Chapter 10
Implementation of Industrial Internet of Things in the Renewable Energy Sector

Somudeep Bhattacharjee and Champa Nandi

Abstract A smart microgrid is becoming a popular approach for power generation due to the scarcity of fossil fuel, increasing air pollution, increasing demand for cleaner energy resources, and better energy utilization. Presently, sensor technology, big data, and data analytics are the hot topics for research for optimizing business operations, such as efficient and balancing supply versus demand as customers connect to a smart microgrid. These advancements based on smart devices and their connectivity via the Internet have given rise to what is now being known as Industrial Internet of things (i.e., industrial IoT or IIoT). These devices help to maximize operational efficiency, optimize business operation, and protect the system. This chapter presents detailed discussion of the concept of IIoT, history and applications of IoT, developments in the energy sector, introduction to renewable energy, role of IoT in developing smart grids and smart microgrids, role of IIoT to combat the challenges of renewable energy sector, and the future vision of the IIoT paradigm in the energy industry. The main objective is to study and analyze the IIoT-based renewable energy sector for reducing fossil fuel usage, increasing cleaner energy resources usage, and better energy utilization. It is also suggested that the IIoT-based energy systems can easily tackle the problems of non-availability of individual renewable energy sources by monitoring energy usage, energy generation, and its integration with other sources.

Keywords Industrial Internet of Things · IIoT · Energy management · Renewable energy · Smart grid · Smart microgrid · Distributed energy · I4.0

10.1 Introduction

Increasing demand for electric power, using coal for electricity generation, increase in population, and the utilization of renewable energy are the fundamental reasons behind the changes coming to the electricity sector. Currently, 85% of the world population utilizes electricity and 40% of world electricity originates from coal. For

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S. Bhattacharjee · C. Nandi (✉)
Department of Electrical Engineering, Tripura University, Suryamaninagar 799022, India
e-mail: cnandi@tripurauniv.in

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electricity generation, coal produces 70% of the carbon dioxide (CO_2) emissions that are proving to be destructive to the environment and human health. To reduce the current levels of emissions, the need for renewable energy is rising. Sustainable sources (such as biomass, hydropower, geothermal, wind, and solar) are becoming popular and in high demand. Battery technology is also becoming an attractive option [1].

Because of the shortage of fossil fuel and increasing pollution, the destiny of technology upgrade and further research relies upon the use of cleaner energy production sources and better use of the available energy. So, to accomplish this objective, government and utility agencies are aiming to develop new energy infrastructures known as the "smart grids" and "smart microgrids". The reason for the smart grids is to adequately deal with the processes of energy transmission, generation, and distribution. Everyone of the stakeholders, including the distributors, consumers, and producers, is permitted to have a two-path communication to create, consume, and distribute energy in an effective way. The greatest energy consumers are buildings, for example, houses, structures, and workplaces in developed countries. The consumption rate is considerably higher in the undeveloped countries because of the absence of adequate industrial sector, in some cases. Hence, energy efficiency can be accomplished by proficiently utilizing the accessible energy sources. The target can be fulfilled if the energy use can be accurately determined in real time. This data must be transmitted to the local smart grid to accomplish the objective of energy minimization. Moreover, the energy utilization can be monitored if the heavy-duty gadgets are planned in a robotized and productive way. Another alternative is to utilize the renewable sources, for example, solar cells and wind turbines that lessen the reliance on the power supply from energy organizations. In addition, energy protection and efficient storage are the most vital in fuel energy production.

The issue of anticipating and reacting to the variable energy demand turns out to be very difficult because of the expansion of renewable energy sources, for example, wind and sun. The energy production planning is required to optimize the energy use and its cost. The planning framework needs to think about various energy resources available and then carry out the optimization based on feedback from various related aspects. The priorities and constraints of consumers should be looked at by the self-managing energy system (SES) for the optimization of energy use by utilizing this data, alongside the demand for power and supply forecast. The SES should have the capacity to incorporate renewable energy, for example, solar and wind energy, in the framework [2–4].

The energy utilization requirements are communicated to the framework by means of the Internet of things (IoT) [2] that helps to communicate with various IoT-based devices and gives feedback to microgrids to carry out the optimizing choice. Four targets can be accomplished utilizing the proposed design as follows [2]:

- First, it designs a localized Internet of things, for transmitting and getting data to/from smart devices and consumers.
- Second, it controls the energy consumption of devices, utilizing the priorities and constraints set by the buyers.

- Third, it gives feedback to the customers of their energy utilization pattern, so as to save energy and cost.
- Fourth, it incorporates renewable sources of energy into the network.

For controlling, overseeing, and accomplishing the two-sided communication with latest advancements in the energy sector, IIoT plays a critical role, particularly with respect to renewable energy technologies. The Internet of things (IoT) is an umbrella vision that has Industrial Internet of things (IIoT) as a particular case. It is a network of smart devices and things that generates gigantic amount of data that is then sent to central cloud-based services where it is processed and further transmitted [5]. Currently, sensor technology, big data, and analytics are receiving more concentration so as to optimize tasks, for example, proficiently adjusting demand and supply as customers associate with smart microgrids, as well as expanding operational productivity, optimizing business activity, limiting unprepared downtime, and providing system secure. It gives applications like cybersecurity, predictive maintenance, and remote monitoring and optimizes business task, laborer well-being, and advanced distributed control [6].

To optimize the utilization of distributed energy resources (DERs), improve traditional grid infrastructure, and guarantee coordination with IoT, the grid needs to get more intelligent. A smart grid permits a bidirectional stream of electricity and communication between electricity providers and consumers. With a smart grid, buildings are changed from being comparatively passive loads on the grid to dynamic associates in the electricity sector, giving (possibly selling) electricity and trading data that takes into account load balancing to help a stable and reliable grid. Increased generation of energy requires extra adaptable and fast-ramping resources, for example, electricity storage facility to further resolve the possible vulnerabilities and discontinuity of utility-scale renewable generation. Transmission operators can account for assets and resources from the distribution and generation components of the grid. Operators can incorporate distribution while controlling essential tasks of the grid. Utilities may move toward becoming stages that offer grid infrastructure for third-party suppliers and aggregators that sell electricity and/or energy services.

Communication-enabled grid infrastructure bolsters optimization of distributed energy resources. A decentralized methodology brings the production near to required load, lessens transmission losses and vulnerabilities, and expands the general dependability, versatility, efficiency, and strength of the grid. Communication is bidirectional and closer to near-real time, empowering clients to be more likely oversee loads and expenses. Also, power rates might be progressively unique. Besides, intelligent building devices empower task of smart equipment by means of the Internet [1].

The smart grid bolsters the usage of more nuanced and successful demand management programs and the execution of progressively educated measures by the buyers. It likewise bolsters dynamic pricing, which could be a winning factor for consumers and utilities alike, enabling both to take more prominent favorable position of inconstancy on the grid, the wholesale electricity market, and DERs.

Intelligent digital meters, also known as “smart meters,” are fundamental to the smart grid. They empower bidirectional, near-real-time communication among buildings and a regional network about demand and supply. These meters can empower utilities to control loads more efficiently and thus guarantee greater grid dependability. Smart meters are likewise vital to consumers getting better, timelier data about utilization and pricing to advise options about loads and expenses. These decisions can likewise reduce load on the grids [1].

With the expanded spotlight on pollution-free energy and efficacy as well as the requirement to create the smart grid business system, an increasing number of stakeholders are focusing on smart microgrids as a practical and vital way to deal with an upgrade of the grid at the neighborhood level. The smart microgrids join the neighborhood energy supply to fulfill the correct requirements of the constituents alongside connecting with the bigger grid. These feature the scope of intelligent technology in a solitary area which boosts the quality of service and the creation of innovative occupation potential, and therefore, it helps to deliver a feasible business case. This helps in energy savings as well as cost saving to the customers. They additionally give neighborhood decision in regard to the source and supply of generating electricity [7].

