Application of AI/IoT for Smart Renewable Energy Management in Smart Cities

Pradeep Bedi, S. B. Goyal, Anand Singh Rajawat, Rabindra Nath Shaw, and Ankush Ghosh

Abstract A city is considered to be smart when the application of Artificial Intelligence (AI) and the Internet of Things (IoT) is integrated with it. This enables the collection of data from people, devices, and buildings, then analyses are performed to optimize control over infrastructure, traffic, energy, etc. A smart city is a collective framework with the integration of Information and Communication Technologies (ICT) and Cloud that makes interaction easily with one another. In this chapter, smart energy infrastructure is studied to monitor energy utilization in the city and to reduce costs and carbon emissions. Energy usage has recently shifted focus to renewable energy sources with minimal carbon emissions, emphasizing the necessity for ongoing environmental and human health preservation. Renewable energy is becoming more abundant, and the issue is to recognize and understand it in meeting the increasing demand for clean, affordable energy. Customers, distributors, and government bodies are all concerned about cost and the climate. Artificial intelligence proclaimed a new age in technology as well as in sustainable development. So, in this chapter, an implication of AI is presented and analyzed for RE research in smart environments. Along with that, an analytical study is also presented with the application of AI or IoT for smart energy management for smart cities. The main aim is to focus on and explore the efficiency level of ML/IoT techniques. This work will

P. Bedi
Computer Science and Engineering, KCC Institute of Technology and Management, Greater Noida, Uttar Pradesh, India

S. B. Goyal
City University, Petaling Jaya, Malaysia

A. S. Rajawat
Department of Computer Science Engineering, Shri Vaishnav Vidyapeeth Vishwavidyalaya, Indore, India

R. N. Shaw
Department of Electrical, Electronics and Communication Engineering, Galgotias University, Greater Noida, India
e-mail: r.n.s@ieee.org

A. Ghosh (✉)
School of Engineering and Applied Sciences, The Neotia University, Sarisha, West Bengal, India

V. Piuri et al. (eds.), *AI and IoT for Smart City Applications*, Studies in Computational Intelligence 1002, https://doi.org/10.1007/978-981-16-7498-3_8

also provide an in-depth analysis of innovative development, deployment, analysis, and management of smart energy in smart cities.

Keywords Smart cities · Renewable energy · Smart grids · Artificial intelligence (AI) · Machine learning (ML) · Internet of Things (IoT)

1 Introduction

Currently, the world is undergoing rapid urbanization that would increase the demand for energy and consumption. With increased consumption, the carbon emission also increases. As can be observed worldwide, urban areas emit about 50–60% of total greenhouse gas (GHGs). With the increasing population in an urban area, there is an increase in demand for energy consumption day by day that subsequently increases the GHG emissions. Consequently, there arises a major issue for managing and reducing carbon emission and needs to be managed. This problem is directed toward the solution of smart energy management (SEM). This principle redirected the energy management toward green and clean energy management and the development of sustainable policies to manage urban energy demand and reduce future carbon emissions [1].

To build an efficient SEM, first of all, it is required to understand the concept of energy management and then its integration with smart cities [2]. Planning and controlling of energy demand, supply, and consumption are considered to be efficient energy management with an aim to maximizing productivity and reduction in carbon emission and energy costs. In easy terms, energy management means "saving of energy". Smart cities are a complex task that covers a wide application, as mentioned in Fig. 1. SEM is integrated into different sectors such as buildings, water management, waste management, and transportation. According to different studies [1–5], different SEM challenges can be identified that hinder the adoption of SEM.

Smart energy management (SEM) is considered to be the most challenging area for future smart cities. The related critical issues are designing of networks and topology, and computational tasks integrated with artificial intelligence (AI) or machine learning (ML). In the context of smart energy management, renewable energy (RE) is considered to be a future energy source. Therefore, there is a need to investigate the benefits of renewable energy (RE) for the development of energy-optimized smart cities. For this, artificial intelligence (AI) can be used to respond to these requirements. This can be possible by the improvement in infrastructure design, production, and distribution of power in smart cities while facing challenges related to growth and resilience.

Smart grid with RE is considered to be the next-generation smart city grid that is a combination of electrical engineering and information and communication technology (ICT). Recently, it is being deployed at a rapid pace with increasing demand in a flexible, environment-friendly, robust, and cost-efficient way. Smart energy

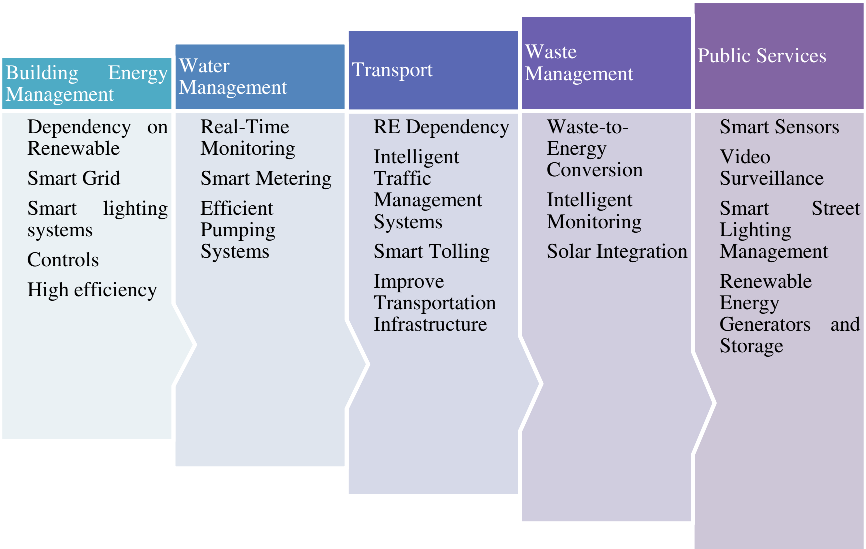


Fig. 1 SEM in different sectors

management includes deployment of smart meters, load forecasting, optimization of energy generation, etc. For example, with the deployment of a smart meter, a consumer can measure power consumption whereas, it can also enable consumers to be aware of the operation status between utility companies and consumers. The following challenges are observed in current grid systems:

- The current energy grid was not built to handle changeable sources of energy or fluctuating load-carrying capacity.
- The labor force presents unique challenges to the renewable energy industry in terms of abilities and labor shortages.
- The key to fixing the issues is not just management of generation, delivery, and storage but also the application of Artificial Intelligence at all levels of renewable energy's chain of distribution.

1.1 Key Contributions

The contribution of this chapter is illustrated as follows:

- The chapter is dedicated to describing the smart grid architecture in smart city applications. The chapter is dedicated to exploring the architectural models needed to be known during the deployment of energy management system in smart cities.

- The chapter also presented different existing research articles that have presented their efforts in deploying machine learning or artificial intelligence for smart grid architecture.
- To explore accurate and precise decision-making systems to analyze the impact of ML/AI techniques to reduce energy losses and their cost.
- The addition of artificial intelligence or Internet of Things (IoT) elements to the current study and to identify AI as a study area with a meaningful effect on smart grid quality and productivity.
- Further, this chapter has explored smart renewable energy design and management with analytical results under different machine learning algorithms for energy management in smart cities through a smart grid system.

1.2 Organization of the Chapter

The chapter is organized in sections: Sect. 2 is dedicated to showing an overview of smart cities with their architecture and applications. Section 3 presents the role of information and communication technology (ICT) while deploying smart cities. Section 4 presents the relationship between artificial intelligence application with renewable energy and its application in the smart city for energy management. Section 5 gives an overview of smart grids and their deployment architecture. Section 6 presents the contribution of machine learning and IoT in the smart grid. Section 7 describes the analytical study of the application of ML and IoT for the identification of future research directions. The last conclusion is presented in Sect. 8.

