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Review

Smart grid (SG) properties and challenges: an overview

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Abstract
The electric power system is undergoing considerable changes in operation, maintenance, and planning as a result of the integration of Renewable Energy Resources (RERs). The transition to a smart grid (SG), which employs advanced automation and control techniques, brings with it new difficulties and possibilities. This paper provides an overview of next-generation smart grids by presenting the most current and cutting-edge developments in the SG sector. This paper discusses the benefits, drawbacks, and prospects of smart grids. The difficulties of integrating RERs into the grid, as well as alternative energy storage solutions, are discussed. The unpredictable nature of resources has an impact on RER output. The energy storage system is critical in dealing with RERs' unpredictable nature and ensuring a smooth and reliable supply to load demand. Smart energy systems provide a number of problems and possibilities in terms of developing, integrating, and implementing electrical grids that incorporate network and communication technologies, as well as important privacy and security concerns for various components within the grid. This paper also shows the influence of SGs on distributed energy generation, as well as a comparative analysis on electric cars (EVs), including classification, i.e., battery, and hybrid electric vehicles, as well as current difficulties and challenges in EV technology. A discussion of SG protection concerns and their resolution is also included.

Keywords Smart grid · Traditional network · SG benefits · Characteristics · And challenges · EV · RER · Distributed generation

1 Introduction

Improving the efficiency, security, economy, and reliability of the electrical grid is applied by upgrading distribution and transmission grid. The Smart Grid (SG) upgrade distribution and transmission grid by employs information, communication technologies, and control methodology. Smart metering, enhanced network operation and management, faster fault diagnosis, and self-healing capabilities employing grid automation can transform the traditional grid into the SG [1]. SG is an integrated system of information, communication, and control technologies and systems that interact with automation and business processes across the whole power sector, including electricity generation, transmission, distribution, and consumers [1]. However, the SG is a large-scale power supply network and is designed to work on large community power supple technology, there are other types of technologies such as microgrids and nanogrids which are designed to work in small community areas. A microgrid is a local energy grid with control capability, which means it can disconnect from the traditional grid and operate autonomously [2]. A nanogrid is a power distribution system for a

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single house/small building, with the ability to connect or disconnect from other power entities via a gateway. It consists of local power production powering local loads, with the option of utilizing energy storage and/or a control system [3].

Oil, natural gas, and uranium are all power sources that the world has relied on for a long time, but they might all run out at any time, Power generation from renewable energy resources (RERs) has increased dramatically in recent decades, and renewable energy power is playing and increasingly key role [4]. Due to the irregular nature of these resources, it is necessary to indicate the responsibilities imposed to the network in order to improve the integration of renewable power in the conventional power network [5]. Significant uncertainty is introduced into the power grid as a result of the integration of variable RERs such as solar PV and wind. Advances in the design and pricing features of energy and services markets are required as electric market structures alter to facilitate the management of renewable sources [6]. Add also that increases in volumes of VREs may achieve a critical mass that require changes in the management approach to the grid to enable supply to lead demand rather than the current paradigm. This could mean shifting demand to times when solar and wind are generating and away from times when they are not. It might also mean integrating large volumes of storage or other forms of demand side management.

In comparison to fossil fuels and other non-renewable energy, renewable energies are more sustainable, dependable, and cost less. It is meant by dependable that, SGs enable increases in the dependability for the network in periods of high VRE generation. Concerning the point of cost less, solar and wind cost less than FFs in many circumstances but other RE does not. Solar energy installation has high capital costs but there are many places where it has a lower LCOE than new FF power stations. Solar energy is becoming more popular throughout the world, particularly in rural areas where people lack access to power or simply cannot afford to pay their monthly electric bills. Because of its benefits, biomass is one of the most widely employed renewable energy today [7]. Table 1 shows the differences between the conventional electricity grid and the SG [8].

The contribution of this paper is that, it provides a detailed overview of next-generation smart grids by presenting the most current and cutting-edge developments in the SG sector. Also, it discusses the characteristics, benefits, drawbacks, and prospects of smart grid. In addition, it discusses the different technologies, smart network protection, and the different challenges of smart grids.

