic and other factors. If first aid takes longer, it leads to the causality of human life. The medical personnel or the traffic police was uninformed of the accident's occurrence and location. It is quite difficult for them to get to the accident scene in a timely manner. This paper was created to quickly notify the appropriate authorities about the accident and its location to avoid these problems. This paper is primarily concerned with the safety of school pupils; hence it is intended for use on school buses. With the help of Arduino, accelerometer, and SIM808, an electronic circuit is created to detect the accident, its position and communicate the information to the police, ambulance, and school principal for urgent action. The accelerometer is utilized to detect the collision, and the SIM808 is used to relay the information to the appropriate authorities.

Keywords School bus · Accelerometer · GPS · GSM · Accident monitoring · SIM808

1 Introduction

Vehicle accidents are one of the most common problems in the world, and they can occur for a variety of causes. Accidents, on the other hand, cost lives, especially when there is a considerable period of time between the incidence of the accident and the provision of first aid. As a result, we have planned to create an electronic circuit in this system that can reduce that time by detecting an accident as soon as it occurs and sending a message to the police, ambulance, and school principal, as this

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article is intended for school buses, to take quick action [1–4]. In addition, to achieve the goal of this system, we used an accelerometer to detect accidents and a GPS and GSM SIM to track location and send SMS messages, both of which are controlled by an Arduino microcontroller [5–7].

Several publications discuss the use of various sensors in an accident alarm system. Any vibration in the car is detected by the vibration sensor [8, 9]. An impact sensor is instaled in the car to detect any shocks [10, 11]. The vehicle acceleration while traveling is measured using an accelerometer [12, 13]. All of these papers are designed to detect an accident and send the information to a registered mobile phone, hospital, or ambulance for immediate response. Furthermore, pinpointing the position is critical for quickly arriving at the scene of an accident and administering first aid in order to preserve human lives.

The components employed in this article were thoroughly discussed. The approach used to complete the job is also detailed. Here's a more in-depth look at the circuit connection. The circuit is put to the test, and the results are discussed.

The goal of this study is to shorten the time between the occurrence of an accident and the provision of first aid by detecting the accident and sending SMS [14, 15] to the ambulance, the ROP, and the school administrator. It is implemented by employing an accelerometer to detect a vehicle collision, GPS to track the car's location, and GSM to convey alarm information based on the GPS location.

2 Literature Survey

This section discusses the many approaches used by the researchers to construct an accident detection and monitoring system in order to save human lives.

Kalyani et al. [16] described a system that alerts the driver if an accident occurs as a result of his carelessness. If an accident occurs, it uses a vibration sensor to detect it. The accident information is delivered to the SIM-registered mobile phone number. The location is also sent to the SIM's registered phone number. Fahim Bin Basheer et al. [17] describe in detail how to detect a two-wheeler accident and inform the responsible parties. This system is based on the vehicle's acceleration and deceleration, as well as changes in pressure on the vehicle's body and tilting. It is possible to calculate the difference in deceleration between the normal and accident times. A tilt meter is used to determine the angle of the motorcycle. The accelerometer is also utilized to locate the accident. The accident prevention and alarm system for two-wheeler transportation was explored by Nicky Kattukkaran et al. [18]. This system has the phone number of a nearby medical center, to which the message should be forwarded immediately. The accident is detected by an accelerometer, and the driver's heartbeat is recorded by a sensor. Bluetooth is used to send the data to the mobile device. The hospital and the driver's accountable personnel are notified about the accident. The location is also sent to the phone. The main cause of the accident, according to Md Syedul Amin et al. [19], is vehicle speed. The vehicle's speed is detected and monitored using GPS technology. Continuously record the vehicle's speed and compare it on a minute-by-minute basis. If there is a significant difference in speed between two consecutive readings, it is termed an accident. GSM technology is used to send the receiver, the corresponding location. The automobile accident and monitoring system are examined by Vaishali Shrivastava et al. [20]. The main cause of accidents is that drivers are ignorant of the hazards as they go along the new route. The late response of the medical team after the collision will result in the death of the passengers in the vehicle. More studies on vehicle-to-vehicle communication methodologies are discussed in order to prevent accidents by communicating between vehicles. The medical team was notified of the accident.

All of the above-mentioned research publications are about various types of automobile accident prevention systems. In this work, an accident detection and monitoring system for school buses is designed in order to save the lives of schoolchildren as quickly as feasible.

3 Methodology

The goal of this paper is achieved through the use of three key components.

3.1 Arduino Mega

The Arduino mega microcontroller was used to complete this project. The Arduino mega board is depicted in Fig. 1. Typically, the board is linked to a laptop or a computer and programmed in the Arduino IDE using the C++ or C programming languages. A USB port is used to connect the Arduino to the laptop. The Arduino Mega features 54 digital pins that can be used as input or output. PWM pins are used on 15 of the 54 pins. A total of 16 pins are used for analog functions. I2C, four UARTs, SPI pins, and a reset button are also included. The Arduino board does not have a direct WIFI connection. A 5 V DC power supply is required. Direct Bluetooth is not available on the Arduino board.

3.2 Sim808

Figure 2 depicts the type of module that combines GPS and GSM technology. It can be powered directly from a 5 V pin or via a barrel jack with a maximum voltage of 26 V. The sensitivity of the GPS signal is excellent. TX, RX, VCC, and ground are among the four pins.

Fig. 1 Arduino mega board

Fig. 2 SIM808

3.3 Accelerometer ADXL355

An accelerometer is depicted in Fig. 3. It’s an electrical sensor that measures the acceleration forces acting on an item in order to estimate its 3D position. The employed accelerometer is a differential capacitive type. There are numerous sorts of accelerometers depending on their function. Because each axis is represented by a three-plate capacitor, two of which are fixed and one of which is moveable, the electric field of the capacitor will change when it detects a change in the distance

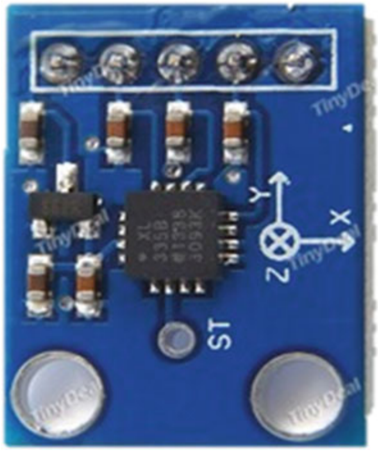

Fig. 3 Accelerometer

between the plates, affecting the reading of the given axis. To calculate the acceleration of a moving vehicle, first subtract the static acceleration, such as Earth gravity, from the object's acceleration, and then divide the reading in that axis by a constant (67.584) to get the acceleration in that axis. In general, the sensor has five major pins: *x*, *y*, and *z* axis, as well as VCC and ground.

3.4 Block Diagram

Figure 4 depicts a block diagram of the design. SIM808 connects with Arduino microcontroller in both directions, receiving and transmitting data. The Arduino receives the data from the accelerometer [21–23].

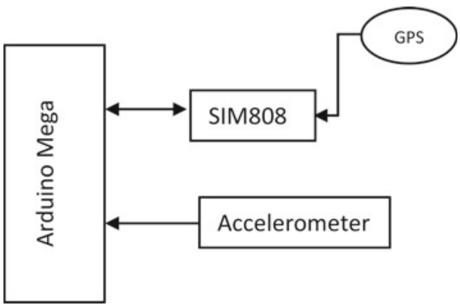

Fig. 4 Block diagram

Figure 5 shows the circuit connection; the accelerometer has 5 pins, *X* with Analog 0 in Arduino, *Y* with Analog 1 in Arduino, and *Z* with Analog 2. Aside from that, the components are grounded and VCC is connected to a 5 V pin. The sending pin of the SIM808 is linked to 10 and the receiving pin to 11. Figure 6 depicts the actual component connections.

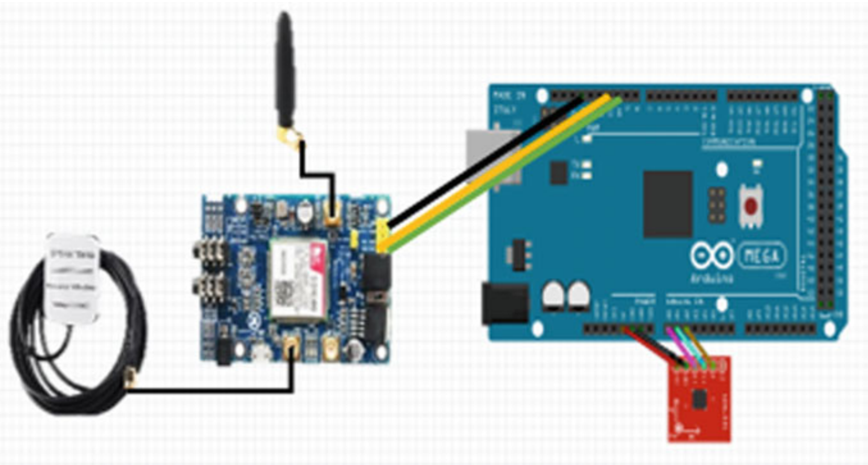

Fig. 5 Circuit connection

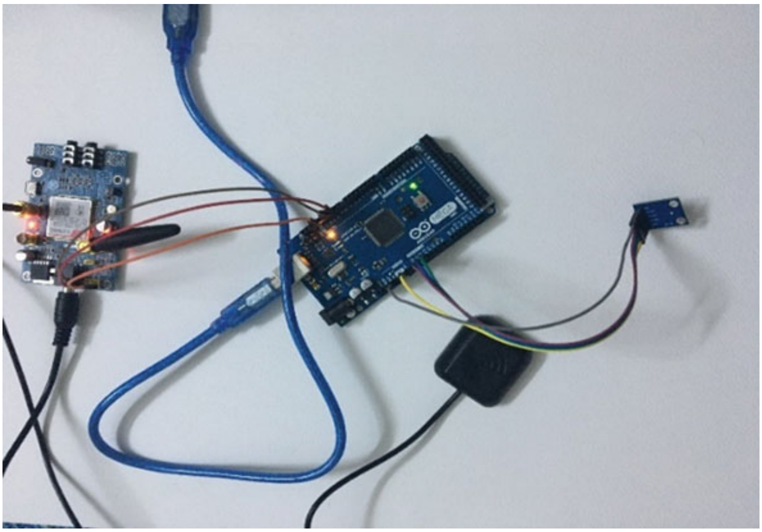

Fig. 6 Actual components connection

3.5 Flowchart

Because the accelerometer will be used to detect acceleration on three dimensions, the change in the bus's speed will be determined by subtracting the static acceleration, such as gravity, from the dynamic acceleration, which is measured while the bus is moving. The result of this subtraction will be divided by a constant 67.584. So, once the bus is on the road, it will begin counting the acceleration; once an accident occurs, the acceleration will exceed 0.5 or be greater than −0.5 (as we have tested the accelerometer). The Arduino will double-check that condition after a certain amount of time, because it is not always an accident; sometimes the driver loses control, causing the acceleration to be greater than the absolute 0.5. By driving the bus back to its normal speed, the acceleration is reduced. If there is an accident, however, the acceleration will not be reduced quickly. So, once the accident has been confirmed, the Arduino will interact with the SIM808 to obtain the bus location and send an SMS to the specified mobile phone numbers in the code.

The system's operation is depicted in Fig. 7.

4 Results and Discussion

An Arduino program was utilized to test this setup. Figure 8 displays the *X*, *Y*, and *Z* axis readings from the accelerometer on the serial monitor of the Arduino IDE before the accident. All the axis values are more than −0.5. Finally, the accident was detected, thus the accident happens, then the *X*, *Y* and *Z* axis values are less than −0.5 or more than 0.5. If an accident occurs, the accelerometer detects it and displays accident information in the serial monitor of the Arduino IDE, along with the SIM808's location information, as illustrated in Fig. 9. Figure 10 depicts the SMS delivered during the accident, which includes the accident information, the latitude and longitude, which may be transferred to the provided link to obtain the bus's location and the wind speed, which indicates the ground speed observed by the satellite. To send message to the concerned persons, their mobile number is registered in the program. One SIM is used in the GPS and GSM module SIM808 to send the message to the required numbers [24, 25]. Using these received information's, the concerned persons can reach the accident spot immediately.

The acceleration value and its condition are given in Table 1. There is no accident if the acceleration value is between 0.5 and −0.5. An accident is recognized if the acceleration value is equal to or greater than 0.5, the location is tracked, and an SMS is sent to the registered cellphone number. An accident is identified if the acceleration is less than −0.5, the location is tracked, and an SMS is sent to the registered cellphone number.