2 Overview of Smart Cities

The concept of a smart city is based on Internet of Things (IoT) [6]. Constant population expansion and modernization have heightened the need for novel approaches to modernization that have minimum impact on the ecosystem, human lifestyles, and administration**.** The early adoption of information and communication technology (ICT) in city administration sparked the notions of a digital city. Smart cities have evolved as a remedy to the issues that come with rapid urbanization and population expansion. With the advent of smart gadgets and their subsequent improvements, the concept of linking everyday things over existing networks has gained a lot of traction. The growth of traditional networks that link zillions of linked gadgets gave rise to Internet of Things (IoT) [7]. Internet of Things has been reinforced by technological improvements in ubiquitous computing (UC). Due to rapid modernization around the world, smart cities have risen to prominence in recent decades. Using ICT to run city management made cities more efficient in a variety of ways. In broad terms, a smart city is an urban ecosystem that makes use of information and communication technology (ICT) and other associated technologies to improve the effectiveness of normal city operations and the quality of services (QoS) given to city residents. Authorities have defined the smart cities' informal words, considering many features and views [3]. mart cities' informal words, taking into account many features and views [3] a smart city links physical, social, business, and ICT infrastructure to improve the city's intelligence.

A smart city links physical, social, business, and ICT infrastructure to improve the city's intelligence. A smart city, according to another conception, is a developed modern metropolis that uses ICT and other technology to enhance the standard of life. Because of its significant realistic necessity and practical foundation in a growing urbanized globe, the notion of a "smart city" has drawn expanding emphasis in both academic and industrial disciplines over the last two decades. However, because of the vulnerabilities that exist in every phase of a smart system, the design of these smart apps may pose several security [8] and privacy issues.

Numerous architectures have been devised to keep up with the advancement of smart cities. However, as far as we are aware, there is no standard IoT [9, 10] architecture. The design presented here is based on the well-known three-layer architecture and the commonly recognized architecture proposed, as the focus of this study is to outline security and privacy challenges in smart cities. The architecture can be separated into four layers, as indicated in Fig. 2; a quick overview is provided below [4].

- The lowest layer of the architecture is the observation layer, also known as the sensing layer, recognition layer, or edge layer. The perception layer is primarily responsible for collecting data from items in the real world (e.g., heterogeneous devices, WSNs, and sensors) and delivering it to the network layer for further computation.
- The network layer is the foundation of the Internet of Things architecture, and it relies on basic networks including the Internet, wireless sensor networks, and

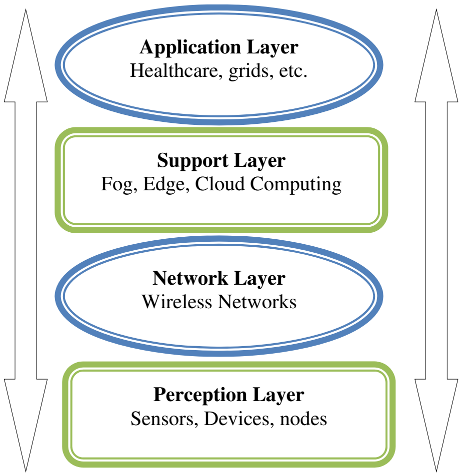


Fig. 2 The architecture of smart city

Fig. 3 Applications of smart city

communications networks. This layer's job is to link smart items, network devices, and servers while also transmitting the data gathered by the perception layer.

- The support layer, which works intimately with the application layer, uses intelligent computing approaches to support the needs of various applications (e.g., cloud computing, edge computing, and fog computing).

As the top layer, the application layer is in charge of supplying intelligent and practical services or applications to users based on their specific needs. In the following subsection, we go through everything in detail. Smart city applications are represented as in Fig. 3.

2.1 *Implementation of Smart Cities*

The availability of real data on urban surroundings is critical for the operation of a variety of useful applications and services. Figure 4 encapsulates a brief explanation of major smart city implementations. The range of application areas is extremely broad. For apps that allow individuals to book travel on mass transportation, for instance, actual travel data is relevant. The client might get real-time updates on when the next bus or train will arrive. Stakeholders will be able to engage in a wide range of online activities, including websites for general details, citizen services, enterprise, and tourism, all of which will be built on a single infrastructure. Urban areas are implementing online services in a variety of fields [5].

Urban areas are resource frameworks, and these services are the means through which people participate with one another inside infrastructure systems. They frequently use or transform resources, and they usually demand payment or interchange. International and local service providers both enable the management and operation of urban apps and services.

Several technology designers and service providers are extending outside identifying, planning, implementing, and distributing products for specific smart urban programs by combining them or promising to complete and manage them in favor of urban administrations or other partners. Smart urban products should be simple to

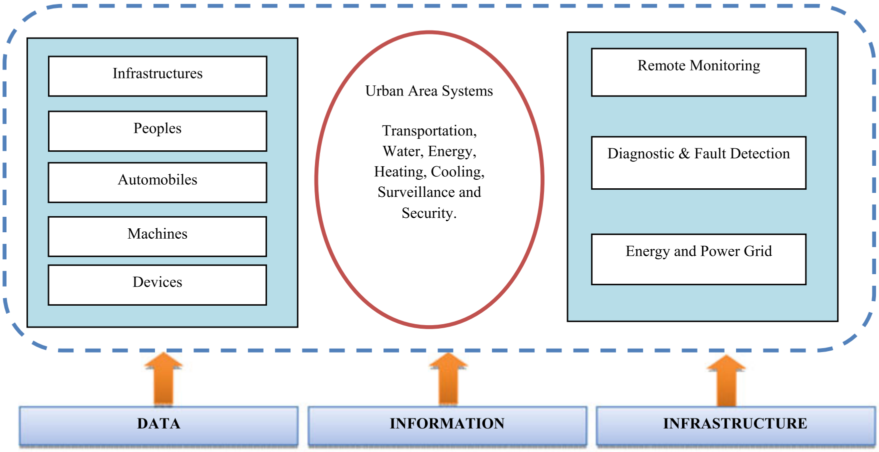


Fig. 4 Relation between ICT components with smart city components

use, effective, reactive, transparent, and environmentally friendly. People as well as other investors want high-level government services that improve and revolutionize their everyday lives. Urban areas are under pressure to improve urban strategic planning, deliver better and more effective infrastructure and operations, and do so at a cheaper cost.

2.2 *Smart Urban Area Services*

There are numerous services and apps available. Public transport, public utilities, learning training, fitness, and social welfare, and public security are among the services provided. People's daily routines, crisis response, intelligent cities, transportation, and smart purchasing are all impacted by evolving apps and services. This portfolio's technologies comprise smart grid, home automation, safety, smart buildings, faraway health and wellbeing tracking, position-aware applications, digital money, as well as other machine-to-machine (M2M) technologies for the linked metropolis. The advanced applications can provide real-time data, increase the ability to forecast and control urban movements, and perform other municipal duties.

A further technique to increase the amount of knowledge available is through social application-based cooperation and spontaneous collective experience. Through the Internet, crowdfunding portals, mash-ups, and other participative real concern methodologies, social media have provided the technical foundation for arranging collective knowledge. One other major area of application is evaluation, intellectual ability collecting, and predicting utilizing information to promote prognostic systems that allow risk modeling and integrated need for urban area resources.