The rest of the paper is organized as follow: Section II introduces the relevant work concerning the SG. Section III represents the SG required characteristics. Section IV introduces the Benefits, Challenges, and Opportunities of smart grid. In section V, SG development required technologies are presented. Section VI shows the renewable energy as a part of SG. Section VII shows the Electric Vehicles (EVs) as a part of SG. Section VIII introduce the Smart Network protection. Finally, the conclusion is presented in section IX.

2 Related work

In [9], the critical issues on smart grid technologies are addressed in terms of information and communication technology issues and opportunities. They give the current state of the art in smart grid communications and point to research issues in this field. In [10] the authors attempt to investigate the role of smart grid in the renewable energy, they introduce the concept of renewable energies and smart grid concepts and its feasibility. In [11], a survey of cyber security issues for the Smart Grid is presented. They discuss security requirements, network, secure communication protocols and architectures in the Smart Grid. In [12] the authors make an overview on the enabling technologies for the Smart Grid. They explore three major systems, the smart infrastructure system, the smart management system, and the smart protection system. In [13], the authors overview the issues related to the smart grid architecture such as perspective of potential applications and the communications requirements needed for ensuring performance, reliability and economics. In [14], a survey on the communication architectures in the power systems. Also, they give a summary of the current state of research efforts in the communication networks of smart grid. In [15], the meaning of smart grid, the communication methods, and the components of the smart grid are introduced. Also, the communication methods are presented regarding to their improvements, and advantages.

Table 1 Difference between conventional electricity grid and SG

Topics	conventional electricity grid	SG
Aspect of technology	Electromechanical power grids are used in traditional power grids. As a result, it lacks communication and has very little internal regulation	SG may use digital technologies. It may allow gadgets to communicate with one another and encourages self-control
Generation	The infrastructure for power generation is extremely centralized. All of the energy is generated by a central system, which minimizes the use of alternate energy sources in the grid	The infrastructure for SG may be dispersed and distributed. It enables electricity to be distributed from different power sources, which may improve load balancing and reduces power interruptions
Monitoring of power plants	Manual monitoring of energy distribution	The SG may use modern technology and can self-monitor, which may help to eliminate the need to resolve outages
Incorporation of sensors	It uses a restricted number of sensors since the infrastructure can't handle them, making problem detection harder	Enables for various sensors to be placed along the line, which aids in the detection of faults
Control of energy	Energy distribution is outside the control of energy providers	Depending on the regulatory structure of each country, energy companies may have broad control over energy distribution due to the availability of specialized sensors and technology
Distribution system	It requires a one-way power distribution. Only traditional infrastructure is used to distribute power from the main power plant	It is one of the technologies that enables two-way power distribution, i.e., electricity to be returned to the distribution lines from a secondary power source
Restoration and repairing	To avoid prolonged power outages, personnel must physically go to the place of the breakdown and conduct the necessary repairs	The sensors in SG technology can detect, evaluate, and correct the needed faults without the need for physical interaction
Equipment	The conventional electrical grid is prone to outages and blackouts due to its age and limited capacity	One of the important equipment of smart grid is alternative energy sources which may allow a smart system to reduce the overall period of power outages
Choices of consumers	The existing power grid system does not allow customers to choose how they want to get their electricity	SG gives customers additional options when it comes to energy delivery or production