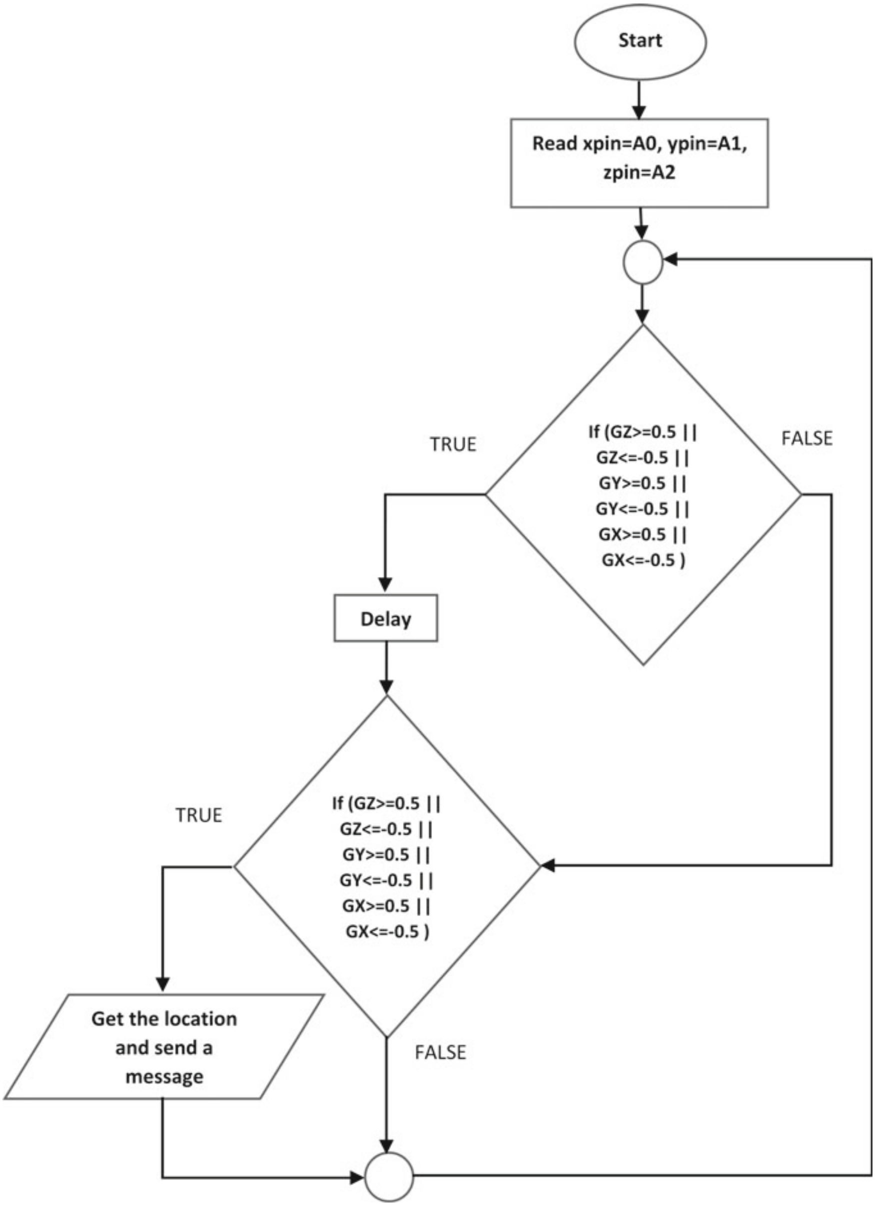

Fig. 7 Flowchart

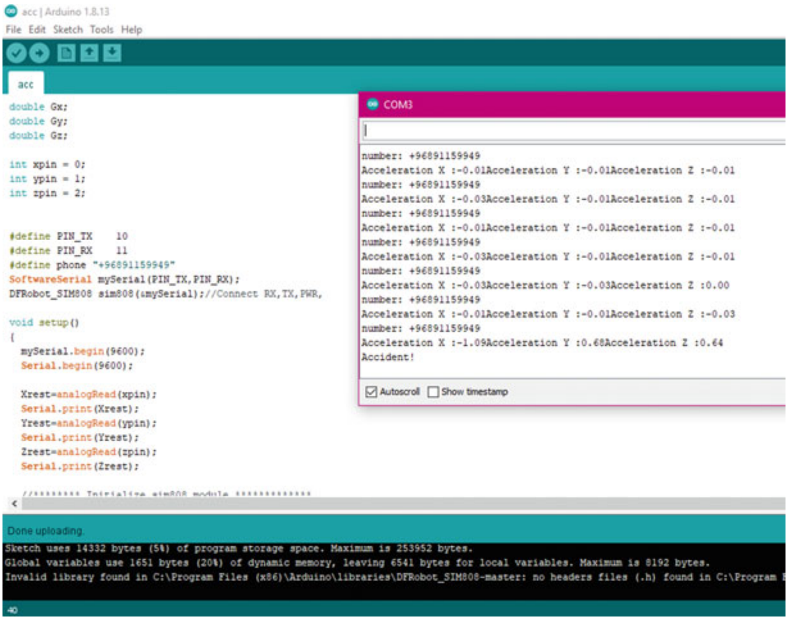

Fig. 8 Detection of accident

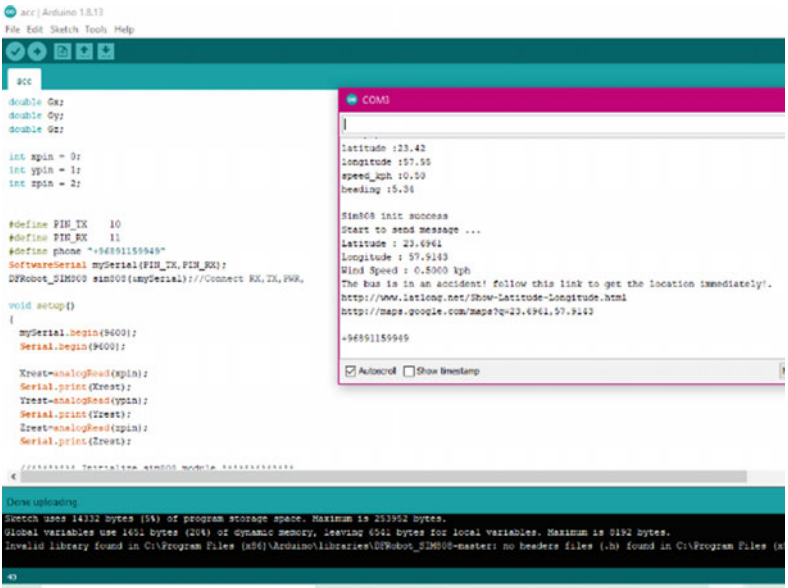

Fig. 9 Sending SMS with location

Fig. 10 SMS received

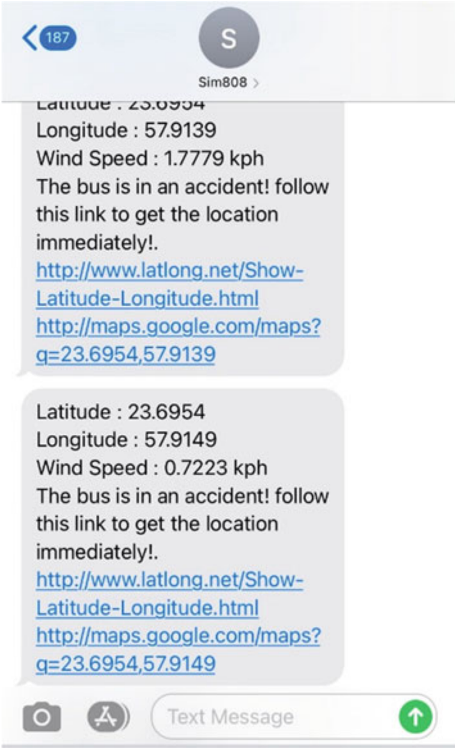

Table 1 Sample table of findings and observations

Acceleration in *y*, *x*, or *z* axis	Accident?	Was the location tracked?	Was the SMS sent?
$a < 0.5$ && $a > -0.5$	NO	NO	NO
$a > = 0.5$	YES	YES	YES
$a < = -0.5$	YES	YES	YES

5 Conclusion

The suggested accident monitoring system is quite effective in determining the accident and sending the location to the appropriate authorities. This is developed specifically for school buses in order to take immediate action in order to save the lives of school children who have boarded the bus. It uses an accelerometer to detect the accident and a SIM808 to determine the location and send an SMS to the school principal, ambulance, and police, who will then take the appropriate action. The Arduino, which serves as a microcontroller, is connected to the accelerometer and the SIM808. The circuit's technique and results were presented in this study.

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Chapter 36
Utilizing Artificial Intelligence to Successfully Communicate and Equip Real Estate Construction Workers with Ergonomic Footwear for Their Health

Sathyanarayana Kaliprasad, Siddhartha Bose, K. Jithin Gangadharan, Rakhi Nagpal, Pritpal Singh, and Veer P. Gangwar

Abstract Artificial intelligence (AI) isn't well understood. In 2017, only 17% of 1,500 US business leaders knew about AI (Feijóo et al., Telecommun Policy 44(6):101988, 2020 [1]). Many didn't understand it or how it would affect their businesses. Business tactics could be adjusted. Despite being unfamiliar, AI is changing everything. It rethinks how we combine and interpret data to improve decision-making. We compare Indian, US, and EU regulatory frameworks and give recommendations (Gherhes et al., Reg Stud 56(4):563–578, 2022 [2]). AI is progressing rapidly due to technology consolidation and affects business and everyday life (Taeihagh, Policy Soc 40(2):137–157, 2021 [3]). Background and methods used: Three-month study from June to August 2022 aims to establish how AI might help create new footwear solutions, notably in the real estate construction sector, and how we can leverage multimedia and comics to convey and promote new items to the market. Results: New measurements construct validation elements (construction worker well-being, communication strategies, and footwear), and demographic questions were introduced. Explored dimensionality, internal (Cronbach's alpha), and construct validity (Spearman's correlation) are used to find dimensions and correlation. Multivariate logistic regression models evaluated the new measures. Screening shortened all measures. 71% of the sample ($n = 139$) had foot problems, 82% were high school dropouts who couldn't read or write and only learned via comics, and 48% were Indian women. Conclusions: AI as technology proves to showcase newer solutions in well-being related to footwear and if communicated effectively via comics can educate and eradicate the issues faced by construction workers.

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Keywords Artificial intelligence · Comics · Real estate · Well-being · Ergonomic footwear

1 Introduction

AI is taking over. It powers self-driving cars, pinpoints store locations, and detects cancer cells early. This upheaval hasn't left real estate behind. Realtors are using algorithms and data pipelines to make decisions. Before real estate organizations completely utilize AI, it's vital to visualize the big picture and answer these questions. AI's enticing skills have dominated almost every industry. Retail, logistics, and health care, all use AI for multiple benefits. AI is entering non-technical areas thanks to fast tech uptake and integration. Fashion and footwear are two of these sectors. Through IoT and wearables, the footwear sector will soon enable AI in fashion. We may become aficionados of this innovation as it grows and costs reduce. The global AI in the fashion market is expected to increase from USD 228 million in 2019 to USD 1,260 million by 2024, at a CAGR of 40.8%. Customers' demand for a personalized experience, expanding inventory management needs, and social media's influence on fashion are also market growth drivers. This growth is tiny compared to the whole footwear market. With new items and inventive solutions, the trajectory can rise [4].

Well-being is the satisfaction of persons with parts of their lives, based on their material and cultural resources and situations. Well-being is physical, social, and psychological. Well-being is also affected by individuals' ability to feel hopeful enough to cope with challenges. Due to the hazardous nature of the job and the inherent risks, construction is consistently ranked among the world's most dangerous industries. Deaths in Europe's construction industry totaled 782 in 2014 due to various causes, including workers falling to their deaths and accidents involving the collapse or malfunction of construction machinery and tools. The work is physically demanding because it is largely done by hand rather than by machines. Most construction workers are at risk of injury due to the hazardous environment in which they work [5]. Researchers in the field of occupational health and safety (OHS) have traditionally prioritized finding ways to lessen the likelihood of, or the severity of, accidents by eliminating or mitigating direct physical hazards [6]. All of the aforementioned factors may contribute to the common association of safety shoes with lower back pain, ankle injuries, hallux problems, and metatarsal head pain, and injuries sustained while at work [7] found that 91% of people who wore safety shoes experienced foot problems, lending credence to this theory. Moreover, injuries and pain appear to be linked to inability to focus (the "danger of accidents") and decreased output. As a result, having a pair of safety shoes that fits properly is crucial. It has been suggested that 3D data on the foot's static and dynamic deformation while standing and walking is crucial for finding the right pair of shoes. Various research teams have provided varying results. However, most studies have only looked at the possibility of improving footwear fit, so their findings are limited. For this purpose, the technology appears to be adequate to take a look at the problems I've already outlined. Understanding observational techniques in real time that provides us with a three-dimensional imaging of the foot to understand the nomoclature of the foot with its height, weight and depth [8]. Artificial intelligence facilitates effective dialog in the workplace. AI can provide insights into the effectiveness of presentations and suggest approaches to audience engagement based on a variety of data. Thus, AI aids the footwear sector in creating safe and healthy footwear for the construction and real estate industries. The industry as whole benefits enormously from this as well.

2 Literature Review

In the real estate industry, foot problems are common and it vary. Athlete's foot is a contagious skin fungus. Infected socks and shoes trigger the infection between the toes. Bunions harm just the elderly, although improper shoes can also cause them. In this illness, the big toe bends toward the next toe; ill-fitting shoes can make it worse. Cushioned shoes are essential. If not, corns form. With friction, the skin builds strong layers to protect foot soles. Multiple layers of skin develop into painful yellow kernel pimples. Diabetic patients often lose sensation due to nerve loss, causing diabetic foot. Tight shoes might cause blisters and sores in this condition. When people wear ill-fitting, narrow shoes, their toes curl and don't lie flat. This disorder causes the toe to harden and dislocate permanently. When someone wears little shoes, their toenails dig into their toes, causing agony. Fungus and incorrect nail trimming can worsen the issue. Thus, wearing the correct shoe is one key aspect of keeping healthy. Nike's COO Eric Sprunk said the corporation will be more customer-focused than before. Nike's Internet component has grown dramatically. Between 2017–2018 and 2018–2019, revenues increased by 12%. Nike bought the data analytics business Zodiac two years ago. Zodiac helps Nike evaluate user habits and predict shopping decisions from the app and Fitbit users. Nike improved consumer purchase and retention by knowing whom to target and when. Nike will urge users to buy if it's been over a year since their last transaction. Nike recently bought 3D scanning business Invertex, which specializes in consumer and medical equipment. Invertex's Nike Fit employs data science, machine learning, computer vision, and a suggestion engine to identify clients' optimum shoe fit. Nike Fit reminds users to use their mobile phone came to scan their feet, and the software immediately presents a suggested size range for that individual. Nike's virtual assistants combine AI and big data. It helps to make sales and segmentation projections, enables voice and photo search, evaluates consumer preferences and behavior, examines reviews, processes orders, recommends solutions, etc. Nike uses chatbots to enhance conversions. The organization uses data analytics to increase client trust. Nike uses AI to tailor customer product communications. This makes it ready to use, with modern apps and personalized programs, loyalty programs, and retail outlets that dissolve the line between virtual and physical interactions. AI solutions help Nike to address client needs. It tells customers what they desire and whether it's possible. Nike's yearly revenue is $39.12 billion, and AI initiatives have helped raise online, app, and retail sales [9]. How one reacts to images varies from person to person and from culture to culture. Do not assume that urban residents have a greater pictorial knowledge or a higher level of symbol decoding than rural residents since the former are more likely to be exposed to advertisements on television, in newspapers, and in magazines. Those who are illiterate might or might not also lack numeracy skills. Numbers can be a useful aid in signaling and guiding. In addition to the cognitive coordination issues that may arise when attempting to construct relations among concepts, illiterate audiences may feel the stress that comes from being presented with complex signals or codes. However, individuals may have difficulty describing the symbols or drawings even if they do understand them. Make sure your ideas are simple to explain and match to real-world concepts people can relate to. These listeners have a propensity to draw connections between unrelated ideas, often to the exclusion of the overall context [10]. Verify your assumptions by putting your data partitioning skills to the test. The challenge of lagging literacy rates among India's rural population is becoming increasingly apparent on the country's building sites. Additionally, we must start utilizing forms of media communication that actually address the needs of the general public. Knowing who is illiterate or has a poor level of literacy is crucial for designing messages that will be understood, and the high cost of miscommunication highlights the need for clear and concise communication. Role-playing considerations in message development, such as the question of which media to employ, will be crucial to the feasibility of effective communication with illiterate rural communities [11].

A study used wearable insole pressure sensors to automatically identify and classify loss of balance episodes in construction workers. The study's goal was to create a unique technique for identifying and categorizing loss of balance incidents that could result in falls on the same level utilizing information about foot plantar pressure distributions obtained from wearable insole pressure sensors [12]. To gather data on foot plantar pressure distributions, ten healthy volunteers engaged in experimental trials that simulated four severe loss of balance occurrences (such as a slip, trip, sudden step-down, and twisted ankle). The distinct foot plantar pressure patterns were learned using supervised machine learning techniques, which were then used to automatically detect loss of balance events. When employing the Random Forest classifier with all feature groups and a window size of 0.32 s, the best classification accuracy (97.1%) was attained. They compared classification performance using different window sizes, feature groups, and classifier types. This study investigates the viability of automated evaluation of construction workers' activities and overexertion risk levels utilizing acceleration and foot plantar pressure distribution data collected by a wearable insole pressure device. To analyze participant performance individually and further estimate physical intensity, activity duration, and frequency data, the accuracy of five types of supervised machine learning classifiers was assessed with various window widths. The findings indicated that for each category of activities, the Random Forest classifier with a 2.56 s window size had the greatest classification accuracy (94.5 and 94.3%), as well as a sensitivity (more than 90.1 and 88.4%). Overall, the suggested method offers a non-intrusive approach and objective assessment of ergonomic risk level based on acceleration and foot plantar pressure distribution data collected by a wearable insole pressure system, which could assist other researchers and safety managers in understanding the level of workers' risks and offering an effective intervention to reduce the risk of developing WMSDs among construction workers. For this reason, it is crucial to educate construction workers on the importance of proper footwear. In this respect, comic strips and other forms of visual storytelling can serve as important tools for fostering both visual literacy and general cultural understanding [13].

3 Methodology

A detailed literature review was used as part of the study strategy, which also included a survey of three scales. There were two goals for this:

a. Gaining a deeper understanding of the phenomenon (the effect of AI on well-being).
b. To gather data on the effects and how AI has impacted C&NC humans in India's listed states.

The three main referenced tools used as a part of this research paper are as follows:

1. Warwick-Edinburgh Mental Well-Being Scale [14].
2. Stanford SPARQ Tool [15].

The above tool's focus on impact of AI on well-being, physiological changes that construction workers have during a period and was found very appropriate to our research work. Each tool has subdivisions to expand and learn deep on the mood, feeling and experience. The key strategy is to narrow down our list from the population to identify real points that can add value to our research; this has been done by identifying and selecting appropriate age, gender, and working and nonworking corporates in five different sectors that indicate the % of the effect of AI and the status of their impact. ***WEMWBS***: WEMWBS "as a scale was developed by an expert panel in reference with qualitative research with focus groups, psychometric testing of an existing scale, and current academic literature. It was validated on a student and representative population sample. Content validity was assessed by reviewing the frequency of complete responses and the distribution of responses to each item. Confirmatory factor analysis was used to test the hypothesis that the scale measured a single construct. Criterion validity was explored in terms of correlations between WEMWBS and other scales and by testing whether the scale discriminated between population groups in line with pre-specified hypotheses. Test–retest reliability was assessed at one week using intra-class correlation coefficients. Susceptibility to bias was measured using the Balanced Inventory of Desired Responding." ***Stanford SPARQ Tool***: Developed by psychologist "Carol D. Ryff," the 42-item Psychological Well-being (PWB) Scale measures six aspects of well-being and happiness: autonomy, environmental mastery, personal growth, positive relations with others, purpose in life, and self-acceptance.

Table 1 Crosstab hypothesis 1

			Yes	No	Total
Industry	Construction worker	Count	27	36	63
		Expected count	21.6	41.4	63.0
	Non-construction worker	Count	11	37	48
		Expected count	16.4	31.6	48.0
Total	Count	38	73	111	
	Expected count	38.0	73.0	111.0	

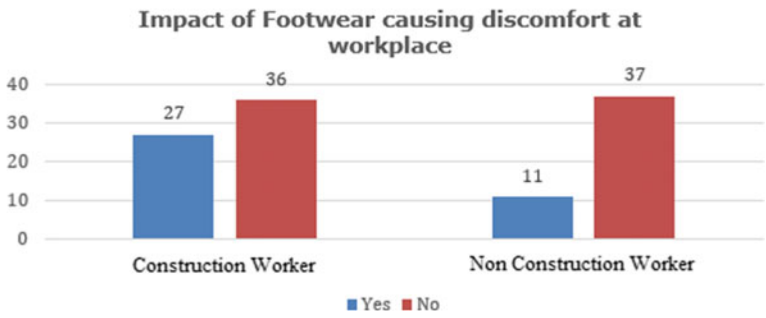

Chart 1 Impact of footwear causing discomfort at workplace

3.1 Data

A customized questionnaire based on WMBWBS and SPARQ Tool were taken to identify our research questions. Hypothesis 1: Following the lockdown, ones socializing habits are influenced by their employment status.

H0: Physical Well-being of construction workers are not influenced by one's choice of footwear.

H1: Physical Well-being of construction workers are influenced by one's choice of footwear.