Smart microgrids are an ideal method to coordinate renewable resources at the network level and take into account customer interest in the electricity venture [7]. Smart microgrids are like the smart grids. To optimize the utilization of renewable energy sources, these grids enhance consumer involvement infrastructure and guarantee to join with IoT at the network level. A smart microgrid permits a bidirectional stream of electricity and correspondence between electricity providers and consumers on the community level. To handle the problem of non-accessibility of individual renewable energy sources, IIoT performs an important task by monitoring the energy use, energy production, and its incorporation, particularly for the smart microgrid. Smart microgrids increase the local dependability through the foundation of an explicit dependability enhancement plan that incorporates the surplus distribution, intelligent switches, energy production, energy storage, automation, and other intelligent technologies [7]. With the upgrades and changes in the energy sector, utilities and energy market continually change for the future. However, with the changes such as expansion of DERs with an assorted variety of proprietorship including third-party suppliers that are not as intensely managed, that scaling is rather less. Nevertheless, the grid will keep on being important to the electricity sector [1].

In this chapter, we provide a detailed discussion of the concept, history, and applications of IoT. We also elaborate on changes coming to the energy sector, introduction to renewable energy, use of IoT in the energy sector, challenges of renewable energy sector, solution to the challenges using IIoT, and future of IIoT in the energy industry. This chapter also includes a detailed discussion of smart microgrids which are mainly based on renewable energy and IIoT concepts. It determines the role of IoT in smart grid and smart microgrid.

The chapter will hopefully help us to understand how an efficient IIoT-based energy system on renewable energy might work for improving the future in terms of better utilization of renewable energy resources as well as limiting the carbon emission. This chapter also includes examples of IIoT-based projects in the energy sector on monitoring of energy usage and generation, especially in case of smart microgrid.

10.2 The Concept of Industrial IoT

This section articulates the basics of Industrial IoT including concepts, historical perspectives, benefits and challenges, as well as the literature review and future directions on the topic. In the later sections, we discuss the IIoT case studies in the energy sector.

10.2.1 Definition and Benefits

The IoT is a network of physical smart devices, home appliances, wearable and handheld intelligent devices, and various other “things” embedded with electronics, software, actuators, and sensors. It is a system of intelligent gadgets and items that share and gather enormous quantities of data. The gathered information is sent to a focal cloud-based service where it is aggregated with other data and afterward imparted to end clients supportively [5]. The IIoT (Industrial Internet of things) can be regarded as a particular application of the Internet of things (IoT) vision. Here, the interconnected devices of industrial nature communicate with each other over the Internet and can be controlled and supervised remotely [8].

The IIoT aims to modernize manufacturing and other industrial sectors by empowering the openness and acquisition of the large amounts of data, at far more prominent speeds, and with much more proficiency than previously witnessed. Various large organizations have begun to employ the IIoT by utilizing smart, associated devices in their factories [5]. The IIoT can extraordinarily enhance connectivity, efficacy, versatility, and time and cost savings for technologically based industries. Companies are now also profiting by the IIoT through predictive maintenance, enhanced security, and other functioning efficiencies. IIoT systems of smart gadgets enable industrial organizations to tear open information silos and join the majority of their workforce, company information, and operational processes from the plant floor to the official workplaces. Business pioneers can utilize the IIoT information to get a complete and precise perspective of how their venture is getting along, which will further enable them to make better choices [5].

10.2.2 Historical Perspective

In 1982, the idea of a system of connected intelligent gadgets was first put forward. In 1991, Mark Weiser, in a paper “The Computer of the twenty-first Century”, introduced the vision of device connectivity now commonly known as the IoT based on the concept of ubiquitous computing. Soon after, Bill Joy presented the idea of device-to-device (D2D) communication in what he called “Six Webs” system at the World Economic Forum held at Davos. The expression “Internet of things” was probably coined by Kevin Ashton of Procter and Gamble, and later by MIT’s Auto-ID Center, during 1999. At this point, it was also observed that radio-frequency identification (RFID) was a vital component of the IoT. This enabled computers to deal and communicate with many other single individual “things.”

An exploration article that mentioned the IoT was submitted at the meeting for Nordic Researchers in Logistics, Norway, in June 2002. The implementation portrayed therein was proposed by Kary Främling and his group at Helsinki University of Technology which became foundation for today’s data management frameworks. According to Cisco Systems, real developments in IoT began somewhere around the years 2008 and 2009, with the ratio of things versus individuals increasing from 0.08 in 2003 to 1.84 in 2010 [8].

10.2.3 Challenges of the IIoT Vision

One of the problems experienced in the progress of the IIoT is the fact that diverse edge-of-network devices have different communication protocols for sending and receiving data, for example, OPC-UA and the Message Queuing Telemetry Transport (MQTT). However, transfer protocols are rapidly developing toward standardization [5]. Interoperability and security are also the most likely the two greatest difficulties encompassing the deployment of IIoT. As technology author Margaret Rouse states, “a major concern surrounding the industrial IoT is interoperability between devices and machines that use different protocols and have different architectures”.

Organizations need to realize and be sure that their data is secure. The development of a diverse variety of sensors and other smart devices has also brought about a parallel blast in security vulnerabilities. This is another factor in the ascent of MQTT since it is an exceptionally secure IIoT protocol [5].

10.2.4 Relevant Research Works

A number of research approaches have been projected to utilize the IoT vision in the energy sector. Some of these are now discussed in this section.

In [9], the authors presented data collection architecture for situational awareness (SA) in connection with the microgrids. This work designed a prototype that can give huge amounts of information gathering capabilities relating to smart meters. An IoT stage is utilized for SA visualization by a customized dashboard. By the utilization of the proposed system, a satisfactory level of SA can be accomplished with a low establishment and equipment cost. Utilizing the proposed system, microgrid administrator can foresee all the obscure occurrences within the microgrid by means of gathering data from the smart meters from different consumers and administrators within the grid [9].

In [10], Kang et al. proposed an energy trading platform of blockchain-based smart homes in a microgrid. This paper explains the management of energy, transactions, and home miners in the blockchain-based smart home. The reported research presented a protected and computerized decentralized renewable energy exchanging stage inside the microgrid utilizing the block chain concept. In a blockchain-based smart home, it is difficult to forge data called transactions. By means of such transactions, the smart homes know the required data regarding energy consumption and requirement. By utilizing this data, they propose renewable energy exchanging stage utilizing Ethereum's smart contract to guarantee protected energy exchanging run consequently without the outsider intercession and involvement in a microgrid [10].

In [11], Roy et al. proposed a smart IoT-based energy metering system with load management algorithm for microgrids. This paper presented modifications in the bi-channel communication of the smart meters. The customary and ordinary utilization of the smart meters was seen as fundamental to set up a bi-channel communication: one channel to provide the pricing details of the energy utilization using GSM modules to the end clients, and the other channel to give energy-related information and other associated data that are of concern to the utility providers. There are two modifications discussed in this paper. Firstly, it focuses on the whole information into a single storage system, i.e., server, instead of utilizing two separate channels of communications. This helps both the client and the associated utility in getting access to the real-time data from any place on the planet. Secondly, this paper has made advancement in that the system automatically senses and secures loads from transients in lines (such as overvoltage, undervoltage, and overcurrent) with a load management algorithm using the smart energy meter IC. The proposed system consumes high power, requires consistent Wi-fi availability, and is restricted to single-phase microgrids—and these are its main drawbacks.

In [12], Aagri and Bisht explain the export and import of renewable energy by hybrid microgrid by means of the IoT. This paper gave an absolute, self-continuing, and open source solution for use of renewable energy by means of power grids. The paper also depicts the way to improve the hybrid power grid system in homes and to attach them to a central grid attaching numerous different homes. The node proprietors can buy and sell the produced/stored power in their homes, through utilizing a Web interface mechanism.