3 SG required characteristics

- Better communication: This is about how consumer engages with the network and how it interacts with the network itself. When consumers live in a house, for example, the electricity will be automatically cut off. Given this, it's simple to understand how much effort goes into the grid's sensing and feedback circuitry as it gets data from the electrical grid.
- Self-healing capability: SG should use technology to help with self-healing in reaction to natural faults or breakdowns without the need for human involvement.
- Adaptability and flexibility: SG should be able to adjust to changes in grid circumstances, particularly in terms of ever-changing load and power flow direction.
- Strength: This relates to the SG's capability to survive attacks.
- Real-time measurements and control: Due to the sensitivity of generated power even within microseconds, the grid must be capable of performing real-time measurements and regulating the grid while monitoring central generation, distribution generation, and other plants in the system.
- Reliable technology: SG should employ state prediction models, which increase problem detection and allow the related system to self-heal without any need for operator interaction [16]. This offers a consistent and steady flow of power and lowers the risks associated with it.
- Flexibility in networking: SG technology allows for more efficient bidirectional transfer of energy, enabling for distributed generation. PV energy, fuel cells, electric batteries, wind turbines, and other similar sources are examples of this.
- Increased efficiency: SG technology has made several contributions to the overall enhancement of the power grid system's and energy infrastructure's efficiency. The SG has benefited demand-side management greatly. It widely used algorithms such as voltage/VAR optimizer (VVO) that minimizes power demand through distribution network in idle time, and advanced metering infrastructure (AMI) technologies, which enhance usage data outage management [17]. All of this has resulted in increased energy efficiency and resource usage.
- Peak curtailment-usage and pricing: During high-cost and peak-use hours, communication networks and metering technology have lowered demand. Smart devices allow consumers to monitor energy usage. It also enables energy providers to cut down on usage and eliminate system overloads. Peak curtailment, which raises the cost of power during peak hours, achieves this.
- Sustainability: The SG system is said to be extremely adaptable since it allows for the coupling of multiple RERs, such as PV and wind energy, without the need for extra storage.
- Demand response: Demand response enables consumers and power stations to engage in real-time in an automatic way [18]. As a result, backup generation expenses are eliminated, and the life expectancy of power systems is increased [19].
- Advanced services in the near future: The integration of powerful two-way connections, along with advanced sensors and distributed technologies, would dramatically increase power generation, transmission, and distribution efficiency, productivity, dependability, and safety.

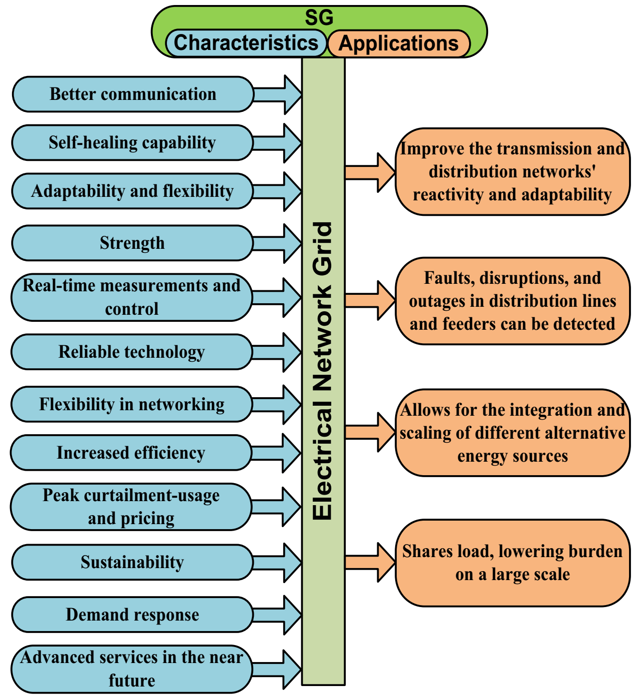
All the above characteristics made the smart grid perform many applications [20–24] as shown in Fig. 1:

1. Improve the transmission and distribution networks' reactivity and adaptability.
2. Faults, disruptions, and outages in distribution lines and feeders can be detected and recovered faster which leads to Lowers energy costs and peak demand.
3. Allows for the integration and scaling of different alternative energy sources including wind and solar electricity.
4. Shares load, lowering burden on a large scale.

4 Smart grids: benefits and challenges

A smart grid (SG), as previously stated, is a system that manages resources connected to the electricity grid by using computerized processing and communication technologies. The increasing reliance on technology and, as a result, the power supply that enables the functioning of these technologies in all aspects of life has raised the demand for asset management that maximizes productivity.