Crosstab: Are you uncomfortable at construction site due to your footwear? (Table 1 and Chart 1)

4 Results

H1 Analysis and Interpretations. To find this, a survey was conducted where the responses were received about the employment status and their discomfort due to footwear causing well-being at workplace. There are 111 responses received.

Employment status based on industry type were observed as 63 were from construction worker and 48 were non-construction. About the impact of well-being due to footwear, 38 have responded as "Yes" they are uncomfortable due to footwear, 73 have responded as they are comfortable as before. Upon closely observing, it seemed that most of the responses are in favor of being comfortable at work. Thus, a serious question arises as does the discomfort of footwear influences the well-being at work. To find this, responses have been cross tabulated between industry type and discomfort at workplace due to footwear based upon the responses (Table 2).

1. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 16.43.
2. Computed only for a 2 × 2 table $X2(1) = 4.811, p \leq 0.5$
3. The calculated value of Chi-square is 4.811 with degrees of freedom as 1. The Asymptotic Significance (2-Sided) is known as the p value 0.28 which is less than 0.5.
4. In such scenario, the null hypothesis is rejected and the alternate hypothesis is accepted.

Result: Well-being is influenced by one's choice of footwear at the workplace based on employment.

Hypothesis 2.H0: Artificial intelligence has had "NO" impact on adaptability to the new footwear solutions.

H1: Artificial intelligence has an impact on adaptability to the new footwear solutions (Table 3 and Chart 2).

H2: Analysis and Interpretations. To find this, a survey was conducted where the responses were received about the ability to adapt change status and their gender. There are 111 responses received. Total 54 male and 57 female participants shared their views. About their approach to adapt the new footwear solution provided by AI as "Yes", they are able to adapt AI solutions footwears. 20 have responded as they are finding it hard and uncomfortable adapting the footwear solutions advised by AI. Upon closely observing, it seemed that most of the responses are in favor of being comfortable adapting the changes in footwear solutions advised by AI. Thus, a serious question arises as does one's ability to respond to change in footwear solutions by AI was affected by gender? To find this, responses have been cross tabulated between gender and approach toward new normal standards based upon the responses (Table 4).

Table 2 Chi-square test for hypothesis 1

	Value	df	Asymptotic significance (2-sided)	Exact sig. (2-sided)	Exact sig. (1-sided)
Pearson chi-square	4.811a	1	0.028		
N of valid cases	111				

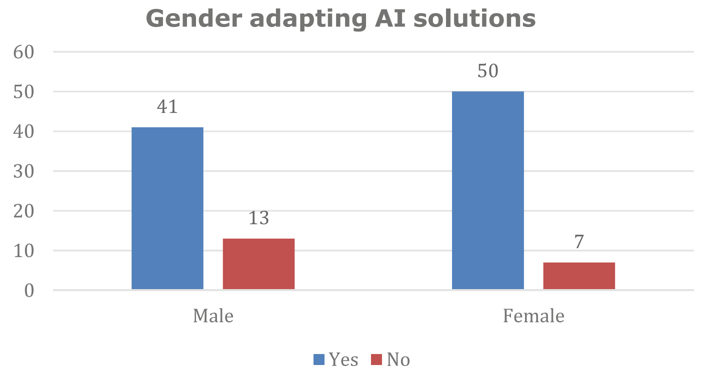

Chart 2 Gender with adapting new normal

Table 3 Crosstab hypothesis 2

	Yes	No	Total		
Gender	Male	Count	41	13	54
		Expected count	44.3	9.7	54.0
	Female	Count	50	7	57
		Expected count	46.7	10.3	57.0
Total	Count	91	20	111	
	Expected count	91.0	20.0	111.0	

Gender * Are you able to adapt the AI solutions to change in footwear?

Table 4 Chi-square test for hypothesis 2

	Value	df	Asymptotic significance (2-sided)	Exact sig. (2-sided)	Exact sig. (1-sided)
Pearson chi-square	2.611a	1	0.106		
N of valid cases	111				

1. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 9.73.
2. Computed only for a 2 × 2 table, $X2(1) = 2.611$, $p \leq 0.5$
3. The calculated value of Chi-square is 2.611 with degrees of freedom as 1. The Asymptotic Significance (2-Sided) is known as the *p* value 0.106 which is less than 0.5.
4. In such scenario, the null hypothesis is rejected and the alternate hypothesis is accepted.

Result: Gender has influenced adaptability to the footwear solutions provided by AI.

5 Conclusion

Construction workers [16], who are at the heart of the issue of occupational health and safety, can use society's image of them as a valuable learning tool in terms of self-criticism, with the end goal of reducing the number of safety accidents and educate them about their well-being. Therefore, cartoons are used to illustrate how society views the duty of workers for the health and safety of their workplace. In any building-related consulting services, such as committee meetings, association meetings, or other gatherings, the use of a cartoon or cartoons within a PowerPoint may help in conveying an idea or emphasizing a certain topic. Cartoon humor can also be used as a tool in any building-related cartoons or comics that are published. Cartoons about the construction industry can be utilized in a wide variety of digital media, such as social media platforms, the websites of businesses and companies, and even email templates, where they can serve as improved visual content to increase the email's overall effect. On addition, cartoons have the potential to serve as a lingua franca for the purpose of occupational health and safety education in international construction projects that use a diverse workforce comprised of migrant employees from multiple countries. Cartoons are a great choice for safety posters and raising awareness about things like the appropriate footwear, head gear, and other items that may be delivered either on-site or at corporate offices and headquarters located elsewhere.

This item emphasizes the welfare of those working in construction. The front line of on-site labor is staffed by craft workers, artisans, technicians, professionals, and managers. Conceptually, it is claimed in this entry that stakeholders need to pay attention to the health and welfare of construction workers. SDG 3's goal to safeguard the health and well-being of all people of all ages is negated if construction workers' health and well-being are not taken into consideration. It is important to address the psychological, physiological, and societal sources of injury and the related impacts that lead to subpar performance at work. Additionally, the business is beginning to have major concerns about mental health problems, such as depression and anxiety. Due to issues with their health, workers are forced to retire early because of the effects of occupational stress at work. Early retirement has ramifications for SDG 3 and beyond when combined with problems associated with an aging workforce in the sector [17]. In this article, the researchers envisioned assessing the health and well-being of real estate construction site workers with ergonomic footwear by communicating with comics and artificial intelligence. The study was conducted from June to August 2022, focusing on how A. I might help in creating a footwear solution for construction site workers and how it can be leveraged by comics to convey the ideas. To gather the data, the researchers used three internationally accepted tools that were validated and reliable. The Warwick–Edinburgh mental well-being scale and the **Stanford** SPARQ tool focused on the impact of A. I on well-being and physiological changes of construction site workers. The researchers also used a self-administered questionnaire, the FCV 19S to access the fear and anxiety of human beings. The study followed the alternative hypothesis that the physical well-being of construction workers is influenced by one choice of footwear and A. It has an impact on adaptability to new footwear solutions. When the compatibility of footwear was assessed among 111 respondents, 27 construction site workers and 11 non-construction site workers were uncomfortable at the construction site due to their footwear, and the rest were comfortable. The data was significantly **analyzed** using the chi-square test. The calculated value was 4.811 with one as the degree of freedom. Since the p value is 0.28, which is less than 0.5 the alternative hypothesis of well-being being influenced by choice of footwear at the workplace based on employment is accepted. When scrutinized for the gender adaptability of AI solutions to change footwear, 54 males and 57 females share their views. Out of 54 males, 41 were able to adopt a footwear solution, whereas out of 57 females, 50 were able to adopt AI solutions. Statistical analysis of the chi-square test revealed a score of 2.611. The p value is 0.106, which is less than 0.5. Thus, the alternative hypothesis of gender has influenced adaptability to the footwear solutions provided by AI is accepted.

The researchers in their study focused on the health and well-being of real estate construction site workers on footwear compatibility and stated that a better AI develop footwear for construction site workers that will have a more positive influence on their health and well-being. The study also stated that the comics can be used to communicate and educate the workers regarding the need for footwear designs and also the safety measures that have to be taken for the better and healthy well-being of a person.

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Chapter 37
Unfolding the Emerging Trends in Non-performing Assets with Special Reference to the Energy Sector in Banking Industry

Pooja Sharma, Vikas Sharma, Kshitiz Jangir, Munish Gupta, and Nitin Pathak

Abstract In this comprehensive study, the focus is on the increasing number of NPA's in the private and public sector banks with special reference to energy sector in India. This study reviews 202 research studies published till December 2021. The study has used a bibliometric and network analysis tool to identify the most cited studies, leading journals, and authors. The thematic structure of research on NPA's till 2021 has been inferred using the co-citation and bibliometric-coupling analyses in this review paper. With the help of Scopus database, the results have been summarized covering the broad topics of profitability, India, commercial banks, private banks, credit risk, risk management, and capital adequacy.

Keywords Non-performing assets · Banks · Efficiency · Energy sector

1 Introduction

The banking sector is very important for the economic prosperity for any country. COVID-19, which has shaken the nation in early 2020, has negatively impacted the growth of many industries. The banking industry was one of the sectors that was negatively affected. The pandemic is having a negative impact on the Indian banking system, which is already grappling with growing NPAs [1]. NPAs are assets that no longer produce returns to the bank. If a borrower intentionally misses a payment or is unable to pay back a due loan amount because of any kind of financial constraints, the result is bad assets (NPA). For financial institutions, this means that under no circumstances will you be able to recover all or part of your loan. NPA is a measure of a bank's overall performance in converting deposits into loans and repaying its debts [2]. Failure to repay or partially repay a loan by reduction in interest charged will affect the bank's financials [3].

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Energy sector of India, specifically thermal power generation sector, accounts for more than $50 billion in standard assets. Numerous factors, such as, availability of finance, supply of fuel, legal environment and even policies of government in power, play role in turning these standard assets as nonstandard or even loss assets. Energy sector in India is underperforming as only around 70% of total requirement of power if fulfilled by thermal sector.

Under the baseline scenario, the ratio of gross nonperforming assets (NPAs) is expected to rise to 15.2% by March 2021. On March 27, 2020, the RBI announced the COVID-19 regulatory package to help the economy, which included lowering the CRR to 100 basis points and the repo rate to 75 basis points, as well as a three-month lending moratorium and other price cuts and regulatory relaxation [4]. The effectiveness of these efforts for financial system improvement will undoubtedly put a lot of pressure on the banking industry [5].

2 Research Methodology

This study has used the systematic approach for the coverage of literature in terms of objectivity as well as comprehensive coverage, not only does a structured review help in mapping of present situation but also helps in outlining the potential research gaps in a specific area of study [6]. Bibliometric analysis has been used for this study which focuses on the information available areas as provided by bibliographic information [7]. Under performance analysis, publication-related metrics (total publications), citation-related metrics (total citations), bibliographic coupling, co-authorship analysis, and co-citation analysis have been used [8].

The most prolific countries, universities, authors, journals, and research articles were identified from the Scopus database for the bibliometric analysis. The aim of this paper is to uncover the evaluation of NPA in banking sector in terms of RQ1, RQ2, RQ3, and RQ4, i.e., most influential countries, universities, authors, and journals having publication in this sector.

2.1 Objectives of the Study

The study was conducted with the purpose to identify and explore the literature review of NPA in banks in terms of their impact on profitability, in comparison with NPA between public and private banks, industrial and agricultural sectors, and counter measures taken to minimize NPAs in banks in connection with focus on the following:

RQ1: Determine the total articles, research trends, and their distribution throughout, i.e., the contribution made by researchers from various nations in the topic of NPA in the banking business.

Table 1 Criteria of search and article selection

Filtering criteria	Reject	Accept
Criteria for search		
Search date: December 21, 2021		
Terms searched: "non-performing assets" and "bank***"		262
Area criteria: "business, management, and accounting," "economics, econometrics and finance," "social sciences," "multidisciplinary"	47	215
Type of document: "articles" and "reviews"	13	202
Language: English	10	192

RQ2: Determine which journals have the most NPA publications and which have the highest citation impact in this field.

RQ3: Who are the most cited pioneer writers in the topic of NPAs in the banking industry?

RQ4: What are the associated topic words and dominant sectors in the banking industry's NPAs?

We have used electronic database covering the inclusion of major relevant studies. The present study uses a popular research tool, i.e., Scopus bibliometric database with several academic resources on the topic of finance. To overcome the chances of omission of a relevant research study, we have determined the relevant keywords which is related to stock option, index option, and open interest. To selecting relevant research studies, the reviewer has used specific keywords related to the area of study in two groups under the titles, keywords, and abstracts of the documents from the Scopus website.

Note(s): Table 1 shows the method used in generation of the final group of (202) articles. The search phrases developed are because of during a thinking session with the other authors

We found 262 research records in the initial search. The search was then filtered using the subject areas, document type, and language.

From 2001 to the December 2021, 262 documents are related to the topic. These were research articles, review papers, conference papers, chapters, book, conference review, and few were from other sources. Out of these, only 202 were articles and review papers and 192 out of them were in English language only [9].

3 Measurement

For this bibliometric study, VOS viewer software has been used, because it analyzes relationship between various authors, co-authorship, coordination among different institutions, countries and keywords [10].

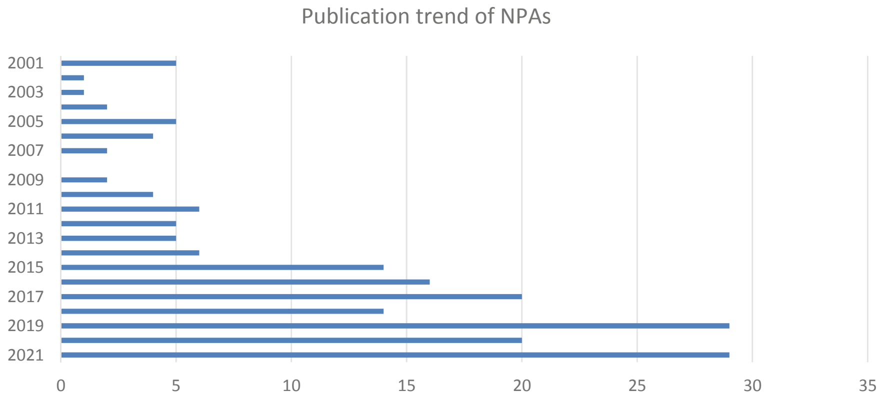

Fig. 1 Count of articles/papers on NPA in banks in Scopus from 2001 until 2021

3.1 Findings

The findings are explained in context of above stated research questions.

Figure 1 provides interesting information about the concept of bad assets in banks. The number of publications fluctuated between 2001 and 2021, but in 2015, 2016, 2017, 2019 and 2021, the idea caught too much attention in the eyes of researchers. Out of 190 publications, 142 were published during these years. This increasing trend in the charts indicates that NPA is still an evolving concept due to the sudden increase in literature [11].

The above heat map of Fig. 2 represents that most of the knowledge is generated in India, related to the topic of NPA (150), USA (11), Australia (6), Malaysia (4), UK (4), and Indonesia (3). Out of 190 documents, these countries produced 178 documents which 93.6% of the total documents. India dominates in with 150 documents, followed by USA (11), Australia (6), Malaysia (4), UK (4) documents. Belize, Canada, China, France, South Africa, and Tanzania share only two documents each. The developing nations generated 101 papers, accounting for 68% of all documents written.

3.2 Analysis Showing Influential Journals

The 15 most widely referenced journals have accepted and published 82 papers, accounting for 43% of the total number of articles. The published articles in these journals provided more information about the academic influence of NPA. Table 2 displays the journal rankings in terms of citation impact [12]. The notion of NPA in

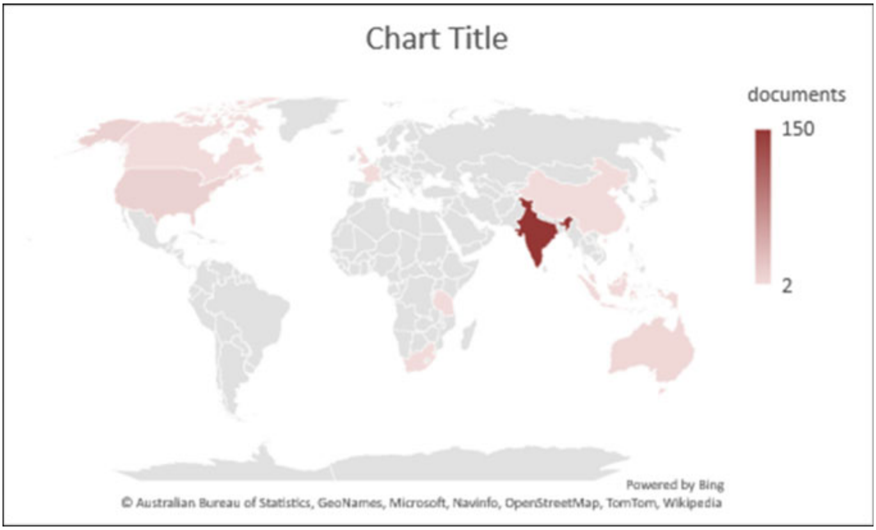

Fig. 2 Worldwide distribution of research related to NPA's in developed and developing countries as per Scopus database

banks appears to have been presented in several periodicals, while most of the business and management literature has been written. Table 3 details the most frequently mentioned journals in the topic of NPA in banks.