The city will perform better because of these decentralized problem-solving judgments. It is all about providing decision-makers with unified data that allows them to anticipate instead of responding to issues as they arise. As a result, numerous methods emerge, allowing urban centers to improve their problem-solving abilities.

3 Role of ICT in Building Smart City

Modern technologies are being used to enhance urban applications and services. It's transforming the way the services are delivered by merging ICTs with municipal infrastructure and altering city system solutions. From a smart urban viewpoint, smart urban services and apps are concentrating on how to design upcoming Web systems and resources. To satisfy the difficulties of advanced cities, creative web services and apps must be deployed, implemented, and approved. People working with data and understanding are particularly affected by this shift and possibility. The generation of information content is not limited to a single area, and the resulting goods are usually distributed via the Internet. Services-driven marketing infrastructure, which includes web services, the extensible markup language (XML), and mobilizing software programs, allows smart urban services to be accessed via wireless devices [11]. The business applications that are designed and run have changed dramatically, thanks to Cloud computing. Platform as a Service (PaaS) is a method of renting operating systems, memory, network bandwidth, and equipment over the Web. It's a type of Cloud computing service that includes both a solution stack and a computing environment. Access to online services does not need to own or license the software to fully utilize it [12].

Such breakthroughs have enabled the provision of more services to a wider group of people, as well as improved access to services with accompanying upgrades and advancements. These enhancements to the services have reduced operating costs and higher productivity. A person can access a variety of city services over the Internet. Relying on their user account and the accompanying security standards, the operator may deliver services to distinct user groups, each of which is defined by certain roles and permitted to engage in a variety of actions. Upcoming online services in smart urban areas will rely heavily on innovative mechanisms that involve people, corporations, and government agencies. Sustainable urban services, architectures, techniques, and ICT systems are deployed and tested before being used by end-users. Verifying cities' performance levels and improving their durability require them to become progressively able to fulfill both anticipated and unanticipated problems.

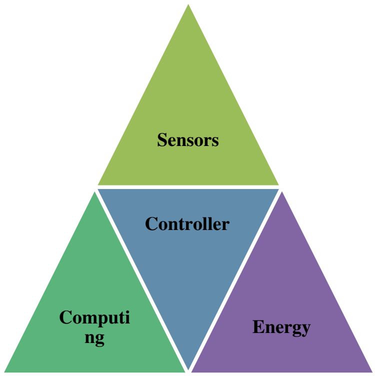


Fig. 5 Topology for sensor nodes for deployment of smart city

3.1 Wireless Communication and Associated Technologies

The goal is to put in place surveillance equipment and create a decentralized system of smart sensor nodes that can detect a variety of characteristics for better city administration. A variety of fundamental technological improvements, particularly developments in MEMS sensor technology, and novel techniques to regulate power usage has driven new progress in wireless communication. Figure 5 topology for sensor nodes for deployment of smart city system, which can sense and also the initial phases of the process, can provide versatile, cheap monitoring. Smart urban solutions based on Wireless Sensor Networks for action recognition will see a significant increment in this market [13]. The wireless sensor network (WSN) is comprised of a large number of diverse and geographically scattered independent sensors positioned inside or near the event. A wide number of "nodes" that are linked to one or more sensors and organized into a cooperative network supports the WSN. The standard sensor node topology is depicted schematically in Fig. 5.

These sensor nodes can gather and process information, and each one can sense, analyze, and transfer data about its immediate community to other nodes and processors nearby. The goal of these networks is to detect and capture physical and environmental parameters like temperature, noise, pressure, and other factors to jointly send associated data over the network to a central point. Sensor networks will give large ensembles of real-time, distant contact with the physical environment, similar to how the Web enables access to digital information from everywhere. Decentralized information from the sensor to the system becomes as important as Internet-based wireless sensor networks in enabling the building of smart cities by allowing for the collection of data that is appropriate for the purpose. Each node in the network has processing power provided by one or more configurable microcontrollers for managing node activities and processing data, ranging from a few to many hundreds or thousands. Small-format, battery-powered, sensor-enabled processors that can execute the role of sensors can now be produced at a low price, thanks to innovative technologies. These sensor nodes, which act as a method of detecting, data analysis, and communication, might be built from these small embedded systems, leveraging the concept of sensor networks built through a collective effort of a large number of nodes. Various kinds of storage, a radio (RF) transceiver for communications with an internal antenna or connectivity to a directional device, an electrical device for sensor interface, and an on-board power supply for power, are all included in this system.

Wireless Fidelity (Wi-Fi), ZigBee, IQRF, Ultra-Wide Band (UWB), and Wireless Hart are examples of sensor network communication systems. Wireless sensor networks (WSNs) are a significant technique that enables to satisfy city conditions surveillance demands, even though they have not been widely deployed on a broad scale yet. By analyzing real-time data, this model enables the efficient and accurate detection of diverse spatial occurrences, such as the issues associated with an area of high pollution intensity. Dense WSNs of nodes with monitoring capability could help with air pollution or tracking of urban areas [14].

4 Relationship Between Artificial Intelligence and Renewable Energy

Renewable energy (RE) has the potential to be a long-term solution to the world's energy needs. The potential of RE cannot be wasted due to traditional resource depletion, growing pollution, and climate change. High power and process quality are required in the generation, transmission, and distribution systems as the trend toward renewable energy growth [15]. As RE is available in remote regions instead of any conventional fossil fuel sources, this arises a challenging development and growth of technology with increased efficiency of control and technology [16]. Its main advantage is that it is independent of dependency on fossil fuels, whose prices may vary considerably. Furthermore, the fluctuation of renewable energy sources may provide a difficulty, necessitating the adoption of technologies to produce and store energy when conditions are favorable and to use it when conditions are not, precise data prediction to eliminate wasteful and inaccurate outputs. Whether isolated or not, intermittent generation of electricity is the main challenge for renewable energy grids. It has the potential to return us as backup fossil fuels if not properly controlled [17–20].

Artificial intelligence and considered it for studying and calculations that allow the perception, reasoning, and action to be perceived and defined according to its objectives. Experts believe that Artificial Intelligence can make recommendations, decisions, and predictions about a given plan of action defined by human beings and influence the real or virtual environment [20]. The grid's complexity is growing all the time; thus, AI should look into data and apply automated algorithms paired with climate prediction to maximize the return on investment in renewable energy and estimate the power consumed by all of the grid's production components. Even when the initial RE investments are high, the cost of RE mass production is very low.

The systems will use AI to gather and evaluate large amounts of information from all of the grid's key features, as well as to provide rapid judgment algorithms for the optimal resource distribution in and out of the grid. AI can detect controls for the generation of energy and regulating energy demand.

Particularly using better operation and maintenance, the following AI applications need to be focused on:

- Production of energy with application of RE.
- Stability and reliability.
- Operational stability and security.
- Demand forecasting with accuracy.
- Optimal energy generation and storage.
- Optimal design and management.

The relationship between AI applications and energy management is presented in Fig. 6.

Some applications of AI in the field of smart Energy Management are as follows.