In [13], the authors proposed an IoT-empowered multi-agent system (MAS) for residential DC microgrids (RDCMG). The system comprises smart home agents (SHAs) that collaborate and help each other to mitigate the peak load of the RDCMG;

and reduce the energy prices for smart homes. These are accomplished by agent utility functions and the best operating time algorithm (BOT) in the MAS. The proposed IoT-enabled MAS and smart homes models were run on five Raspberry pi 3 boards and verified by experimental investigations for an RDCMG with five smart homes.

In [14], the researchers proposed a reliable control system dependent on the IoT to control and manage the flow of energy gathered by solar panels inside a microgrid. Information for reliable control incorporates measurements from neighboring sensors as well as meteorological data recovered in real time from online sources. For the fault tolerance of the system over the entire distributed control system featuring numerous controllers, reliable controllers are designed to control and optimize the tracking operations of photovoltaic arrays. This also maximizes the catch of solar radiation and keeps up the system flexibility and dependability in real time in spite of malfunctions of one or more redundant controllers (because of possible issues with communication, cybersecurity, and hardware). Experimental results are presented to verify the proposed methodology [14].

In [15], Saleem et al. provide a review of IoT-aided smart grids (SGs) systems, which incorporate architectures, technologies, applications, prototypes, and future research directions. They report challenges in the traditional grid due to which these are transformed into the smart grid. These challenges refer to a unidirectional flow of information and energy, energy wastage, increasing energy demand, dependability, and lack of safety. The power wastage occurs in traditional grids due to several factors, such as consumer inadequate machines, the absence of smart technology, ineffective routing, dispensation of electrical energy, unreliable communication and monitoring, and absence of energy storage system.

The conventional grid has operated superbly from its introduction in 1870 until 1970. By 1970, the consumer demand for energy also steadily increased, but it was predictable. However, a remarkable change in the nature of electricity consumption has occurred since 1970 because of the growth of the utilization of electronic devices and electric vehicles—this raised the demand for electrical energy tremendously. Furthermore, the demand for use of renewable energy sources also increased due to the impact of climate changes that forced the transformation of the traditional grid into a smart grid.

In order to combat the inherent challenges, smart grid technology was introduced. These grids can advance the efficiency, power quality, dependability, protection, scalability, and stability of the traditional grid. Smart grid reduces the energy wastage and optimizes the usage of electrical energy. These grids have capabilities of self-healing, real-time pricing, power consumption scheduling, and bidirectional flow of energy between service providers and customers. This is accomplished with the help of the IoT paradigm that helps smart grids in terms of connectivity, automation, and tracking of smart devices. These smart devices help in monitoring, analyzing, and controlling the grid [15–21]. The research in [15] also highlights the challenges, open issues, and future research directions of IoT-aided smart grid systems.

In [22], the authors proposed an IoT-based smart solar photovoltaic remote monitoring and control unit. Currently, the solar photovoltaic (PV) energy usage is increasing and it is one of the most attractive renewable energy sources. Due to the increase in usage of rooftop solar photovoltaic systems, the need for monitoring of real-time generation is also rising in order to optimize the overall performance of the solar power plant. This also helps to maintain the grid stability [22, 23]. The generated power from the solar power plant is unpredictable in nature because of the changes in solar irradiance, temperature, and other factors. Therefore, remote monitoring has become an essential requirement. For installing a remote monitoring system in a solar photovoltaic system, IoT approach is used in the work of [22]. The remote monitoring removes the dangers linked to the conventional wiring systems. It also measures and monitors the data very easily and accurately; therefore, it makes the system more cost-effective. IoT-based systems help to intelligently monitor and control through the Web. This helps to increase the flexibility of deployment of the systems [22, 24].

Research in [22] has mainly proposed an IoT-based remote monitoring system for a solar power plant. This method has studied, executed, and successfully accomplished the remote transmission of information to a server for management purposes. The IoT-based remote monitoring system increases the energy efficacy of the system by utilizing the low-power-consuming wireless modules. This also diminishes the carbon footprint [22, 25].

10.2.5 Future Developments in IIoT

The IIoT is broadly viewed as one of the essential patterns influencing industrial businesses today. Enterprises are pushing to modernize frameworks and equipment to meet new directions, to stay aware of the expanding markets, and to manage problematic technology. Industries that have adopted the IIoT approach have seen huge upgrades to security, effectiveness, and benefits, and it is normal that this pattern will continue as IIoT technologies are all the more broadly embraced. The ignition IIoT remedy extraordinarily enhances connectivity, productivity, adaptability, time savings, and cost savings for industrial companies. It can likewise enable enterprises to get most value from their framework without being obliged by financial and innovative restrictions. Due to these reasons and more, ignition offers the perfect stage for bringing the power of the IIoT into further undertaking [5].

The IoT can encode 50–100 trillion items along with the ability to pursue the movement of those items, e.g., in smart transportation. In urban situations, each network is encompassed by 1000–5000 trackable items. In 2015, 83 million smart devices were previously present in a typical home. This figure is heading for an increase of up to 193 million gadgets in 2020. It will obviously continue rising perhaps exponentially. The figure for online competent gadgets became 31% from 2016 to 8.4 billion in 2017 [8]. The IoT's major critical pattern in current years is the explosive increase of devices controlled and connected by the Internet. An extensive utilization of this technology implies that the points of interest can be altogether different, starting with one gadget, then onto the next; however, there are several fundamental attributes of these devices shared by most. Internet of things makes it straightforward for the more straightforward mix of the physical world into computer-based systems, bringing about product upgrades, financial advantages, and decreased human efforts. The quantity of IoT devices has expanded 31% every year; now toward 8.4 billion in the year 2017. It is expected that there will be expansion of up to 30 billion gadgets by 2020. The global market estimation of the IoT is anticipated to arrive at $7.1 trillion by 2020 [8].

This latest level of connectivity within the IoT is going past the laptops and smartphones. Connectivity is now across connected cars, smart homes, connected wearables, smart cities, and connected healthcare. Fundamentally, it is presently intended for a connected life in connected environments. As indicated by a Gartner report, connected gadgets will reach around 20.6 billion by 2020 [26]. HP recently completed a review in which they evaluated the increase of connected devices throughout the years and the outcomes are astounding. These being that:

- In 1990, there were 0.3 million connected devices.
- In 1999, the number increased to 90 million.
- In 2010, there were 5000 million connected devices.
- In 2013, connected devices increased in number to 9000 million.
- In 2025, there will be around 1,000,000 million devices.

This level of connectivity will overcome any issues among physical and digital worlds to enhance the quality and efficacy of life, society, and industries [26]. Utilization of IoT in smart homes is the most anticipated development, with new brands entering into the competition with yet smarter appliances. The second trending feature of the IoT vision is intelligent wearables. An analysis, as shown in Fig. 10.1, directed by KRC research in the UK, USA, Japan, and Germany, the early adopters of IoT, has exposed which gadgets are the most consumers bound to use in the coming years. Smart appliances like thermostat, smart refrigerator, etc., are some examples

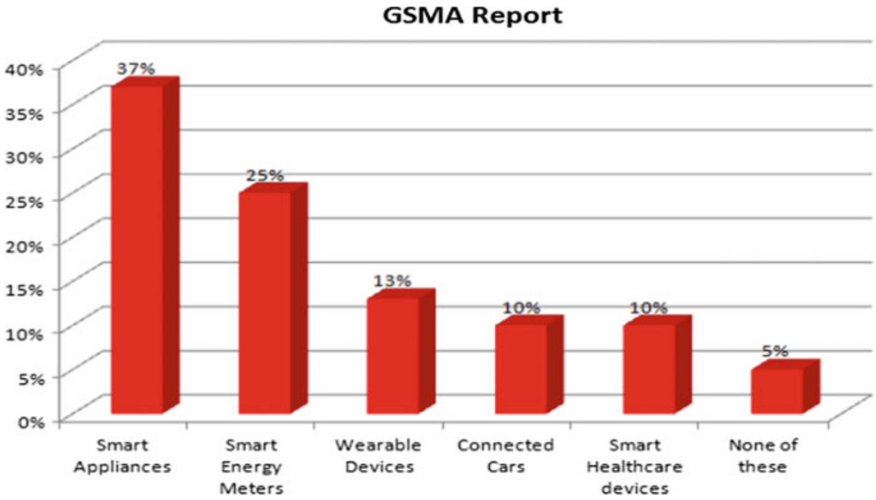

Fig. 10.1 GSMA report results

which are mostly enjoyed by the consumers and are appearing to change the manner in which human individuals live and operate [26]. This analysis in Fig. 10.1, supported by GSMA, also indicates that smart devices will play a crucial role in the future to further improve the world through the Internet.

