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Review Article

Energy Management Systems Using Smart Grids: An Exhaustive Parametric Comprehensive Analysis of Existing Trends, Significance, Opportunities, and Challenges

Nitasha Khan,[1] **Zeeshan Shahid**,[2] **Muhammad Mansoor Alam**,[3,4,5] **Aznida Abu Bakar Sajak**,[4] **M. S. Mazliham**,[5] **Talha Ahmed Khan**,[5,6] **and Syed Safdar Ali Rizvi**[6]

[1]*British Malaysian Institute, Universiti Kuala Lumpur, Sungai Pusu 53100, Kuala Lumpur, Malaysia*
[2]*College of Engineering and Computing, Al Ghurair University, Dubai, UAE*
[3]*Faculty of Computing, Riphah International University, Islamabad, Pakistan*
[4]*MIIT, Universiti Kuala Lumpur, Wilayah Persekutuan, Kuala Lumpur 50250, Malaysia*
[5]*Multimedia University (MMU), Cyberjaya, Malaysia*
[6]*Computer Sciences, Bahria University, Karachi, Pakistan*

Correspondence should be addressed to Aznida Abu Bakar Sajak; aznida@unikl.edu.my

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The integration of widely fluctuating distributed generation (such as photovoltaic panels, wind power, electric vehicles, and energy storage systems) puts the stability of power technologies and distribution structures in jeopardy. However, the fundamental reason is that the electrical supply and demand ratio may not be balanced. An excess or scarcity of electricity in the production or consumption of energy can disrupt the system and cause serious difficulties such as voltage drops/rises and, in extreme cases, power outages. Energy management systems can efficiently increase the balance between supply and demand while reducing peak load during unscheduled periods. The energy management system can handle distributing or exchanging energy among the many energy resources available and economically supplying loads in a stable, safe, and effective manner under all power grid operating situations. This article examines the energy control system's structure, goals, benefits, and challenges through an in-depth investigation of the various stakeholders and participants involved in this system. This review provides a detailed essential analysis of the operation of several programs used inside the power management system, such as demand response, demand management, and energy quality management. It also includes a summary of the smart grid's functionalities, features, and related techniques and has discovered research gaps, challenges, and issues. Furthermore, in this article, the authors review the literature on the enabling technologies of smart grid and investigate the energy management system, which is among one of the major emerging technologies and quantifications of the various uncertainty techniques. In this paper, the authors also discussed the comprehensive review of researchers' efforts and contributions to the smart energy management system in the smart grid. It also compares and evaluates the key optimization approaches utilized to achieve the remarkable aims of energy management structures while also fulfilling a variety of constraints. This comprehensive review will be very beneficial for the new researchers, and it would be a great contribution to the research community.

1. Introduction

Electricity is the form of energy that can be utilized to meet the demand of individuals for a balance and developing countries. The genuine and reliable transmission of electrical power is the main element of a nation's economy [1]. Because CO_2 emissions are the primary causes of global warming, focusing on the most contributing factor to these emissions, especially transportation and power generation, is the most effective approach to combat it. The best option for a sustainable future appears to be switching to renewable energy sources (RESs) with electric automobiles. Furthermore, replacing traditional fuel-based transportation with electric vehicle transportation, such as plug-in hybrid electric vehicles (PHEVs) and plug-in electric vehicles (PEVs), and integrating battery energy storage systems (BESSs) or energy storage systems (ESSs) into the current network are two other possible solutions to address the exponential growth of greenhouse gas (GHG) emissions. Renewable energies differ from conventional energy sources in that their output is variable and intermittent [2, 3].

The intermittent nature of RES can be eliminated by combining numerous RES and the ESS and backup sources. On the other hand, this intermittency can dramatically alter the system's voltage profile, interfere with standard on-load tap changer control systems, and negatively impact the power grid's performance. As a result, in addition to GHG mitigation, the technologies impose a slew of challenges, such as uncoordinated grid parameters, increased system complexities, intermittent renewable generation, and high PEV price requirements, all of which exacerbate serious issues such as power quality issues, energy imbalance, resilience, loss of reliability, system security, and regulatory issues such as unequal benefit distribution to consumers. Furthermore, with the advancement of renewable energy sources, a shift from a historically passive to an active distribution system has occurred. When there are many energy sources and a storage system, energy flow must be managed. An energy management system (EMS) is critical for maximizing the potential of new resources and new types of loads on the electricity network while minimizing their negative effects, ensuring load continuity in all conditions, and improving the electricity network's stability. The International Electrotechnical Commission's IEC 61970 standard defines an EMS as "a computer system that consists of a software platform that provides essential support services and a set of applications that provide the functionalities necessary for the efficient operation of generation and transmission system to ensure energy supply security at a minimal cost." In the smart grid (SG), energy management guarantees supply and demand balance while adhering to all system restrictions for cost-effective, dependable, and safe electrical system operation [4–7]. It also contains optimization, which ensures that power generation costs are reduced. Thus, by grouping all systematic procedures, the EMS maintains and reduces the quantity and price of energy required for a particular application to the lowest. Although energy management in a distribution system improves system performance, it also has constraints and obstacles, including client confidentiality, large-scale operations, frequent system upgrades, and EMS dependability issues. A comparative analysis of the smart grid in EMS and its main related technologies is illustrated by the authors (seeFigure 1).

The energy management system of SGs is the subject of this research. This review is chosen to assist the readers in grasping the role and application of each EMS-based method more clearly and have a clearer vision. As a result, it will assist us in determining the scope of our issue. The following issues are addressed in this paper: smart grid and all its technologies and techniques, its challenges and advancements, SG roles and responsibilities of the various parts participating in the EMS, and a detailed study of the DER's behaviour; general overview of the EMS in the SG and its numerous aspects; and uncertainty management, demand response, demand-side management, and power quality management, which are all subjects of critical analytical investigation. Approaches to EMS solutions are compared and criticized. The definition, benefits, and overall overview of the SG are presented in Sections 1 and 2. Section 3 examines EMS's structure, benefits, and limitations through a detailed examination of the system's distracting investors and players. Finally, Section 4 describes the approaches for the EMS that should be considered, including DR, DSM, and PQM. Section 5 discusses several EMS solution approaches. Finally, the concluding remarks are presented in Section 6.

2. Smart Grid

In spite of the popularity and increasing number of related research work, smart grid definitions do not exist. Rather than what occurs in many other developing areas, various other definitions are suggested in the literature. One of its examples is the definition by the Electric Power Research Institute [9] about the smart grid: "the overlaying of unified communications and control system on the existing power delivery infrastructure to provide the right information to the right entity." Various other authors have different perspectives on the smart grid, such as, e.g., consumers' commitment to other stakeholders, the part of ICT, the exposure of market opportunities with new value-added services, and so on [10–14]. The term smart grid characterizes the combination of sensors, digital technologies, and ICTs to allow and make the system more efficient, reliable, and manageable on the use of electricity. Smart grid is an integration of technologies for the customer and the grid. Smart grid technologies combine software and hardware [8, 15], including creations and essential services, from generation to transmission and distribution. A smart grid is an intelligent and intellectual network in which the current power system blends with information technology [16]. The increasing complexity of the power grid results in the high potential of the smart grid network. The problem is the old infrastructure supporting current energy requirements [17–20].

It is necessary to recognize and acknowledge the inheritance of electric systems worldwide. The current controlling infrastructure of electric power systems includes four basic elements, i.e., generation, transmission, distribution, and consumer (see Table 1), and detailed classification is also illustrated by the authors showing the overall concept of smart grid (see Figure 2).

Smart grids are divided into seven categories by the National Institute of Standards and Technology (NIST) [12], which include applications of smart grid. System devices, control systems, programs, stakeholders, and telecom stations can be connected to design a smart grid. Energy management, site automation, and energy storage are also the crucial domains while designing a smart grid (see Figure 3).

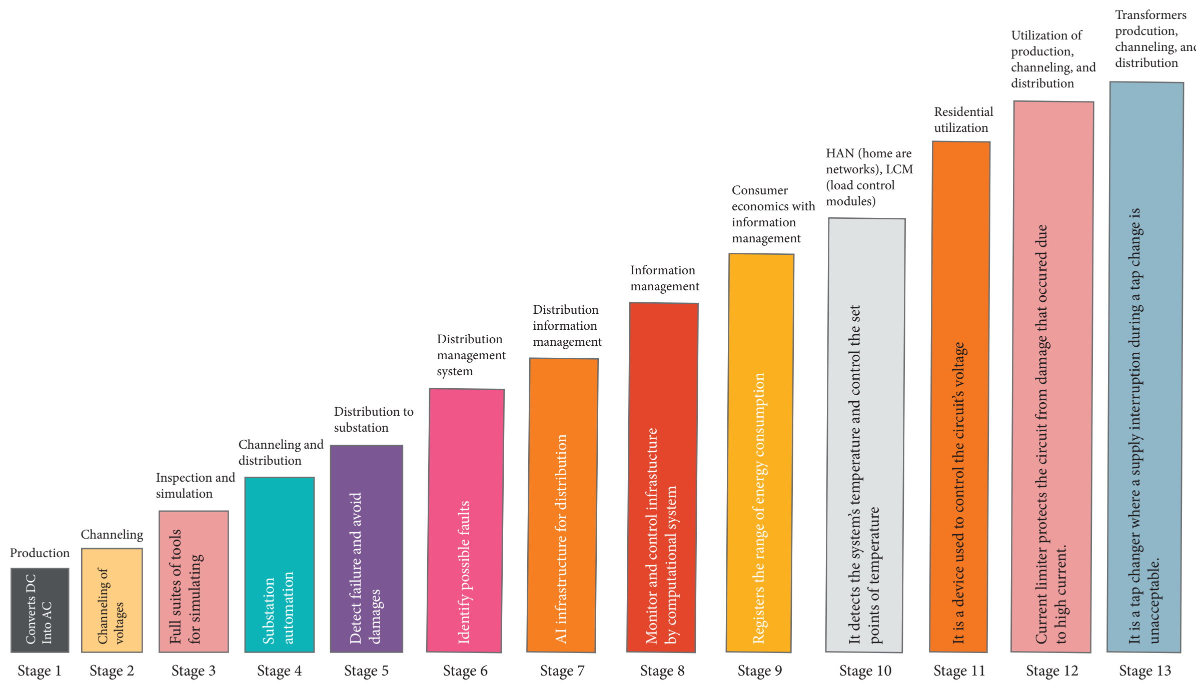


Figure 1: Smart grid main technologies [8].

Table 1: Smart grid elements.

Elements of smart grid	Explanation
Generation	Generation consists of system devices, control systems, programs, and stations which are the actors who generate the electricity in bulky quantities that can also be stored for later distribution.
Transmission	In transmission, the generated power is transferred from stations to distribution centres.
Distribution	In distribution, the generated, transmitted, and stored power interconnects with the consumer.
Customer	Customers are the end users who consume the power and can also be categorized into domestic and commercial consumers.

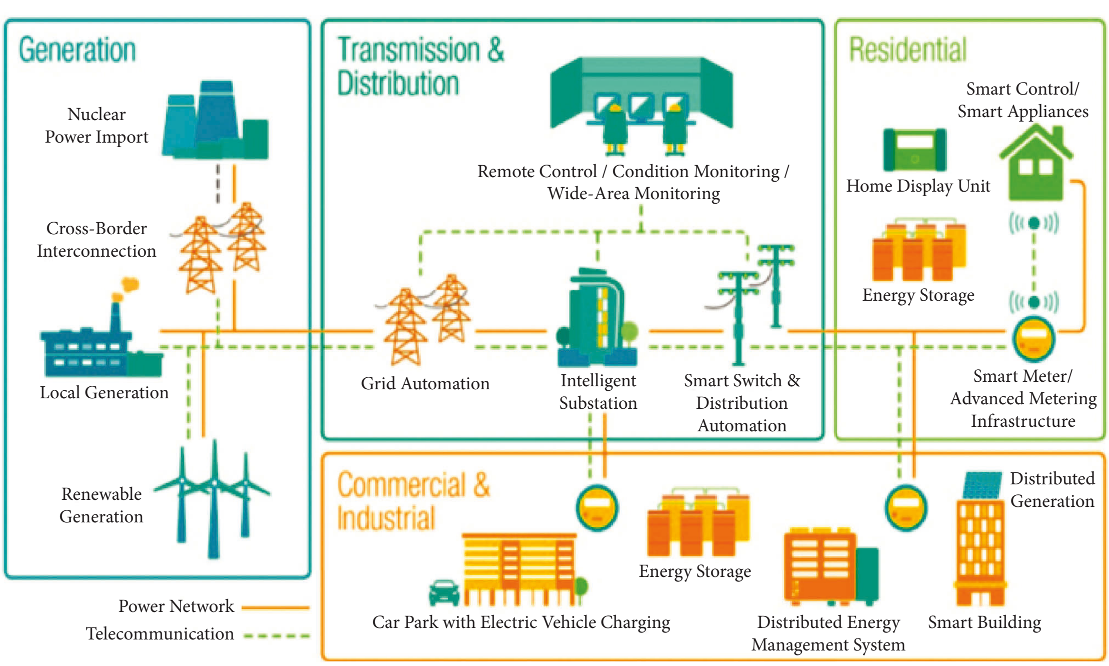


Figure 2: The smart grid concept. It can generate electricity from a variety of sources that are widely scattered, such as wind turbines, solar power systems, and plug-in hybrid electric vehicles. It employs digital automation technology for supply chain monitoring, control, and analysis [21].