Fig. 1 Characteristics and applications of SG



4.1 SG benefits

- Traditional energy sources are more expensive than RER. because of SG technologies that enable RER to be increased in electrical network, so SG have credit for technology advances and energy costs decrease with time [25].
- The SG and its components' manufacturing, installation, maintenance, and operation will generate job possibilities for both skilled and unskilled workers [26]. Furthermore, it will assist in corporate growth while also giving innovative technical solutions.
- Customer satisfaction has increased as a result of enhanced dependability and decreased expenses [27]. Furthermore, SG gives customers more control over energy distribution and consumption.
- SG decreases power outages while also increasing power efficiency.
- SG decreases power outages while also increasing power efficiency.
- SG has a beneficial environmental impact since it aids in the reduction of greenhouse gas emissions by permitting alternative RERs and electric cars (EVs) [28]. Furthermore, due of efficient power generation, it minimizes oil usage.
- SGs improve the existing power grid's capacity and capabilities. They also include self-healing and predictive maintenance capabilities.

4.2 SG challenges

- Because SG technology is still in its infancy, there are few strong regulatory laws in place to prevent waste, loss, and exploitation of the power grid. In addition, there are no uniform standards governing the safety and threshold limits of SG systems.
- Since the SG does not depend heavily on the human factor in its work, as it has become reliance on smart devices, it is easily hackable and cyber-attacks. It might lead to hackers gaining access to a large number of smart meters and manipulating data [29]. Furthermore, because the system is totally automated, privacy worries about data collecting and the usage of smart meters have arisen.
- The current energy infrastructure scenario is insufficient for the development of SG technologies [30]. As a result, SG systems have a higher installation cost since they need the purchase of smart meters and other sensors for data collection and delivery.
- SG is a volatile network because it is very intelligent at both the transmission and distribution ends yet fragile along the way owing to a lack of comprehensive network intelligence.

- A constant network channel is required for the smooth operation of an SG. This might cause network congestion, busy hours. Furthermore, there is no assurance of service under unusual weather circumstances such as strong rain, storms, or lightning.

To address the above—mentioned challenges, a number of methods and systems have been developed. The electricity grid should be flexible strong enough to handle the electricity needs. The electrical grid is one of the world's most complicated and interconnected physical systems. As a result, extreme caution should be exercised in maintaining the grid network. To improve and upgrade the grid's level and performance, SG should be tailored to incorporate all types of sensors and digital devices.

In order to ensure dependable functioning, all of the components must work together and communicate effectively. Data signals may now travel quicker thanks to fiber optics, which reduces propagation time. It entails a net-metering system that incorporates a smart meter as well as the infrastructure necessary for two-way energy transmission.

It entails cost optimization of electrical power analysis, as well as the reduction of production and distribution expenses. In addition, the intermittent coordination of several generators allows for the integration of diverse energy sources such as solar and wind.

The use of SCADA has allowed for improved SG monitoring and utility control. AMI has aided real-time voltage and current phasor readings. We were able to precisely determine the location of the defect and decrease the outage duration thanks to GPS [31, 32].

4.3 SG development required technology

4.3.1 Technologies for sensing and measuring

Sensing and measurement are the most important level in the SG. Accuracy and real time sensing and measurement enhance the reliability, security, rapid analysis, and efficiency. Wide area monitoring, protection, and control (WAMPAC) and phasor measuring units (PMU) assist in preserving the electrical grid's security and dependability [1]. For protective relays and fault detection, intelligent electronic devices (IED) are utilized. Integrated sensors and automated systems are used for quick analysis and diagnosis, resulting in prompt resolutions [33]. They also help to prevent outages by reducing network congestion. As a result, the efficiency and functioning of the SG produced by these devices is improved. The control and communication component of the power grid system is made up of smart devices [34]. They keep an eye on the efficiency, dependability, and safety of household equipment. The smart meter and the software that goes with it are the core of SG system. It improves power management and gives users more control over their electricity usage. They also hold customers accountable by giving real-time information and accurate invoices.

4.3.2 Communication technologies

Two-way communication, advanced architecture, and hardware and software are among the different communication technologies. Two-way communication creates a back-and-forth bridge that allows electrical energy to flow in both directions across distinct loads in a power system. EVs, micro generation, and plug-and-play household products are all possible thanks to advanced architecture [35]. Hardware and software, which are system's building elements, are in charge of ensuring the utility's security and dependability.