In summary, to comprehend the effect of the IoT on the economy according to the CISCO report, IoT will produce \$14.4 trillion in value over all industries in the upcoming decade [26].

Industrial Internet, i.e., IIoT, is the latest buzz in the industry sector. It is enabling industrial engineering with sensors, software, and big data analytics to build smart equipments and environments. The driving factor behind IIoT is that smart equipment is more exact and predictable than humans in communicating the information. Furthermore, accurate and timely information can enable organizations to notice ineffectiveness and limitations quicker. IIoT holds extraordinary potential for quality control and maintainability. As indicated in Gartner report, the enhancement of industry productivity will create \$10 trillion to \$15 trillion in GDP worldwide over the next 15 years [26].

A smart city is another incredible illustration of the use of IoT creating interest among the world's population. Smart supervision, automated transportation, smarter energy management systems, water distribution, urban security, and environmental monitoring are some of the other related applications of the Internet of things in relation to smart cities. IoT will also take care of other significant city-related issues such as pollution and traffic jamming [26].

10.3 Applications of IoT

There are various applications of the IoT paradigm, especially in the fields of consumer requirements, commercial, industrial, and infrastructure domains. IoT devices are used within vehicles, home automation, wearable technology, connected healthcare gadgets with the ability of remote monitoring. Smart devices are used in lighting, media, safety, heating, and air-conditioning system for saving energy expenses through automatic controls. IoT-based homes, also known as smart homes, are helpful in controlling smart devices as well as being helpful in taking care of those with inabilities and elderly people.

IoT plays a crucial role in medical and health-related domains and also information gathering and examination of research and checking. IoT-based devices are helpful for health observation, for monitoring blood pressure and heart rate, for example. IoT-based devices are also used in smart beds to provide further patient care in the hospital. These beds mainly help hospitals by sensing that the patient is trying to get up or is in difficulty.

IoT-based devices empower faster manufacturing of new items. It empowers real-time optimization of the manufacturing industry. The smart industrial systems can be incorporated with the smart grid to empower real-time energy optimization. IoT-based devices are useful in farming and also for gathering data on temperature, rainfall, the speed of the wind, humidity, pest infestation, and soil content. This information is utilized in robotized farming techniques for taking educated choices to enhance the amount and quality of crops. It helps to minimize danger and waste. With the help of IoT devices, farmers are now capable to check soil moisture as well as temperature from a distant location. IoT devices can be used for checking and analyzing air quality, water quality, atmospheric conditions, and soil conditions. This helps in reducing water and air pollution especially. Such devices can be used to observe movements of wildlife and their inhabitants [8]. IoT-based devices can also check the structural conditions of infrastructure for avoiding future danger from a distant location.

IoT-based connected devices increase and promote paperless work processes and help to increase the efficacy of the construction industry. This improves work quality. IoT devices help to build a communicative relationship between energy-consuming devices and utilities using the Internet, which in turn enables to adjust energy production and energy consumption and also to optimize for savings in energy bills. IoT helps in monitoring different components of the smart grid and smart microgrid including consumer meters. This enhances security and helps in fault detection and correction.

10.4 Changes in the Energy Sector

This section looks at the changes and developments taking place in the utilities sector, especially the energy sector.

10.4.1 Reasons for Such Changes

New advancements and emerging methodologies are bringing huge changes in the electricity sector. Figure 10.2 illustrates some of the significant causes for such changes. Underlying reasons include: increased demand for electricity, new approaches to production of electricity, increase in population, and the attraction of renewable energy, together with the storage of energy. Currently, 85% of the world population uses electricity. Buildings utilize 60% of electricity worldwide, and buildings in the developed world utilize over 70% of electricity. By 2040, 33% of all vehicles are anticipated to be electric [1]. With the passing of time, demand is on the rise.

By 2050, the world population is expected to rise to 9.7 billion, of which 66% are expected to live in cities. Expanding urbanization will result in the construction of new cities, each on average about the size of Singapore (currently, population of 5.8 million) every month until 2050 [1]. Presently, 40% of world electricity originates from burning coal; and this contributes 70% of the carbon dioxide (CO_2) emissions from electricity generation. Coal contributes to the kind of emissions that are more

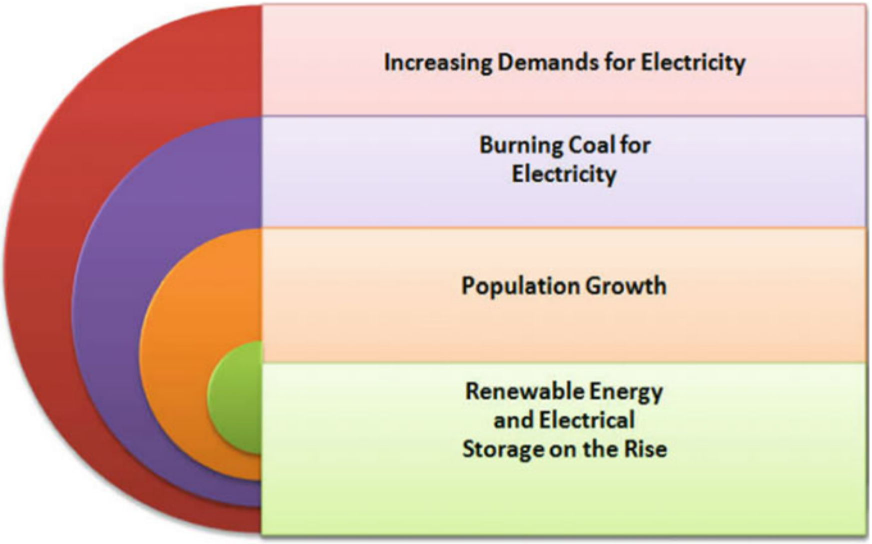

Fig. 10.2 Major reasons behind changes coming to the electricity sector

dangerous to the environment and human health than other fossil fuels. It is in order to reduce these emissions that the utilization of renewable energy and its storage is rising. Renewable sources of energy (biomass, hydropower, geothermal, wind, and solar) are the world's fastest-growing new energy production resources. Battery technology is also enhancing, and the associated costs are reducing [1].

Based on these facts, it is clear that there are reasons for changes and further beneficial developments in the electricity generation and supply sector. Since electric lights firstly showed up in buildings, the electrical grid and buildings have had a critical relationship. This relationship is mainly one-sided: The grid provides electricity, and the buildings are passive consumers. Nonetheless, new technologies and methods to reduce energy costs and the environmental impacts of electricity (produced from fossil fuel) are quickly changing the way the buildings communicate with the electrical grid. Additional factors for the change incorporate technological advancements and falling costs in renewable energy technology, batteries, sensors and controls, remote access technologies, and building management systems [1]. For controlling, overseeing and accomplishing these two-sided communications with new technologies, IIoT plays a vital role, particularly due to the emerging new renewable energy technologies.

10.4.2 *The Electrical Grid Today*

The present-day electrical grid model has served those with access to electricity, exceptionally well for quite a while. In spite of the fact that the model is transforming, it is essential to comprehend the systems that got us to where we are today. The provision of electricity generally depends on three key segments: generation, transmission, and distribution. Figure 10.3 demonstrates the flow of electricity in the traditional electrical system.

Conventionally, utilities produce or purchase electricity in bulk from centralized power plants located a long way away from end buyers. Conventional generation comes mainly from thermal plants (fossil fuel, nuclear, and geothermal) and hydroelectric projects. Wind and solar technologies, including solar thermal and electric, also contribute, but these are still at development levels of generation [1].