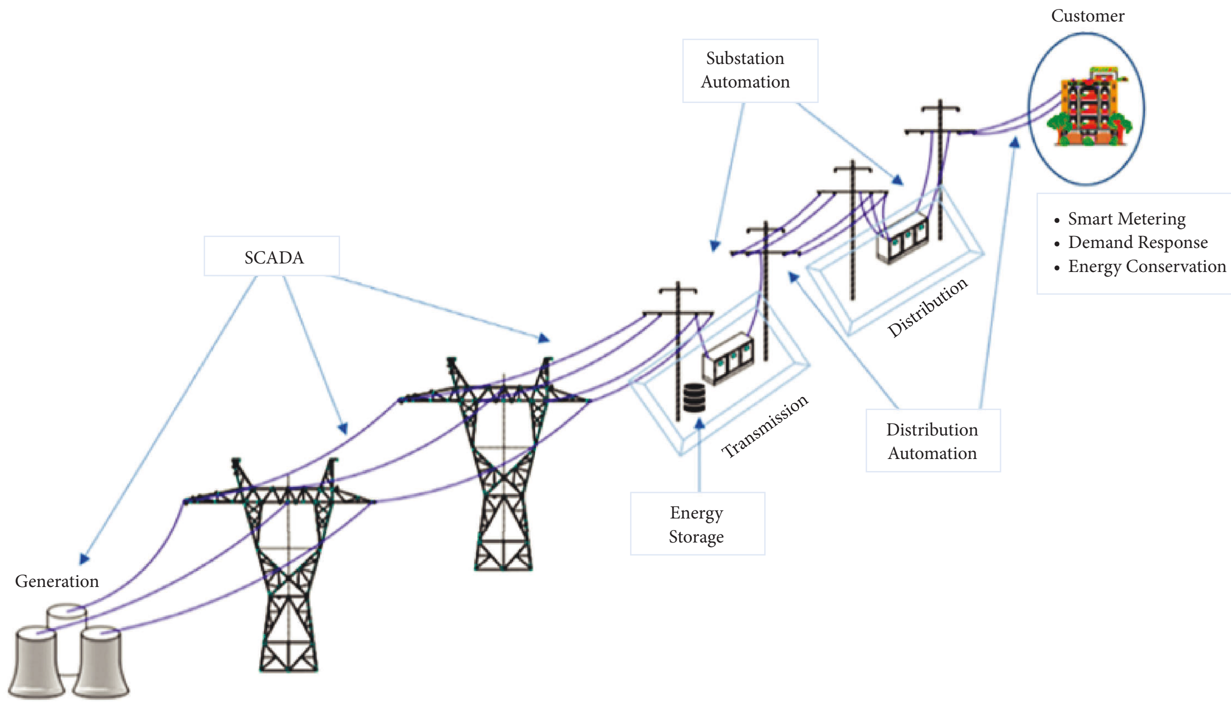


Figure 3: The idea of a communication and control system in smart grid [15].

3. Technologies of Smart Grid

The current power generation system includes the mechanism of heat production by burning fossil fuels or the division of atoms in nuclear energy [22–24]. Excluding solar cells, almost all other forms of power generating include fossil fuel burning, biomass, nuclear, wind, and solar [25, 26]. In addition, several smart grid technologies enable the system to work effectively and are helping designers to have a cost-effective solution [27]. The most important technologies are mentioned briefly and various approaches used in smart grid are also explained by the authors (see Figure 4).

3.1. Energy Management System (EMS). An energy management system (EMS) is an operator which revitalizes the execution and performance of the system and supervisory control and data acquisition (SCADA). EMS is implemented in many industrial and commercial sectors [27].

3.2. Advanced Metering Infrastructure (AMI). AMI is the term that enables the gathering and transfer of energy usage information from smart meter to two-way communication networks in near real time. It has several advantages such as AMI upsurging efficiency, decreasing loss and cost, and controlling load and theft protective capability like Vattenfall's and Fortum's intelligent system [28]. Automated metering infrastructure employs smart meters in homes that monitor and measure electricity consumption. The main goal of AMI for homes is to take benefit of smart meters to examine the consumption of energy, battery storage, generation of solar or wind connected with an on-site grid, and electric vehicles (plug-in) [29–32]. Furthermore, AMI enables configuration of remote meter with dynamic tariffs and monitoring of power quality. AMI also plays an important role in smart homes and smart appliances. Smart homes are outfitted with a home automation system that connects security, lighting, and other appliances using an AMI system that modulates and controls their operation [33–36].

3.3. Geographical Information System (GIS). GIS is the system that controls modelling, data integration, and management of infrastructure. It is one of the important solutions for converting a huge amount of data. The smart grid receives a lot of data from SCADA, AMI, renewable energy, and so on [37].

3.4. Meter Data Management (MDM). MDM guarantees mechanization of sharing of data and real-time processes that result in useful and effective operations while improving the decision-making process. It also helps in handling a large volume of data.

3.5. Demand-Side Management (DSM). DSM controls the energy to the consumer's side of the meter that helps efficient use of system resources without installing new transmission and generation structures. Load and response demand management are the issues solved by DSM [38–40].

3.6. Outage Management System (OMS). OMS is the system that gives solutions for energy restoration and maintains better response time. They also minimalize manual reporting and give a solution for stated problems.

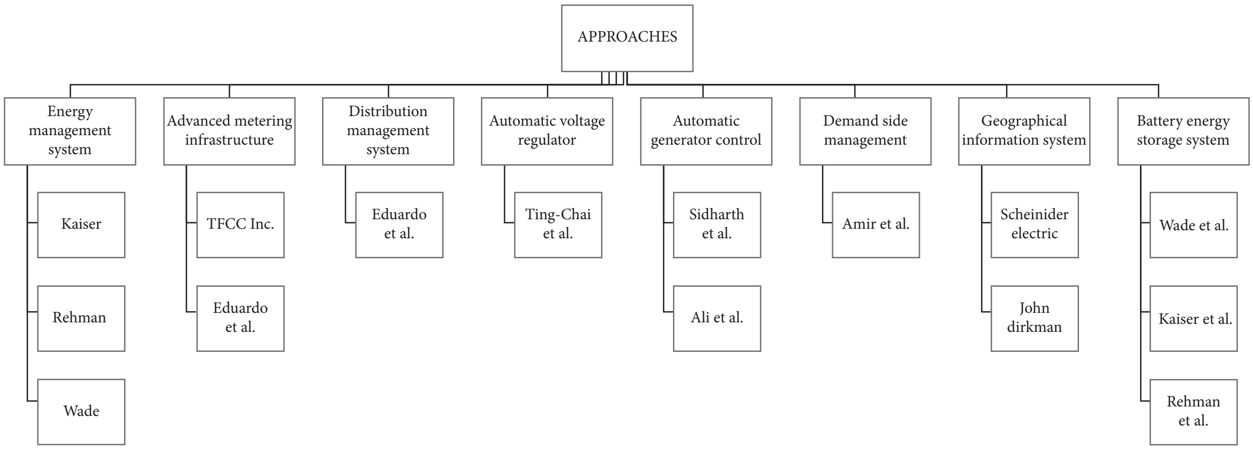


Figure 4: Different approaches to smart grid.

3.7. Wide Area Management System (WAMS). WAMS is executed in high-voltage power grids to guarantee synchronization, precision, and verification of flexible AC transmission system (FACTS) control and systematic validation of dynamics models. WAMS, through PMUs, also give accurate and time-stamped measurements.

3.8. Battery Energy Storage Systems (BESSs). BESS employs storage systems based on electrical and mechanical enhanced performance and efficiency [41].

4. Techniques of Smart Grid

The researchers created many artificial intelligence techniques to implement different techniques of smart grid described in Table 2. These techniques included data mining techniques and communication techniques. However, different techniques are extensively used in the data mining technique, such as fuzzy logic, neural networks, expert systems, and artificial intelligence. A communication system is the main component of the smart grid [57–59]. A combination of enhanced technologies and applications can generate a huge amount of data from different applications for advanced analysis, control, and methods of real-time pricing. It is very difficult for electric utilities to identify the communication requirements and discover the finest communications infrastructure to deliver a secure, reliable, and cost-effective service [57]. Two wired and wireless media are maintained for data transmission between the electric utilities and smart meters. Wireless communications have a low-cost infrastructure, and wired communication is free from interference problems and is not reliant on batteries. For a flow of information, two types of infrastructure are needed in a smart grid system. The first is from the sensor to smart meters achieved via wired or wireless communications like 6LoWPAN, Zigbee, and so on. The second is between the utility's centres and smart meters achieved via cellular technologies [17].

5. Functionalities of Smart Grid

The utility companies and government funding development of the grid (United States Department of Energy's Modern Grid Initiative) defined the smart grid functions required for its modernization, and according to its report, the advance smart grid must have the following.

Customer Participation with Smart Grid Services. Smart grid authorizes customers to alter their actions against fluctuating rates of electricity. Customers can manage the utilization of appliances of smart grid in their homes and businesses. The link between smart grid and energy management systems allows customers to control energy better and examine the pricing of real time (two-way communications). A smart grid is more secure and can identify the attack. The power grid smart monitoring can access and control smart grids to prevent system disruptions. Advance technologies of state monitoring are required to attain the objectives of the smart grids [60].

Recovery Capability from Disruptions of Power. Managers/operators can utilize information based on real time from controls and sensors that predict, detect, and respond to the system's issues to automatically bypass and diminish blackouts, power outages, and quality problems. In addition, a grid based on smart system will be expected to have a system that can examine its performance by utilizing independent and distributed controllers that can work on successful strategies to overcome challenges like equipment failures [61].

Offering Enhanced and Power Quality Resources. According to the latest research, there is an approximation of $100 billion in losses in US business annually because of electric failure on average. This issue can be resolved through the balanced power offered by the smart grid [62]. Furthermore, smart grid can enhance capital assets by reducing and preserving low costs. This quality of smart grid can utilize the lowest-cost generation and minimize waste.

Table 2: Comparative analysis of smart grid technique.

	Technique	Technology/ tools	Features	Limitations
Data mining technique	Fuzzy logic technique [42]	MATLAB, LabVIEW, Scilab, FLINT	It takes a noise-free input from the system and executes the function in the absence of the mathematical models and then it maps the input to the output of that system.	Results are not always accurate.
	Forecasting technique [43]	Stata, RATS, OxMetrics	Very effective method because of its use in signals in time series for load forecasting and its usage in the making of the seasoned patterns. Widely used in digital signal processing, load forecasting, and economics.	It is not a cost-effective technique.
	The regression technique [44]	Minitab, SAS	Extensively used to create a bond between the load forecasting functional models and the other factors such as customer class, data type, and weather.	The weather component relative to load demand is not fixed. The technique is incompetent to discover the physical variations in various models necessary for the next day's peak forecasting.
	Expert system technique [45]	FLINT, Prolog++	Has an ability to gather scarce expertise and utilize it efficiently, and this technique has improved decision quality.	It is not a cost-effective technique
	Support vector machines [46–48]	MATLAB, LIBSVM, Weka	Used to resolve the issues of regression and classification. Used to process short-term load forecasting. Compared to the autoregressive method's result, the support vector machine is a much better technique.	Not suitable for large datasets. It does not perform well when the dataset has more noise.
Communication technique	GSM [49–51]	Proteus	Very secure. Provides good authentication and signalling protection.	It is designed to carry only voice data, so it has an issue with handling smart metering.
	Cellular network (2G, 3G, 4G, 5G, WiMAX, and LTE) [52]	MATLAB	Capable of supporting tens of millions of devices and has very low power consumption with low interference.	It is not a cost-effective technique. It has a high delay in transmission of data related to its distance.
	Zigbee [53, 54]	Xbee	Considered good for energy management and metering and its low cost, low bandwidth, and easy implementation.	It has a high interference ratio. Has very small memory with limited data rates and low processing capability.
	Wireless mesh [55, 56]	OMNet++	Very cost-effective, i.e., mesh networking has a quality of self-healing. Self-organizing. High scalability, which improves the performance of the network.	Has a fading issue with high interference

Empowering Innovative Commodities and Essential Services. The blending of limited and local power generation lets commercial, residential, and business customers produce and offer additional power to the grid with fewer hassles. With this scenario, consistency and quality will enhance, minimizing costs and offering more choices to the customer. In addition, the smart grid will empower small manufacturers to produce and offer electricity to the local market using different sources like solar systems and wind turbines. The authors illustrated all functions of the smart grid (see Figure 5).

5.1. The Current Advancement in Smart Grid Techniques. Various research works are in process for the development of smart grids. These ongoing research works focus on different technologies. Some of them are explained in this paper.