4.3.3 Smart meters and advanced metering infrastructure (AMI)

AMI is described as the integration and connectivity of a large number of smart meters and communication devices that work together to permit a two-way flow of power between utilities and customers in the power grid. It has data management systems and smart sensors that allow the SG to track its power consumption. Through smart meter sensors, an AMI system delivers precise records and warnings on outages and their related repair. This aids in the speedier resolution of outages as well as the provision of power. Smart meters come with power monitoring software that allows for speedier fault identification and diagnosis, as well as techniques to fix power issues [36]. Furthermore, by monitoring power losses, AMI prepares the grid for self-healing, allowing for faster problem identification.

AMI provides data to improve the operation and management of the utility network. The use of AMI minimizes meter readings on a daily basis because measurements are collected automatically at regular periods [37]. It has built-in analytical tools and software that can identify and prevent energy theft and manipulation. The AMI systems, when combined with SCADA, automatically create investigative reports for field managers, making their job simpler.

4.4 Renewable energy as a part of SG

Renewable energy is a resource that can help to improve the electric power system by improving its efficiency, sustainability, and dependability. Photovoltaic (PV), tiny wind turbines (WT), heat or electricity storage, combined heat and power (CHP), and controlled loads are all examples of distributed energy resources (DER) in a micro-grid. Renewable energy sources are almost unlimited since the majority of their energy comes from natural sources such as the sun, which will continue to exist in the future. Renewable energy is an area of research and development that will continue to expand; more money has been invested in the discovery of both new and current renewable sources. Solar, the most widely utilized, has dramatically increased its use in our world with the introduction of solar-powered electrical vehicle, lights, and residences [38].

To establish a future where green power is the main energy source, more work needs to be done to remove non-renewable energy in our society. Finally, considerable study on maximizing the available RER's efficiency is required for renewable energy to solve energy shortages. Additionally, main RER should be implemented in locations across the world depending on their most important natural resource. Locations with high winds, for example, will use more hydropower, whereas areas with steady sunlight will utilize solar.

More enterprises have gained operational expertise with renewable energy technology as a result of research and government incentives. But the topic of renewable energy and its use raises concerns about the resources' efficiency, dependability, traceability, and accountability. Most renewable energy technologies, on the other hand, fail to compete economically with conventional fuel technologies, resulting in lower budgets and money for renewable energy [39]. The utility business is divided into three categories by the regulatory commission: generating companies (which include both utility and non-utility enterprises), transmission companies, and distribution companies.

As public and political demand grows to boost the percentage of renewable production, this constraint is becoming a challenge for grid operators. This is due to the inherent unpredictability in renewable natural resources. Because natural resources cannot be predicted with high precision, the system will need to carry additional reserve capacity in addition to the reserves already set aside to cover unit failures and demand prediction mistakes. Connectivity, sustainability, cost, environmental effect, security, and other aspects of renewable energy might be explored.

Renewable energies often require varied levels before they can be utilized as electricity for its users' stages from production to transmission to distribution, as well as the utilization levels in its connectivity, depending on the renewable technology [40]. Some RERs are stand-alone, grid-connected, or hybrid, combining stand-alone and grid-connected functionality. In compared to non-renewable sources, renewable energy technologies have challenges for connection.

There is no doubt that renewable energy has many advantages [41]. One of the major advantages of renewable energy is its capacity to be sustainable. It is readily available to be harnessed in compared to non-renewable energy. Because most RER comes from nature, such as wind, sun, and water, it will always exist, while others, such as bio-mass, will exist as a result of human waste. It is claimed that the cost of implementing RE technology is less than the cost of producing power. The majority of money is spent on research into renewable technology and how to use them efficiently, rather than how they are put up.

Renewable energy is referred to as "green power" since it is environmentally friendly. The majority of RERs emits very little carbon and produce very little trash. It has a detrimental influence on areas such as landscape, animals, and land usage. The majority of RER facilities/instruments are large, land-consuming, and unsettling to the surrounding environment.

The safety of the buildings, gadgets, and instruments employed in the activities is a major issue for RERs. Companies aim to prevent vandalism, waste, and maintain stringent standards throughout the process, from manufacture to transmission to distribution and finally consumption.