In today's electrical grid, the thermal power plants (not including solar thermal) are just about 30–40% productive and are noteworthy contributors of carbon and pollutant emissions. Generation resources are of two varieties: baseload resources and peak generation resources. Baseload resources are those that cannot be effortlessly ceased and begun (e.g., coal, hydroelectric, and nuclear). Peak generation resources give short-term and variable production capacity over the baseload resources to take care of peak demand. Peak demand is a period of time (e.g., time of day or season) during which customer demand for electricity is at the highest, or at its "Peak". A choice about which peak generation asset to set up is commonly made on cost. However, more recently, it is likewise being organized dependent on environmental and sociological impact [1].

After production, electricity voltage gets stepped up and transmitted over a long distance to progressively local distribution, where the voltage is stepped down and provided to consumers. For transmission, this happens over a long distance with about 5% of electricity in line losses.

The present electrical grid was intended to satisfy twentieth-century demand. Power flows in one direction (i.e., provider to consumer), and there are no data trade between electricity providers and consumers. Grid infrastructure is intended for one-

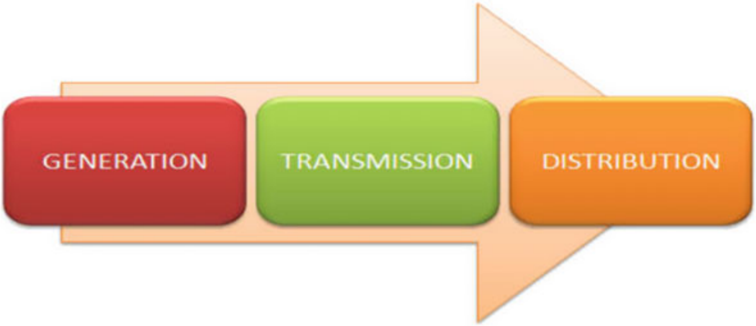

Fig. 10.3 Flow of electricity in the traditional electrical system

route stream of electricity from generation through transmission and distribution to end customers [1].

Operational control and communication excludes the customer side of the meter and frequently exclude distribution infrastructure. Communication with the customer is one way. For bigger purchasers of electricity, charges for generation, transmission, and distribution generally appear on their bill. At the residential level, the three expenses are frequently combined into one. Utilization and cost information are commonly given in the aggregate every month, constraining the capacity to determine what drives costs and consumption over the charging time frame. To the extent that communication from consumer is concerned, a utility typically does not know that there is an issue to the point when the customer calls to report an outage, etc. [1]. This just shows the basic infrastructure of the current electrical grid, and its generation and supply scheme.

10.4.3 The Buildings Today

Buildings consume over 70% of the electrical load in developed countries. Grid loads from buildings vary by changing season and due to climate changes that can occur quickly, as well as due to activities inside the buildings. The traditional electrical grid puts the burden on the grid to give dependable generating capacity and a transmission and distribution system that reacts to load changes promptly and takes care of peak demand. Although buildings and the grid do not communicate, the grid is required to meet building demands whatever the situation [1].

The business models of the electricity sector are focused on selling electricity. However, from an intended and infrastructure investment perspective, they do not want consumers to purchase everything in the meantime. Without the capability to speak with customers about loads, utilities have created expense structures to send signals to customers to utilize electricity steadily with the efficient operation of the grid infrastructure. These expense structures can include three variables: Time of use rates, demand charges, and ratchets. Time of use rates is the cost of electricity changes depending on the time of day. Demand charges, based on real-time power usage (over a period of time: regularly month to month), are extra charges levied depending on peak demand in kW for the considered periods of time. Ratchets are like demand charges, yet they consider the peak consumption for a yearly period of time. These customary expense structures impact the design and activity of buildings. For instance, thermal storage might be utilized to move cooling loads. While this decreases peak load electricity charges, it can permit to utilize more energy generally. At the point when fossil fuels are utilized to create power, this sort of load moving can result in excessive amounts of carbon emissions and different pollutants [1].

A building automation system (BAS) might be utilized to restrict demand charges. The BAS monitors the peak electricity usage by the buildings and can shed interior loads (e.g., reset room temperature, or switch off lighting) to remain under a suggested electricity demand. In any case, without two-way communication between the building and the grid, these measures can occur only on days when there is no requirement of decreased loads to assist the grid. Planning, developing, and executing a building that foresees potential electricity expense structures without grid communication can prompt superfluous occupant inconvenience and increase in emissions [1].

All things considered, utility demand response programs have started to close the gap caused by the absence of communication among utilities and consumers. The utility and consumers enter into a relationship in which, under certain characterized conditions and specialized strategies, the utility suggests incentives to diminish or move loads. At the point when the utility decides that a load decrease is required, the consumer is informed. The notification may happen, for instance, in expectation of higher demand; BAS may slow down or shut down a predetermined system. The signal could likewise be automatic. Generally, the activity of the building does not always align with the utility objectives. Demand response is a genuine precedent in which objectives are adjusted, while energy efficiency measure is a progressively more unpredictable subject [1].

The conventional business plan for utilities, selling electrical energy to be beneficial, clashes with energy efficiency; yet utilities are frequently required by government policy and regulators to subsidize customers to execute and work with such energy-saving measures. Citizens, government, and regulatory entities around the world enact policies to support more noteworthy energy efficiency and utilize renewable energy and the decrease of carbon emissions and different pollutants in the electrical and building sectors. These policies influence making of decisions in the two sectors: decisions that influence costing mechanisms for the utility providers, and decisions that influence consumption by the customers. It is significant that in the USA, 80% of the decrease in carbon emissions in 2005–2016 originated from the electricity sector. Despite the fact that policies regularly command utilities to execute energy efficacy programs, some policies additionally support energy efficacy as a way of guaranteeing production capacity without putting resources into new power plant development and activity. However, utilities regularly battle with out-of-date business models that clash with the necessities of consumers and societal values around the effective utilization of resources and the environment [1].

10.4.4 Development of Zero-Energy Buildings

Zero-energy buildings (ZEBs) are a precedent for building structures that are driven by societal ethics around energy efficacy and renewable energy. The structures both react to and put stress on the present grid model. The Department of Energy (DOE) of the USA gives a basic description of a ZEB, that is, an energy-efficient building where, on a source energy premise, the genuine yearly delivered energy is not exactly or equivalent to the on-location renewable exported energy. Here, source energy incorporates all the generation, transmission, and distribution losses in the electrical energy delivery to the buildings. Electrical energy is produced on-location for renewable energy, for example, solar photovoltaic (PV). But the building may even now require electrical energy from the grid on occasions, except if the battery storage is accessible on the building location. At the point, when the renewable production or battery storage (or both) do not meet building loads, the grid fulfills the additional requirement. At the point, when excess renewable energy is created, it might be sent to the grid [1].

The US DOE ZEB definition has been extended further, to incorporate zero-energy campuses, communities, and portfolios. This resulted in a few difficulties at first noticed by ZEBs. For example, the necessity for on-location renewable production restricted various environmentally benevolent alternatives such as power purchase agreements and community solar. Also, the on-location production measure disheartened urban density, contributing to undesirable sprawl, which can likewise result in poor walk capability. With the growth of the ZEBs, the "on-site" would now be able to be characterized as a gathering of building destinations in an explicit region that have renewable production and that are claimed by a single entity or numerous entities or that are rented by a single entity [1].