Energy Management System. It is important to work with all components from production to consumer for a reliable grid. The grid contains many tricky components, and they all work and communicate together with the help of software. NIST (National Institute of Standards and Technology)

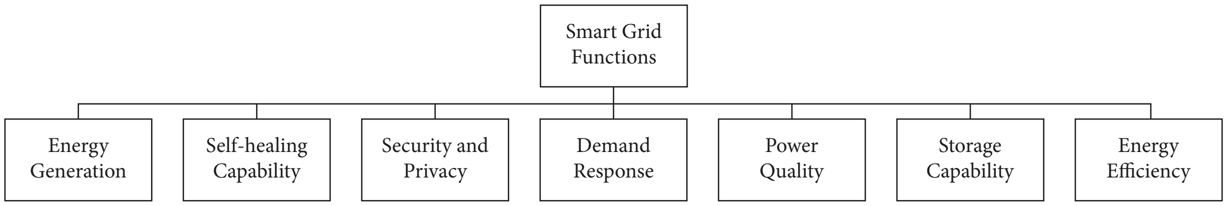


Figure 5: Functionalities of smart grid.

worked on smart grid interoperability (SGIP), having a charge to develop and sustain the components and standards involved with smart grids. It was also responsible for giving power grid stakeholders the platform to work together [63]. In addition, advanced metering infrastructure (AMI) technology makes smart grids more reliable [64].

Internet of Things (IoT). The Internet of Things (IoT) takes our life to the next step by making it more automatic, easier, and handy to communicate with a computer. IoT has the capability of evolution. However, besides all its characteristics, serious issues are like overdosing, authorization, privacy concerns, tapering, and cyberattack. IoT guarantees to accomplish all these features taking the smart grid into a new era. But with advanced technology, some severe security issues developed, including impersonation, data altering, exaggeration, approval issues, privacy issues, and cyberattack [65]. Researchers are trying to deal with these concerns. A smart grid based on IoT should have services like authentication, privacy, and data integrity to prevent any security threat.

Big Data. Smart grid works as a backbone of the grid and is fully dependent on the data it receives. Data collection plays an important role in the smart grid as it receives data from production, channelling, and transmission [66]. Huge information is collected from sensors and devices in the smart grid. This data collection is made possible with the help of algorithms. Secure data and storage are the main challenges in the smart grid [67]. These algorithms made smart grids reliable, but big data still has some issues, like its collection, processing, integration, privacy, and security [67].

Smart Grids with Electric Vehicles. Vehicles are responsible for pollution, causing environmental problems which can be solved by electric vehicles. Electric vehicles also face many problems like controlling, communication, and infrastructure [68, 69]. Smart grids contain advanced communication technologies like control and smart meters, and they can also offer electric vehicles as a load and a flexible energy source [70]. Smart meters have bidirectional communication capability that can smart schedule to improve the grid's power [71]. Mwasilu et al. [72] presented an overview of communication and power transmission. They gave predictions on the dynamics of the power system. Another important part of charging is the vehicle to grid technology. Researchers have made a lot of contributions to charging and discharging. One of the many types of research was done in Portugal. Research shows excellent communication between the charging of solar energy and EV. Ota et al. [73] proposed a solution that requests battery condition and charging and battery status for the next drive.

5.2. Advanced Challenges in Smart Grid. According to compiled information from different research papers, the smart grid faces many challenges. Some of them are discussed below.

5.2.1. Regulation and Policies. Many countries' smart grid regulations and policies start from the need to compose innovative policies to assist end user pricing systems and competitive offerings, resulting in improved efficiency while reducing risk in the energy market, thus encouraging investors [74, 75].

Many authors have published their work to examine the regulatory and social issues relating to smart grid development, sustainable development of energy, and advancement in the technologies of smart grids [76–79]. Numerous global smart grid policy implementation methods are connected to the power industry [80]. It was proposed by Lin et al. that that the USA choose an approach "environmental side policy" that emphasizes "financial, technical, and scientific development." With the help of the European Union (EU), 80% of the European Union will deploy smart meters for households in 2020 [81, 82]. With the help of these smart meter programs in many European countries, they became the main part of energy policies. These policies will support other policies of sustainable energy or climate change [74, 83]. In the US, the Act of American Recovery of the year 2009 ordered the advancement of smart grid technologies, and they offer grants for smart grid investment for this purpose [84]. China's Law on Renewable Energy (2009) focuses on advancing and developing energy storage and smart grid technologies that will automatically improve grid operation [85]. Another policy of China's "Special Planning of 12th Five-Year Plan on Smart Grid Science and Technology Industrialization Projects" shows China's interest in developing a smart grid [82]. By 2030, Japan will reduce its emissions by 30% by changing its energy system by constructing "the world's most advanced next-generation interactive grid network" in their country [86]. Denmark has established a policy on efficiently executing economic, social, and political changes. Developing rules, regulations, and policies for stakeholders to execute smart grids is underway in many other countries. Plan should be created to expand involvement from all sectors, whereas threats should be divided among every stakeholder.

The rules and procedures should consider the following points:

(i) Define standards and roadmaps.
(ii) Share the cost among the customer, utility, stakeholder, and government.
(iii) Meet anticipations of each region participating involving customers.
(iv) Outline the objective and time frame.
(v) Appropriate attention to workforce innovation and awareness plans.

5.2.2. Technical Challenges. The major technical challenge in the operation of the power system in a competitive environment is to increase the power transfer capability of existing transmission systems. Therefore, various approaches have been planned to handle the technical issues, including generation scheduling based on the finest power flow and utilizing the latest technologies such as distributed generation and FACTS. The authors presented different technical challenges faced by the smart grid briefly (see Table 3). The following factors consider concerns in limitations for the smart grid development.

(i) Lack of expert knowledge of engineers and system operators who operate power utility services.
(ii) Expanded demand response and distributed generation in the electric market; modification of device parameters in fluctuating conditions prevents utility companies from supplying smart solutions with technical goals.
(iii) Complex power system due to the complex tools.
(iv) Perception of renewable energy resources and strategies of bidding of participants prevent utility companies from offering solutions with environmental goals.
(v) System highly dependent on power and control system planning prevents utility companies from giving technical goal solutions.
(vi) Forecasting price and load demand services stop utility companies from giving economic goals and solutions.

5.2.3. Socioeconomic Challenges. Smart grid technologies can utilize advanced inventions and services merged with enhanced technologies for communication, control, and monitoring to optimize generation from renewable energy sources. Moreover, smart grid technology offers consumers instruments to enhance their utilization and performance.

According to Verbong et al., apart from smart grid technologies' advantages, it is still not clear to customers whether they are interested in them or not. Therefore, smart grids need to introduce more new technologies to let customers rethink them. All this process is not easy because all this process will create more technical issues and socioeconomic issues. The authors presented various challenges faced by the smart grid in terms of social economics briefly (see Table 4). Advancement in smart grids significantly affects the whole value chain and then shifts the consumer practice, behaviour, and whole series of new socioeconomic aspects.

Many researchers have researched socioeconomic aspects; according to Semadeni et al. and Kaldellis, the socioeconomic hurdles are not deeply examined by the social sciences, or maybe it is too early. Still, it could considerably affect smart grid implementation: customers' satisfactoriness, confidentiality, prices, and cyber security. All of them are the major factors of recognition. Wolsink proposed that obstructions to new infrastructures like wind power are usually related to the syndrome called NIMBY (not in my back yard). For example, there is pretty strong support from the public for wind power, but when the projects come into existence, people suffer the NIMBY syndrome.

In their papers, Anderson and Broman Toft et al. proposed that public opinion is the best way to discover the public's interest. These opinions were carried out through a survey on smart grid acceptability. Those surveys were on the conception of the smart grid and how electricity customers observe the advancement of smart grids and how their actions shift accordingly. Most report surveys show consumers' positive attitude towards smart grids, but tariff increment was their main concern. According to the customer, the main issue towards the socioeconomic acceptance of smart grids is privacy and security. The major reason behind the introduction of smart grids is the large collection of data from smart devices, increasing many issues, including privacy concerns. The smart grids can detect every consumption of power of consumers and its utilization, and these data of the customer are very sensitive. The major privacy issue is associated with smart meters. People believe their activities to be confidential because their sensitive data might be utilized by commercial, illegal, and law enforcement agencies (McKenna et al.).

5.3. Impacts of Smart Grid on Electric Utilities. Smart grids cover the overall areas of the electric system, having an impact that is translated into giving promising benefits to different associates. According to the authors, one of the main benefits of the smart grid among all is cost savings surety to end users and its capability of producing potential energy. However, besides having such many capabilities, the smart grid is also facing barriers that decrease its implementation. Figure 6 describes the strength and qualities of the smart grid, which can be reviewed as the main impacts. Smart grid strengths are divided into two parts, enabling strength and primary strength [106]. However, the advantages accomplished by the smart grid include better social assets utilization, decreased costs of operational utilities, and decreased consumer costs [107, 108].

5.3.1. Enhancing Asset Usage. In 2005, investors spent approx. $40 billion on utilities to manage and sustain the power system. Among the advantages of the smart grid, there is a drastic decrease in maintenance costs and a longer

Table 3: Technical challenges of smart grid.

Reference	Challenges	Description
Li et al. [87]	Interoperability concern	Interoperability explains the technological architecture and software systems through which different systems and technologies are possible. To enable the abilities of smart grid technology, implementations must link large numbers of systems and smart devices, including hardware and software [88]. Besides interoperability, a few more challenges include exploring smart energy management, power consumption, and energy distribution stored in batteries [3]. In addition, researchers are still working on the evolution of control systems like (i) Movement of power from the vehicle to the grid (V2G) and then from the grid to the vehicle (G2V) and then vehicle to vehicle (V2V) (ii) DC link voltage control (iii) Reactive power control (iv) Grid voltage assistance
Amin [89];Aillerie et al. [90];Wang and Lu [91];Kappagantu et al. [92]	Cyberattacks	Cyber security is one of the crucial operational problems. A single threat can transform into a mess for individuals and utilities engaged with the grid. A smart grid consists of multiple layers, and each layer requires security. Secure cyber can enhance innovative methods for blocking the growing complicated cyber risks. According to Kappagantu et al., availability, integrity, and confidentiality are the three main concerns of a smart grid. In contrast, Wei et al. pointed out that the advancement of a secure smart grid would face the following four concerns. Many legacy devices have been used in power automation systems for decades. Most of them only focus on a certain functionality and thus lack sufficient memory space or computational capability to deal with security problems. It is challenging to integrate the existing legacy equipment into the smart grid without weakening control performance. The power delivery system has new communication requirements regarding protocols, delay, bandwidth, and cost. Therefore, avoiding early obsolescence is essential in smart grid security development. Networking in the current power grid uses heterogeneous technologies and protocols such as Modbus, ModBus+, ProfiBus (process field bus), ICCP (inter-control centre communication protocol), DNP3, and so on. Nevertheless, most of them were designed for connectivity without cyber security. Current power systems are usually proprietary systems that provide specific performances and functionalities but not security.
Reynolds and Mickoleit [93]; Lindley [94]; Byars [95]	Storage concern	The smart grid includes renewables for power as well as distributed power production. Power production from renewables is not consistent, requiring storage, and among all common storage devices, the battery has a very small life duration of 4 to 5 years. The portability of batteries is their advantage, but researchers have also been concerned about weights, size, and low energy. Besides batteries, thermal storage, hydrogen storage, and flywheels have issues. The smart grid needs to store energy, directly or indirectly. Economical storage technology is the biggest concern for any electrical power system. Though many good storage technologies are available, they are either costly or ineffective.
Arnold [96]; IBM Software [97]	Data management	Database management is a critical issue in the smart grid. Voluminous data are challenging to gather and store and cause critical challenges and can slow down the data collection process. Defined standards and protocols are very important. Cloud technologies may support in management and assessment of big data. The smart grid immerses the power network with an immense quantum of sensors, meters, and controllers. Their data and other sources like security cameras and weather forecasts enhance operators' capability. Through correct data analysis, a breakdown could be prevented. Big data could be employed for alarms, generation, forecasting demand, price, etc.

Table 3: Continued.

Reference	Challenges	Description
Gungor et al. [59]; Ma et al. [98]; Fang et al. [99]	Communication issues	Transmission and communication protocols are not properly stipulated in the smart grid. For example, GSM (global system for mobile communications) and GPRS (general packet radio services) coverage spectrum is restricted to 10 km. However, 3G requires a higher range and Zigbee is limited to 30 to 50 m. In addition, wired communication has interference challenges. All-optical fiber is more reliable and faster but very costly. Currently, the smart grid faces challenges in terms of reliability and security in both wired and wireless communication.
Gopakumar et al. [100]; Kappagantu et al. [101]	Stability concerns	Renewables in a smart grid have various advantages but raise stability concerns like low-frequency power oscillation; inability to serve as system reserve; angular constancy due to decreased inertia in the overall system; and constancy in voltage due to reduced support in power distribution.

Table 4: Socioeconomic challenges of smart grid.