On the basis of research articles in Scopus database, Singh S., is a dominant researcher in the subject of NPA in banks till now. His contributions to the topic of non-performing assets in banks are mostly concerned with the determinants of non-performing assets in banks [13]. After Singh S., the writers who dominate the topic literature include Swaminarayan A., Ayyappan S., Kashiramka S., Ramachandran A., and Rizvi N.U. (Table 4).

3.3 Stressed/Non-performing Assets in Electricity Sector

A report titled "Stressed/Non-Performing Assets in the Electricity Sector" was submitted by the Standing Committee on Energy on March 7, 2018, (Chair: Dr. KambhampatiHaribabu). The Committee took notice of the double balance sheet concern highlighted in the Economic Survey 2016–17, which has been linked to stressed assets. Financial institutions are losing money because businesses are unable to repay their loans within the agreed upon time frame (90 days as per the RBI). When this happens, the loans are considered NPAs, and the bank must take action to fix the situation (such as rectification, restructuring, and recovery). As a result, both the businesses and the banks are hesitant to invest in new capabilities due to the presence of bad loans. For example, the thermal power industry is largely responsible

Table 2 Highly cited journals in field of NPAs

Source	Documents	Citations	2001–2010	2010–till date
Banks and Bank Systems	3	3	0	3
Economic and Political Weekly	14	44	1	13
Finance India	4	0	0	4
Global Business Review	6	32	1	5
IIMB Management Review	3	25	0	3
Indian Journal of Finance	15	43	1	14
International Journal of Applied Business and Economic Research	12	5	0	12
International Journal of Economic Research	3	2	0	3
International Journal of Finance and Economics	3	14	0	3
International Journal of Recent Technology and Engineering	3	0	0	3
International Journal of Scientific and Technology Research	8	0	0	8
Journal of Banking and Finance	3	45	1	1
Journal of Emerging Market Finance	4	26	1	3
Journal of Quantitative Economics	3	4	2	1
Managerial Finance	3	45	1	2
Margin	3	4	0	3
Vikalpa	4	45	4	0
Vision	3	2	0	3

for the increase in NPAs in recent years. Non-performing assets (NPAs) and stressed projects both fall within this category [14].

NPAs in the electrical industry were Rs 37,941 crore as of June 2017, indicating that there are a significant number of stressed assets in this market. The Committee reviewed 34 strained thermal power plants. The output of these is 40 GW. Some of the issues that have caused these thermal power projects to struggle financially are as follows: (i) a lack of fuel (coal), (ii) a deficiency in power purchase agreements (PPAs) from states, (iii) the promoter's inability to infuse equity and working capital, (iv) tariff-related disputes, (v) bank-related issues, and (vi) delays in project implementation leading to cost overruns [15].

One of the biggest bottlenecks in the supply chain of the energy industry is the transmission and distribution of electricity. Long-term power purchase agreements, outdated infrastructure, and inefficient operations are only a few of the problems that contribute to the widespread financial losses experienced by distribution utilities. Due to these increasing losses, utilities are sometimes unable to invest in upgrades to the power grid or in preparation for a more widespread adoption of renewable energy

Table 3 Top 12 authors, institutions, and countries contributing in literature on NPA in banks ranked by Scopus

TC	Author	TP	TC	Institution	TP	TC	Country	TP
65	Singh S.	5	0	Amity Business School, Amity University Uttar Pradesh, Lucknow Campus, Malhaur, Lucknow, Uttar Pradesh, 226 010, India	2	476	India	150
27	Samantaraya A.	2	3	Amity University, Noida, India	2	76	USA	11
24	Ayyappan S.	2	4	Jawaharlal Nehru University, New Delhi, India	2	71	Australia	6
24	Kashiramka S.	3	0	Department of Management Studies, Anna University of Madurai, India	2	12	Malaysia	4
24	Ramachandran A.	2	7	EPW Research Foundation, India	2	23	UK	4
24	Rizvi N. U.	3	6	Faculty of Management Studies, Sathyabama University, Chennai, 600 119, India	2	1	Indonesia	3
24	Thiagarajan S.	2	24	Faculty of Management, University of Belize, Belize	2	24	Belize	2
22	Basu S.	3	19	Indira Gandhi Institute of Development Research, Mumbai, India	3	26	Canada	2
21	Bawa J. K.	2	0	KJSIMSR, Mumbai, India	2	0	China	2
20	Cole R. A.	2	5	National Institute of Bank Management, Pune, India	2	16	France	2
19	Bardhan S.	2	0	School of Management Studies, Bharath University, Chennai, India	2	14	South Africa	2

(continued)

Table 3 (continued)

TC	Author	TP	TC	Institution	TP	TC	Country	TP
19	Mukherjee V.	2	24	SNR Sons College, Coimbatore, India	2	29	Tanzania	2

Note TC is total citations. TP is total publications

Table 4 Top articles on NPA in Banking Industry

Author	Title	TC
Singh S., Sidhu J., Joshi M., Kansal M.	Measuring Intellectual Capital Performance of Indian Banks: A Public And Private Sector Comparison	38
Mayur M., Saravanan P.	Performance Implications of Board Size, Composition and Activity: Empirical Evidence from the Indian Banking Sector	26
Sathye M.	Privatization, Performance, and Efficiency: A Study of Indian Banks	26
Kanungo S., Sharma S., Jain P. K.	Evaluation of a Decision Support System for Credit Management Decisions	21
Meeker L. G., Gray L.	A Note on Non-performing Loans as an Indicator of Asset Quality	21
Thiagarajan S., Ayyappan S., Ramachandran A.	Credit Risk Determinants of Public and Private Sector Banks in India	21
Bawa J. K., Goyal V., Mitra S. K., Basu S.	An Analysis of NPAS of Indian Banks: Using a Comprehensive Framework of 31 Financial Ratios	19
Seenaiah K., Rath B. N., Samantaraya A.	Determinants of Bank Profitability in the Post-Reform Period: Evidence from India	17
Saha P., Bose I., Mahanti A.	A Knowledge Based Scheme for Risk Assessment in Loan Processing by Banks	17
Otchere I.	Competitive and Value Effects of Bank Privatization in Developed Countries	17
MvulaChijoriga M.	Application of Multiple Discriminant Analysis (MDA) as a Credit Scoring and Risk Assessment Model	16
Mohapatra S., Jena S. K., Mitra A., Tiwari A. K.	Intellectual Capital and Firm Performance: Evidence from Indian Banking Sector	16
Bardhan S., Mukherjee V.	Bank-Specific Determinants of Nonperforming Assets of Indian Banks	15
MostakAhamed M., Mallick S. K.	House of Restructured Assets: How Do They Affect Bank Risk in an Emerging Market?	14
Chernykh L., Cole R. A.	How Should We Measure Bank Capital Adequacy for Triggering Prompt Corrective Action? A (Simple) Proposal	13

Note(s) TC is total citations

sources. When power distribution companies don't pay their power generators, it may have a disastrous effect on the economy since it threatens the financial security of all power generators and lenders. Distribution systems in several states have seen significant shifts since then. Competition from alternative energy sources and a shift in policy away from coal has created the additional difficulty of a stranded asset for the coal industry.

Stranded renewable assets have a major effect on the economy. Bank non-performing assets (NPA) are a useful economic indicator since they impair liquidity and raise banks' default risk. In addition, it shifts resources away from alternative energy sources. The government and RBI took several measures to deal with the stressed assets in the banking industry, including dealing with the issue of non-performing loans. To implement comprehensive metering using prepaid and smart meters while being attentive against cyber security issues, several discoms will need to improve their billing efficiency through improved metering. Establishing coordinated action between nations and different discoms can help put people at ease. Prepaid metering has the potential to decrease instances of theft while also increasing revenue. Not being able to be paid is a major factor in the local action, as is the failure of the state government and its agencies and different municipal entities to pay their bills. Since discoms have already committed to pricey PPAs over extended periods of time, they shouldn't enter any further long-term thermal PPAs while the market continues to supply cheap electricity.

3.4 Top Words in NPA in Banks and Emerging Themes in NPA in Banks

Figure 3 depicts the most often appearing subjects in the field of NPA in the banking sector based on network visualization mode in VOS viewer [8]. There are certain big nodes that reflect the primary concepts or topics that form this field: profitability, India, commercial banks, private banks, credit risk, risk management, and capital adequacy. However, it is noteworthy that certain topics of development phase and are creating more attention despite the fact that the node size is not very huge (Fig. 3). Risk management, asset quality, efficiency, capital sufficiency, and data envelopment analysis are among the subjects covered [16].

Based upon the visualization made in VOS viewer that few nodes are larger in size as NPA, profitability, liquidity, financial crisis, and India has bigger nodes, we can say maximum work has been done directly on these but there are many small nodes as well like panel data regression, corporate governance, efficiency, data envelopment analysis, financial crisis, asset quality, performance, and credit risk, they are topics which are in still developing stage. They are niche area related to NPAs [9].

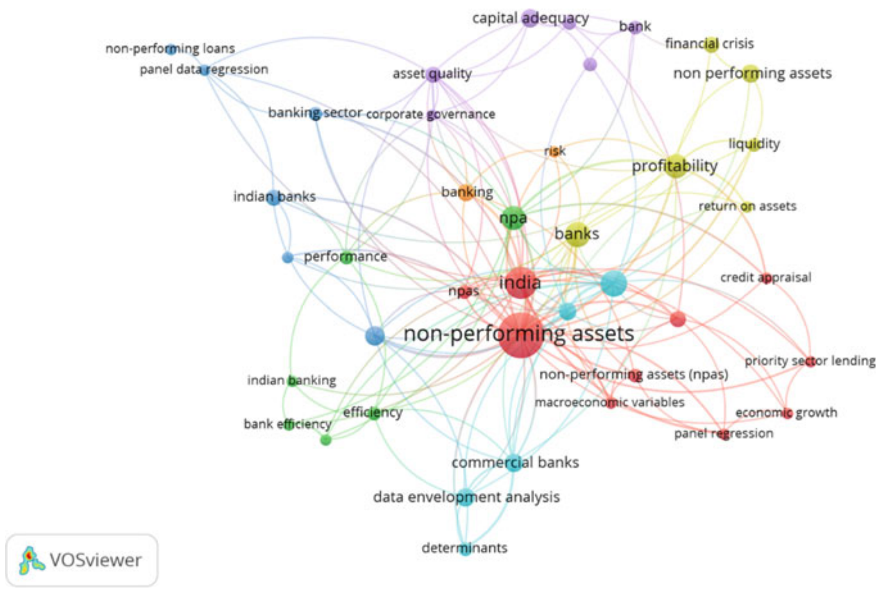

Fig. 3 Most frequent variables

4 Discussion

With the help of this paper, an attempt has been made to put some light on bibliometric analysis of NPA's in banking industries research articles between 2001 and 2021. This paper provides comprehensive overview of studies, trends, and popular topics related to this area. Basically, this study provides direction to those research scholars who are interested in NPA's. In addition to this, this paper provides the past and present scenario information as well as throw some light on future advancements related to NPAs to aid in development of theoretical and conceptual modeling.

5 Limitations

First limitation of study is that it relies only Scopus database. Researchers who wish to study in this area may consider database of Web of science along with Scopus database [17]. Another limitation of study is that this study only focuses upon the research papers and articles from journals. It excludes other forms of literature such as conference proceedings, book chapters, working papers, and various reports published by different organizations. Adding on other form of literatures may provide additional insight [18].

6 Conclusion

Today, the banking sector is one of the largest service industries in India. Rising NPA can negatively impact a bank's earnings and lending capacity. As defaults increase, banks will need to recapitalize. In other words, more money needs to be put into the bank to keep it going. In addition to recapitalization, proper credit risk management helps banks reduce NPA and enable the development of the banking industry. It is very important for bankers to avoid the formation of new bad assets (NPAs) [19].

The present study has tried to find current themes and trends in non-performing assets in banking industries with the help of evaluative and relationship bibliometric techniques. NPA is a topic which is of utmost importance for the people from academics as well as industries. This topic has gained massive growth in past few years. There is heterogeneity in number of studies conducted in private and public sector banks; therefore, studies may be conducted in NPA of co-operative and foreign banks and also identify the level of NPA at each sector like priority and non-priority, small-scale industries, agriculture, infrastructure, etc. [20].

NPAs have grown during the previous decade. Various studies have shown that private sector banks manage NPAs better than public sector banks. NPAs have an impact on bank profitability by limiting lending activity. This, in turn, will have an impact on development initiatives. In certain circumstances, NPAs are the result of the government's incorrect debt forgiveness policy. In India, the NPA problem is exacerbated by lending to non-priority and sensitive industries like as personal loans and real estate loans.

7 Future Implication

This study will help researchers working in domain of NPA in banking industries as it outlines the knowledge framework of non-performing assets. This knowledge framework will help researchers to understand the evolution of NPAs in banking industries. Second this study highlights keywords and themes which are popular and emerging in this area.

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Chapter 38
Analyse the Problems and Prospects of SDGs in India with Future Technology

Puja Sharma, Vandana Aggarwal, Rumit Kaur, and Priya Saroj

Abstract All seventeen Sustainable Development Goals (SDGs) emphasize the overall development of nations pointing on environmental, social, and economic concerns with respect to future technology. India has implemented various programmes and schemes to achieve these goals; however, India ranked at 120th position in Sustainable Development Index 2021 (Leal Filho et al. in Int J Sust Dev World 26:179–219, 2019). Therefore, the present paper tries to analyse a few indicators that act as an impendent in accomplishing SDGs. The first part of the paper reflects the backdrop of SDGs. In the next part, objectives and research methodology has been described. The paper is primarily based on secondary data to understand the existing gaps. Therefore, a few of the indicators on the socio-economic aspects have been taken for the critical appraisal of SDGs. Lastly, a few suggestions have been made for the better execution of the efforts made by the Indian government to achieve the national target value for 2030 (Kamau et al. in Transforming multilateral diplomacy: the inside story of the sustainable development goals. Routledge, 2018). Digital technology is evolving everywhere nowadays with full zeal which assures blooming progress. So, we can understand that technology plays significant role in achieving our goals.

Keywords SDGs · India · Indicators · Socio-economic · Problems · Future technology

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1 Introduction

Technology has transformed the world. Countless studies show the disparity in wealth, and the influence of technology has built a gap between countries. The UN publicized all tenable Goals (SDGs), also known as Universal Goals, in the year 2015. These goals importantly address various issues such as poverty and global warming. Since these goals offer a comprehensive agenda for the better future, we can better understand them through understanding our past. The world leaders set a commitment in the form of SDGs to visualize an end of poverty, hunger, disease, and gender injustice, in which all forms of life can flourish. International society in 2015 proposed a bold universal set of seventeen Goals (refer to Table 1) and 169 targets to be attained by 2030.

The Indian reign is strongly dedicated to towards 2030 agenda, embracing the set goals. In 2015, sustainable development-related conference was organized in India; the Prime Minister strongly affirmed India's allegiance to Agenda by 2030 and the SDGs. He cited that we stay in "an age of unprecedented prosperity, but also unspeakable deprivation around the world" and intend that "much of India's development agenda is mirrored in the Sustainable Development Goals" (SDG India Index: 2018, Baseline report). In order to get Sustainable Development Goals, numerous initiatives are made by centre and state governments; for instance, to end poverty schemes have been implemented such as, MGNREGA, NRLM, and Pradhan Mantri Dhan Yojana. Likewise, the government has made various other efforts to obtain the other

Table 1 17 Sustainable Development Goals (SDGs)

Goal No.-1	End all poverty
Goal No.-2	Cease all hunger and accomplish full food security
Goal No.-3	Affirm healthy life and promote well-being
Goal No.-4	Provide equitable standard education
Goal No.-5	Attain full gender equality and empowering every women
Goal No.-6	Ensure continuous water management
Goal No.-7	Affordable and modern energy for all
Goal No.-8	Recommend employment productivity with economic growth
Goal No.-9	Build and promote sustainable industries, innovation, and infrastructure
Goal No.-10	Reduced inequality within and outside the countries
Goal No.-11	Make sustainable cities and inclusive human settlement
Goal No.-12	Responsible consumption and production
Goal No.-13	Ensure combat climate action
Goal No.-14	Life below subaqueous
Goal No.-15	Protect and promote land with full survival of life
Goal No.-16	Promote peaceful and inclusive societies
Goal No.-17	Promote partnership to achieve the goal

SDGs. The SDGs work by logic and consciousness to help countries all over the world, to pursue the goal of a good life for people to come [1].

This become clear for all countries to work upon accordingly with reference to conditions and hardship at large.

However, after consistent efforts and strong commitment, India ranked at 120th position in Sustainable Development Index 2021 behind many South Asian countries, for instance, Bhutan, Sri Lanka, Nepal, and Bangladesh. Further, various concern areas have been elaborated in the report, for example, India's lagging in eradicating hunger, quality education and gender equality. The present paper will try to analyse a few of the SGD indicators faced by India to accomplish the goals related to socio-economic aspects.