ZEB plan offers a solid way ahead for an environment that advances the health and prosperity of the inhabitants while increasing energy efficacy and utilizing renewable energy options. All things considered, the vision must keep on progressing to some degree in view of the fact that ZEBs may not be very much lined up with the necessities of the electricity sector. For instance, if the on-location production fails, the expectation is that the utility will still provide the required power. But the reality is that utility gets paid to provide electrical energy, not reliability. In numerous locations, the utility is required to accept and pay for surplus power from the ZEB, regardless of whether it is or is not accessible when the utility needs it. Sharp deviations in ZEB load profiles can be troublesome for the grid to handle. Sometimes, electrical energy peak demand corresponds with decreases in the renewable production (e.g., in late summer afternoons when cooling loads peak yet solar PV production starts to diminish). This can result in a lofty increase in demand for power. Furthermore, the movement of electrical energy onto the grid from on-location production was not part of the preliminary grid structure. In view of the above, changes in grid infrastructure, utility business models, and building load management become essential to adjust electrical energy and building sector needs and provision [1].

High-performance, low-energy-use buildings are vital for our future, and especially in the smart homes scenario. Therefore, ZEBs will play an imperative role. The ZEB definition has been and will keep on developing and encompassing more to help accomplish the superior objective of high performance. Aligning the objectives and concept of ZEBs with the objectives of the electrical energy sector, particularly as utilities advance in view of changing customer demands and emerging new technologies, will necessarily drive positive outcomes [1].

10.5 Renewable Energy and IoT in the Energy Sector

This section has a focus on renewable energy vision. The following subsections discuss in some detail the underlying concept along with developments in electric grids. Applications of the IoT, including developments on electrical vehicles, are also presented.

10.5.1 Renewable Energy

Societal demand for renewable energy is increasing, while the cost for the relevant technologies is coming down. So, the utilization of renewable energy for electrical energy production is only expected to increase; however, the utilization of renewable puts a strain on the current electrical grid system. The advantages of renewable energy are clearly evident for both the building owners and the electricity sector. The building owner can diminish energy expenses by selling surplus renewable electrical energy to the utility company or utilizing net metering to get a credit from the utility for excess electrical energy produced by renewable systems. The utilization of renewable energy likewise lessens the emissions associated with the buildings. The utility may likewise have the benefit of decreased peak demand and evade expansive capital investment in new ways of generation and transmission. Utilities likewise would also construct large-scale wind and solar farms to enhance their production resources [1]. There is no doubt that full advantages of renewable electrical energy are increasing and the vision is becoming more attractive.

The conventional grid was intended for steady flow of electrical energy from the high-quantity base load and not intended to accommodate broadly distributed, smaller, and discontinuous (not constant) production from sources such as solar PV and wind. Additionally, transmission and distribution assets were intended to move electrical energy from remote production to customers. They were not intended to empower one building to impart surplus capacity to/from another close-by building. Besides, the present grid is not intended to successfully monitor and deal with the huge amounts of bidirectional flows of electrical energy that are simple to envision as the demand for and viability of renewable electrical energy grows. Dealing with a huge and scattered number of production resources with a diversity of owners is even more difficult. Electrical energy flows from high voltage to low voltage; therefore, for surplus electrical energy to move out of a building back to the grid in turn, this also required the voltage to be raised above grid voltage. With an extensive number of production resources that are not under the operational control of utilities, the grid rapidly keeps running into voltage issues [1].

10.5.2 Electrical Grid in the Era of the IoT

The conventional grid infrastructure is now changing with the emergence of new technologies, more efficient methods, and emphasis on ZEB configurations. Additional technological changes and rising demands are also being projected to drive much more change to the physical grid and compel utilities to employ new business models, possibly changing the fundamental market requirements of electrical energy. In the generation sector, grid infrastructure is intended for vast, controllable production and one-way flow of electrical energy. In this sense, solar and wind resources are irregular. Without storage, they can disturb the stable maintenance of demand and supply. In the transmission sector, utilities sell electrical energy for earnings and profits. Utilities keep up a grid infrastructure to empower the delivery of their products. Proprietors of DERs (Distributed Energy Resources) may not purchase as much electrical energy as other consumers; however, in the distribution sector, electrical energy is presently being provided from the distribution part of the grid, requiring a bidirectional flow of electrical energy. Net metering empowers bidirectional flow of electrical energy from limited distributed production and yet may not be the main answer for higher infiltrations of distributed production. In the communication sector, operational control and communication does exclude the consumer side of the meter and frequently does exclude distribution infrastructure. Communication with the consumer is one way and does not utilize the grid network infrastructure. It is utilized just for the unforeseen events, for example, power outages.

Changes in the electricity sector will open doors for its customer as well as the building sector. Technical changes predicted to affect the two sectors incorporate DERs (of which distributed production of renewable energy is a key segment), an expansion of plug-in electric vehicles and transportation sector as well as the generic IoT and the smart grids [1].

10.5.3 Distributed Energy Resources (DER)

Distributed energy resources (DERs) are a noteworthy element of progress for the electrical grid. The traditional grid was intended for centralized generation and one-way flow of electrical energy. DERs change that by installing generation assets on the distribution segment of the grid and compelling bidirectional flow of electrical energy. DERs are mainly related to buildings. It is therefore essential for building professionals to inform themselves and their clients about DERs since DERs signify critical technologies and strategies through which buildings advance from passive consumers to dynamic partners with the grid. DERs are also termed as: distributed energy systems, distributed generation, and distributed power. The propensity is to consider DERs simply physical resources (e.g., solar PV, wind, batteries), yet DERs incorporate virtual resources, for example, plans to diminish or better supervise loads [1]. DERs include distributed generation, community solar, electric storage, nano-grids, microgrids, third-party providers, third-party aggregators, and plug-in electric vehicles.

Here, distributed generation is comprised of a small number of electric generating units, from 3 kW to 50 MW. These smaller-scale power sources (as opposed to large utility scale) are well situated to electrical grids. They are, generally, “behind” the meter on the customer side and near to the loads for which they give power. These power sources can be linked to the grid, or they can be stand-alone; the output from various units can be collected to take care of the standard electricity demand.

Distributed generation challenges the centralized generation model of the current grid and is the main thrust in changing the model of the grid from one-way to bidirectional electricity flow [1]. Some examples are: Solar PV (including rooftop solar arrays, building integrated photovoltaic, on-site ground-mounted solar arrays), wind turbines (including utility scale larger than 100 kW, small wind 100 kW and smaller and offshore wind), generators (utilizing diesel, oil, natural gas, or a combination of fuels), co- and tri-generation, fuel cells, microturbines, and reciprocating engines.

Solar community is a business infrastructure for distributed renewable production in which electrical energy is generally produced off-site (i.e., not on a building or building site) and gives power relative to the number of customers it serves. This is especially advantageous to consumers who need solar PV for an assortment of reasons [1].

Electric storage choices incorporate batteries, even those used in electric vehicles. Electric storage can help balance the grid and make it increasingly adaptable. It can be utilized when generation surpasses demand, and the stored energy can be discharged to fulfill demand at some other time (e.g., when intermittent renewable production is not fulfilling demand). Otherwise, when a short-term peak in demand happens, storage can lessen the requirement for short-term peak generation, which is frequently the most costly generation [1].

Nano-grids and microgrids are smaller nearby electrical grids that utilize distributed generation and incorporate advanced controls and battery storage. Their distinction is one of scale:

- Nano-grids are smaller in size than microgrids, frequently residential or single building. They normally utilize solar PV for the generation, batteries for storage, and on-location “grid” components.
- Microgrids are bigger, campus or multi-building in scale and utilize a more widespread array. Sometimes, they utilize an integration of generation technologies (e.g., solar PV, wind, combined heat and power generators) and storage. Their grid components are typically not situated nearby to a single building, but rather regularly require their very own devoted space. They empower numerous buildings to share electrical energy and storage.

Nano-grids and microgrids are connected to the bigger electrical grid at a point of basic coupling that keeps up the voltage at an identical level from the primary grid and adjusts the frequency except if there is motivation to disconnect (e.g., outage or need to control electricity flowing back onto the grid). A switch can isolate the nanogrid or microgrid from the primary grid automatically or physically, and the smaller grid at that point works separately as an island (called “islanding”). Nano-grids and microgrids offer benefits to utilities as well as to customers. They can give backup power in case of grid failure [1].