Supply-Demand Management: Even while the increased usage of RE provides a wonderful potential for current cultures to combat resource scarcity [21], because RE is so dependent, AI can give precisely power supply in order to respond to natural oscillations, alter operations so that plans are not disturbed, and adapt to anticipated actual consumers' needs. It is expected to boost RE efficiency by automating operations, which would necessitate the employment of AI on a wide scale. The ultimate target for RE networks is to maximize production capabilities' intakes because of the volatility and associated cost of uncertainty. Artificial intelligence is being used to predict energy requirements to better respond to peaks. The energy demand and

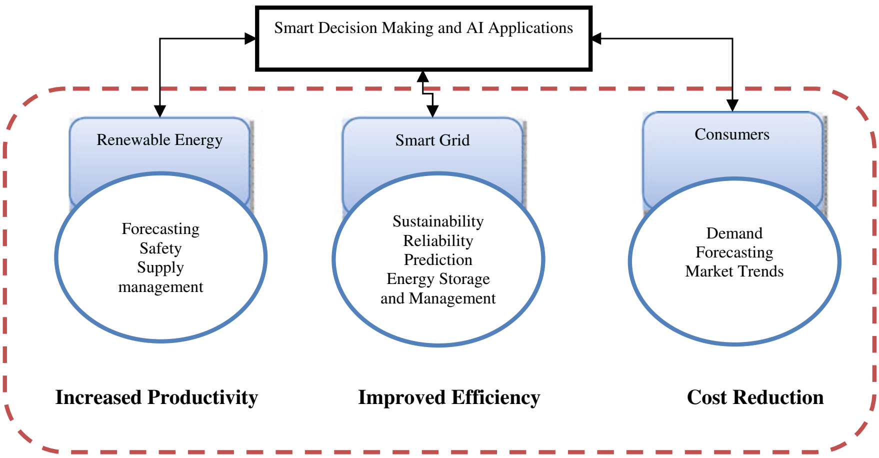


Fig. 6 Relation between AI and energy management system

energy supply of decentralized manufacturing systems (private customers generating energy from renews) which use grid power when development is below their requirements and return supplementary power to the grid when it produces more than it consumes are essential. The exchange of energy between consumers and suppliers would be continuous.

Intelligent Storage: Recent trends have shown that AI can provide optimization, even without extensive weather information on a long-term basis [21]. The inclusion of smart storage in the RE project maximizes investment revenues and enhances flexibility for changing demand and renewable inputs caused by climate circumstances. Smart storage must be fully utilized, and smart renewable energy systems must be developed. The result will affect both energy producers and consumers because they have low-cost access to energy. The improving distribution networks and storing systems are significant advantages for renewables' integration (the use of RE output in the electricity system). In addition, a useful adaptation mechanism is the ability to switch between energy sources. Storage technology can help to tackle the challenges of renewable energy volatility (mainly wind or solar) and demand cyclicality. More energy can be produced if it is not required.

Control System: AI integrated for control will help to prevent energy shortages by detecting problems early and reducing the time it takes to repair them. The control system is basically designed on alarm-based reporting, web-based interface, security keys, and backup server for unexpected cases, for authentication for users from multiple locations, and other features to be effective in these directions. The platforms required for controlling the supervised locations are referred to as centralized intelligent control. AI could help to manage this exponentially rising data by providing techniques for dealing with RE variations based on experience and forecasts. It will aid in the integration of renewable energy into the energy chain, as well as the improved utilization of the capabilities of these forms, regardless of their fluctuation.

Smart Grids or Microgrids: A microgrid can function as a "'island" as well as being connected to the grid. Microgrids are small integrated grids that are considered to be regulated systems to increase grid connections [22]. In these cases, they could also be cost-effective. In microgrids, RE can not only be used as a primary power supply but can also be used as emergency support to reduce disturbance in the event of energy shortages. As fossil fuels are becoming more and more costly and emissions, a growing trend is toward the use of standalone hybrid renewable energy systems. Renewable energy, the increased storage capacity, and interaction linkages have determined the need for much greater development of grid control and protection that provides the energy system with greater flexibility and reliability [23]. Intelligent microgrid technologies symbolize a shift away from the previous centralized energy production and delivery system and toward a new and modern network that includes decentralized energy transmission, generation, and distribution.

5 Overview of Smart Grids

For upcoming smart grid technology, there have been enough operational and analytical standardization approaches. Among all the different ideas of smart grid construction, the National Institute of Standards and Technology (NIST) smart grid theoretical framework, the IEEE 2030 guideline, and the smart grid architectural model (SGAM) are the most frequently acknowledged (Fig. 7). The SGAM is a cube-shaped framework made up of five compatibility layers (component, communication, information, function, and business). Inside of coming generations' advanced technologies, the layers considerably interweave among information and communications technologies (ICT), energy informatics, and commercial viewpoints. Domains and zones are subdivided inside each layer. Beginning with mass production, transmitting, distributing, distributed energy resources (DER), and customer premises or loads, the domains cover the entire energy conversion cycle. Processes, area, stations, function, business, and marketplace are the organization chart of power system administration that the zones are separated into. The processing zone contains the majority of mechanical energy conversion devices. The security, controlling, and surveillance systems are located in the zone of the field, while the information concentrating and functioning aggregation modules are located in the station zone. The microgrid energy and distributing administration modules are housed in the operation zone.

Every element (physical equipment, information transfer, information, program, compatibility, and limitations) must be integrated into mathematical models, and their connections must be studied. The location of zonal components is characterized based on their intended use. The processing zone houses key elements such as energy and cable exchange, loads, detectors, and actuators, whereas the field zone houses control, security, and detection systems. The station zone houses data reflectors, functional aggregators, substation mechanization and monitoring units,

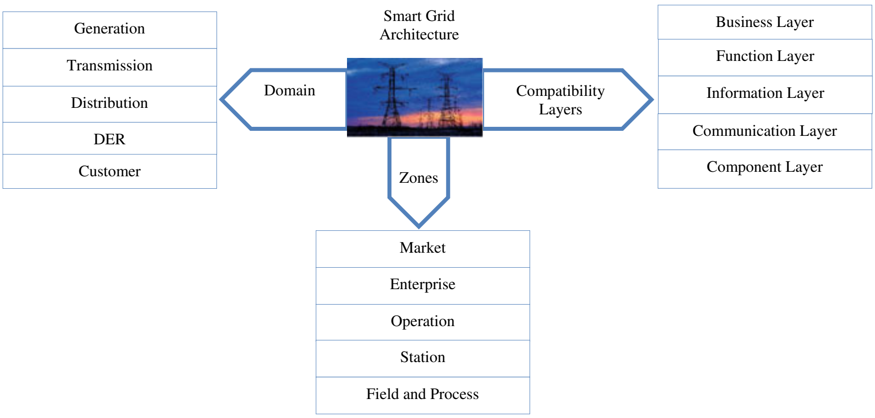


Fig. 7 Smart grid architecture models

and equipment, while the operational zone houses the microgrid's energy management and dispersal modules. Huge power systems, intermediate mechanization, and distribution channels are all described by the SGAM [24].

A smart grid ontology should include ICT algorithms as well as terminology and taxonomies for smart grid design. The ontological description acts as a central foundation for a variety of abbreviations that are used to express models in various layers. The framework will aid in the validation of various smart grid protocols, allowing for compatibility between virtualized and physical devices via globally diverse Internet of Things (IoT) or interaction taking into account faster dynamic phenomena and communication delay.

6 Smart Grid: A Perspective of Smart City with Machine Learning and IoT

Smart grids are one of the most concerning parts of the electrical transmission system. Modern power grids when integrated with the machine learning and IoTs have operational domain to control and monitor, analyze the data, service provider domain for customer management, emerging services, building, and home management, account and billing management, market domain for ancillary operations, trading and market operations as well as it has a custom domain for various service. A brief literature review related to smart grids using the machine learning and Internet of Things algorithm is presented here.