Reference	Year	Challenges
Guo et al. [102]	2015	Differences in wholesale and retail prices: the difference between changing wholesale prices and retail prices leads to inadequacies. Demand risk: the system can become inoperative in the case of a failure to match supply and demand. Energy integration of renewable sources: the irregularity creates a problem due to a lack of controllability over influxes to the system.
El-Hawary [12]	2014	Security: as a foundation of smart grids, the importance of information technology may bring in vulnerabilities in new cyber security. Mitigating security risks is the most important research activity of smart grids nowadays. Initially over-priced: costly pilot systems can limit the recognition and implementation of smart grids. Stakeholder engagement: in a smart grid, early implementations and stakeholders' adverse perceptions can unsettle the most valuable project. Advocates play an important part in explaining and identifying the smart grid's advantages to customers, which are the key to service success. Privacy: the issue of privacy violation must be tackled properly to gain consumer approval and trust. Fear of obsolesce: the implementation of innovative instruments can increase costs. This issue can be tackled via standard enhancement and retrograde compatibility of technologies.
Gupta [103]	2012	According to the researcher, privacy, RF safety, and rate increases are three main concerns. According to him, these issues may negatively impact the implementation of smart grids.
Chandrasekaran [104]	2012	Power theft: power theft is one of the major issues in many countries. It can be prevented using insulated and the LT overhead lines and wires to minimize the theft of energy via hooking. Inadequate grid infrastructure: modern and intelligent grids which are reliable and economically secure can provide a stable atmosphere for investments in electric infrastructure. Low metering efficiency: low metering efficiency and theft can be eliminated by improving the efficiency of the meter, proper energy auditing and accounting, and improved efficiency of billing and collection. AT&C losses can be decreased by fixing the accountability of the personnel and feeder managers. Lack of awareness: customers should be made aware of the energy utilization pattern at the office, home, etc. Consumers should focus on the overall skills of smart grids instead of the extra execution of smart meters. Policymakers and regulators must be very clear about the smart grid possibilities.
Sinha et al. [105]	2011	The researcher focused on the following challenges: (i) Inadequately planned networks of distribution (ii) Overburdening components of a system (iii) Power stealing (iv) Lack of reactive power support and regulation services (v) Low metering productivity and collection of bills

maintenance life among some assets. In future, integrated communications technologies will reduce the demand for costly hard assets.

5.3.2. Improving Reliability. The smart grid will reduce the cost of power interruptions and increase reliability. Control and communication technologies employed in the grid will identify faults and allow more rapid repair of identified faults.

5.3.3. Increased Economics. Productivities accompanied by the smart grid should reduce the increasing electricity costs. Real-time price signals will let customers contribute to the electricity market based on existing supply and demand estimating circumstances. Exchange among these consumers and retailers should decrease grid overcrowding and unplanned outages and define the real price for electricity at different times during the day. At present, though, business cases for financing the smart grid developments and technologies are often inadequate when viewed strictly

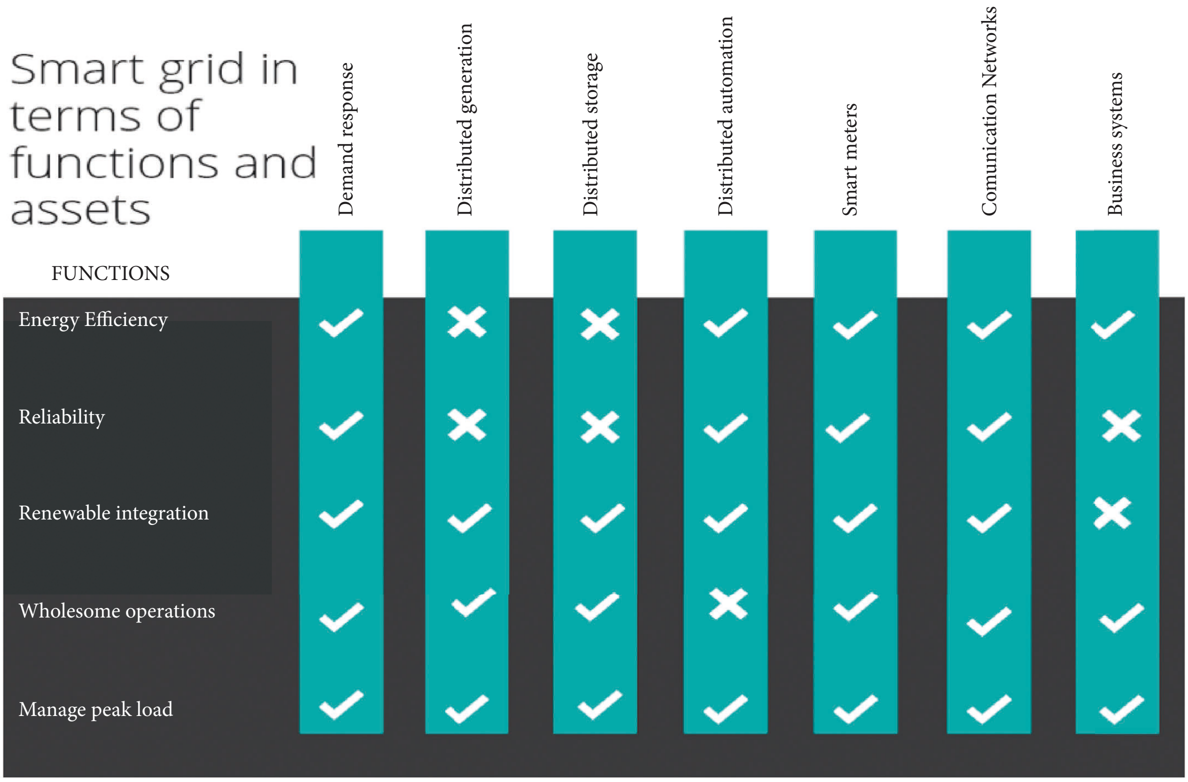


Figure 6: Strengths and qualities of smart grid.

concerning near-term cost-effectiveness. As study after study indicates, the societal case for smart grid adoption is fundamental, lasting, and real: growing energy efficiency, distributed generation, and renewable energy would save a projected $36 billion annually by 2025 [109]. Distributed generation can significantly reduce transmission costs, presently estimated at $4.8 billion annually. Smart appliances costing $600 million can give as much backup capacity to the grid as power plants worth $6 billion [109]. Over 20 years, $46 billion to $117 billion [109] could be saved in the avoided cost of constructing power plants, transmission lines, and substations.

5.4. Current Achievements of Smart Grid on the Economy of Developed Countries. Different countries throughout the globe have advanced in the smart grid and understand its existence. Many smart grid projects are in process in different countries, and some of them are taking initiatives for research and testing to examine probability before implementation. In different countries like the USA, China, Australia, England, Japan, and South Korea, the government considers the smart grid option for reducing CO_2 emission [84, 109, 110].

5.4.1. Australia. The government of Australia has been interested in projects of smart grid since 2009 and was willing to invest about $100 million in it. The government raised awareness among consumers about the use of energy and generation management systems. Many parts of Australia, including New South Wales, were nominated to establish a smart grid with GE Energy, IBM, and Grid Net. This project was to create a smart grid based on WIMAX having capabilities of the automatic substation that can support 50,000 smart meters' networks and adjust electric vehicles. One more project was introduced to assess network fault detection, restoration, power quality monitoring, and isolation.

5.4.2. Europe. In early 2005, the European Union established European Technology Platform 2005 for smart grid advancement to encourage the European electricity vision 2020. Italy is performing a major role in smart grid research and development, and Portugal implemented a control and management system for smart grids in their projects [111–113]. The Czech Republic has analyzed the smart grid for cost-benefit [114].

5.4.3. China. The government of China is more interested in the policies of protecting the environment, conservation, relying on domestic resources, and encouraging diverse development [115]. Chinese policy includes improving energy efficiency, increasing renewable energy mix, and reducing CO_2 emission. The Chinese agency National Development and Reform Commission is in charge of developing and researching smart grid technologies [115]. In 2009, China declared a context for the smart grid, which was extra transmission centric than other countries like USA and other regions like Europe [116].

5.4.4. Canada. Smart meter installation for businesses and households in Ontario was made compulsory by the Canadian government in 2010 via the 2006 Act of Legislation Energy Conservation Responsibility. This year, the government spent $32 million on different projects on smart grids. For the smart grid campaign for awareness and promotion, an association Smart Grid Canada was established, responsible for research and different smart grid policies [84].

Cost is one of the biggest restrictions on the advancement and execution of the smart grid, especially in the emerging world. Transmission and supply systems, metering, and other technologies are associated with many financial resources. Most of the financial and economic data for this calculation were used from the World Bank's report of 2015. The summary of these results is illustrated by the authors (see Figure 7).

One day, smart grid will unite the whole world to plentiful, cheap, clean, and effective power anywhere. The smart grid will provide the finest and most reliable electric services. This type of current electric infrastructure will perform a vital role in the future, like substations and power transmission lines. "Smart grid is a fully automated power delivery network that monitors and controls every customer and node, ensuring a two-way flow of electricity and information between the power plants and appliances and all points in between" [117]. Aside from the numerous benefits, smart grids confront other challenges, such as bidirectional communication systems, grid integration with renewable energy resources, inefficient DG utilization, and insufficient existing grid infrastructure and storage, to name a few. Handling electricity generation, energy storage, and loads as a localized group is one technique for optimal DG use. A microgrid is an important part of the smart grid concept. It is a part of a larger grid that includes nearly all of the utility grid's components, but these are smaller. Microgrids are smaller and can operate independently from the larger utility grid, whereas smart grids take place at a bigger utility level, such as massive transmission and distribution lines.

5.5. Future of Smart Grid. Microgrids can be self-contained or connected to the utility or main grid. If a problem occurs while the microgrid is connected to the grid, it has the potential to separate from the grid and operate independently, supplying its own load. As a result, microgrid operation modes can be divided into grid connected, islanded, and transition from grid-connected to islanded mode and vice versa. The heat generated by some of the microsources can be utilized to meet the heat demand of the local load in any mode of operation.

Various units are integrated into a microgrid. It is made up of a DG unit, an energy storage unit, a controller unit, and a conventional load. The DG unit is made up of a variety of microgenerating devices. As a result, depending on the components employed, microgrid modelling differs from one configuration to the next. While the network is ignored, the dynamics of all the DG units are approximated by a first-order linear model with a time constant and a gain factor. The transfer functions of various components are determined, and time-domain analysis is carried out by taking into account various components at different times.

The following are the transfer functions of various components, and the configuration in one of the cases is illustrated (see Figure 8).

Wind turbine:

$$\frac{\mathrm{KWTG}}{1 + \mathrm{sTWTG}}. \tag{1}$$

PV system:

$$\frac{\mathrm{KPV}}{1 + \mathrm{sTPV}}. \tag{2}$$

Fuel cell:

$$\frac{\mathrm{KFC}}{1 + \mathrm{sTFC}}. \tag{3}$$

Diesel engine generator:

$$\frac{\mathrm{KDEG}}{1 + \mathrm{sTDEG}}. \tag{4}$$

Aqua electrolyser:

$$\frac{\mathrm{KAE}}{1 + \mathrm{sTAE}}. \tag{5}$$

Storage system:

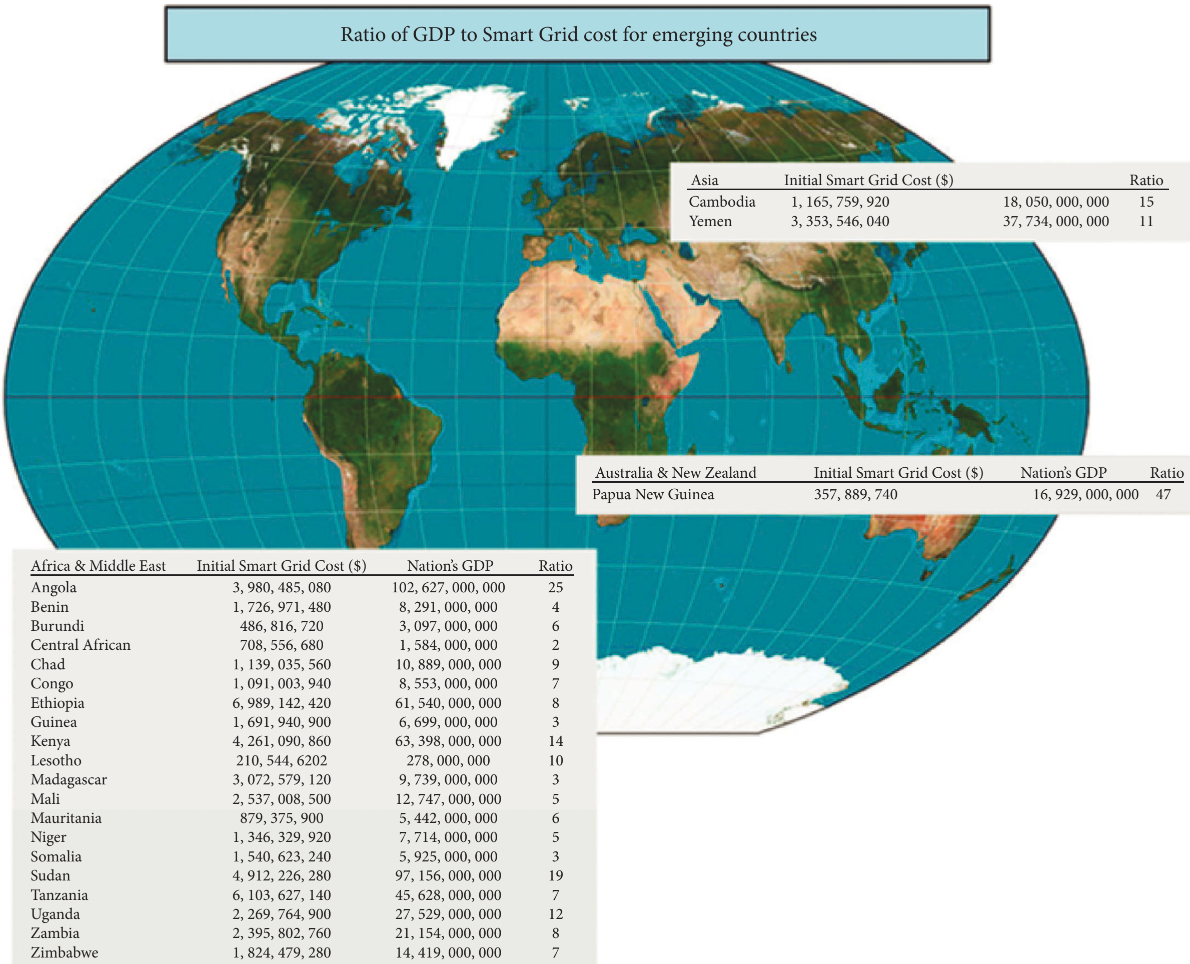
$$\frac{\mathrm{Ksto}}{1 + \mathrm{sTsto}}. \tag{6}$$

Microgrids can be divided into three categories depending on how the AC and DC buses are connected. The following is the proposed classification: AC microgrids, DC microgrids, and hybrid AC/DC microgrids are all types of microgrids.