Third-party providers and third-party aggregators perform a critical job in DERs. Third-party providers offer a variety of products and services to buyers and utilities. Aggregators offer products and services of various third-party providers. These products and services are dispersed across the grid and incorporate the following: distributed production, at times, combined with storage; energy efficacy products and services; billing software and services; energy management services; grid dependability products and services for utilities [1].

10.5.4 Plug-in Electric Vehicles

Plug-in electric vehicles perform a critical role in transforming the electric grid. Overall utilization of electric vehicles (EVs) is estimated to increase from about 1% of the global light-duty fleet today to about 7% by 2030 and 33% by 2040. EVs indicate both the difficulties and opportunities for the electrical grid and buildings. From the grid viewpoint, EVs are regarded as a noteworthy factor in the increase in overall demand for electrical energy. As they confront selling less and less electrical energy, utilities might look more favorably at electrified transportation sector as a genuine advantageous factor for their business model. From the buildings point of view, EV proprietors hope to establish means for charging these vehicles at home, at work, and in public locations [1]. The beneficial impact of this change on buildings include the following: benefits to the owners of EV by way of charging; converting a fossil-fuel-based fleet to electric mode of transportation; EV charging incentives; and future EV charging requirements and desires. For the electrical energy and buildings sectors, EV charging can possibly essentially change the load patterns. The energy stored in EVs offers steadiness to both the grid and the buildings, particularly in case of distributed generation. EVs can, for instance, counterbalance the discontinuity of solar PV or wind power by charging around midday or at night when these resources are at their peak production, separately. EVs can likewise limit frequency and voltage fluctuations during grid interruption, profiting both the electricity providers and the consumers. Additionally, with dynamic pricing as an alternative, the owners of EVs could charge batteries when demand and prices are low, and then sell electricity back to the grid at a more expensive rate when demand spikes. This avoids grid overload [1].

10.5.5 Other Applications of the IoT

In addition to DERs, the electrical and buildings sectors will see changes from the expanding IoT, as already mentioned. Since IoT is a system of interconnected everyday devices, appliances, and objects fitted with computer chips and sensors (that can gather and transmit data through the Internet), we can apply this idea to commercial buildings, and then, we have Buildings IoT (BIoT). Buildings IoT devices can contribute to much smarter and more energy-efficient activity of building apparatus and devices, for example, in relation to HVAC, lighting, and security. Generally, buyers are now implementing IoT vision that associates with both the electricity sector and residential buildings. Numerous products are already available that offer Internet-enabled controls for household functions (e.g., lighting, HVAC, home safety, etc.), to make their living environments as smart homes. IoT devices are likewise commonly changing human anticipation regarding the speed and effortlessness with which we can control our immediate environments (e.g., tone and color of led lighting, home entertainment alternatives, speaker volume), which can possibly affect the electrical energy and buildings sectors [1].

A couple of speculative conceivable outcomes are worth taking into account. Even though numerous IoT device manufacturers' guarantee energy savings, these devices could really result in more noteworthy utilization of electricity and change load patterns just on the grounds since they make the task of electric equipment so natural and trouble-free. IoT devices may likewise change assumptions regarding the assortment and granularity of data. For example, without data on the explicit electric load of HVAC equipment, which can be hard to discover in a few buildings, such a suspicion cannot be affirmed. We have smart watches that track biometric data such as heart rate and sleep quality to enable us to examine our health. It is conceivable that building occupants may want to effortlessly contrast biometric information and data about building activities, for example, lighting levels and color to decide the effect of those measures on health [1]. However, as said before, without enough appropriate data, the afore-mentioned suspicions cannot be affirmed.

Utilities intend to further utilize IoT-based devices to enhance business and grid tasks. They are likewise anticipating to give services companionable with IoT devices to enable purchasers to all the more likely deals with their loads and in this manner reduction in their expenditure. This enables utilities to oversee generation, transmission, distribution, and loads in a much better way too. At the end of the day, the IoT could turn into something by which utilities "can see" loads and cooperate with buildings inhabitants to deal with those loads in the future [1]. IoT can enhance occupant comfort, support health and wellness, promote energy efficacy efforts, and facilitate the utilization of cloud computing infrastructures. Those are only a few instances of how IoT can team up with buildings environment. Similarly, as smartphones and intelligent devices are changing human expectation about the speed and security of data and the capabilities to get support with daily activities, the IoT vision needs to change the desires for buildings occupants and buildings activities [1].

10.5.6 IoT/IIoT-Based Electricity Generating Project Examples

There are several examples of projects that embed the required changes as suggested above and utilize latest technologies.

Jacobabad Institute of Medical Sciences in Sindh Province, Pakistan, is one such project. This institute has around 130 beds, occupying around 115,000 ft^2 (107,000 m^2) and overall spread over around 8 acres (3.25 ha) of space. It incorporates rooftop solar PV that produces approximately 490 MWh/year via a two-bank battery system, 6900 and 20,700 Ah [1].

The Sacramento Municipal Utility District (SMUD) and Sunverge Aggregated Distributed Energy Storage and Solar PV in California, USA, is another such model. SMUD and Sunverge Energy cooperated to assess how high infiltrations of renewable electrical energy generation could yield better outcomes with consumer-sited energy storage. In 2016, around 28% of electrical energy created in California originated from a blend of renewable fuels, and the maximum level of the blend was about 10% solar. The state has a policy mandate that half of the produced electrical energy will originate from renewable fuels by 2030, and solar is estimated to make up the biggest level of the blend. The SMUD/Sunverge project incorporates a mix of 2.25-kW PV installations and 11.64-kWh Sunverge Energy Solar Integration Systems (SIS) installed in 34 houses. The SIS incorporate lithium-ion batteries (versatile from 7.7 to 19.4 kWh), a hybrid inverter (adaptable to 6 KW), and advanced controls software and electronics that Sunverge guarantees will convey power at the opportune time and the most minimal conceivable cost [1].

Pura Energía and sonnen are solar plus storage microgrids in Puerto Rico is another such precedent. Su Matrullas is a school providing kindergarten through Grade 9 education for around 150 students in a remote, mountain community in southern Puerto Rico. Indeed, even before Hurricane Maria struck Puerto Rico in September 2017, utility grid services were not dependable. After the hurricane, grid services were absent. The solar company Pura Energía and a US backup of the Germany Company Sonnen worked with other public and private party sources to set up an off-grid solar plus storage microgrid system. It comprises a 15-kW solar PV array, one 4-kW and one 8-kW battery (both lithium ion with inverters), and a backup diesel generator. Expectation is that the microgrid system will give electrical energy to keep the school open and fully operating; the school does not plan to interface with the bigger grid [1].

10.6 IoT in Smart Grid and Smart Microgrid Sectors

This section is focused on discussions on smart grids and smart microgrids. We also present project examples and application scenarios.

10.6.1 The Smart Grid

To optimize the utilization of DERs, enhance overall grid infrastructure, and authentically connect with the IoT, the grid needs to be more intelligent. A smart grid permits a bidirectional flow of electrical energy and communication between electrical energy providers and customers. With a smart grid, buildings are changed from passive loads on the grid to active partners in the electrical energy sector, giving (possibly selling) electrical energy and trading data that permit load balancing to maintain a stable and reliable grid. In the generation sector, the bulk production is developing to greener sources, for example, renewable energy and natural gas. Production incorporates progressively adaptable and quick-inclining resources and mechanisms, for example, electrical energy storage system to keep up with the uncertainty and discontinuity of utility-scale and distributed renewable production. In the transmission sector, the transmission operators can utilize assets and resources from the distribution and bulk production parts of the grid. Operators can incorporate distribution while controlling grid activities. In the distribution sector, the utilities may move toward becoming stages that offer grid infrastructure for third-party suppliers and aggregators that sell electrical energy or potential energy services. In the communication sector, the optimization of distributed energy resources is supported by the communication-enabled grid infrastructure.