With all the advantages offered by renewable energy sources, there is a point that needs a lot of research, which can affect the continuity and reliability of renewable energy. Solar and wind RERs are only available during certain times of the year, i.e., they are seasonal. As a result, it's critical to store as much energy as possible while minimizing losses. Energy storage is required by the SG, either directly or indirectly. Pumped hydroelectric storage is a bulk energy storage technique in the current context. To establish a hybrid system, proper storage units linked to OFF-grid systems are further connected to the utility, improving robustness and preventing occasional outages. Batteries, flywheels, and compressed air systems are examples of older storage devices. As a storage unit, a hydrogen network is now connected in parallel to the grid utility. To match generation with demand in SGs, storage devices like as batteries, super capacitors, and flywheels might be employed [42]. Storage systems may compensate for generating shortages, minimize load spikes by offering a short-term ride-through capability, reduce network losses, and increase protection by contributing to fault currents. V2G and EV mobility can help SG become less reliant on grid power as shown in Fig. 2.

4.5 Electric vehicles (EVs) as a part of SG

This section focuses on electric vehicles (EVs), which have been popular in recent years as a means of fulfilling energy demands and replacing internal combustion engine (ICE) cars. In comparison to traditional internal combustion engine vehicles, EVs have received a lot of attention in recent years. This thought is prompted by the economic and environmental risks associated with the use of natural gas and petroleum fuels [43].

The fully electric vehicle is called battery electrical vehicles (BEV). A BEV is a vehicle that operates solely on electricity and has no internal combustion engine. These cars must be connected into an external power source to recharge their batteries. A hybrid electric vehicle (HEV), which combines an internal—combustion engine and an electric motor with an engine or generator, is powered by one or more energy sources [44]. A plug-in hybrid electric vehicle (PHEV) is equipped with rechargeable batteries or other power storage devices that can be recharged by connecting to external power sources [45].

The BEV is powered by a massive traction battery pack, and it must be connected into a charging station because it runs on electricity. The car has no tailpipe emissions and no fuel components such as a gasoline pump, fuel line, or fuel tank. The automobile has a battery pack that stores the electrical energy that operates the motor. The batteries are charged by connecting the car into an electric power source. BEVs are more expensive than hybrid automobiles [45].

The large number of batteries in BEVs, which need to be recharged every period to provide the motor with energy to move the car, could be a reason for the emergence of challenges on the SG in the near time, with the increase in the number of cars and charging centers and the increase in humanity's dependence on them. The BEVs could be considered a large electrical load that will be introduced to the electrical network in the near future. Therefore, it is necessary to study its challenges, the standards by which it must work, and the laws regulating it so that it does not cause problems on the SG.

Also, just as BEVs should be studied as a new electrical load, it should be studied as an electrical energy storage that can be used to store electrical energy from renewable energy sources that need an electrical storage due to its seasonal operation. In the event that BEVs are used as storage of electric energy, which will be connected from time to time to benefit from the energy stored in them, it is also possible that these stores cause more problems on the electric network. It is necessary to study these problems and the limitations that will face the SG from these sources.