Zhuzhu Wang et al. [25] presented a lightweight secure, privacy-preserving Q-learning framework (LPSG) for developing smart grid energy management strategies that were implemented using IoTs as the world's largest Internet of Things (IoT) deployment; the smart grid substantially decreases energy dissipation for urban planning operations. The smart grid's power data comprises a significant amount of valuable data, such as shipping orders and bills. The dataset is always provided to Cloud servers in an unencrypted manner for the Q-learning-based energy plan creation, giving the intruder the chance to abuse the customer data. In order to get to the control panel, the energy the information present in the supply site in LiPSG is divided into evenly random secret shares. LiPSG's security and productivity are further demonstrated through comprehensive theoretic research and experiments. Unlike prior smart grid confidentiality and integrity approaches, LiPSG is the first to provide wide Q-learning-based confidentiality and integrity energy utilities with good precision and minimal performance loss. The presented model of power grids provides the secure machine learning algorithm, computer efficiency, privacy preserving. The only disadvantage of the work is that the handling capacity of accuracy does not allow the accuracy reduction.

Abir et al. [26] reviewed the present hazard and threat models for the Internet of Things power sources, as well as mitigating strategies for such security flaws also explained how emerging innovations (such as deep learning and machine intelligence) may help the Internet of Things power grid systems and related technologies become more reliable and protected, as well as solve current problems, resulting in improved, strong, and dependable functioning. This article will specifically assist in comprehending the structure for Internet of Things smart grid energy systems, as well as connected potential threats and the opportunities for new technologies to increase the efficacy of smart grids. Supervisory Control and Data Acquisition (SCAD) are used and this research chapter introduces a smart meter for billing and enhanced security. The only disadvantage is that the present work focuses only on the security domain and control domain of the smart grids.

Han et al. [27] focused on alternative energy like renewable sources and its management with the smart grids in a cost-effective way to improve environmental sustainability, but the research so far hasn't focused on the possibilities of edge computing in the controlled Internet of Things (IoT). Researchers work for the betterment of today's smart grids on households, and businesses to offer a machine learning framework for smarter power management. The research provides an economical and reliable means of communication between electricity distributors and households, and users by predicting future power energy use for short periods. Edge device-based real-time energy management via a common Cloud-based data supervisory server and an optimum normalization approach are among the main contributions. This research work gives multiple data pre-processing approaches to cope with the various kinds of power data, accompanied by such an optimal decision-making system for relatively brief forecasts and implementation on resource-constrained electronics devices. To applying diffrent comprehensive tests of mean-square error (MSE) and root MSE (RMSE) reductions of 0.15 and 3.77 units for residential and business databases, respectively. Also, it is suggested that in the future, resource-constrained devices can be joined in an IoT network for reciprocal energy sharing to meet each other's demand and conserve energy resources, in addition to edge intelligence utilizing reliable IoT. Similarly, for successful real-time energy forecasting approaches, researchers can also combine sequential learning with fuzzy logic, to investigate efficient set theory principles combined with effective CNN's employing weighted fusion methods, as well as Cloud and Fog computing for extremely accurate and fast output forecasts from time to time.

Siryani et al. [28] provided a data-driven decision-support system for improving ESM operations on the Internet of Things ecosystem. The suggested technique is innovative and reliable since it uses and compares four distinct ML algorithms: complete Bayesian network, naive Bayes, decision tree, and random forest to forecast either to send a technician to a delivery site or handle issues remotely. A random forest is a notable approach; the study of those IoT-based meter data for big datasets, with the greatest accuracy of 96.69 percent, provides the best alternating cost reduction techniques.

Hossain et al. [29] defined the structure of an IoT-based smart grid that processed the data on the processing layers, Application layer, Network layer, Aggregation layer, and Sensing layer from which the different infrastructure of smart grid. The application layer provides the Service domain, NL provides the Access points, AG provides the Data collection, and the SL provides the Smart meters. The heart of this new grid architecture is IoTs. The Smart Grid system with IoT integration may give optimized energy predictions and data gathering techniques while also being cost-effective. To gain these effects, predictive analytics and machine learning approaches are required. Cybersecurity becomes a key concern. In a smart grid complex linked system, IoT devices and their data are becoming important targets of assaults. This study provided a chronology of the grid's evolution into a smart grid, as well as how the Internet of Things (IoT) has become an integral element of the energy system. Other security problems in the smart grid, such as those connected with IoT-generated large data, such as their analysis and protection, were also highlighted. The big data analysis techniques discussed here have various disadvantages like Cloud sourcing and clustering, also the constraints of switching to a smart grid centered on renewable energy, as well as possible solutions, which must be studied.

The Dynamic Membership Data Aggression (DMDA) using ML for the power grid is presented by Song et al. [30] to ensure the collective usefulness of large data while maintaining the security of independent sources. The findings and model are provided to demonstrate that the security and performance standards are met. Particularly when users join or depart often, the Dynamic Membership Data Aggression is more lightweight, ensuring that the standard is more suited for the virtual aggregation area of Internet of Things settings. Results show that the Dynamic Membership Data Aggression (DMDA) is more appropriate for advanced future-based smart grid and other Internet of Things scenarios than standard privacy-preserving data aggregation schemes. Implementation time, Communication cost, Execution time with different numbers of users 100,200,300, and so on are discussed.

Mortaji et al. [31] discussed the use of a unique algorithm for smart direct load control and load shedding to lower the Peak-to-Average Ratio and minimize power outages in unexpected grid load fluctuations by changing data into intelligent predicted actions using IoTs. It also provides real-time power transfer and produces a daily plan for clients with Integrated Electronic Devices, using Internet of Things and ML. The findings showed that load shedding utilizing the ARIMA time series prediction model, smart direct load control (S-DLC), and Internet of Things may considerably minimize power outages for customers. Load shedding varies from 380 to 400 during 24 h of span which means an almost 30% reduction in the peak loads. Big data collection is the drawback because many database and control base methods are implemented.

Chin et al. [32] focused on the management domain of smart grids. The big data collected for various domains should be intelligently stored and handled to obtain useful information to cope with security risks, and vulnerability and blackout alerts should be issued at an initial point. The authors provide detailed research and questionnaire to emphasize problem statements on Internet of Things-based smart grid concerns. To deal with network-based threats, the research relies on automated detection techniques. Grid vulnerabilities should be identified as soon as possible. More study on quick and auto-recovery methods is required.

Li et al. [33] discussed the use of LPWAN with the IoTs which is emerging day by day. In this work, NB-IoT is integrated into the smart grid and compared to existing representative communication technologies in terms of data rate, latency, and range in the context of smart grid communications. Monte Carlo simulations are used to assess the effectiveness of NB-IoT in typical smart grid communication settings, such as urban and rural locations. The result shows that the NB-IoT-based smart grids have several advantages like low cost, covering a range of more than 35 km, etc.; also, it has a drawback that it is latency-insensitive which is less than 10 s and it does not provide distribution automation. It has been demonstrated that NB-IoT is capable of providing communication services with an extended range, suitable data rate, and high reliability.

Yao et al. [34] presented a smart grid energy theft detection system that preserves energy privacy. The research work employed integrated convolutional neural networks (CNNs) in particular to detect aberrant metered data behavior from a long-period sequence. Furthermore, it uses the Paillier algorithm to preserve energy privacy. In other words, the transfer of users' energy data is safe, and data leakage is kept to a minimum. Security and privacy are both achieved in this approach, according to a security study updated, the CNN model can detect aberrant behaviors with an accuracy of up to 92.67%, according to experimental data.