5.5.1. AC Microgrids. Mixed loads (DC and AC loads), distributed generation, and energy storage devices are connected to a shared AC bus in AC microgrids. Because most loads and the grid are AC, AC microgrids are simple to integrate into a traditional AC grid. It has increased capacity, controllability, and flexibility as a result. However, connecting DC loads, DC sources, and energy storage devices to the AC bus via a DC/AC inverter reduces efficiency dramatically [119–121].

5.5.2. DC Microgrids. A common DC bus is used in DC microgrids to connect to the grid via an AC/DC converter. The operation of a DC microgrid is comparable to that of an AC microgrid. Compared to AC microgrids, DC microgrids are a good way to reduce power conversion losses because they only require one power conversion to connect DC buses. As a result, DC microgrid systems have improved system efficiency, cheaper costs, and smaller systems.

Furthermore, due to the lack of reactive power, DC microgrids are more compatible with integrating distributed energy resources (DERs) and provide superior stability.



Asia	Initial Smart Grid Cost ($)		Ratio
Cambodia	1, 165, 759, 920	18, 050, 000, 000	15
Yemen	3, 353, 546, 040	37, 734, 000, 000	11

Australia & New Zealand	Initial Smart Grid Cost ($)	Nation's GDP	Ratio
Papua New Guinea	357, 889, 740	16, 929, 000, 000	47

Africa & Middle East	Initial Smart Grid Cost ($)	Nation's GDP	Ratio
Angola	3, 980, 485, 080	102, 627, 000, 000	25
Benin	1, 726, 971, 480	8, 291, 000, 000	4
Burundi	486, 816, 720	3, 097, 000, 000	6
Central African	708, 556, 680	1, 584, 000, 000	2
Chad	1, 139, 035, 560	10, 889, 000, 000	9
Congo	1, 091, 003, 940	8, 553, 000, 000	7
Ethiopia	6, 989, 142, 420	61, 540, 000, 000	8
Guinea	1, 691, 940, 900	6, 699, 000, 000	3
Kenya	4, 261, 090, 860	63, 398, 000, 000	14
Lesotho	210, 544, 6202	278, 000, 000	10
Madagascar	3, 072, 579, 120	9, 739, 000, 000	3
Mali	2, 537, 008, 500	12, 747, 000, 000	5
Mauritania	879, 375, 900	5, 442, 000, 000	6
Niger	1, 346, 329, 920	7, 714, 000, 000	5
Somalia	1, 540, 623, 240	5, 925, 000, 000	3
Sudan	4, 912, 226, 280	97, 156, 000, 000	19
Tanzania	6, 103, 627, 140	45, 628, 000, 000	7
Uganda	2, 269, 764, 900	27, 529, 000, 000	12
Zambia	2, 395, 802, 760	21, 154, 000, 000	8
Zimbabwe	1, 824, 479, 280	14, 419, 000, 000	7

FIGURE 7: Current achievement of smart grid on current economy of different countries.

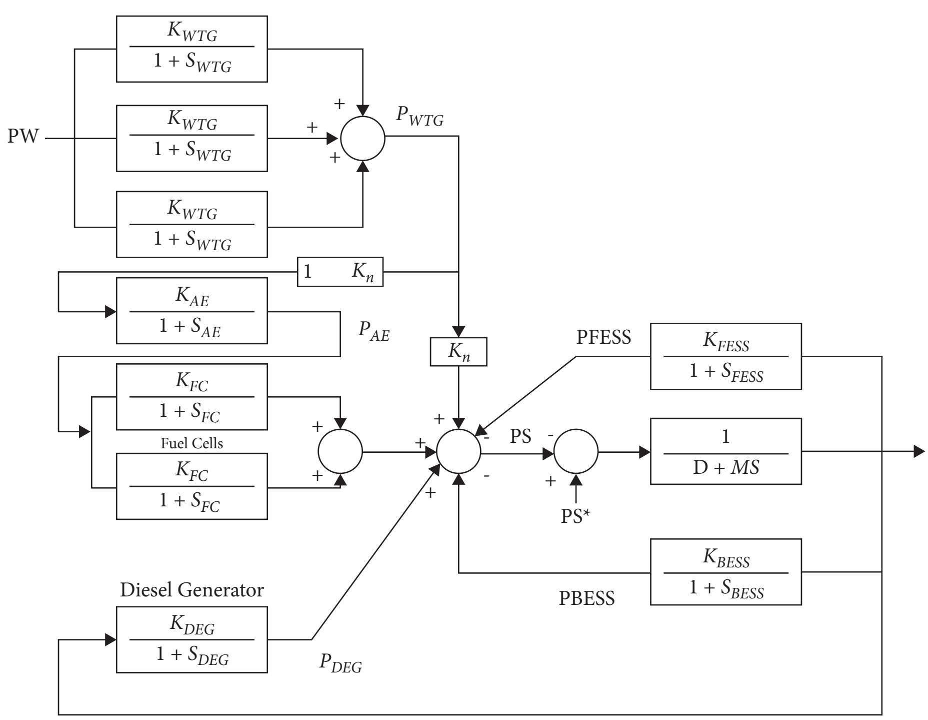


FIGURE 8: Block diagram of a microgrid [118].

There are three forms of DC microgrids described in the literature [122–124]: monopolar, bipolar, and homopolar.

5.5.3. Hybrid AC-DC Microgrid. A hybrid AC/DC microgrid combines AC and DC microgrids in the same distribution grid, allowing direct integration of both AC and DC-based DG, energy storage system (ESS), and loads. This architecture combines the benefits of both AC and DC microgrids, including a smaller number of interface elements, easier DER integration, fewer conversion stages, lower energy losses and total costs, and increased reliability. Furthermore, when DG, loads, and ESS are directly connected to AC or DC networks, there is no requirement for generation and storage units to be synchronized [125, 126].

Distributed and hybrid RES generators (e.g., PV (photovoltaic) panels and wind turbines) are used in hybrid microgrid systems to create renewable energy (e.g., solar and wind), with energy storage devices built to compensate for the fluctuation between RES generation and load consumption. Depending on the desired and established objectives, these hybrid systems can operate in grid-connected or freestanding modes. However, as the number of distributed generators grows, new energy management systems are needed to ensure their seamless integration into the existing electrical grid. Table 5 shows recent literature on hybrid system implementation, with batteries being the most widely utilized energy storage component cited.

5.6. Optimization and Control Techniques in MG Systems. Numerous studies on MG optimization and control have been conducted based on system topologies, architectures, and operating modes [132–134]. For example, optimization and control approaches should handle the stochastic character of installed RES generators by assuring a reliable supply of power to consumers while maintaining appropriate operation conditions for the storage system, electricity bill, and occupants' comfort.

5.6.1. Comparison of Control Approaches for MG Systems. The selection of method in a microgrid is a prerequisite for the MG system's reliable and stable operation. An EM can be chosen based on the characteristics of the deployed system (for example, topologies, operation modes, and structure). However, the deployment of one way does not imply that the others are unreliable, and the essential issue in determining the utility of the deployed method is to examine the investigated limitations and the determined target of the control strategy. The remainder of this section discusses the comparative analysis of various control techniques of microgrid (see Table 6).

A successful strategy must take into account the stochastic nature of various control parameters, installation costs, component lifetimes, distributed resources, and the MG system's dependable and safe operation. In fact, deploying an EM control approach necessitates categorizing the entire system into distinct levels, with each level cooperating with the others from the sources (e.g., maximum power point tracking) to the end consumers, which can be a local or adjacent MG consumer. Smart components are now implemented for each source and each MG system, allowing them to communicate with one another thanks to new ICTs. The actual inverters, in particular, can implement a variety of control schemes, ranging from source power regulation to interconnection with the utility grid or a neighbouring MG. Furthermore, inverters can be constructed for a large number of MG systems, forming a data and electricity exchange cluster, with these inverters connected to the Internet to store historical data in the cloud.

The primary job of each inverter is to ensure uninterrupted power delivery to consumers, regardless of the battery storage system's lifetime or the cost of electricity. In this case, an EM control technique that takes into account electricity price fluctuations while minimizing the battery cycle is necessary. These two difficulties allow for increased system profitability by lowering the electricity bill and reducing the need for regular battery storage replacement in MG systems. The major goal is to create an intelligent and predictive control strategy that can optimally regulate the distributed resources in the MG while also taking into account different limitations and objective functions. In a microgrid, it is important to sustain the balance between power supply and demand for stability because generating sources such as wind turbines and photovoltaics is tough to forecast. Therefore, it may cause fluctuation in the generation of power. The supply-demand balancing challenge is adversely affected when the microgrid operates in standalone mode, with only a limited supply available to balance the demand. The optimization of energy management in microgrids is typically seen as an offline optimal control problem. Furthermore, energy management inside the smart grid is a critical component in increasing renewable energy usage and energy efficiency. In the smart grid (SG), energy management maintains supply and demand stability while adhering to all system restrictions for cost-effective, dependable, and safe electrical system operation. It also contains optimization, which ensures that power generation costs are reduced. By bringing all systematic procedures together, the EMS controls and decreases to a minimum the quantity and price of energy required for a certain application. However, while energy management in a distribution system improves system performance, it also has constraints and obstacles, including client confidentiality, large-scale operations, frequent system upgrades, and EMS dependability issues.

5.7. Energy Management System in Smart Grid. Power plants generate most of the world's electricity by burning fossil fuels, which are inadequate in availability and have harmful impacts on the environment [142]. Current research reveals that if the utilization rate stays stable, the fossil fuel reserve of the world will last only 50 to 60 years. Moreover, the Paris Climate Agreement and United Nations Sustainable Development have set targets to decrease the pollution of CO_2 to the environment [143]. Balancing energy production and

Table 5: Recent literature survey on hybrid system implementation.

Reference	Components	Accomplishment analysis
[127]	Distributed generation, wind turbine, fuel cell, and battery	To increase electric energy utilization in remote places, the multi-objective particle swarm optimization technique is applied. The simulation results are shown in this paper by the researchers.
[128]	Wind turbine, fuel cell, grid, and battery	Standalone mode is used to operate a grid-connected hybrid PV-wind system. The results of experiments are provided.
[129]	Distributed generation, wind turbine, battery, fuel cell, and battery	A multi-objective optimization problem with control horizon is used for sharing of renewable energy resources and energy storage dispatch in MG. The multi-objective optimization is constructed as a lexicographic algorithm to allow preferential treatment of various MGs. The simulation outcomes are displayed.
[130]	Wind turbine, battery, and fuel cell	The suggested method is described by an EM model capable of determining the schedule of each programmable unit in order to meet community needs at the lowest possible cost of operation. The simulation results are shown.
[131]	Distributed generation and battery	Because of the short lifecycle of storage devices, the deployed technique efficiently handles the source. When the storage devices are charged to their maximum capacity, it avoids the requirement for a dump load in the MG. The simulation results are shown.

utilization is known as energy management which can have major influences on the journey of electric energy from production to utilization. Energy management in power distribution systems considers various traditional energy sources like energy storage systems, renewable energy sources, critical loads, and energy management system operations and functions illustrated in Figure 9. The scholars have curiosity about the energy management system topic because of numerous reasons, which include

(1) Reduction of losses in the distribution systems by the service companies to decrease operational costs, ultimately facilitating the customers by paying fewer electricity bills.

(2) Cost reduction by precisely monitoring and observing the loads and energy resources.

(3) Decreasing greenhouse gas discharges that affect the society by power and electric companies.

Figure 9 shows that energy management system in the smart grid performs a major role in functioning and management so that the power system strategy works more effective by examining, regulating, and conserving energy. Integration of smart grid with energy management system can evaluate complicated power system data, decrease power utilization, and enhance smart grid reliability and effectiveness.

In this scenario, urgency for a more effective and efficient way to produce and utilize energy is exhibited. It also facilitates giving power to the consumers of critical load in the power lines during scheduled load shedding [144]. Various research papers have been published on the energy management of smart grids for reducing operational costs and system losses; for example, the authors [145] presented a model that shows the schedules and controls of the generators based on diesel and units of battery storage to reduce the cost of the system. They presented an energy management system based on multi-agent that regulates the supply in the existence of high levels of renewable energy sources and electric vehicles [146]. The authors [147], in their paper, presented a model of the optimal dispatch of microgrid distributed generation for system sustainability. Researchers discussed control of the distributed generators to reduce the costs of the system by increasing the use of renewable energy sources. The authors in [148] presented a model to accommodate the output of the generation according to the network's reasonable scenario. The model in [149] considers the distinct size and increases the allowable distributed generation of the systems. In addition, numerous papers focused on controlling distributed generation for different aspects of smart grid energy management systems [150]. Search optimization technique based on tabu is useful for energy management in multi-microgrids [151], the MINLP technique is functional in a rural distribution system and [152], two-stage optimization technique is practical in microgrids with different levels of penetration of electric vehicles [147]. The energy management system authenticates the schedules, and optimal dispatch of the distributed energy sources in microgrids and hence is accountable for their reliable and economic operation. The authors in [153, 154] also addressed different distributed generation strategies. Moreover, many papers have been published in the literature on energy management and addressed the cost minimization and losses of distribution systems using reconfiguration techniques [155, 156].