2 Objectives

In this study, only six goals related to socio-economic aspects were selected to assess the betterment of India towards 17 SDG goals. On the basis of the same objectives have been formulated as follows:

(1) To elicit the problematic socio-economic areas which put hindrance in achieving the SDGs.
(2) To put forth suggestions in order to give a better vision for accomplishing these goals by 2030.

3 Methodology

In this study, indicators related to socio-economic goals were selected to assess the headway of India towards Sustainable Development Goals. NITI Aayog (the National Institution for Transforming) is the main policy think tank of the Government. It has been given the task of analysing the SDGs' performance in various states and UTs.

Therefore, indicators have been taken from the NITI Aayog indicators index, and a further few of the indicators are prepared by reviewing the literature on SDGs. To analyse the problems faced in achieving goals, efforts have been made to gather the data from various sources such as the Census of India, Central Statistical Office, National Crime Records Bureau, and National Family Health Survey (Table 2).

Table 2 Indicators taken for the study

Indicators	Poverty estimate, percentage of stunned children, percentage of anaemic women, good health and well-being of individual, maternal mortality, rice, wheat and coarse cereals produced annually per unit area, sex ratio, crime against women, labour force participation, unemployment rate, net enrolment ratio, gross enrolment ratio, and adult literacy

Table 3 Poverty estimate during 1993–94 to 2011–12

Year	Poverty ratio (%)		
	Rural areas	Urban areas	Sum total
1993–94	50.1	31.8	45.3
2004–05	41.8	25.7	37.2
2009–10	33.8	20.9	29.8
2011–12	25.7	13.7	21.9

Source Computed from report by Planning Commission (1993–2012)
(Tendulkar Methodology) [3]

4 Goal 1: No Poverty: Ending All Types of Poverty in Different Conditions

The Indian government has commenced vital development to tackle swear poverty, headway access to basic services, and generate gainful employment. Multiple programmes have been initiated, Bima Yojana and so on [2] (Table 3).

The table indicates the poverty estimates from 1993–94 to 2011–12 using the Tendulkar methodology. The number of poor in 1993–94 accounts for 45.3% of the total Indian population. Further, a significant rural–urban gap exists during 1993–94 to 2011–12. However, the rate of poverty has declined over the years. A developing country like India still has a high rate of poverty, which acts as an impediment to the country's socio-economic development.

5 Goal 2: End All Hunger and Achieve Full Food Security

In developing countries, extreme hunger and malnutrition are huge barriers to accomplish goal 2, i.e. zero hunger. A few indicators have been taken to analyse the zero hunger goal, such as the percentage of stunted, underweight, and anaemia. Around 35.5% of children under the age of 5 years are stunted, and approximately 32.1% are underweight. The UN's Food and Agriculture Organization (FAO) estimate is that around 195 million people are hungry. Furthermore, an evaluation performed through India Spends indicates that to obtain 0 starvation through 2030, India will need to carry 48,370 human beings out of starvation each day. The statistics depicts that with those facts it might be hard for India to obtain SDG 2 through the 12 months 2030. Therefore, the government must make sincere efforts to achieve this goal [4] (Table 4).

The productive power of the country largely depends on children's health conditions and food security in the country. Many studies have highlighted that compared to those with normal BMI, persons with low BMI are more susceptible to tuberculosis. Furthermore, cases of anaemia in children and women increased during the

Table 4 Percentage of people reflecting lack of nutrition

Children (under 5 years)				BMI below normal		Anaemic	
Stunted	Wasted	Underweight	Anaemic (6–59 Months)	Women	Men	Women	Men
35.5	19.3	32.1	67.1	18.7	16.2	57.0	25.0

Source NFHS, 5

Table 5 National targets for zero hunger

Ratio of rural families included below public distribution machine to rural families in which month-to-month earnings of maximum incomes member is much less than Rs. 5000	One rural family is included below PDS for each low-earnings rural family
Rice, wheat, and coarse cereals produced yearly according to unit area (kg) country wide goal 2030: 5018.forty four	2509 annual agricultural productiveness of wheat, rice, and coarse cereals

Source SDG India Index: Baseline report, 2018 [6]

past five years, according to the most recent National Family Health Survey (NFHS). Many factors are responsible for malnutrition; among these, poverty, unemployment, ignorance, and a lack of education are all serious issues. Data also elicit that 57.0% of women in India are anaemic, and 18.7% are BMI below normal. 32.1% of the children under 5 are underweight [5]. Again, there is no dearth of policies and schemes; however, there are multiple gaps and challenges in the Indian setting that obstruct us from achieving SDGs goals (Table 5).

In addition to this, different indications such as ratio of rural households included beneath public distribution machine to rural households ought to solely one rural family included below PDS. Furthermore, in order to acquire the goal of producing cereals per unit place is 5018.44 however India is producing only 2509 annually.

6 Goal 3: Good Health and Well-Being: Ensure Healthy Lives and Promote Well-Being for All at All Ages

See Table 6.

It is obvious from the statistics that the toddler mortality charge has decreased from 78.5 to 35.2. Likewise, toddler mortality, neonatal mortality, and Beneath 5-yr mortality have declined. However, the dedication for 2030 is to stop preventable deaths of newborns and kids Beneath 5 years of age. It aimed towards lowering neonatal mortality to at the least as little as 12 in line with 1000 stay births. Further, it's far aimed to lessen Beneath-five mortality to at the least 25 in line with 1000 stay births [7].

Table 6 Infant, Neonatal, and under-five mortality rate in India

	Infant mortality rate (IMR)	Neonatal mortality rate (NNMR	Under-five mortality rate (U5MR)
NFHS 1 1992–93	78.5	-	109.3
NFHS 2 1998–99	67.6	43.4	94.9
NFHS 3 (2005–06)	57.0	39.0	74.3
NFHS 4 (2015–16)	40.7	29.5	49.7
NFHS 5 (2019–21)	35.2	24.9	41.9
Computed in NFHS data			

Source NFHS-5

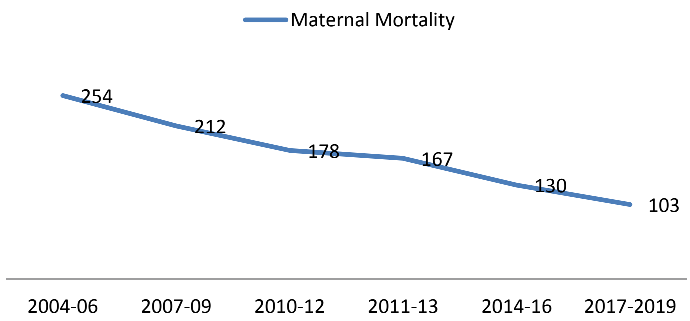

Fig. 1 Maternal Mortality rate over the years. *Source* NFHS 2004–2019

(Govt. of India, SDG retrieved from https://ggiindia.in/goal-3-good-health-and-well-being/) (Fig. 1).

Several important programmes have been rolled out under the ICDS the National Rural Health Mission and the Reproductive and Child Health (RCH) programme (NRHM). However, maternal mortality rate over the years elicits that due to better healthcare facilities, MMR is improving slowly. It has come down to 103 from 254. India's gift MMR is below the Millennium Development thing (MDG) target, i.e. below seventy by 2030 additionally to the present, issue three conjointly supposed to scale back one-third unseasonable mortality from non-transmissible conditions through forestallment and treatment. Asian country is insulation during this space too as regarding sixty three of deaths area unit calculable due to non-communicable conditions.

7 Goal 4: Ensure Equitable Quality Education

India has taken several steps to achieve universalization of primary and secondary education. Further quality education in India is one of the utmost concerns. SDG

4 on education emphasizes on various aspects such as access, equity, and quality in education. It is apparent from the table that India is performing low in many indicators due to lack of access and poor-quality education. The table also indicates that unemployment among males and females is high, i.e. 63.5. Therefore, to achieve the national targets, effective measures must be undertaken (Fig. 2; Table 7).

Further enrolments were analysed to understand the gaps. Data reflect that school enrolment has increased in all levels above primary, i.e. upper primary, secondary, and higher secondary. This kind of increase reflects an improvement in the ability of the system to retain more and more children in the system of school education. However, the mission to achieve the national target for the year 2030 is still far from reach; hence, merely schemes cannot increase the rate of enrolment and literacy. Constant efforts must be made to understand their problems at school and the official level. Thus, it is suggested that research is needed to understand the socio-cultural factors that act as an impediment from time to time.

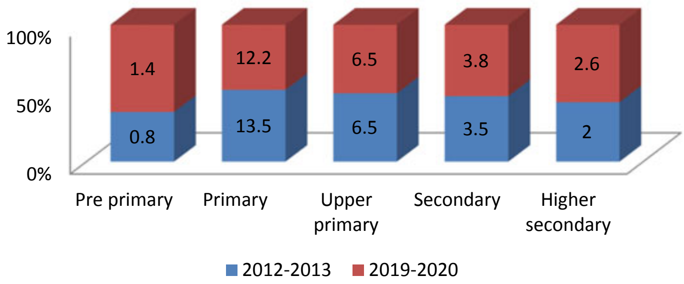

Fig. 2 School enrolment (in crore), India, 2012–13, 2018–19, and 2019–20

Table 7 Indicator for SDG India

Indicator for SDG India	National target value for 2030	Current situation (as on 2017–18) [8]
Adjusted Internet enrolment ratio at elementary (magnificence one to eight) and secondary (magnificence nine to ten) faculty	100	75.82
Gross enrolment ratio (GER) for better training	43	25.8
Average unemployment fee in step with one thousand humans for ladies and men	14.8	63.54
Adult literacy rate	100	70.5

Source KPMG report Education Quality of Education in India, 2019 [8]

8 Goal 5: Gender Equality: Empowering Women

Gender inequality is a crucial social issue that impedes in achieving SDG goals. There are various forms of gender inequality in India, and the most pervasive is the low sex ratio in India. Census data reflect that there has been a lesser number of women in India. Many states in India have recorded low sex ratio and child sex ratio. It is apparent from the figure that India's sex ratio has been increasing over the last two decades. However, many states practise female feticide leading to a low sex ratio in various states such as Punjab and Haryana (Figs. 3 and 4).

Sustainable Development Goal five aims to eliminate discrimination and violence against ladies publicly and personal spheres. Further, the prime minister of Asian nation has created numerous initiatives like Beti Bachao and Beti Padhao to regulate the adverse sex magnitude relation and provide equal educational opportunities for girls in India. To minimize VAW, One-Stop Centres have been set up in every state. Nonetheless, crime against women is increasing at an alarming rate. The data above reflect that crime against women is very high, and cases of sexual harassment, rape, are increasing at alarming rate. Therefore, stringent actions must be taken by the government to control CAW in India.

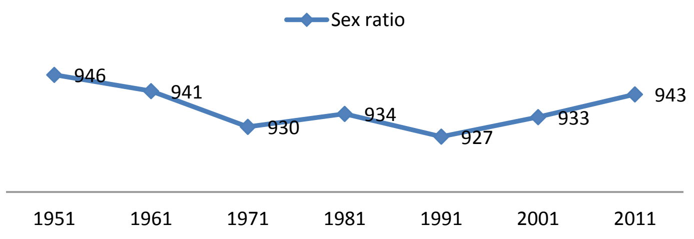

Fig. 3 Sex ratio over the years

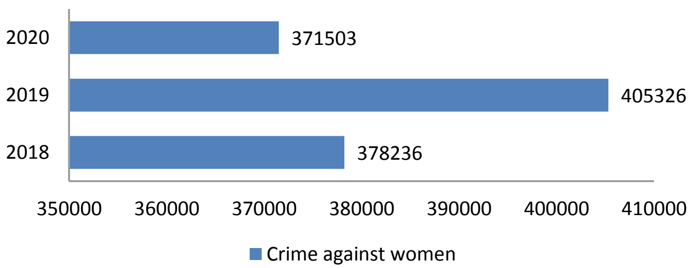

Fig. 4 Crime against Women (IPC + SLL)—2018–2020

9 Goal 8: Advocate Good Economic Growth and Productive Employment Outcomes

The basic aim of this goal is to support decent work and economic growth in the country. SDGs goals are interlinked with each other, for instance, if India wants to achieve the goal of zero hunger and poverty elimination only possible through stable and well-paid jobs. Further, it is also pertinent that working conditions must be safe and sustainable. The ILO estimates that due to activity accidents and work-related diseases, almost 2.8 million employees die each year. Non-fatal injuries are calculable to have an effect on 374 million employees annually. These injuries even have an enormous impact on workers' earning capacity in the long term [9]. To meet this target, the government has started several programmes to generate employment opportunities, enhance skill development, and accelerate economic growth. Some programmes include—Prime Minister's Employment Generation Programme (PMEGP), Start-up India, Skill India, the Pradhan Mantri Kaushal Vikas Yojana, etc., [10]. Thus, to understand the problem, data was collated from secondary sources, and it came out that labour force participation has been decreasing over the years in rural and urban areas. It has come down from 449 to 406 in urban areas. Furthermore, labour force participation among women has declined further, raising questions about the attainment of decent work and India's economic growth. The latest data show that the labour force participation rate varies in a rural and urban settings (Figs. 5 and 6; Table 8).

Unemployment is another challenge faced by the youth in India. Regular employment is essential for the smooth running of the nation; however, 7.9% of the people are unemployed in urban areas and 7% in rural areas. This gap widens in terms of gender as the unemployment rate is higher among women, i.e. 12.8%.

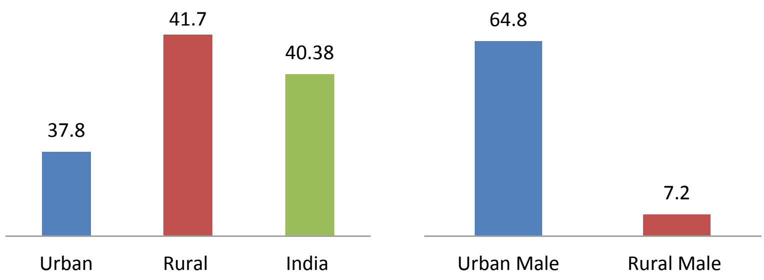

Fig. 5 Labour Participation Rate (LPR) (%)

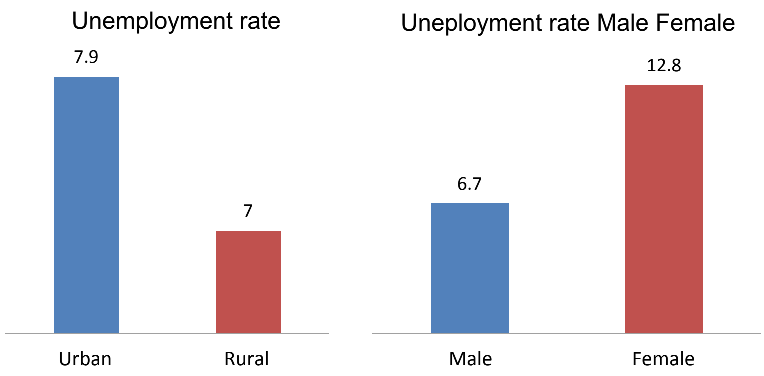

Fig. 6 Unemployment rate (India)

Table 8 Labour force participation

Rural overall				
1993–94	1999–00	2004–05	2009–10	2011–12
449	**423**	**446**	**414**	**406**
Urban overall				
1993–94	1999–00	2004–05	2009–10	2011–12
363	**354**	**382**	**362**	**367**

Bold numbers shows the number of forced labour participation in rural and urban areas with specific years for example 1993–94 is 449 in 1999–2000 is 423 in rural areas and 1993–94 is 363 in 1999–2000 is 354 in urban areas and so on

10 Role of Technology in Bringing SDG

Technology development plays a vital function in accomplishing SDG goals through improving the efficiency and effectiveness of recent and more sustainable methods of development. The creation of recent technologies that foster research and stimulate innovation is for that reason required. Those techniques can be boosted by using strengthened expertise sharing and collaboration amongst stake holders in each countrywide and worldwide contexts. We are quickly coming into a decade of movement from 2020 to 2030 [11]. Ambitions and plans need to grow to be truth. Financial setup that governments around the world have signed the maximum amount as would need radical transformation of every space. Transformative modification and turbulent innovation throughout all sectors of our economy is needed. However, this can be to boot what we have a tendency to personalities do nicely and have achieved frequently before.

11 Conclusion and Recommendations

Data for all the aspects reflect that India is either stagnant or lagging in achieving SDGs. Thus, there is an urgent requirement to provide infrastructure and services to help accomplish these goals by 2030. First and foremost, the indicators must be universally applicable because India needs to consider our national realities. India is a heterogeneous country which has many regional diversities. For instance, north India is patriarchal in nature while in south in various parts one can observe matriarchal form of society hence, sex ratio, and crime against women is better in terms of north. Technological optimism does now no longer get away the want for essential social alternate and a shift in priorities. That turned into the error many with inside the Appropriate Technology Movement made. It takes extra than the life of suitable or smooth technology to make sure their huge adoption. Further, schemes made for the attainment of SDGs must be implemented properly, and the state and centre would make a timely assessment of these schemes. It is also essential each nation will select the indicators that are first rate ideal to the tune of its growth which is closer to the improvement. Sincere efforts must be made by the monitoring agencies at centre at state level to ensure quality, timely and reliable disaggregated data. Many problematic features are there in measuring various indicators taken for the SDGs; hence, steps must be taken to boost the statistical manner in the nation through sufficient financial and human resource investments [11].