Tet al. [35] studied the comprehensive description of the dangerous environment that develops when CC and IoT are combined in a Smart Grid. The confluence of the Smart Grids, CC, and IoT concepts is centered on meeting client demands, increasing efficiency, and retaining total control. However, integrating various technologies under a single architecture creates a slew of new interdependencies, posing new difficulties ranging from overall power system stability to unique cybersecurity threats.

Proposed field of smart grid safety with sensor and communication techniques integrated into power systems were highlighted, along with a variety of security and vulnerability issues that the IoT-based grid is vulnerable. Only a few articles focus on neutralizing computer security, whereas the majority of studies focus on detecting and preventing cyber-threats. As a result, future advances in this field of research are expected to focus on cyber-threat mitigation with various robust machine learning techniques for effective cyber-threat identification. The security domain of the smart grid is discussed in this paper.

Qadir [37] categorized a machine learning model that might be effective and beneficial in predicting energy and electricity. Data from the past is handled both with and without data modification. Data modifications are done via cross-validation and recursive feature elimination using cross-validation (RFECV). Artificial neural network regressors are used to train the data, and correlations between different characteristics within the database are discovered. The proposed computational approach offers a lot of promise for improving the efficiency of smart grids. The model has a mean square error of 0.0000001041, an R-squared of 99.60%, and a calculation time of 0.02 s. This research work focuses on the management and service domain of the smart grid. It does not provide any accuracy on the security threats by the use of big data.

Babar et al. [38] presented safe demand-side management (DSM) engine for the Internet of Things-enabled grid utilizing machine learning. The suggested DSM engine is in charge of maintaining efficient energy consumption depending on priorities. To administer IoT-enabled HAN, an Interface Control Agent is suggested. An AEME is also proposed for effective energy use in smart grids. The results of the research show that the proposed DSM engine is less sensitive to attack and good enough even to minimize the smart grid's power consumption. The result shows that with the implementation, the power consumption decreases to 6000 W from 8000 W in a given simulation time. This research work focuses on the management and service domain of the smart grid. It does not provide any accuracy in the security domain.

Razavi [39] proposed the threat detection technique using five different algorithms using the data of 4000 households and six different cybersecurity attacked cases were created and the model is checked. The clustering method found five household groups using half-hourly power usage data from over 4000 households over 18 months. Out of the five algorithms used, the Gradient Boosting Machine algorithm outperformed all the others. This research work focuses on the security domain of the smart grid.

Gumaei et al. [40] presented an accurate prediction technique for smart grids, which increases accuracy and lowers computational burden, combining the CFS technique with the KNN algorithm to identify assaults on a SCADA power system The CFS technique reduces the number of characteristics required in classification, improving detection accuracy while reducing detection time. The KNN method helps increase prediction performance by tackling the issue of overlapping between SCADA electric grid features. The efficacy and efficiency of the suggested technique were assessed using 15 public datasets from a SCADA power system. 17 of the 128 smart-grid network characteristics are used in the proposed study to obtain the greatest detection rate. Other controlled techniques, such as deep learning algorithms, will be used in the future to manage vast volumes of smart grid data of various sizes.

Liu [41] presents the CNN model for the smart grids for forecasting to predict the various energy domain characteristics. Edge sensing data in the electrical system grids provide a lot of information that encourages the development of new power management applications in IoT-driven smart cities and societies. In smart cities and society, DIC is being proposed to enhance forecasting accuracy. The suggested DIC method improves training speed by 61.7 percent, decreases RMS error by at least 32.9%, and increases prediction accuracy by 1.4% when compared to support vector machines (SVM), and CNN, LST memory, according to observed measurements (Table 1).

7 Discussions and Challenges

The energy requirement is a key research area while implementing smart cities during the last decades. Information and Communications Technology (ICT) is considered

Table 1 Different approaches for MI/IoTs in smart grids

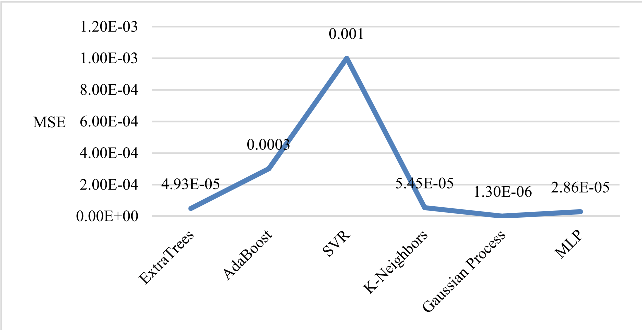
References	Year	Approach	Security domain	Bulk domain	Energy management	Description
Barbierato et al. [25]	2019	LiPSG machine learning algorithm	Yes	Yes	No	Provide cyber-threat, does not provide accuracy correction
Wang et al. [26]	2021	SACD algorithm, smart meter	Yes	No	Yes	Billing and enhanced security
Abu Adnan Abir et al. [27]	2021	Edge device-based real-time algorithm, CNN	Yes	Yes	Yes	Observed reduced MSE of 0.15 and RMSE of 3.77
Han et al. [28]	2017	Smart meter, different algorithm used	No	Yes	Yes	Random forest outperformed with greatest accuracy of 96.69%
Siryani et al. [29]	2019	Big data analysis, smart meters with IoTs (different layers)	Yes	Yes	Yes	Big data analysis is studied, Disadvantages are clustering and Cloud sourcing
Hossain et al. [30]	2020	DMDA machine learning algorithm	Yes	Yes	Yes	More focused on energy and customer domain not on security domain
Song et al. [31]	2017	ARIMA algorithm of IoTs	No	Yes	Yes	Handling big/large data is the only disadvantage, many data and control base method are used
Mortaji et al. [32]	2017	Internet of Things	Yes	Yes	Yes	More quick and auto-recovery methods required
Chin et al. [33]	2018	LPWAN+IoT	No	No	Yes	Extended range, highly reliable and suitable data rate, disadvantage is this is Latency-insensitive
Liet al. [34]	2019	Smart metres, CNN	Yes	Yes	Yes	Accuracy of 96.67% attained with CNN

to be the most promising technique for SEM in smart cities. In this section, some of the major contributions of AI/IoT and their performance are analyzed to prove their effectiveness. In [37], the energy and power output was predicted based on changing weather conditions using renewable resources in smart grid applications. For prediction, an Artificial Neural Network (ANN) was used for the prediction of energy output. The prediction was done based on weather data. Figure 8a represents the efficiency of different ML techniques for the accurate prediction of power output. In [42], the author worked on the topology of the smart grid using renewable energy (RE) sources for efficient energy savings and the use of cleaner energy. The topology was based on cellular networks to increase or decrease their grid consumption. Energy management policies are designed using the Markov chain. The weather pattern was also focused on smart control design to evaluate the performance of the system and to minimize the energy operational cost. Figure 8b represents the performance evaluation concerning renewable energy utilization. The figure shows with the integration of AI, the energy cost is reduced. In [43], the author presented a survey on AI applications for smart energy management by load forecasting. The smart grid scenario was implemented and deployed using a deep learning application. In [44], the author presented an ANN-based control and management of smart grid for improvement in power efficiency. Figure 8c represents the efficiency analysis of different ML techniques and shows that ANN is more efficient as compared to other algorithms.