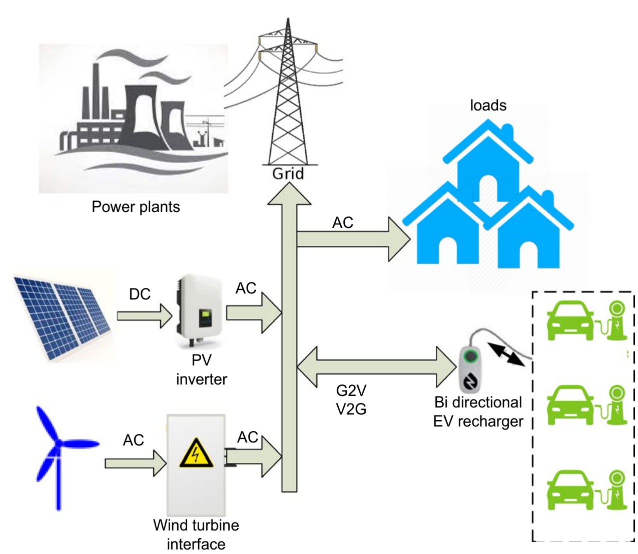


Fig. 2 Vehicle to grid and grid to vehicle

4.6 Smart network protection

When additional resilience is added to the existing electric network and it is made ready for unforeseen tragedies and natural disasters, the grid becomes more efficient. As a result, if the present grid is reinforced with certain more powerful features, it becomes an SG. Advanced grid protection techniques might be one of the most potent aspects. This will make the present grid network more efficient, faster in terms of electricity transmission and self-repair after power outages, less costly, and safer, among other things [46]. Although SG offers multiple advantages, it also presents critical security challenges, as it brings together heterogeneous communication networks [47] such as Internet of Things (IoT) devices, industrial devices, wireless components, and wireless sensor networks (WSNs) that feature diverse security threats. Also, the integration of smart devices, such as smart meters, that communicate with each other without human intervention, raises further security concerns.

Protection in the SG refers to the safeguarding of devices linked to it from inadvertent failures like as faults, overloads, and so on. Quick fault diagnosis is one of the power system protection applications in the SG, which helps to reduce voltage instability and power outages. It is referred to as physical protection of SG when various plans defend the physical infrastructures of the country. This form of protection pertains to unintentional occurrences such as equipment failure, human mistakes, natural calamities, and so on. Two important considerations must be made in this form of security. The system's dependability is one thing, and the failure of the protective plan is another [48]. Reliability relates to the dependability of SG's components and how they are situated, and it may be accomplished in four different ways:

- Distributed generation's reliability.
- Measurement infrastructure reliability.
- Before to any action, ensure that the network is reliable.
- Sub-station decision-making performance

RERs are utilized as DG in an SG, and their penetration into the system makes cooperation with other protective devices difficult. As a result, the protection engineer is concerned about the system's dependability and stability. The smart measurement infrastructure, which helps monitor network dependability, stability, and healthiness, is one SG operating need that may be satisfied with a phasor measuring unit (PMU). Assume that sub-station decision-making performance can be attained. In this situation, the time span may be decreased since the system does not have to wait for a decision from the control network, and the system is more stable and reliable [49].

The two most critical parts of SG physical protection are failure prevention and prediction. Prediction entails locating the failure event in the SG, whereas preventive is preventing the failure from occurring. Another essential part of the SG that may be improved by establishing effective procedures is recovery.

A smart meter, for example, is used to restore lost data from the system. The operational parameters of the SG differ from typical distribution networks due to the inverter-based DGs, making the protection engineer's job more difficult. Another problem that power system engineers face is achieving reliability and efficiency in a wired and wireless communication network for control and data transfer. In order to provide adequate unit protection and relay coordination in SG, internet of energy (IoE)-based communication technology has recently been used, which primarily exchanges data that is then gathered by integrated electronic devices (IED). This sort of protection technique is known as i-protection, and it uses IEDs and IoE to accurately identify the problem over a wide-area wireless network.

5 Conclusion

Recently, the smart grid has become one of the most important technologies that are used in the electrical field, and its popularity continues to grow as a result of its numerous advantages. Transitioning from a normal power grid system to the SG system, like any other major change, is difficult and time-consuming. At the same time, it is a fantastic option to fulfil contemporary civilization's expanding electrical need. A successful transition necessitates precise planning, complete comprehension, and adequate information, as well as their corresponding effects on every aspect of the ecosystem. The uses of distributed energy resources (DER) will improve energy supply efficiency while lowering power delivery costs and carbon footprint in SG.

The SG must be well-designed, have a strong structure to withstand the stress, be efficient and reliable, be environmentally friendly, be intelligent enough to detect outages and fault locations, be secure and safe from cyber-attacks, be able to monitor and act on real-time data, and be scalable and interoperable with other energy sources. To develop a symbiotic relationship that benefits grid operators, energy providers, customers, and the environment, several characteristics of the SG must be implemented cost-effectively. In SGs, there are several protection challenges, such as ensuring dependability, stability, and coordination, to name a few. All of these problems can be handled by creating optimal algorithms, which is also a current research project.

Author contributions Author AAA, TMH write the manuscript. Both authors read and approved the final manuscript.

Declarations

Competing interests The authors declare no competing interests.

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