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Chapter 39
Design and Modeling of Water Pumping System for Irrigation

Richa Adlakha, Ashish Grover, and Anita Khosla

Abstract Presizing is one of the issues in analysis solar-based water pumping system. The integration of pumping system for irrigation purpose is gaining the utmost importance. This paper deals with the presizing of photovoltaic solar pumping system using PVsyst as the simulation tool for economic analysis considerations. This tool takes the consideration of the daily water, site location, power conversion technique used, types of the photovoltaic panel, types of pump used. Based on these factor results are calculated for the geographical area. The results will depict the factor like pump efficiency of the system, power loss factor, water supply availability, economic analysis, etc.

Keywords Power converter · Photovoltaic system · Water pumping · System · DC–DC converter · PVsyst

1 Introduction

With the population expected to grow exponentially in the future decades, the need for energy is expected to rise quickly. Additionally, the demand for electrical energy will increase at the same time. According to prior study, a sizable amount of electrical energy is being utilized by the use of motors in a variety of pumping systems, including fixed speed centrifugal pumps, compressor and fan appliances, etc. The depletion of fossil fuels is imminent, and they also have detrimental effects on the environment, which have intensified the impact of global warming since CO_2 gas emissions are a big worry and have an impact on the stability of the environment. It has become crucial to conserve energy in order to save the environment. It has become crucial to switch to green energy in order to protect the environment. There are many renewable energy sources, such as sun and wind, but it's necessary to use them effectively [1].

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Given that India has an abundance of solar energy, it is becoming more and more important in this industry. The price of PV panels has significantly decreased due to power electronics technology advancements as well, which has increased the adoption of solar PV systems. Solar photovoltaic system converts solar energy into direct current to produce electricity. The generation of power using PV system employs solar panels which are composed of number of solar cell connected either in series or in parallel to form one PV module. Further, these PV modules combined for the high power applications. There is the requirement of optimal operation of PV systems because the efficiency of the output from the solar panel is low. There is the effect of changing ambient temperature and solar irradiance level on the nonlinear characteristics of PV systems. Therefore, maximum power tracking technique is required to obtain maximum power operating point from a PV system irrespective of temperature and radiation condition and transferring that power into the load. A DC/DC converter act as interface between the module and the load for transferring the power. The main goal of MPPT is to find the voltage operating and operating current at which maximum power is obtained under given temperature and irradiance. The maximum power is obtained by adjusting the duty cycle of the interface which is DC/DC converter. There are different algorithm for tracking maximum power like perturbation and observation, incremental conductance, constant voltage algorithm, hill climbing technique, fuzzy logic, and neural network. Almost all the techniques would automatically respond to the changes both in irradiance and temperature but some are more specific for temperature.

The chances of having multiple local maxima in case of effect of partial shading but overall there is only one true peak power point. The heart of the photovoltaic system is MPPT techniques which are dependent on the DC–DC converter. There are various DC–DC converter topologies each having its own implications and limitation. The basic property of these converter is that degree of control over its output voltage is achieved by varying the duty ratio of the converter, thus by changing switch drive ratio converter can be controlled. The DC–DC converter topologies are categorized into isolated or non-isolated topologies. A small-sized high-frequency electrical isolation transformer which provides the benefits of DC isolation between input and output is used in isolated topologies and by changing the transformer turn ratio step-up or step-down operation is achieved (Fig. 1).

This solar photovoltaic (SPV) system generated electrical energy for numerous applications as far as possible used in various application. The one of the application gaining the importance is the standalone solar power-based water pumping application in the field of irrigation, household, and industrial applications. There is numerous research which is being carried out in this era. The solar pumping system basically includes the main blocks. The first is the solar photovoltaic block which includes the number of series and parallel photovoltaic panels depending upon the output required. Now the output from the PV is fed to the DC–DC converter to convert it to the required level. The first step of designing the solar power PV pumping system is presizing of the system. It helps in the economic analysis of the system. The tool for the presizing is PVsyst. In this paper, the presizing is done using the sample geographical area of New Delhi.

2 General Layout of the Water Pumping System

There are various components available which are required for the water pumping system. The selection of the appropriate configuration for the required site is dependent on the economic factors, and steady performance of the system as shown in Fig. 2 shows the possible configuration which can be selected for the particular site.

There are three basic blocks in the general layout (a) solar generator, (b) power conditioning, and (c) pump/motor.

(a) ***Solar generator***:
The solar generator comprises the photovoltaic modules which are connected in series or parallel in order to increase the power delivered by the photovoltaic systems. These PV modules are made either of crystalline silicon technology or thin film technology. Out of these, the crystalline silicon technology is the most common. Ultra-pure silicon materials which are generally used in fabrication of semiconductor chips are used in making crystalline cells. 150–200 micron thick silicon wafers are used in this technology.

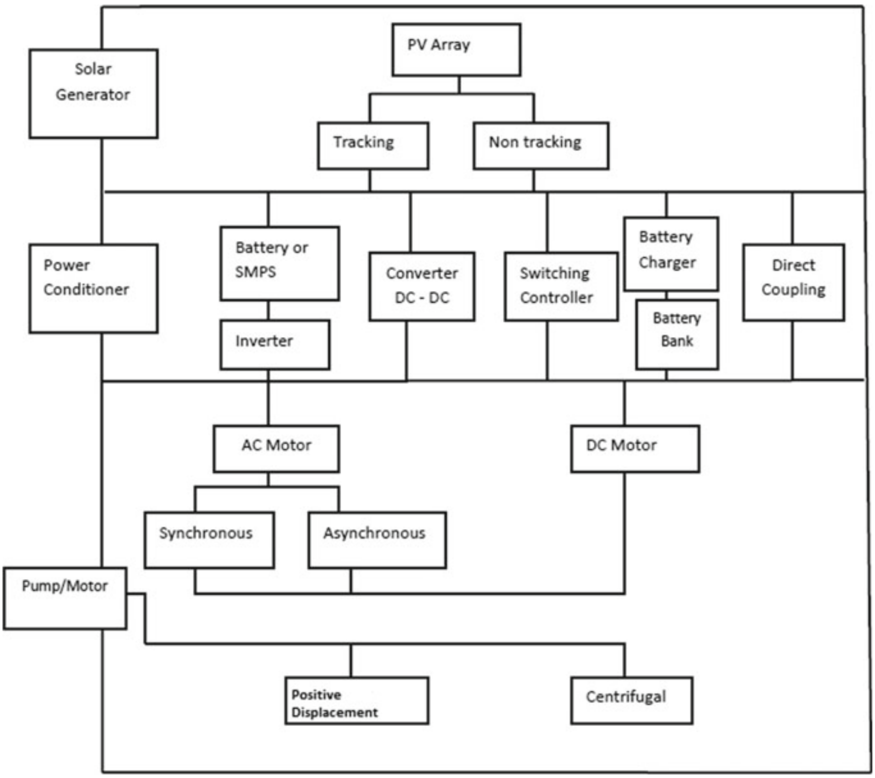

Fig. 1 Generalized flow of the pumping system

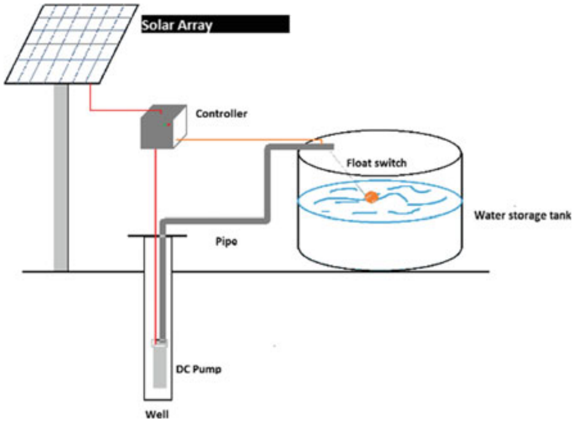

Fig. 2 Components of solar pumping system

Solar generator constitutes the photovoltaic array with or without the maximum power point tracker (MPPT). The MPPT controller boosts the efficiency of the photovoltaic system. There are various algorithm for this such as perturb and Observe, Incremental Conductance or soft computing for the designing of MPPT controllers.

(b) ***Power Conditioning**:*

In order to match the output power received from the solar panels with the power conditioning unit is required. This power conditioning unit constitutes of the power converters which matches the power with the pump required power. Maximum power point tracking is also done with help of these converters. The pumps employing the DC motors need DC–DC converters to provide high current at low voltage level. The pumps which use AC motors [2] need DC–AC inverters [3] so as to produce the suitable voltage. When synchronous motors are used, the role of converters is to modulate the frequency [4] so as to operate the pump at optimum speed.

(c) ***General Pumps***:

Pumps are used to provide the energy to boost the flow of liquid and transport the water between different locations. The pumps are used for industrial, domestic, and irrigation applications. The type of the pump used for the particular application will depend on energy demand, flow, head, performance, and cost evolved. Generally, there are two types of pumps: dynamic pump and positive displacement pump. These pumps are further classified as surfaced mounted and submersible pumps.

Dynamic pump: In these pumps, rotating blades are positioned in such a way so that they either increase or decrease the pressure of the liquid, thereby rotating these special blades, and the flow of liquid is altered. The rotating blades are also called as impeller. The centrifugal pumps come under the category of dynamic pumps.

Positive Displacement pumps: These pumps work on the principle of altering the volume of liquid in the closed loop. These pumps are installed in deep wells or bored. These pumps are either piston type of pumps or use diaphragm or rotary screw or progressive cavity system [5].

These all constitute the major part of the solar-based water pumping system. Many algorithms are developed for the maximizing the efficiency of the system. Software package PVsyst is used for the sizing and economic analysis so as to obtain the optimum results in this paper.

3 Pump Designing and Sizing Using PVsyst

One of the main objectives in designing the complex water pumping system is component sizing, as there are many variable quantities involved in the system which are operating at different conditions and vary with day to day. The prerequisites of pumping system such as water needs, size of the storage tank, and distance at which water is to be pumped are defined by the user. Keeping in view, these constraints of the PVsyst simulation package determine the size of PV array, pump and tank volume needed to meet the required water needs. This also estimates the rough cost involved in the system and the technology need to be adopted so as to increase the efficiency of the pumping system. The whole calculations are done for the one year based on the daily needs. The software uses the built-in meteo database, or its data files can also be used to determine the irradiance on the PV plane and other in-built techniques which will increase the efficiency.

The meteo file is generated for the site of the Ahmedabad with the file "Ahmedabad_MN71_SYN.MET." It is considered that the region contains 1260 plants. It is fed by the 115-m-deep bore which is being powered by the diesel generation. This is a remote are with no grid connection available. So due to the transportation problems, the solar powered is preferred.

The utmost important point is to choose the proper design of the system and presize it according to the needs of the user. It will increase the efficiency, and economic analysis will be done. Proper technology chosen will effect the performance of the system. Following factors are need to be considered for the proper sizing [6].

(a) Available water source: The selection of the water pump depends on the type of the source available well or pond. The factor such as head and flow rate of the water source is important in choosing the pump. In this paper, it is considered that a well with 115 m depth and pump at the 111 m. Four meters are kept for underground water.
(b) It is considered that for the farm which contains 1260 plants the average daily water need is 184.4 l/day []. It is assumed that the plant consumes 95% of the water []. So the average daily consumption can be calculated as Number of trees *consumed water/0.95, which is 244900 l/day or 244.9 m^3/day which is pumped from deep well using 4 inch pipe.

(c) Pump size calculation is based on the estimation of total dynamic head (TDH). TDH is based on the below parameters:

- The diameter of the pipe which is 4 inch.
- The depth of the bore is 115 m but at 111 m pump is installed but the average water level is 45 m.
- There are 3 elbows and friction is 1.8[], thus
- TDH = 111 m + [1.8 * 3 + 20 m] * 0.2 + 4 m ~ 120 m.

These above factors are important for sizing the water pumps. The software packages such as homer and PVsyst are available for the purpose. In this paper, PVsyst is used as the software package.

4 Simulation Using PVsyst

The PVsyst supports in selecting the appropriate pump and the photovoltaic system. The efficiency of the system can be increased by selecting the appropriate components. For the purpose of storing energy, the batteries are not considered but tank is taken.

The meteo file of Ahmedabad site has been considered. Deep well storage system is taken with well depth of 115 m and pump depth is 111 m. There are three elbows at an angle of 90 degree. Based on these THD has been calculated to be 120 m. Daily need of the water is calculated as 249 m ^{3} per day. The layout is shown in Fig. 3.

The water need of the system and the pump installation specification has been fed to the PV system [7] by taking the path of designing the pumping system. Figure 4 shows hydraulic circuit of the pumping system and Fig. 5 shows the water needs.

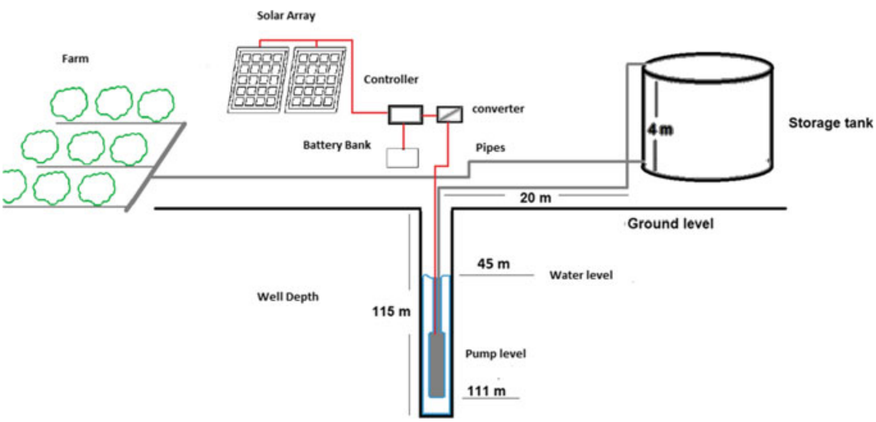

Fig. 3 Detail layout of the pumping system

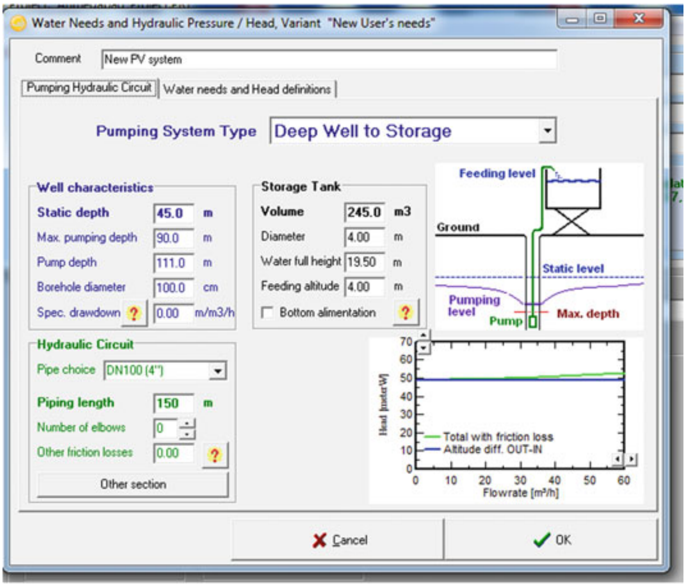

Fig. 4 Hydraulic circuit of pumping system

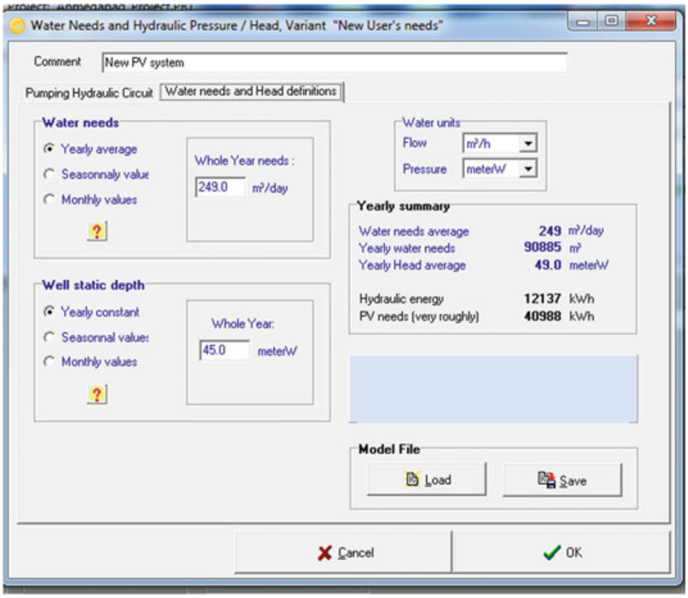

Fig. 5 Water needs

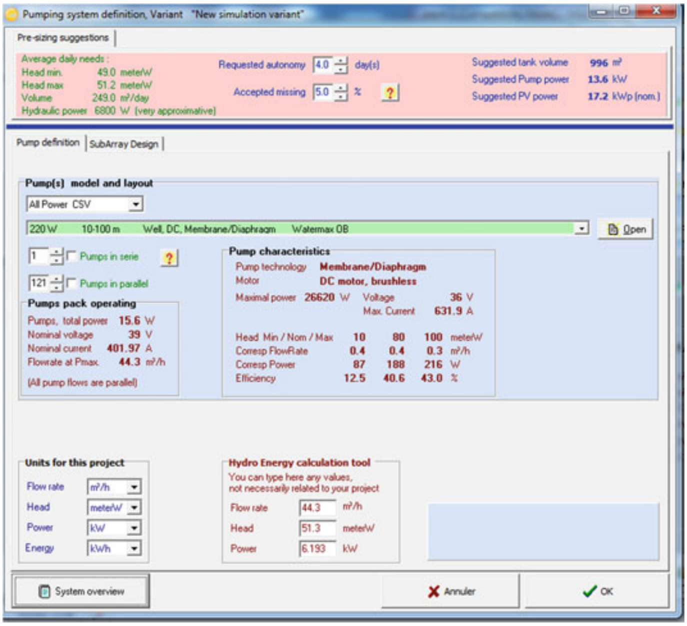

Fig. 6 Pump defining

After defining the general layout of the water pumping system and water needs of the utility, the technological details of the system are defined. There are two options in this: First is pump design and second is subarray design. In pump design, various alternatives are available, and the appropriate pump is being chosen. The second is subarray design in which the type of photovoltaic system and the power conditioning required is selected as shown in Figs. 5 and 6.