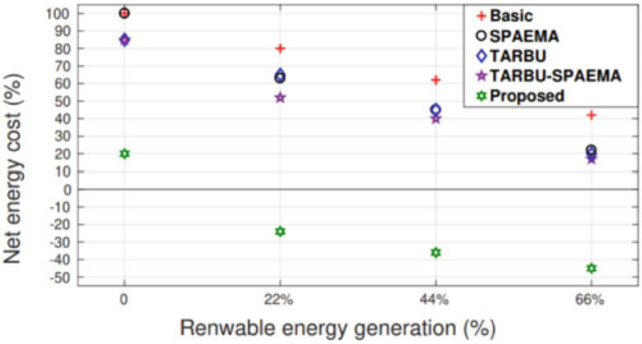
The chapter concludes that the existing works combine technical, control, and management approaches to achieve the sustainable green and sustainable energy management system. But still, there are many research scopes that need to be focused on in the future. From the study, some future research scopes are identified that are shown in Fig. 9. Real-time deployment in smart cities and its monitoring are performed using smart electrical equipment, AI-integrated sensors, and ML controls. Therefore, there is scope for optimization of the overall objectives at an affordable cost and need to be sustainable.

8 Conclusion

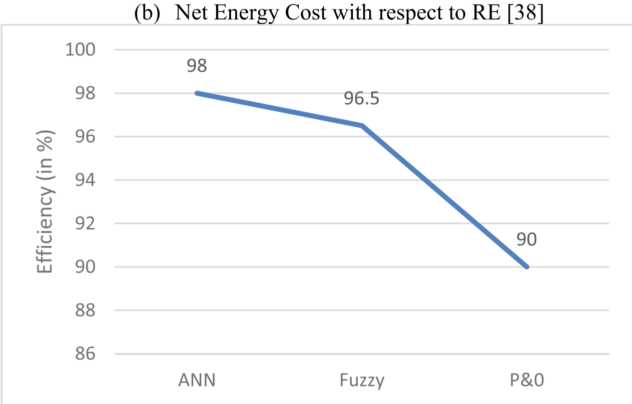
Renewable energy services powered by AI/IoT have a big environmental impact and are cost-efficient. A qualitative method for employing artificial intelligence (AI) as a disruptive technology to support and encourage the establishment of a new region of smart energy infrastructure as a service in the renewable energy industry is successful. In a changing climate and market context, AI will improve in the management of energy production and consumption. Among the most significant issues in this industry is the unpredictability of renewable energy sources, which is becoming increasingly important as the proportion of renewable energy in overall energy output rises. For minimizing the risk of the unpredictability of RE sources, AI will become the approach that really should be implemented at the economical level.



(a) MSE Analysisusing ML Techniques [33]



(b) Net Energy Cost with respect to RE [38]



(c) Efficiency Analysis using ML Techniques[40]

Fig. 8 Result analysis of ML techniques

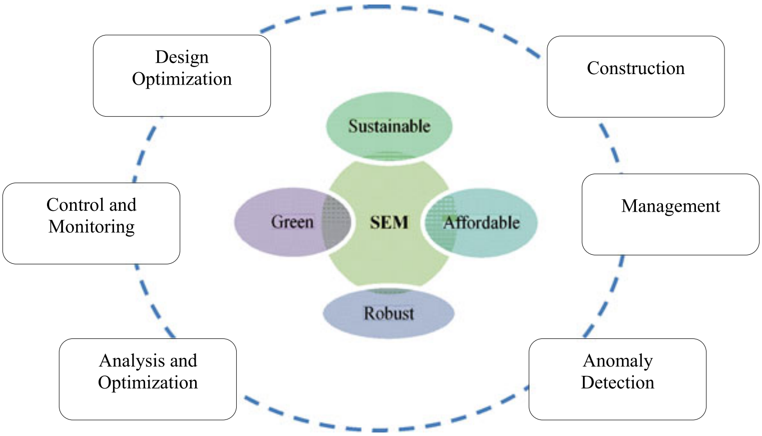


Fig. 9 Future research direction in SEM

References

1. Masera M, Bompard EF, Profumo F, Hadjsaid N (2018) Smart (electricity) grids for smart cities: assessing roles and societal impacts. Proc IEEE 106(4):613–625. https://doi.org/10.1109/JPROC.2018.2812212
2. Morello R, Mukhopadhyay SC, Liu Z, Slomovitz D, Samantaray SR (2017) Advances on sensing technologies for smart cities and power grids: a review. IEEE Sensors J 17(23):7596–7610. https://doi.org/10.1109/JSEN.2017.2735539
3. Chen X (2019) The development trend and practical innovation of smart cities under the integration of new technologies. Front Eng Manage 6:485–502. https://doi.org/10.1007/s42524-019-0057-9
4. Javadzadeh G, Rahmani AM (2020) Fog computing applications in smart cities: a systematic survey. Wirel Netw 26:1433–1457. https://doi.org/10.1007/s11276-019-02208-y
5. Cimmino A, Pecorella T, Fantacci R, Granelli F, Rahman T, Sacchi C et al (2013) The role of small cell technology in future smart city. Trans Emerg Telecommun Technol 25:11–20
6. Rajawat AS et al (2021) Fusion protocol for improving coverage and connectivity WSNs. IET Wirel Sensor Syst 11(4):161–168. https://doi.org/10.1049/wss2.12018. Accessed 21 Aug 2021
7. Rajawat AS, Upadhyay AR (2020) Web personalization model using modified S3VM algorithm for developing recommendation process. In: 2nd International conference on data, engineering and applications (IDEA), Bhopal, India, 2020, pp 1–6. https://doi.org/10.1109/IDEA49133.2020.9170701
8. Rajawat AS, Rawat R, Barhanpurkar K, Shaw RN, Ghosh A (2021) Vulnerability analysis at industrial internet of things platform on dark web network using computational intelligence. In: Bansal JC, Paprzycki M, Bianchini M, Das S (eds) Computationally intelligent systems and their applications. studies in computational intelligence, vol 950. Springer, Singapore. https://doi.org/10.1007/978-981-16-0407-2_4
9. Rajawat AS, Rawat R, Barhanpurkar K, Shaw RN, Ghosh A (2021) Blockchain-based model for expanding IoT device data security. In: Bansal JC, Fung LCC, Simic M, Ghosh A (eds) Advances in applications of data-driven computing. Advances in intelligent systems and computing, vol 1319. Springer, Singapore. https://doi.org/10.1007/978-981-33-6919-1_5
10. Rajawat AS, Rawat R, Shaw RN, Ghosh A (2021) Cyber physical system fraud analysis by mobile robot. In: Bianchini M, Simic M, Ghosh A, Shaw RN (eds) Machine learning for robotics