Though some research papers have been published on energy management, the literature requires a comprehensive energy management review in smart grid and distribution systems. This paper aims to make a comprehensive literature review of the published research papers on energy management systems in smart grids and distributed networks to address this gap. Furthermore, the objective is to summarize the work concerning various factors, including energy management approaches, objective functions, and solution algorithms, and to recognize the challenges of such research [157–161].

5.8. Significance of Energy Management System. Energy demand is directly proportional to the need for the production of power. Growth in the number of consumers is causing several issues for electric companies. First, the

Table 6: Comparison analysis of microgrid control approaches.

Technique	Implementation	Features	Drawbacks
Artificial neural network (ANN) [135]	(i) DG units (ii) Several MG system connections	(i) Technique used by the researchers can optimize, control, and classify the system's parameters (ii) Resolve complications with nonlinear data methods in large-scale systems in MG as well as able to rectify the system's fault tolerance and stability.	(i) Complex model (ii) Finding the optimal network structure when adding or increasing units from the MG topology is difficult
Multi-agent-based control [136, 137]	(i) DG units (ii) Several MG system connections	(i) In the MG system, a group of agents may address larger problems than any one agent can (ii) The ability to work in a variety of environments and under varying situations (iii) Redundancy and large-scale economies	(i) Agents and the LC must have a high level of connectivity (ii) For voltage and frequency regulation, the agent should function at the same settings as the other agents
Conventional droop [138]	(i) Inductive transmission lines (ii) Dependable for DC-MG	(i) Easy to implement	(i) There is no guarantee of voltage control (ii) The voltage lowers across the bus resistance, resulting in a reduction in current sharing
FL-based control [139]	(i) Consistent primary control (ii) Voltage and frequency regulation	(i) Improved voltage and frequency regulation and power sharing for multiple MGs	(i) Requiring a powerful processor (ii) Time-consuming procedure and error-prone methods for the participation function
Model predictive control [140–142]	(i) Reliable for power sharing between the utility grid and MG having hybrid AC/DC combined MG	(i) Optimal control (ii) Robust against uncertainty	(i) Requiring the usage of modern ICTs (ii) Information on control parameters should be defined ahead of time

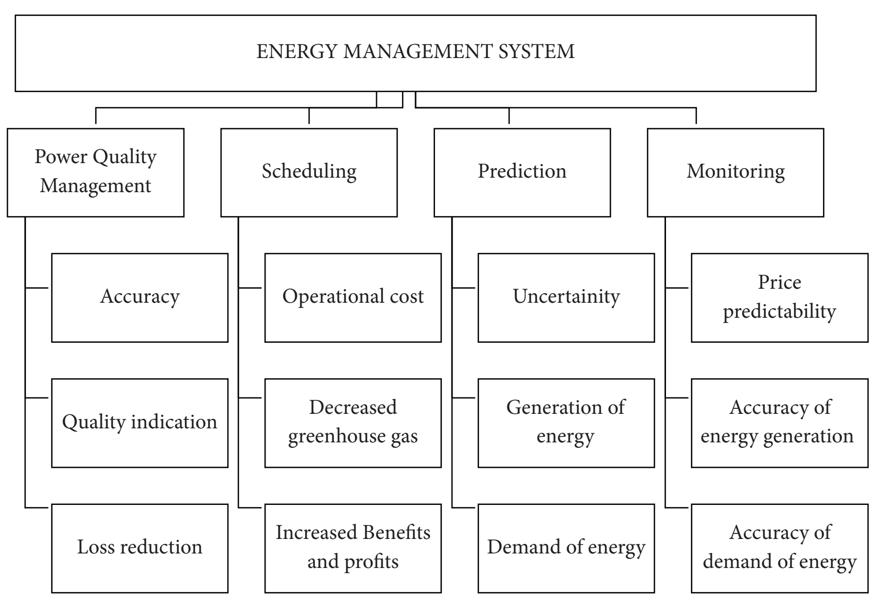


Figure 9: Combination of power quality management with energy management system.

system's performance can be threatened due to high peak demands. To solve this problem, the system operators and electric companies have two solutions:

Employ energy management to decrease the high peak demand during peak hours.

Expanding the network in terms of size and dimension will require time for implementation and can be costly [162–165].

Energy management is considered essential for a smarter grid for many reasons:

It increases the efficiency of the system.

It preserves the resources.

It decreases pollution, which helps to protect the climate.

It provides precise outcomes and predictions.

It facilitates the end users to manage and reduce their electricity bill.

It helps the electric utility to lower the cost of generation.

It helps in decreasing the energy losses on the lines and network [166, 167].

5.9. Application of Energy Management System. Energy management has two most important categorizations. One is from the electricity supplier's perspective, while the other is from the electricity consumer's perspective. The electricity supplier, which includes power plant operators, electric utility, and production units, can use energy management to control its production units. For example, the electric utility can reduce the production operation cost by turning on some generators, which may have the least operation cost. In contrast, the generators with high operating costs are left to supply extra load demand in specific peak periods [168, 169]. The system operators (distribution and transmission systems) can utilize energy management to adjust the flow of power to reduce the energy losses on the network. Finally, the end users (such as householders, residential and commercial buildings, industries, and faculties) utilize energy management to schedule their load demand and effectively decrease their electricity bills.

5.10. Energy Management System Objectives. In this section, the authors briefly explain the objective of energy management, and different literary works of researchers with different approaches are also addressed in this section of the paper with brief literature (see Table 7).

5.10.1. Cost Management. Energy management supports decreasing the system's functioning costs and enhancing the system's production by reducing extra costs during peak hours. For example, in a distribution system, system modification and scheduling lower the losses and costs of the system. However, the load can affect the customers by line losses, which are at a distance from the production station because of environmental, economic, and geographical problems [211].

5.10.2. Controlling Greenhouse Gas Effects. Global warming is one of the most important matters for the Earth, which increases the regular temperature of the Earth's weather system. Numerous reasons are accountable for global warming, like emissions from fossil fuels, factories, and gas using vehicles. The explanation for utilizing power production based on fossil fuel is their consistency and low cost related to sources of renewable energy. To reduce the effects of greenhouse gas emissions, the energy management system plays a vital role by accurately dealing with and limiting energy sources in distribution systems while focusing on productivity and reliability of the system [212].

5.10.3. Enhancing the Performance of Voltages in the Distribution System. Variability in loads can disturb the voltage permanence in a distribution system. Voltage levels can vary due to sudden changes in loads and production failure. This voltage constancy issue can perhaps be improved by applying reactive sources [213–215].

The fluctuations and variations in voltages can increase and be a reason for the ripple effect in the adjacent section if the reactive power cannot supply enough support to the voltage limits. In a current distribution system, the demand response gives the customers the benefit of taking the load in an improved way [216–218].

5.10.4. Reliable and Reduced Outage Interval of Energy Management System. The energy management system evaluates the data for all the connected devices to the energy system through data centre consumption. It categorizes the regions with the highest capacity or lowest capacity. The system consistency could be enhanced by controlling the energy storage system and demand response using an energy management system in a distribution system. Researchers are dedicated to energy management systems created for economic development, where the mixture of power generation and storage meets the load requirement in an energy system [219–221]. However, the system can suffer outages when it fails to meet the required load demand during peak times. Numerous steps have been taken to reduce outage intervals, and some of them are mentioned in this section [222, 223].

5.10.5. Effective Efficiency. Energy management supports examining the distribution of energy in an enhanced way. With the help of an IoT sensor, the customers can get informed about the data usage of energy from the system and enhance the energy by rescheduling the energy-using devices. An energy management system helps the customers and utility minimize energy use while guaranteeing the efficiency of the power system. Additionally, energy management can supervise and manage the energy reserves situated at the consumer's side to help minimize the stress of transmission lines and system loss by enhancing the system's efficiency [224, 225].

5.11. Energy Management System Approaches. To balance energy management in the distribution system, it is necessary to perform different approaches on the distribution system. These approaches are briefly explained by the authors (see Table 8).

5.11.1. Capacitor Bank. Capacitor banks play a vital role in the system. It provides reactive power, which corrects the phase shift inherent and power factor in AC energy

Table 7: The objective of the energy management system.

Reference	Name	Year	Objectives
[145]	Taha et al.	2018	Cost management
[146]	Divshali et al.	2017	
[170]	Anglani et al.	2017	
[148]	Wang et al.	2016	
[171]	Pourmousavi et al.	2010	
[150]	Arefifar et al.	2017	
[153]	Zhang et al.	2016	
[172]	Rodríguez-Gallegos et al.	2018	
[173]	Pradhan et al.	2017	
[174]	Yuan et al.	2017	
[175]	Wang et al.	2015	
[176]	Bo zhao et al.	2018	
[177]	Heidari et al.	2015	
[178]	Falaghi et al.	2009	
[179]	Ba et al.	2017	
[145]	Taha et al.	2018	Controlling greenhouse gas effects
[151]	Bahram et al.	2018	
[180]	Othman et al.	2015	
[174]	Yuan et al.	2017	
[181]	Falahi et al.	2013	
[182]	Tahboub et al.	2015	
[156]	Ganesh and Kanimozhi	2018	
[183]	López et al.	2016	
[184]	Levitin et al.	2000	
[185]	Mousavi et al.	2017	
[145]	Taha et al.	2018	Reduced pollution release
[147]	Solanki et al.	2017	
[171]	Pourmousavi et al.	2010	
[153]	Zhang et al.	2016	
[186]	Kanchev et al.	2014	
[187]	Zhang et al.	2014	
[188]	Pérez-Mora et al.	2017	
[189]	El Bidairia et al.	2018	
[190]	Alavi et al.	2015	
[191]	Aghajani et al.	2015	
[192]	Chaouachi et al.	2013	
[193]	Elsied et al.	2016	
[194]	Dou and Liu	2013	
[191]	Aghajani et al.	2015	
[195]	Bornapour et al.	2017	
[196]	Muttaqi et al.	2014	Enhance the performance of voltages in the distribution system
[181]	Falahi et al.	2013	
[197]	Rao et al.	2013	
[198]	Farahani et al.	2012	
[199]	Ghanegaonkar and Pande	2017	
[200]	Bagheri Tolabi et al.	2015	
[201]	Sepulveda Rangel et al.	2018	
[202]	Yang et al.	2019	
[203]	Moradi et al.	2015	
[204]	Chen et al.	2015	
[205]	Roy Ghatak et al.	2018	
[206]	Xiao et al.	2016	
[170]	Anglani et al.	2017	
[207]	Byrne et al.	2018	
[208]	Marzband et al. et al.	2013	Reliable and reduced outage interval of the energy management system
[209]	Mendes et al.	2013	
[178]	Falaghi et al.	2009	
[177]	Heidari et al.	2015	
[210]	Olivares Quero et al.	2015	
[144]	Guo et al.	2016	

Table 8: Approaches to the energy management system.

Reference	Name	Year	Approaches
[145]	Taha et al.	2018	
[146]	Divshal et al.	2017	
[147]	B. V. Solank	2017	
[170]	Anglani et al.	2017	
[144]	Guo et al.	2014	
[148]	Wang et al.	2015	
[150]	Arefifar et al.	2016	
[151]	Bahrami et al.	2017	
[152]	Nafisi et al.	2015	
[180]	Othman et al.	2014	
[153]	Zhang et al.	2015	
[186]	Kanchev et al.	2014	
[207]	Byrne et al.	2017	
[154]	Craparo and Sprague	2019	
[226]	Chen et al.	2011	
[227]	Marzband et al.	2014	
[158]	Marzband et al.	2013	System modification
[228]	Cau et al.	2014	
[190]	Alavi et al.	2015	
[229]	Fujimoto et al.	2016	
[230]	Rahbar et al.	2016	
[231]	Van der Meer et al.	2016	
[232]	Azizivahed et al.	2017	
[233]	Liu et al.	2014	
[234]	Liu et al.	2017	
[193]	Elsied et al.	2016	
[235]	Gao et al.	2018	
[236]	Elgammal and El-Naggar	2018	
[237]	Roy et al.	2019	
[238]	Ju et al.	2016	
[195]	Bornapour et al.	2017	
[239]	Barklund et al.	2008	
[240]	Kumar et al.	2008	
[241]	Wang et al.	2017	
[198]	Farahani et al.	2011	
[242]	Rupolo et al.	2019	Capacitor bank
[184]	Levitin et al.	2000	
[243]	Choudar et al.	2015	
[145]	Taha et al.	2018	
[170]	Anglani et al.	2017	
[150]	Arefifar et al.	2016	
[244]	Li et al.	2017	
[176]	Zhao et al.	2018	
[245]	Tani et al.	2014	
[246]	Fossati et al.	2015	
[192]	A. Chaouachi	2012	
[201]	C. A. Sepulveda range	2017	
[247]	Xu et al.	2018	
[248]	Azizivahed et al.	2018	
[249]	Kumar Nunna and Dolla	2013	Managing energy storage system
[250]	Jabir et al.	2019	
[251]	Westermann et al.	2008	
[252]	Papari et al.	2017	
[205]	Roy Ghatak et al.	2018	
[253]	Wu et al.	2018	
[254]	Nasr et al.	2019	
[255]	Yang et al.	2017	
[256]	Thirugnanam et al.	2018	
[257]	Mendes et al.	2017	
[258]	Mousavi et al.	2009	
[259]	Manandhar et al.	2017	

Table 8: Continued.