Based on the above setting, the water pumping system is simulated by using the simulation package. Here the DC–DC converter is used for the providing the maximum power point tracking. The technical specification of the solar panel is also defined. These are then simulated for obtaining the efficiency.

5 Results

The results obtained after simulating in the package are shown in Figs. 7, 8, 9, 10, 11 and 12. The figure shows the overall review of the pumping system; this software package helps in calculating daily water needs and methods to improve the efficiency. It helps to analyze the performance which helps in the presizing of the water pumping system. Economic analysis can also be done using this software.

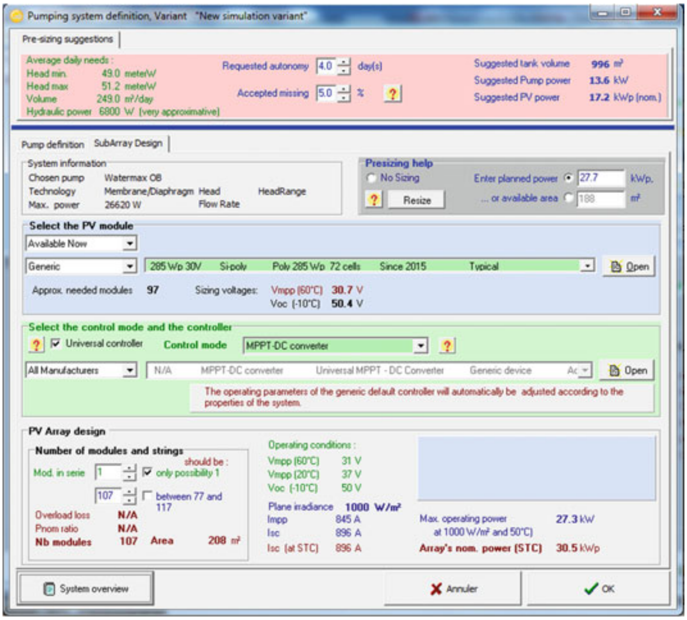

Fig. 7 Subarray design specification

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Pumping PV System: Basic simulation parameters

Project :	**p1**			
Geographical Site	**Ahmedabad**		Country	**India**
Situation	Latitude	23.07° N	Longitude	72.63° E
Time defined as	Legal Time	Time zone UT+5.5	Altitude	58 m
	Albedo	0.20		
Meteo data:	**Ahmedabad**	Meteonorm 7.1 (1981-2010) - Synthetic		

Simulation variant : New simulation variant

Simulation date 05/11/18 22h58

Simulation parameters

Pumping System parameter	System type	**Deep Well to Storage**		
Well characteristics	Static level depth	45 m	Specific drawdown	0.00 m / m³/h
(Diameter 100 cm)	Pump depth	111 m	Max. pumping depth	90 m
Storage tank	Volume	245.0 m³	Diameter	4.0 m
Feeding by top	Feeding altitude	4.0 m	Height (full level)	19.5 m
Hydraulic circuit	Piping length	150 m	Pipes DN100	Dint = 105 mm
Water needs	Yearly constant	249.00 m³/day		
Pump	Model	**Watermax OB**		
	Manufacturer	All Power CSV		
Pump Technology	Membrane/Diaphragm	Deep well pump	Motor	DC motor, brushless

Operating conditions	Head Min	Head Nom	Head Max	
	10.0	80.0	100.0	mWater
Corresponding maximum Flow Rate	0.40	0.35	0.34	m³/h
Required power	87	188	216	W

Number of pumps	In parallel	121 pumps		
Coll. plane: Seasonal tilt adjustment	Azimuth	0°	Winter season	O-N-D-J-F-M
	Summer Tilt	20°	Winter Tilt	50°

PV Array Characteristics

PV module	Si-poly	Model	**Poly 285 Wp 72 cells**		
Original PVsyst database		Manufacturer	Generic		
Number of PV modules		In series	1 modules	In parallel	107 strings
Total number of PV modules		Nb. modules	107	Unit Nom. Power	285 Wp
Array global power		Nominal (STC)	**30.5 kWp**	At operating cond.	27.31 kWp (50°C)
Array operating characteristics (50°C)		U mpp	32 V	I mpp	845 A
Total area		Module area	**208 m²**	Cell area	187 m²
Control device		Model	Generic device (optimised for the system)		
		System Configuration	**MPPT-DC converter**		

Fig. 8 Basic parameters of pumping PV system

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Pumping PV System: Basic simulation parameters

Project :	**p1**			
Geographical Site		**Ahmedabad**	Country	**India**
Situation	Latitude	23.07° N	Longitude	72.63° E
Time defined as	Legal Time	Time zone UT+5.5	Altitude	58 m
	Albedo	0.20		
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Simulation variant :	**New simulation variant**	
	Simulation date	05/11/18 22h58

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Array operating characteristics (50°C)	U mpp	32 V	I mpp	845 A
Total area	Module area	**208 m²**	Cell area	187 m²

Control device	Model	Generic device (optimised for the system)
	System Configuration	**MPPT-DC converter**

Fig. 9 Basic simulation parameter

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Pumping PV System: Detailed Simulation parameters

Project : **p1**
Simulation variant : **New simulation variant**

Main system parameters		System type	**Deep Well to Storage**		
System Requirements		Basic Head	49.0 meterW	Water needs	249.0 m³/day
Pumps	121 units	Model / Manufacturer	Watermax OB / All Power CSV		
PV Array		Model / Manufacturer	Poly 285 Wp 72 cells / Generic		
		Nb. of modules	1 S x 107 P	Array Power	30495 Wp
System Configuration		Control Strategy	**MPPT-DC converter**		

System Operating Control (Generic device, params adjusted acc. to the system)
Power conditioning unit MPPT - DC converter

Operating conditions	Minimum MPP Voltage	25 V	nominal power	26620 W
	Maximum MPP Voltage	42 V	Power Threshold	266 W
	Maximum Array Voltage	53 V	Max. efficiency	97.0 %
	Maximum Input Current	997.5 A	EURO efficiency	95.0 %

PV Array loss factors

Thermal Loss factor	Uc (const)	20.0 W/m²K	Uv (wind)	0.0 W/m²K / m/s
Wiring Ohmic Loss	Global array res.	0.65 mOhm	Loss Fraction	1.5 % at STC
Module Quality Loss			Loss Fraction	-0.8 %
Module Mismatch Losses			Loss Fraction	1.0 % at MPP
Strings Mismatch loss			Loss Fraction	0.10 %
Incidence effect, ASHRAE parametrization	IAM =	1 - bo (1/cos i - 1)	bo Param.	0.05

Fig. 10 Detailed simulation parameter

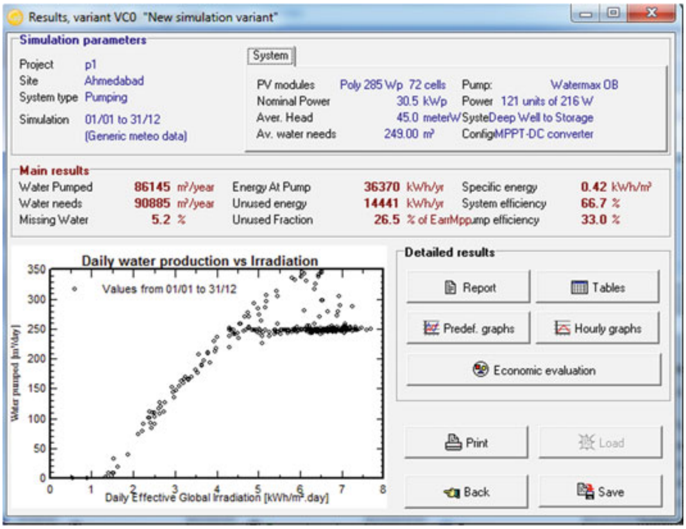

Fig. 11 Overall system performance

New simulation variant

Balances and main results

	GlobEff	EArrMPP	E PmpOp	ETkFull	H Pump	WPumped	W Used	W Miss
	kWh/m²	kWh	kWh	kWh	meterW	m³/day	m³/day	m³/day
January	205.7	6572	3288	3011	51.54	247.4	245.5	3.53
February	188.7	5935	2979	2716	51.47	249.0	249.0	0.00
March	197.3	6115	3300	2486	51.21	248.7	249.0	0.00
April	204.0	6168	3190	2571	51.28	249.1	249.0	0.00
May	199.1	6053	3366	2288	51.04	249.0	249.0	0.00
June	160.6	5062	3228	1378	50.73	247.9	247.9	1.07
July	121.8	3943	2718	659	50.33	192.8	198.5	50.49
August	121.5	3949	2876	572	50.37	203.7	203.7	45.31
September	159.2	5053	3179	1441	50.97	247.3	243.1	5.88
October	187.8	5820	3214	2159	51.29	244.0	246.2	2.77
November	190.0	5957	3173	2499	51.63	252.1	248.3	0.70
December	195.0	6178	3196	2719	51.89	249.0	249.0	0.00
Year	2130.7	66804	37706	24501	51.10	239.8	239.7	9.30

Fig. 12 Table showing the water pumped in the year

6 Conclusion

The presizing of the water pumping system has been done in this paper using the software package of PV Syst. The meteo data of the site of the Ahmedabad was taken. The daily water need of 244.9 m^3/day is pumped from deep well using 4 inch pipe. The deep well to storage type pumping system is considered in the paper. The system is defined, i.e., number of the solar panels connected in series or in parallel. The motor used is defined which is the brushless DC motor, and the MPPT tracking is also used. These all effect the efficiency of the application.

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Chapter 40
Key Factors Influencing Electric Vehicle Purchase Decisions by Consumers: An Empirical Study of Indian Consumers

Vikas Sharma, Kshitiz Jangir, Sudhinder Singh Chowhan, and Nitin Pathak

Abstract The study aims at consumer perceptions and the factors that influence electric vehicles and their willingness to shift to electric vehicles. The government is worried about how to protect the environment from the harmful emissions of vehicles, which are growing at a very fast rate. It has become imperative to undertake some empirical study to explore the various variables (dependent, independent, and control). People who buy cars and other vehicles are becoming more educated, aware, and worried about how the overuse of petroleum-based vehicles is causing oil resources to run out and the environment to get worse. To prove the hypothesis, the structural equation model was applied to software version 3.2.9 to test the determining factors. This study tries to find out how willing Indian consumers are to buy electric cars and what the government and industry experts can do to get more Indians to buy electric cars to save the environment and protect mother earth and society. Except for the fuel cost and infrastructure for charging, the effects of the other six factors on Indian consumers buying willingness are all significant.

Keywords Electric vehicles · Consumer perception · Indian market · Government policies · Opportunities · Environment · Structural equation modeling

1 Introduction

Over the years, India is facing serious environmental problems which are responsible for much malevolence in society. The depleting natural reservoirs of fossil fuel and deteriorating environmental conditions are the major issues before every sensible

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government. The growing demand for vehicles and subsequent harmful emissions especially carbon dioxide (CO_2) are much responsible for this situation. Therefore, electric vehicles are being developed to counter this menace as an effective solution to this problem. Similarly all other developing nations are also contributing their bit to disturb the environment by discharging CO_2 into the atmosphere without the realization its impact on the society [1]. India by and large is also not spared from this situation, and the growing population and ever-increasing demand for automobiles have created much destruction in the environment. As a result, the Indian government has put in place beneficial policies to address environmental challenges, such as encouraging people to drive electric vehicles. Today, too few EVs are powered by renewable energy [2].

In recent history, India has and have made significant progress. Electric vehicle registrations in Europe climbed by 41% to 126,885 units in the first quarter of 2019 [3]. As a consequence, many countries have imposed environmental protection policies and encouraged the adoption of electric vehicles by encouraging more people to do just that in light of the need to combat climate change [4]. Just in time of 4 years from 2014, total electric vehicle sales in the USA reached 361,307 units, a 70% increase over 2017. Such examples show that the market opportunities for electric vehicles in developed countries such as India are things relatively. Energy consumption more than doubled in the twentieth century [5], when energy cost is low and solar power is unavailable [6].

This study is targeted to understand the trend of accelerated development of electric vehicles and to start investigating consumers' adoption of electric vehicles. Before making a final decision, it is critical to research the popular issues of individual willingness to purchase any vehicle, especially electric vehicles, as well as the factors that influence consumers' perceptions [7, 8].

Due to energy scarcity from non-renewable sources and environmental concerns, developing countries, especially India, have begun to promote and market electric vehicles in recent years. India is still in the initial stages, when it comes to the development of electric vehicles, coupled with limited knowledge. This research has tried to explore the factors from a cultural and social perspective [9] and the scope of electric vehicles in the Indian market. This study focuses on the elements of cost–benefit analysis which consists of nuances, and restraints; this research focused on the willingness to purchase and cost–benefit analysis elements, which include subtleties, restraints, kilometers per charge EV range, infrastructure for charging, initial investment, incentives offered by the government, fuel prices, environmental awareness of individual, and social influence perceived by individuals [10]. Due to energy shortages and environmental concerns, emerging nations have infrastructure their support of electric vehicles.

2 Review of Literature

Several pieces of research were conducted around the world to better understand consumer preferences and electric vehicle purchasing behavior. The willingness to purchase, battery capacity [11], infrastructure for charging [12], purchase cost, government policy [13], environment awareness, social influence, fuel prices, and maintenance cost were all accepted. Previous study looked at the driving range per single charge as well as the incentives offered, both monetary and non-financial [12].

Innovation in a vehicle is the technological facet of a vehicle. Previous research has identified the less range per single complete charging of the battery, as a considerable barrier for electric vehicle technology. Infrastructure attributes are focused with the recharging stations that are available. These variable have been found to improve study results. Suitable charging facilities will save consumers time and money during the initial search for the charging stations, and will reduce their frustration, and concerns [14].

3 Variable, Model, and Hypotheses

3.1 Dependent Variables

3.1.1 Willingness to Purchase

With the swift advancement of EVs, number of research is done to investigate them. One major goal of these studies is to find the willingness of individuals to purchase electric vehicles and the considerations that influence them [7, 8, 15–18]. Because developed countries are driving the concept of electric vehicles, generally, authors from Western countries actively engage in these studies, as in the USA [7, 16, 17], Germany [8, 15], in Sweden [18], etc. As a result, it is critical to analyze Indian consumers' willingness to buy electric vehicles and to start investigating major factors that affect purchasing decisions. The aforementioned common factors of previous research were evaluated review of the literature: performance attributes [15, 19, 20], cost of purchase [12, 19, 21], infrastructure for charging [12, 20, 22], government policies [13, 23], social influence [13, 22], environmental awareness [20, 24], fuel price [25], maintenance cost [26], etc. Consumers are discouraged from purchasing electric vehicles due to factors such as performance, the initial cost of purchase, and infrastructure for charging. However, some studies support differing views [21]. When compared to conventional vehicles, the high purchase cost of electric vehicles is stated to be a significant barrier to sales. In many studies, various factors were proposed to foresee purchase willingness for electric vehicles which is utilized as a dependent variable for adoption decision [22, 27].

3.2 Independent Variables

3.2.1 Battery Capacity and Driving Range

H1: The battery capacity and driving range of electric vehicles influences India's willingness to purchase electric vehicles.

Battery capacity and driving range increases are the most valuable, accompanied by charging efficiency, effectiveness, and emissions reduction, implying the battery capacity and driving range. The most key factor is driving range, feature, and convenience of Evs, influencing personal willingness to purchase [7]. Several articles have found battery capacity and driving range as critical factors impact on electric vehicle acceptance [15, 19, 28]. However, due to limited technological development, EV battery capacity and driving range has a long way to go in terms of development and improvement. Trying to travel thousand kilometers in a short time is difficult. As a result, the battery capacity, as a significant feature of usability in the daily use of Evs, can impact Indian buyers' preferences and perceptions toward Evs acceptance.