applications. studies in computational intelligence, vol 960. Springer, Singapore. https://doi.org/10.1007/978-981-16-0598-7_4
11. Hao L, Lei X, Yan Z, Chun Li Y (2012) The application and implementation research of smart city in China. System Science and Engineering (ICSSE), Dalian, Liaoning, China
12. Jawhar I, Mohamed N, Al-Jaroodi J (2018) Networking architectures and protocols for smart city systems. J Internet Serv Appl 9:26. https://doi.org/10.1186/s13174-018-0097-0
13. Poulkov V (2021) The wireless access for future smart cities as a large scale complex cyber physical system. Wirel Pers Commun 118:1971–1985. https://doi.org/10.1007/s11277-019-06343-9
14. Klaina H et al (2020) Aggregator to electric vehicle LoRaWAN based communication analysis in vehicle-to-grid systems in smart cities. IEEE Access 8:124688–124701. https://doi.org/10.1109/ACCESS.2020.3007597
15. Li G, Jin Y, Akram MW, Chen X, Ji J (2018) Application of bio-inspired algorithms in maximum power point tracking for PV systems under partial shading conditions—a review. Renew Sustain Energy Rev 81:840–873
16. Sobri S, Koohi-Kamali S, Abd Rahim N (2018) Solar photovoltaic generation forecasting methods: a review. Energy Convers Manage 156:459–497
17. McGovern A, Elmore K, Gagne DJ, Haupt SE, Karstens CD, Lagerquist R, Smith T, Williams J (2017) Using artificial intelligence to improve real-time decision-making for high-impact weather. Bull Am Meteor Soc 98(10):2073–2090
18. Jha SK, Bilalovic J, Jha A, Patel N, Zhang H (2017) Renewable energy: Present research and future scope of Artificial Intelligence. Renew Sustain Energy Rev 77:297–317
19. Voyant C, Notton G, Kalogirou S, Nivet ML, Paoli C, Motte F, Fouilloy A (2017) Machine learning methods for solar radiation forecasting: A review. Renew Energy 105:569–582
20. Das UK, Tey KS, Seyedmahmoudian M, Mekhilef S, Idris MY, Van Deventer W, Horan B, Stojcevski A (2018) Forecasting of photovoltaic power generation and model optimization: a review. Renew Sustain Energy Rev 81:912–928, Part 1
21. Ssekulima EB, Anwar MB, Al Hinai A, El Moursi MS (2016) Wind speed and solar irradiance forecasting techniques for enhanced renewable energy integration with the grid: a review. IET Renew Power Gener 10(7):885–898
22. Chaouachi A, Kamel RM, Andoulsi R, Nagasaka K (2016) Multiobjective intelligent energy management for a microgrid. IEEE Trans Industr Electron 60(4):1688–1699
23. Dawoud SM, Lin X, Okba M (2018) Hybrid renewable microgrid optimization techniques: a review. Renew Sustain Energy Rev 82:2039–2052
24. Barbierato L, Estebsari A, Bottaccioli L, Macii E, Patti E (2020) A distributed multimodel cosimulation platform to assess general purpose services in smart grids. IEEE Trans Ind Appl 56(5):5613–5624. https://doi.org/10.1109/TIA.2020.3010481
25. Wang Z et al (2019) LiPSG: lightweight privacy-preserving Q-learning based energy management for the IoT-enable smart grid. IEEE IoT J 2327–4662. https://doi.org/10.1109/JIOT.2020.2968631
26. Abu Adnan Abir SM et al (2021) IoT-enabled smart energy grid: applications and challenges. Digital Object Identifier. https://doi.org/10.1109/ACCESS.2021.3067331
27. Han T et al (2021) An efficient deep learning framework for intelligent energy management in IoT networks. IEEE IoT J 8(5):3170
28. Tanju SB, Eveleigh TJ (2017) A machine learning decision-support system improves the internet of things' smart meter operations. IEEE IoT J 4(4):1056–1066. https://doi.org/10.1109/JIOT.2017.2722358
29. E. Hossain et al.: "Application of Big Data and Machine Learning in SG, and Associated Security Concerns", https://doi.org/10.1109/ACCESS.2019.2894819, 13962 VOLUME 7, 2019
30. Song J et al (2020) A dynamic membership data aggregation (DMDA) protocol for smart grid. IEEE Syst J 14(1)
31. Mortaji H, Ow SH et al (2017) Load shedding and smart-direct load control using internet of things in smart grid demand response management. IEEE 0093–9994 (c). https://doi.org/10.1109/TIA.2017.2740832

32. Chin W, Li W, Chen H (Oct. 2017) Energy big data security threats in IoT-based smart grid communications. IEEE Commun Mag 55(10):70–75. https://doi.org/10.1109/MCOM.2017.1700154
33. Li Y, Cheng X, Cao Y, Wang D, Yang L (2018) Smart choice for the smart grid: narrowband internet of things (NB-IoT). IEEE IoT J 5(3):1505–1515. https://doi.org/10.1109/JIOT.2017.2781251
34. Yao D et al (2019) Energy theft detection with energy privacy preservation in the smart grid. IEEE IoT J 6(5)
35. Mavroeidakos T, Chaldeakis V (2020) Threat landscape of next generation IoT-enabled smart grids. In: Maglogiannis I, Iliadis L, Pimenidis E (eds) Artificial intelligence applications and innovations. In: AIAI 2020 IFIP WG 12.5 international workshops. AIAI 2020. IFIP Advances in information and communication technology, vol 585. Springer, Cham. https://doi.org/10.1007/978-3-030-49190-1_11
36. Sakhnini J, Karimipour H, Dehghantanha A, Parizi RM, Srivastava G (2019) Security aspects of internet of things aided smart grids: a bibliometric survey. Internet of Things. https://doi.org/10.1016/j.iot.2019.100111
37. Qadir Z, Khan SI, Khalaji E, Munawar HS, Al-Turjman F, Parvez Mahmud MA, Kouzani AZ, Le K (2021) Predicting the energy output of hybrid PV–wind renewable energy system using feature selection technique for smart grids. Energy Reports. ISSN 2352-4847,https://doi.org/10.1016/j.egyr.2021.01.018
38. Babar M, Tariq MU, Jan MA (2020) Secure and resilient demand side management engine using machine learning for IoT-enabled smart grid. Sustain Cities Soc. https://doi.org/10.1016/j.scs.2020.102370
39. Razavi R, Gharipour A, Fleury M, Akpan IJ (2019) A practical feature-engineering framework for electricity theft detection in smart grids. Appl Energy 238:481–494. ISSN 0306-2619, https://doi.org/10.1016/j.apenergy.2019.01.076. https://www.sciencedirect.com/science/article/pii/S0306261919300753
40. Gumaei B, Hassan MM, Huda S, Md. Rafiul Hassan, Camacho D, Ser JD, Fortino G (2019) A robust cyberattack detection approach using optimal features of SCADA power systems in smart grids. Appl Soft Comput 96:106658. ISSN 1568-4946. https://doi.org/10.1016/j.asoc.2020.106658. https://www.sciencedirect.com/science/article/pii/S1568494620305962
41. Goyal SB, Bedi P, Rajawat AS, Shaw RN, Ghosh A (2022) Smart luminaires for commercial building by application of daylight harvesting systems. In: Bianchini M, Piuri V, Das S, Shaw RN (eds) Advanced computing and intelligent technologies. Lecture notes in networks and systems, vol 218. Springer, Singapore. https://doi.org/10.1007/978-981-16-2164-2_24
42. Banerjee A et al (2022) Construction of effective wireless sensor network for smart communication using modified ant colony optimization technique. In: Bianchini M, Piuri V, Das S, Shaw RN (eds) Advanced computing and intelligent technologies. Lecture notes in networks and systems, vol 218. Springer, Singapore. https://doi.org/10.1007/978-981-16-2164-2_22
43. Akhtaruzzaman M, Hasan MK, Kabir SR, Abdullah SNHS, Sadeq MJ, Hossain E (2020) HSIC bottleneck based distributed deep learning model for load forecasting in smart grid with a comprehensive survey. IEEE Access 8:222977–223008. https://doi.org/10.1109/ACCESS.2020.3040083
44. Goyal SB, Bedi P, Rajawat AS, Shaw RN, Ghosh A (2022) Multi-objective fuzzy-swarm optimizer for data partitioning. In: Bianchini M, Piuri V, Das S, Shaw RN (eds) Advanced computing and intelligent technologies. Lecture notes in networks and systems, vol 218. Springer, Singapore. https://doi.org/10.1007/978-981-16-2164-2_25