Reference	Name	Year	Approaches
[146]	Divshal et al.	2017	Demand response in the energy management system
[147]	Solanki et al.	2017	
[153]	Zhang et al.	2015	
[191]	Aghajani et al.	2015	
[260]	Anvari-Moghaddam et al.	2017	
[261]	Kyriakarako et al.	2012	
[249]	Kumar Nunna et al.	2013	
[262]	Mazidi et al.	2014	
[263]	Ma et al.	2018	
[264]	Jadidbonab et al.	2019	
[265]	Brusco et al.	2014	

supplies and DC energy supplies; it increases the storage energy with an improvement in the ripple current of the power supply.

5.11.2. Managing Energy Storage System. In an energy management system, the energy storage system can reserve additional energy during off-peak times for future use and support improving the system's productivity and consistency. The energy storage system in energy management includes electric vehicles, flywheels, and batteries for storage.

5.11.3. Demand Response in Energy Management System. Demand response helps in managing time-based utilization from the production side. It helps to reduce the customer's utilization and shifts the unnecessary load requirement to off-peak time, which reduces the additional costs.

5.11.4. System Modification. System update encourages reducing transmission line losses while posing more challenges for circular distribution networks to synchronise shielding relays [266].

5.12. Enhanced Approaches to the Energy Management System. This section discusses EMS enhanced solution approaches. The machine learning method and its various models are highlighted since they are critical for energy forecasting and highly valuable for the efficient operation of the EMS in the grid. The solution methodologies for EMS are then divided into four categories: mathematical programming, heuristics, metaheuristics, and another approach [267–269]. Finally, the applications of various methodologies are discussed, and a table compares each approach's techniques. Many optimization techniques and programming methods have been developed for energy management schemes, such as RES management, charge controller, LC management, and PEV charge/discharge management [270–272]. An EMS strategy's ultimate purpose is to decrease or maximize the objective function, which could be GHG emissions, cost, power quality, effectiveness, load profile, reliability, etc. As a result, the IoT and deep learning (ML) are rising in popularity simultaneously, and both are extremely beneficial to the network's EMS's effective operation. Because of their precision, efficiency, and speed, ML models in EMS are now required to predict production, consumption, and demand analysis [273–275]. ML models can also better understand how energy systems work in complicated human relationships [276–279]. Therefore, applying machine learning models to traditional power systems and alternative and renewable energy systems seems promising [280, 281]. However, because of the field's prominence, various policy statements have been produced that provide an overview of existing uses and future difficulties and prospects. Existing synthesis articles [282], on the other hand, either focus on a specific ML model, such as ANNs [283], or a single energy sector, such as solar radiation predictions. Artificial neural network (ANN) [284], support vector machine (SVM), tree-based modelling technique (decision tree), ensemble prediction (EPS), adaptive neuro-fuzzy inference system (ANFIS), wavelet neural network (WNN), multi-layer perceptron (MLP), and deep learning are the most popular machine learning methods.

ANNs are frameworks that allow various machine learning algorithms to process complex data inputs. It can be used for various tasks, including forecasting, regression, and curve fitting.

It can be used in various smart city applications, such as hazard detection, water system, energy, and urban transportation. A neuron that uses a frequency response for output formulation is a basic unit of an ANN. Its key benefit is that it is simpler to solve multi-dimensional issues. Another machine learning method for energy forecasting is SVM [285]. Researchers of paper [286] suggest a new strategy for residential energy management (REM) that differs from previous approaches. They define a REM problem to maximize customers' utility under numerous practical limitations such as human contact, power supply unavailability, consumer preferences, and priority using advanced mathematical algorithms. In [287], the authors proposed the scheduling algorithm for energy consumption management systems. To construct a smart city, researchers have used DTs to solve challenges such as companies, air pollution, urban transportation, and food [288].

Few enhanced solution approaches such as fuzzy logic, game theory, ant bee colony, multi-agent, and so on have been used in energy management systems, as shown in Table 9, for accomplishing advantages and accuracy in results, and Table 10 summarizes some existing EMS analyses. Each reference uses a distinct scenario and methodology for analysis.

Table 9: Enhanced approaches to the energy management system.

Approach	Reference	Year	Pros	Cons
Particle swarm optimization	[174]	2017	Obtaining the result to decrease losses in the system	Decreasing losses may increase the cost
	[236]	2018	Achieves an efficient data flow	Complex
	[179]	2017	Reduction in losses	Needs more enhancement to recover faults
	[190]	2015	Increased reliability in system	Costly
Fuzzy logic	[253]	2018	Control fluctuations in power	Costly
	[246]	2015	Efficiently controlling power	Increase in losses
	[261]	2012	Decrease in cost	Demand response ignored
Game theory	[289]	2018	Cost-effective system	Complex system
	[290]	2018	Improved strength and cost-effective	Needs more work on losses and privacy
Ant bee colony	[291]	2017	More efficient	Ignored outflow cost
Model predictive control	[292]	2016	System lifetime can increase	Has more losses
Multi-agent	[293]	2018	Reduction in cost	Needs more enhancement in storage
	[260]	2017	More secure	Costly
	[194]	2013	Fewer variations in voltages and fewer losses in the system	Complex system

Table 10: EMS techniques with description.

Reference	Primary goal	Technique	Description
[294]	Energy management	MILP and linear technique	A microgrid with power sharing, continuous operation, and on/off based on different configuration EMS is presented. The battery's DOD is increased, leading to its rapid depreciation.
[295]	Consumer energy management	PLC and SCADA	The provision of a control scheme employing SCADA and PLC control systems has resulted in a customer EMS with a smart meter.
[149]	Intelligent energy management	Fuzzy logic technique	The MG's operational costs have been reduced by optimizing the battery scheduling process.
[296]	Management of frequency	Stochastic optimization	The EMS system is used to control the frequency variations of an isolated MG while also fulfilling technical, economic, and environmental restrictions.
[297]	Energy efficiency regulator	Homeostatic controller	The application of DR in the domestic segment is beneficial in achieving energy efficiency and economic targets.
[286, 287, 291, 298–300]	Energy cost reduction Electricity cost reduction Minimized peak power consumption Energy management Optimized energy consumption Energy management in residential buildings	Genetic algorithm Joint energy management and energy trading model Unified DSM model Heuristic algorithm SEMS-CCGS REM approach	The multi-objective EMS approach describes the cost of operation, the price of emissions, and the profit from energy trade as objectives for optimal microgrid operation. The proposed model reduced the cost of electricity for microgrids with the highest percentage of self-generation using trading and EM model. Energy cost reduction, CO_2 emission minimization, PAPR reduction, peak clipping, and distribution losses reduction are achieved in the proposed model under the canopy of a unified DSM. A novel technique to energy efficiency was used by the researchers that combines the power of distributed energy resources, load scheduling, energy storage, and power distribution to a group of numerous residences. The proposed strategy is based on a distributed approach, which means that it is tailored to each individual user, and it aims to contribute to grid stability and greater grid energy utilization. Authors not only attempted to reduce the number of variables in this innovative concept but also simplified the proposed mathematical model in terms of difficulty for optimizers and ease of installation for consumers.

5.13. Aspects of Energy Management System Implementation

5.13.1. Estimating Strategy. Several electricity authorities are trading plans, generally connected to industrial events like offering electricity, metering, procuring, billing, and pricing [301]. Wholesale electricity products are divided into two categories, ensured cost product and the spot cost product. Ensured cost product has characteristics of price allocation for a particular period of the agreement or in advance. Another element related to the end user's concern is supply capacity. Both cost products have building units like ToU, temporary and fixed billing, and flat rate. A flat-rate tax is more attractive to the consumer as it is simpler to understand. Additional schemes are fixed pricing policy, usage-based dynamic pricing, distributed demand response, and so on [302] According to Misra et al. [303], in dynamic policy (D2P), there is 34% growth in plug-in hybrid electric vehicles compared to optimal ones [304]. After explicit promotion, renewable energy sources are permitted in the power trade. Demand response and demand-side management increase the consumption of current resources, improving productivity and consistency and smoothing the load profile, among other advantages. Conventional techniques are not productive in dealing with the investors and customers for decision-making steps.

5.13.2. Power Quality Management (PQM). PQM is the procedure that reduces the effect of external and internal disruptions that can lower the performance of a specific procedure. The power supplied to customers depends on the source and load at the customer's end. Poor power quality can be caused by the development in electronics technology of power and the increment in nonlinear loads. Problems in power quality differ from high-voltage impulses to wave shape faults, harmonics, and voltage fall and drops. Moreover, the recently appended bidirectional charger with PEV load injects harmonics into the system, deteriorating the power quality. The traditional task of the energy management system was to handle scheduling and transmitting. Therefore, the duty of the energy management system was restricted to the utilization of energy and cost, although the quality of power stayed trackless simultaneously. Quality of power is very important for effectiveness and to attract consumers. Therefore, an energy management system should consider constraints while scheduling significant loads/sources and power quality events. Figure 8 illustrates modern energy management systems' functioning incorporated with power quality management.

Few researchers suggested the utilization of static VAR compensator (SVC) and unified power quality conditioner (UPQC) to maintain the quality of power in a microgrid instead of using costly and complicated devices [305]. If energy allocation helps reduce power quality issues, it is hopefully an improved method to simultaneously achieve two tasks, such as power quality and energy allocation.

Ovalle et al. [306] presented a scheduling method for optimal charging of PEV and retaining the customers' benefits in a residential building. In their study centred on sustainable buildings, the authors Luo et al. [307] discussed work on DC microgrid and how PEV batteries are utilised to balance voltage fluctuation. Naidoo et al., in [308], disagreed with an alternative approach to estimating symmetrical components when there are harmonic and noise signals. EMS is itself a difficult task. Combining the energy management system and power quality management would give better grid functioning and an inexpensive solution.

5.13.3. Unpredictable Techniques of Management. With the help of new technologies, the grid became smarter with lots of new limitations through various doubts like ambiguity in the generation, ambiguity in predicted load, or unexpected breakdown of generation or transmission unit equipment. These uncertainties make the forecast and prediction difficult, affecting the system's consistency and safety. There are two types of uncertainty parameters, economic and technical [309]. Technical one is more categorized in topological and operational parameters. Operational parameters include the info on renewable generation and demand, and topological parameters consist of the info about the trouble of any generation unit. Additionally, the economic parameter can be categorized as macroeconomic.

5.14. Contributions of Energy Management System in Smart Grid. Lots of researchers have done investigation on energy management systems (EMSs) in recent years, including papers on different types of EMS strategies like BEMS (building energy management system), HEMS (home energy management system), SHEMS (smart home energy management system), and EMSA (energy management system aggregator). In this paper, the author presented several comprehensive review papers on energy management systems.

Zakaria et al. [310] proposed a survey paper using unique approaches for renewable energy applications in which the authors included methods for better performance. Azuatalam et al. [311] presented seven different strategies for HEMS, including a forecasting method. They discussed that practical implementation of these approaches is inadequate because of the presupposition of designing different energy management systems. Cheng et al. [312] reviewed a paper on microgrid energy management systems, including microgrid components, consolidated and distributed architecture evaluation, and regulatory approaches. Khan et al. [313] presented a paper on different optimization techniques, including multi-agent systems for distributed microgrid energy management systems. Shareef et al. [314] provided the review paper on the HEMS considering demand responses (DRs), intelligent controllers, and smart technologies. Zou et al. [315] reviewed different topologies of MMG and existing working on the energy management system for unified multi-microgrids (MMGs). Rafique and Jianhua [316] proposed a review paper on the energy management system and production, including techniques for forecasting for load, wind, and solar.

Salimi and Hammad [317] proposed a critical survey of different control in HVAC to recognize the advantages and challenges of current approaches and future research gaps.

Table 11: Contributions of energy management system in smart grid.

Reference	Author	Year	Types	Framework	Components				Unpredictability	Solution techniques
					Solar	Winds	ESS	PEV		
[310]	Zakaria et al.	2020	BEMS	✗	✗	✗	✗	✗	✓	✗
[311]	Azuatalam et al.	2019	EMS	✗	✓	✗	✓	✗	✓	✓
[312]	Cheng et al.	2018	EMS	✓	✓	✓	✓	✗	✗	✓
[313]	Khan et al.	2019	EMS	✓	✗	✗	✗	✗	✗	✓
[314]	Shareef et al.	2018	HEMS	✓	✗	✗	✗	✗	✗	✓
[315]	Zou et al.	2019	EMS	✓	✗	✗	✗	✗	✗	✓
[316]	Rafique and Jianhua	2017	EMS	✗	✓	✓	✗	✗	✓	✓
[317]	Salimi and Hammad	2019	BEMS	✗	✓	✓	✓	✗	✗	✗
[318]	Zia et al.	2018	EMS	✗	✗	✗	✗	✗	✗	✓
[319]	Hannan et al.	2018	BEMS	✗	✗	✗	✗	✓	✗	✗

Zia et al. [318] presented a survey paper on EMS based on microgrids, including different approaches and communication requirements for a microgrid. Finally, Hannan et al. [319] presented the Internet of Energy (IoE) predictions based on BEMS for better energy utilization, in which they included the concerns and limitations associated with cost, scalability, consistency, and privacy of access data. In this paper, the authors presented an existing literature review in Table 11, which includes energy management types, framework, components, and solution techniques.