3.2.2 Infrastructure for Charging

H2: The construction of a high-quality charging infrastructure increases Indians' willingness to buy electric vehicles.

Consumption can be restricted by both financial and public contexts. According to recent research, the majority of customers are concerned not only with driving distance but also with the desire to travel a long distance [29]. One of the major barriers to long-distance driving is a lack of charging infrastructure. By several experts, expanding charging infrastructure will encourage more people to buy electric vehicles because it will allow them to travel long distances [26, 30–32]. When purchasing an electric vehicle, interested customers will examine these factors: charging 360-degree, charging point compatibility, charging fees, and charging station quantity [33].

3.2.3 Purchase Cost

H3: The cost of purchase has a detrimental impact on Indian willingness to buy an electric vehicle.

Budget is one of the most prevalent restrictions on consumer choice problem [34]. It may cause consumers to prefer conventional vehicles because they have no other option if their budget is limited. The higher cost of EVs is largely due to the battery pack which is often the most expensive part, and due to a lack of economies of scale [17].

3.2.4 Government Policy

H4: The government's financial incentives increase Indian willingness to purchase electric vehicles.

Government policies are including monetary as well as non-monetary benefits [13]. This study focuses only on financial incentives provided by the government for electric vehicles, which can alleviate the economic strain of purchasing electric vehicles [12]. Financial incentives from the governments can significantly cut the cost of purchases, promoting consumers to acquire electric vehicles. Monetary benefits can effectively lower the cost of purchases and motivate customer to buy Evs. Positive government benefits have significantly reduced consumers' financial constraints. As a result, government financial benefits aid in increasing consumers' motivation to buy electric vehicles.

3.2.5 Environment Awareness

H5: Individual environmental awareness influences Indian consumers' willingness to purchase electric vehicles.

Environmental concern is also a significant factor and is described as one's awareness of environmental issues and willingness to address the issues. Environmental benefits have a significant influence on consumer implementation intentions [16]. People who believe in global warming are more likely to buy EVs [35].

Individuals who are involved in environmental protection and energy conservation are more likely to adopt. Consumers who are pro-environmental are likely EV adopters. Furthermore, environmental protection served as a powerful motivator. EVs should not only highlight energy conservation, but also environmental protection, which may increase implementation.

3.2.6 Social Influence

H6: The inclination of Indians to acquire electric automobiles is positively influenced by social influence.

Social influence cultural impact, subjective norms, neighbors, and peer pressure as a notion. Individuals seek approval from relatives and mates for their actions.

Consumers are inspired by the attitudes of relatives, or mates, and seek societal approval by purchasing products acceptable to people whose opinions matter [36, 37].

3.2.7 Fuel Prices

H7: The fuel prices influence India's willingness to purchase electric vehicles.

The private sector has a different factor of motivation when it comes to demand for alternative fuel vehicles (Ulmer et al. 2004). People who are willing to buy EVs prefer them because of their very low running cost not just because of environmental concerns [29]. The relative cost of gasoline is also considered during the purchase of the vehicle [38]. Prior awareness of the existence of alternative fuels like hydrogen also affects the acceptability of E-Vehicles; this acceptability is also affected by various variables like gender, education, environmental knowledge, and age [39, 40].

3.2.8 Maintenance Cost

H8: The Maintenance costs of an electric vehicle influence Indian's willingness to buy Evs.

The maintenance cost of electric vehicles and plug-in hybrid vehicles are comparable to the maintenance costs of internal combustion engine vehicles. EVs can save a deal when it comes to their comparison with traditional vehicles; however, they are more expensive than traditional vehicles even after the provision of financial incentives offered by the Central or State Governments. Certain consumers who prefer value performance will be inclined toward EVs [41].

4 Research Methodology

The research is based upon quantitative and qualitative methodology. This survey's population consists of household members who are owners of at least a vehicle and the ones who do not own a vehicle or do not have access to vehicles. Adults were the study's focus group. The sample contains 460 people who seem to know about vehicles and seem willing to purchase vehicles in near future. A questionnaire was circulated online with participants to get feedback on measure in the questionnaire on 5-point Likert scales ranging from 1 to 5 ("strongly agree" to "strongly disagree" (5 = strongly agree to 1 = strongly disagree)).

Table 2 represents the measures used in the model, and the theoretical model developed is represented in the Fig. 1 with the path results.

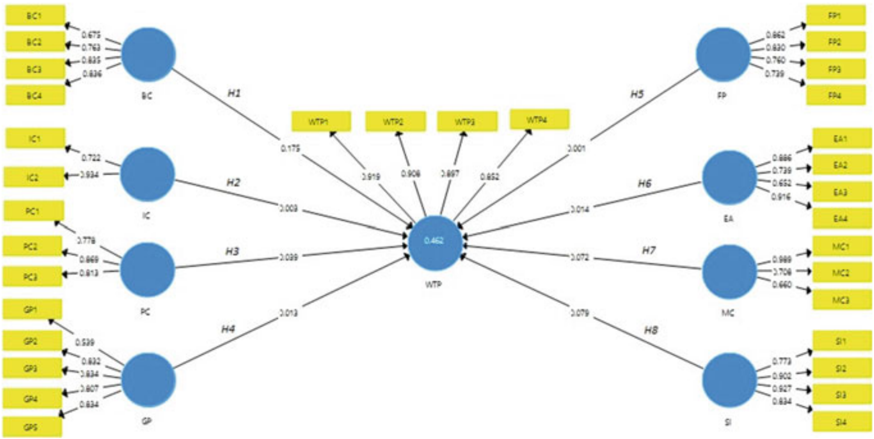

Fig. 1 Path relationship diagram. *Source* Author's Calculations. *Note* BC—battery capacity, **PC—**purchase cost, EV—environment awareness, FP—fuel prices, GP—government policy, IC—infrastructure for charging, MC—maintenance cost, SI—social influence, WTP—willingness to purchase

Convenient sampling was used to test the hypothesized framework; the following nine major constructs with 33 items were adapted from the existing literature with some modifications in the Indian context. The primary data was collected through a structured questionnaire, and secondary data on the research topic was collected using the compilation method from various scientific and professional papers. Table 1 represents the socio-demographic details of participants. For this study, structural equation modeling was used to test the model developed.

5 Results

5.1 Factor and Reliability Analysis

See Table 2.

5.2 Structural Equation Model

See Table 2.

Table 1 Respondents' demographic profile (N-460)

Particulars	Components	Frequency	Present (%)
Gender	Male	265	57.60
	Female	195	42.39
Age	18–24	120	26.08
	25–34	170	36.95
	35–45	125	27.17
	Above 45	45	9.78
Level of education	Graduation	90	19.56
	Post-graduation	145	31.52
	Doctorate (Ph.D.)	210	45.65
	Other	15	3.26
Annual income	Up to 5 Lac	185	40.21
	5 Lac–10Lac	190	41.30
	10 Lac–15 Lac	55	11.95
	Above 15 Lac	30	6.52

5.3 PLS-SEM Outcome

This research follows Hair et al. (2019) for the evaluation of construct validity. We used the work to find the common technique variance in empirical studies [42, 43]. To reduce uncertainty, we incorporated context data, introductory statements, and extensive explanations in our studies. The responses of all respondents were kept private, and there were no right or incorrect answers in the study, see [44, 45]. Second, using a collinearity test, the internal variance inflation factors (VIFs) were found to be less than 3.76 [43]. This shows the independence of the model from common method bias.

We used the bootstrapping process with sub-samples of 10,000 and the one-tailed test of various aspects related on a 95 percent level of significance. Indicator reliability, internal consistency, convergent validity, and discriminant validity were used to evaluate the reflective measurement models. The reflective and formative measurement model's indicator loadings are all significantly above the acceptable level of 0.708 (Table 3). All the items were accepted as the average variance extracted (AVE) values exceeded the criteria of 0.5 [46]. As a result, we assume consistency and convergent validity. The validity of measure was analyzed using the discriminant validity. It shows the extent to which a construct is different from other constructs. The results are given in Table 4. The diagonal values are greater, then respective correlation coefficients confirm the validity of variables. Further, the Heterotrait–Monotrait criteria were also used to assess the validity of constructs [47, 48]. The resultant values were under the conservative cutoff value of 0.9 and hence accepted signifying further validity of constructs (Table 5). No collinearity difficulties were

Table 2 Measures used in the model

Constructs
Willingness to purchase
WTP1: I am interested in purchasing EVs **WTP2**: I intend to purchase electric vehicles over the next 10 years **WTP3**: At the same price level, I will recommend electric vehicles over conventional (non-electric, fuel-based) vehicles **WTP4**: I find an electric vehicle is more appealing than a traditional vehicle
Battery capacity
BC1: The battery capacity and driving range is one of the major issues of Evs **BC2**: It is better if a battery with more capacity is available for EVs **BC3:** I keep myself up to date with innovations in batteries for EVs **BC4**: Larger battery capacity and driving range will give me more satisfaction
Infrastructure for charging
IC1: I don't believe existing charging stations will support long-distance electric vehicle journeys **IC2**: I think the number of charging stations is less in India
Purchase cost
PC1: I am satisfied with the prices of EVs in India **PC2**: I cannot afford an EV in the current price range **PC3**: I think that price of an EV is more than a conventional vehicle (fuel-based) in India
Government policy
GP1: I am well aware of the government policy for EVs in India **GP2**: I am happy with the financial incentives given to customers by the Government of India on EVs **GP3**: Policy of the Government of India on EVs has an optimistic influence on the development of EVs in India **GP4**: I think that it is easy to qualify for financial incentives offered by the Government of India on EVs **GP5**: The government policy indicates that EVs are a trend in the future
Environment awareness
EA1: I think that driving EVs will reduce pollution **EA2:** I'm extremely concerned about the environment **EA3**: I am willing to pay more for eco-friendly things **EA4**: I think that EVs are more environmentally friendly
Social influence

(continued)

Table 2 (continued)

Constructs
SI1: I think that driving EVs creates a positive image as perceived by others **SI2**: I feel proud when I drive an EV **SI3**: My family feels proud when I drive an EV **SI4**: I think that driving an EV increases the social status of an individual
Fuel prices
FP1: Increase in the prices of traditional fuels such as diesel and petrol, I prefer EVs to conventional vehicles **FP2**: I feel that the prices of petrol and diesel have increased too much **FP3**: I feel that the cost of charging an EV is less than the cost of driving a conventional vehicle **FP4**: I think that increasing the cost of petrol and diesel will have an optimistic influence on the adoption of EVs in India
Maintenance cost
MC1: I think that the maintenance cost of EV is very high **MC2**: I think that owning an EV is more expensive than owning a conventional vehicle **MC3**: I feel that one-time service charges for EVs are higher than that of a conventional vehicle

faced as the greatest value of inner VIFs is 3.76. The regression coefficients of each path for bootstrap sample are given in Fig. 3 and Table 6.

5.4 Hypothesis Result

There were eight hypotheses in total, all of which were tested on Indian consumers. As per the data processing results, battery capacity and the initial cost are not directly related to a consumer's willingness to buy. However, consumers' preferences for electric vehicles are influenced by charging infrastructure, government policy, environmental awareness, fuel prices, and social influence. It is not difficult to conclude that hypotheses 4 and 6 are not supported by the results. The following hypotheses are supported: hypothesis 1, hypothesis 2, hypothesis 3, hypothesis 5, hypothesis 7, and hypothesis 8.

6 Findings

The main purpose of this research was to conduct an empirical investigation of consumers' willingness to purchase electric vehicles and a test of the consumers'

Table 3 Reliability and validity

Items	Loading	CR	AVE
WTP1	0.919	0.941	0.8
WTP2	0.908		
WTP3	0.897		
WTP4	0.852		
BC1	0.675	0.86	0.608
BC2	0.763		
BC3	0.835		
BC4	0.836		
IC1	0.722	0.819	0.697
IC2	0.934		
PC1	0.778	0.861	0.674
PC2	0.869		
PC3	0.813		
GP1	0.539	0.882	0.605
GP2	0.832		
GP3	0.834		
GP4	0.807		
GP5	0.834		
EA1	0.886	0.879	0.649
EA2	0.739		
EA3	0.652		
EA4	0.916		
SI1	0.773	0.919	0.741
SI2	0.902		
SI3	0.927		
SI4	0.834		
FP1	0.862	0.876	0.639
FP2	0.83		
FP3	0.76		
FP4	0.739		
MC1	0.989	0.837	0.638
MC2	0.708		
MC3	0.66		

Table 4 Discriminant validity

	BC	C	EA	FC	GI	IC	MC	SF	WTP
BC	0.78								
C	0.258	0.821							
EA	0.416	0.174	0.805						
FC	0.548	0.21	0.624	0.799					
GI	0.269	0.268	0.318	0.339	0.778				
IC	0.149	0.117	0.062	0.187	0.16	0.835			
MC	−0.002	0.147	0.202	0.104	−0.038	−0.024	0.799		
SF	0.401	0.295	0.433	0.51	0.398	0.05	0.002	0.861	
WTP	0.569	0.308	0.362	0.428	0.213	0.134	−0.155	0.486	0.894

Table 5 Heterotrait–Monotrait (HTMT) values

Construct	BC	PC	EA	FP	GP	IC	MC	SI
Battery capacity and driving range								
Purchase cost	0.36							
Environment awareness	0.464	0.274						
Fuel prices	0.642	0.277	0.665					
Government policy	0.314	0.339	0.416	0.403				
Infrastructure for charging	0.281	0.224	0.183	0.313	0.418			
Maintenance cost	0.214	0.242	0.334	0.188	0.154	0.116		
Social influence	0.454	0.362	0.52	0.613	0.459	0.169	0.217	
Willingness to purchase	0.621	0.368	0.358	0.464	0.211	0.165	0.123	0.528

effective factors. All the possible research was conducted on the decided areas to determine driving range, charging infrastructure, cost of ownership, financial incentives provided by the government, personal environmental consciousness, and perceived societal influence are some of the considerations. The impacts of the other six factors on the purchase willingness of Indian customers are all substantial, according to the findings of the PLS-SEM study, with the exception of fuel cost and infrastructure for charging.

7 Conclusion

We started by collecting data using an online survey tool. Therefore, future studies could use our findings to examine consumers who make purchases offline. Second, EV purchase intention rather than actual behavior is the dependent variable in our

Table 6 Path analysis

Analysis		*t*-statistics	*p*-values	Supported
1. BC → WTP	The battery capacity and driving range of electric vehicles influences India's willingness to purchase electric vehicles	6.287	≤ 0	Yes
2. PC → WTP	The purchasing price of electric vehicles influences Indians' willingness to acquire them	3.123	≤ 0.002	Yes
3. EA → WTP	Individual environmental awareness influences Indian consumers' willingness to purchase electric vehicles	2.336	≤ 0.02	Yes
4. FC → WTP	The rising fuel prices does not affect Indian willingness to purchase electric vehicles	0.501	≤ 0.617	No
5. GP → WTP	Government policy influences Indian consumers' willingness to purchase electric vehicles	1.661	≤ 0.097	Yes
6. IC → WTP	The infrastructure for charging electric vehicles does not has effect on willingness of Indians to acquire electric automobiles	1.143	≤ 0.253	No
7. MC → WTP	The maintenance costs of electric vehicles influence India's willingness to purchase electric vehicles	2.853	≤ 0.004	Yes
8.SI → WTP	The social influence of an individual influences Indian's willingness to purchase electric vehicles	3.781	≤ 0	Yes

Note(s) *** $p < 0.001$: ** $p < 0.01$: * $p < 0.05$: ns 5 not supported: Explanatory power of Structural model

research paradigm. Despite the substantial correlation between actual behavior and behavioral intention (Hung et al., 2003; Tan and Teo, 2000), research using actual behavior as the dependent variable will produce more satisfactory results, and electric vehicles will boost the penetration of renewable energy sources [49].

Consumer preferences are changing, regulations are tightening, and technological breakthroughs are causing an individual's mobility behavior to dramatically shift. To fulfill their excursions, participants are increasingly employing numerous forms of transportation. Consumers receive goods and services rather than fetching them. As a result, the customary car-selling range of diverse business concepts will augment the business plan. Model will be supplemented by a variety of diverse, movement on consumption solutions, particularly in dense inner-city environments that actively discourage personal use and EVs pattern and renewable energy generation estimation [50]. Evs businesses must move to a continuous process of predicting new market trends, researching alternatives and complements to the existing business model, and evaluating new mobility business models and their economic and customer feasibility by 2030. Advanced scenario planning and agility will be required to identify and create new compelling business models.

8 Future Implication

Based on the findings of the future scope of electric vehicles in the Indian market, firstly, a considerable amount of concessions should be given to the consumers for the purchase of battery-operated electric vehicles, secondly, relaxation in the driving license should be allowed by the authorities, thirdly, reduced GST and other taxes be permissible on the electric vehicles by the government regulatory authorities, fourthly, low terrify charges should be allowed for the charging of the battery of electric vehicles, fifth, government should allow subsidy on the purchase of electric vehicles, sixth, offer dedicated parking and free parking for electric vehicles, and seventh, the government must launch a drive to enlighten the benefits of electric cars and contribution in environmental safety. It would also be essential to conduct further research from a larger perspective across India.

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