5.15. Practical Execution of Energy Management System in Smart Grid. Current and prearranged executions of smart grids offer a wide range of features to achieve the following essential functions.

5.15.1. Minimizing Excess Load. The total load linked among the grids can alter amazingly, indicating that the total load is not stable and has varying power consumption. Generally, the reaction time of a quick rise in power consumption should be greater than the initial start-up time of a large generator. Therefore, a few additional generators are put on standby mode. A smart grid may limit all single devices to minimize the load temporarily. With the help of mathematical prediction algorithms, it is simple to find out the number of standby generators that need to be used to achieve a certain failure rate. Still, on the traditional grid, the failure rate can only be minimized by executing more standby generators [320].

5.15.2. Removal of the Demand Fraction. Grid systems have variable degrees of communication using control systems, such as transmission lines and different parts of substations. Generally, the flow direction is from the users towards the loads, and then they control back to the utilities. The utilities try to distribute the demand and succeed or fail in uncontrolled blackouts and brownouts. Demand response permits generators as well as loads to cooperate in real time. Eradicating the fraction of demand in these spines reduces the cost of additional generators and extends the equipment's life [320].

5.15.3. Power Generation Allocation. Distribution of generation permits particular customers to generate power in their place by themselves. By this process, customer can manage their load and can make them separate from the public power grid and can avoid power failures.

5.16. Challenges in the Practical Execution of Energy Management Systems in Smart Grid. Energy management system execution looks comparatively easy in the modern era because of development in technology, contemporary sensors, and infrastructure; besides all these advancements, there are still many challenges in the energy management system's practical implementation. There must be simple maintenance for control architecture. There is still a solution available in a decentralized structure, but it needs synchronization between components, and nonstop two-way communication makes the system less cost-effective. Another most important factor for real-time application in energy management systems is communication. Data rate and cost are two factors for the energy management system's deployment in rural and residential areas. Therefore, Zigbee, Bluetooth, and Wi-Fi are chosen in those rural and residential areas [321]. Data and coverage rates are important for the execution of energy management systems in microgrids and utilities, whereas optical networks, 3G, and 4G are considered less [322]. Nevertheless, ABB, General Electric, Siemens, and Schneider have several energy management system executions.

5.17. A Review of Research Efforts on the Energy Management System for Smart Grid. A smart grid is a way towards the next-generation grid and needs to do more for the researchers, industries, public sector undertakings, policymakers, etc. Therefore, a review of literature has been done to keep in mind the objective of the present study. In this context, some of the reviews of the literature are discussed as follows by the authors (see Table 12) who presented the critical literature review of the researchers' proposed models in the field of energy management systems in smart grid.

Table 12: Researcher's contributions to the energy management system in smart grid.

Author	Reference	Description
Malheiro et al.	[323]	The researchers described the significance of online error analysis in energy transmission systems. Fault analysis helps operators in assistance for assessments of the maintenance renewal. Another challenge discussed by the researchers was the usage problems of the SCADA system. The Portuguese power and energy transmission system, which the Siemens SINAUT spectrum SCADA integrates, presented the SPARSE II system, which is explained in this paper in which architectural employment and installation in the control centre are discussed.
Azevedo and Oliveira Filho	[324]	The researchers clarified their work in software advancement. They explained that new technologies are announced as innovative solutions nearly daily, but they vanish silently after some time. Finally, about 10 years after their theory, they have demonstrated an effective technological method. But it does not solve the problems, and it is still under development and still increasing issues for the future.
Changqin et al.	[325]	SCADA/EMS/DMS architecture presented by the researchers makes the approach much more extendable. This architecture depends on service bus and client-server computing, which acts as an intermediate layer between the operating system and application modules. It is accountable for networking the system, managing the services, and establishing links between the system modules.
Janardhan et al.	[326]	The researchers explained the analysis that clarifies the influence of deregulated environment on IT systems. Conventional systems such as SCADA and energy management systems are essential to the stakeholder's result.
Grasberg and Osterlund	[327]	The authors described the conventional SCADA using an energy management system that will change into perceptions containing smaller self-sufficient released products. They will be modified into evolving standards from various vendors. These vendors will be traditional and will be fully responsible for the installation and delivery at the customer's site.
Marihart	[328]	The researcher explained various technology reviews accessible for use with energy management system projects and SCADA.
Wen-duo et al.	[329]	The authors described the combination of automated mapping/facilities management/ geographical information system (AM/FM/GIS) with SCADA. The researchers discussed the sorting and purpose of the operational monitoring system. This discussed system will broadly consider the electric power system and its equipment state.
Shang et al.	[330]	The authors explained that huge amounts of data must be gathered, relocated, and reserved for controlling and analyzing the performance of energy and power systems. Compressing the large data of the power system is highly required. The transform process of wavelet can benefit all fields of big amounts of data in SCADA.
Okafor et al.	[331]	The authors discussed the power industry and explained that it is undergoing major changes such as deregulation, a new modest climate, and fast ongoing reorganization. All these changes will increase demand for information systems in utilities, including SCADA, energy management systems, call centres, billing systems, and so on.
Liu et al.	[332]	The authors explained the developed applications of technologies and computers. They discussed two techniques of automated meter reading (AMR) systems. The first technique shows the combination of AMR data with SCADA and trouble call information to identify an outage and then uses polling of AMR to verify the outage. In another suggested technique, it offers a method to utilize automated meter reading for confirmation of the recovery of all clients below an outage device.
Reddy and Swarup	[333]	The researchers discussed the regulatory functions in the energy management system based on SCADA. They explained that the increase in the growth of the power systems network is the result of the demand for increased power.
Kusic and Garrison	[334]	The researchers explained the error parameters in the transmission line computed by the SCADA system. They discussed that these errors could double the costs and incorrection in billing.
Pimpa and Premrudeepreechacharn	[335]	The researchers discussed the expert-based SCADA system for voltage controlling up to 22 kV levels in Thailand. Purpose of this system is to help the worker who is experiencing abnormal conditions.

Table 12: Continued.

Author	Reference	Description
Thomas et al.	[336]	The researchers explained the reports of SCADA for energy systems at Jamia Millia Islamia, New Delhi, India, which has been designed for students, utilities, and faculty members to function as a research and training centre. In this paper, the authors covered the designing, functioning, and commissioning of the laboratory based on SCADA, which will give practical involvement to engineers and students.
Stojkovic and Vujosevic	[337]	The researchers described an energy management system where they mentioned that it depends upon the SCADA system, which collects the data of the power system, then processes them, and gives commands. The automatic generation control functions of an energy management system are the most important functions. This paper illustrates the system's characteristic, which depends on the comparatively inadequate dataset of the power system of about 70 input data with excellent complete evidence of around process information of 300 outputs.
Fischer et al.	[338]	The researchers described the importance of employing AMR (automated meter reading) systems that support the process of restoration. They discussed the restoration procedure of distribution systems and declared it a complex process, specifically when many outages like a storm can occur.
Shaffer	[339]	The researcher described the changing rate in the power authorities in his paper. He mentioned that this change is rapid and persistent. It drastically changed how companies work, like intense competition and major ups and downs in the market structure.
He et al.	[340]	The researchers illustrated how deregulations and privatization have produced a desire to evaluate information from various resources. These demands necessitate a SCADA energy management system with high-performance solutions. They also explained its functions.
Hua et al.	[341]	The researchers described that integration techniques are proposed to unify with the existing SCADA energy management system.
Meliopoulos et al.	[342]	The researchers explained the discrete method to alter checking, assessment, and loading with the help of the existing methodology and structure. This method is valid for any main power system equipment. For example, it can be employed to evaluate a detailed electrothermal model of a production unit.
García et al.	[343]	The researchers explained the use of advanced communication technologies and programming forums and mentioned that it extremely increases the performance of industrial control systems.
Qiu et al.	[344]	The researchers described the occurrence of load shedding as a precaution of an emergency in case of dropping frequency situations or failure of power production. A more wisely constructed load-shedding plan is needed for a large unified system.
Qiu and Gooi	[345]	The researchers described the importance of the World Wide Web (WWW) and its features and connectivity with SCADA. In this paper, they mentioned that WWW features integrated with the economical investment are particularly applicable for retrieving information from the SCADA system.
Cosse et al.	[346]	The researchers enlightened the interconnectivity of current and new communicating devices. From a safety and maintenance point of view, they mentioned that IEDs, touch panels, programmable logic controllers, SCADA, digital combat simulators, communications tools, and protocols are growing each day, so it is time to develop the industrial substation into the era of smart, collaborative communications.
Bose	[347]	The researcher explained that the power system is not only a network connecting producers through a supply and transmission system but also a control system that allows economic and reliable processes. Supervising the grid is still completed by SCADA systems whose classified design for sampling data was suitable for vertically integrated utilities. Its speed in seconds yet shows the theoretical strategy of the 1960s.
Wu et al.	[348]	The researchers reviewed the purposes and designs of control centres in the past, present, and future. They discussed that the growing variations in power systems need a flexible, open, integrated, and distributed control centre.
Amanullah et al.	[349]	The researchers outlined and clarified the network issues like security involved in SCADA and the energy management system. They showed the actions to increase the security of the SCADA network in their paper.

Table 12: Continued.

Author	Reference	Description
Car and Jakupovic	[350]	The researchers described the SCADA system, which controls and monitors industrial equipment or a plant such as water and waste control, transportation, telecommunications and energy, oil, and gas refining. It is also a vital part of the energy management system. In this paper, the authors described the security issues in the SCADA system as the main point of complete system constancy.
Gujar et al.	[351]	The researchers explained the significance of smart mini-grid and its existing challenges in this paper. They identified the key steps several industries took in the sector of smart mini and microgrid in India. They presented the structure of TERI's own mini smart grid system which combines various distributed energy sources and showed how such execution can be used for flexibility, efficiency, and reliability of the overall system.
Chandler	[352]	The researcher illustrated in his paper the important effect of technology on automated meter reading and power monitoring in the last few years. The cost has been decreased in communication protocols and power technology with an increment in system capabilities.
Klump et al.	[353]	The researchers explained the process that focuses on threats to the security of the power system by showing data from SCADA and phaser measurement units simultaneously. The software system described in this paper collects data from PMU and SCADA and shows them on a plot of the system where it displays the complete measurement with a location.
Cannon	[354]	The researcher presented the system that allows real-time examination and management of the energy distribution procedure and equipment of substation so that any electrical power industry can use similar information.

6. Conclusion

The necessity to meet ever-increasing electricity consumption and maintain a sustainable and safe supply of electricity to the power system justifies the global transition to the smart grid. The application of energy management has a bright future. The move from a traditional grid to a smarter grid, on the other hand, necessitates a long-term financial investment. Energy management is crucial to improve the efficiency and reliability of supply and distribution networks. This is accomplished by using clever algorithms and modern control systems to optimize and schedule load demand efficiently. Energy management lowers the cost of electricity by about 20–30%, which is significant and helpful in the long run. This paper provides a thorough and critical examination of the EMS idea, objectives, benefits, types, and difficulties and a thorough examination of the main actors and contributors. It addresses the various uncertainties associated with the numerous loads and sources in SG, as well as effective methods for dealing with them, such as power quality management, DSM, active DR, and optimization solution approaches used in energy management to meet the desired objectives while keeping all constraints in mind. Various parties are currently discussing some topics and concerns linked to EMS deployment, leading to more research and development for a more advanced EMS. The following areas for further research should be considered:

(a) The main challenge is to improve the cost-effectiveness of SGs through secure and reliable communications, which can be addressed by developing a multi-agent system that is hybridized with optimization algorithms based on metaheuristics to achieve energy management that meets various objectives and constraints. Numerous applications could be used, such as managing gas power plants with emissions, trading among microgrids, and so on. It is also feasible to factor in (electric vehicles, users, demand management, line losses, etc.) and simulate interconnected networks in real time.

(b) Accurate and quick uncertainty modelling is an area that has to be improved further and can be thought of as an alternate optimization paradigm for utility system design that takes into account unpredictable circumstances and gives more operational detail. The framework must be capable of simulating the effects of flexible SG technologies that can effectively alter the demand for traditional solutions. As an example, when considering flexible operational solutions that optimize investment in an SG context, effective modelling of operational restrictions and uncertainty is required in the planning phase.

(c) The EMS should be conceived and implemented in a cost-effective, real-time hardware implementation. It is possible to propose an IoT-based system architecture that implements specific communication technologies for connected devices and can be applied to various types of SG simulators, such as communication network simulators, power system simulators, and combined power and communication simulators.

(d) Applied to distributed energy grid systems, an integrated system reconfiguration and operation management approach would be a powerful way to achieve high performance, cost-effectiveness, resilience, and sustainability.

Conflicts of Interest

The authors declare that there are no conflicts of interest.

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