A decentralized methodology brings production nearer to load, diminishes transmission losses and vulnerabilities, and enhances the overall dependability, flexibility, and stability of the grid. Communication is bidirectional and nearer to near-real time, empowering clients to more readily oversee loads and expenses. Electrical energy rates might be progressively dynamic. Smart building devices empower the task of smart equipment by means of the Internet [1].

The smart grid bolsters the usage of more nuanced and efficient demand management programs by the utility and also bolsters the execution of more educated measures by the customers. It additionally strengthens dynamic pricing, which could be a win for customers and utilities alike, enabling both to gain benefits of inconsistency in the grid, the wholesale electricity market, and DERs. Smart digital meters are important to the smart grid. They empower bidirectional, near-real-time communication between buildings and an area network about demand and supply. These meters can empower utilities to control loads more efficiently and in this way guarantee superior grid reliability. Smart meters are likewise important to buyers getting more accurate and timely data about users and electricity usage and to notify users of alternatives about loads and costs. These alternatives can likewise lessen the load on the grid. Even though numerous buildings utilize BAS and energy management software that provides them with insights into variable loads and expenses, most customers do not have the advantage of such frameworks. Without smart meter technology, these buyers have no method to monitor those sorts of fluctuations [1].

Smart equipment and appliances additionally use sensors and software to communicate by means of an area network. Through a smart meter, utilities might have the capability to speak with smart equipment and appliances to control loads. This would need a transfer in the present-day utility–customer relationship. The customer would enable the utility to control loads on the customer side of the meter. It remains to be seen to what degree this transfer would be perceived as an undesirable interruption or a societal advantage that advances the execution of the electrical infrastructure. Customers can likewise utilize smart equipment and appliances to improve control time of activity to exploit the accessibility of more affordable electricity. Smart meters, equipment, and appliances can be linked to client interfaces that visualize data about energy supply, loads, and expenses and empower educated choices about which loads to include and when. The interface would likewise enable utilities to communicate in near-real time with consumers about any utility-controlled loads or outages [1].

As an ever-increasing number of buildings with distributed generation are on the grid, it is generally helpful to the proprietors of DERs and the utilities to work on a smart grid. Renewable electrical energy is irregular, yet it may be planned with an assorted variety of frameworks (e.g., solar, wind, and biomass) to lessen irregularity and fulfilled base load demand. A smart grid enables the utility to improve grid tasks to take full benefit of accessibility of electrical energy from irregular sources, which might be claimed by the utility, the client, or another third party. A smart grid could empower the non-utility proprietor of electrical energy and the utility to set up a strong business relationship that enables the proprietor to sell its electrical energy and the utility to purchase that electrical energy or distribute it on the grid for others to purchase.

The smart grid also faces a few difficulties. At the point when the electrical grid incorporates bidirectional flow of electrical energy, the assignment of keeping that electrical energy from hurting workers, people on the call, and building occupants turn out to be all the more challenging. Interoperability is another key problem faced by the smart grid, which will incorporate expanding quantities of DERs and DER owners; smart buildings, equipment, appliances, and electronic devices; and progressively refined communications. Interoperability is the capability of these components (networks, systems, devices, and applications) to cooperate viably and trade and use data safely without causing bother or issues. The smart grid supports and confronts resiliency in buildings. To maintain resiliency, for instance a preference for life, well-being and crisis structures can be incorporated within the electrical grid. Nevertheless, cybersecurity concerns must be considered to guarantee resilience [1].

10.6.2 The Smart Microgrid

With the growing attraction of pollution-free energy and efficacy as well as the requirement to create the smart grid business system, an increasing number of stakeholders are concentrating on smart microgrids as a practical way to deal with an upgrade of the grid at the neighborhood level. These grids are mainly created for a community e.g., college, school, or other similar environments. The smart microgrids join the neighborhood distributed energy supply to fulfill the correct requirements of the constituents alongside connection with the bigger grid. It includes the scope of intelligent technology in a solitary area. This boosts the quality of the service and helps in the creation of innovative occupations. Therefore, it helps to deliver a feasible business case and also energy and cost savings for the customers. They additionally give the neighborhood the decision about the source and supply of generating electricity [7].

Microgrids are small-scale versions of the central electrical energy system. They accomplish explicit neighborhood objectives (e.g., reliability, carbon emission reduction, diversification of energy sources, and cost reduction), set up by the community being served. Similar to the bulk power grid, smart microgrids produce, distribute, and control the flow of electrical energy to customers at the neighborhood level. Smart microgrids are a perfect method to coordinate renewable resources at the community level and take into account client interest in the electrical energy enterprise [7].

To optimize the utilization of renewable energy sources, to enhance consumer participation infrastructure, and to guarantee incorporation with IoT at the community level, the microgrid needs to get smarter. A smart microgrid permits bidirectional flow of electrical energy and communication between electricity providers and consumers on the community level. So, to handle the issues of non-accessibility of individual renewable energy sources, IIoT performs a critical job by observing the energy usage, energy generation, and its integrated form, particularly for the smart microgrid. The expression “microgrid” mirrors another state of mind about planning and constructing smart grids. At the neighborhood level, smart microgrids proficiently and financially incorporate buyers and buildings with electrical energy distribution and production. Smart microgrids provide financial as well as environmental benefits to the customer.

Smart microgrids increase dependability locally through the implementation of an explicit dependability enhancement plan that incorporates the excess distribution, intelligent switches, energy production, energy storage, automation, and other related intelligent technologies [7]. Neighborhood electricity production and storage permit segments of the grid and significant services to work autonomously on the big grid whenever essential and therefore remove blackouts. Technologies such as intelligent switches and sensors automatically repair the instability of power, not at all like the present-day electricity systems where switches must be reset manually in the occurrence of an electricity outage. With the help of redundant sources, electricity keeps on flowing even if the storms, ice, or squirrels do any interruptions in the power system. Microgrids also back up the bigger grid when energy demands and expense are most elevated by providing electricity auxiliary facilities [7]. Buyers and businesses in the US pay around $150 billion per year in expenses because of the outages of power. The dependability of smart microgrids considerably lessens these expenses. It enables buyers to secure energy in real time that again brings down expense at the same time as utilizing neighborhood production to evade peak energy expenses. Furthermore, the smart microgrid infrastructure often incorporates outsider finance. Also, the futuristic upgrade plan for decreasing infrastructure enhancement expenses are mainly paid by ratepayers. Likewise, smart microgrids reduce the cost of energy transmission as compared to traditional grid systems [7].

Buyers and businesses can provide profitable services to the grid as an end result of expenses from the serving utility or autonomous system operator. Smart microgrids likewise set the platform for extra customer earnings from disseminating energy production, plug-in electric vehicles, and carbon credits [7]. This increases fresh business opportunity for stakeholders. Japan and Denmark are leaders in executing the microgrid approach. Recently, Japan's Energy Agency, NEDO, joined with the state of New Mexico to co-fund and create microgrid projects for a number of communities [7].

One of the main advantages of smart microgrids is that they are effectively strategically situated (unlike the centralized grids locations) to fulfill the known and unknown requirements of the future. They permit local communities and commercial campuses to expand the overall electrical energy delivery rapidly and economically through moderately small neighborhood generators, solar cells, wind turbines, etc. This eliminates the waiting for power companies to set up a centralized power plant that is expensive and takes much longer time to start working. The energy management technology of smart microgrids empowers plug-in hybrid vehicles to be connected to the electrical energy system as smart energy storage assets [7].

Another important advantage of a smart microgrid is its capability to utilize neighborhood production and subsequent "waste" heat to uproot coal-fired production. A neighborhood power generator can be renewable or natural gas-fueled. Also, the smart microgrid can recycle the energy generated during electrical energy production for heating buildings, hot water, sterilization, cooling, and even refrigeration. Smart microgrids additionally make it conceivable to take full advantage of clean, renewable energy since they have the adaptability required to utilize an extensive range of energy sources including solar and wind. A smart microgrid empowers customers to meet most of their requirements of electrical energy by producing their own energy, regardless of whether it is through sources like wind, solar, geothermal, microturbines, etc. This would also help to lessen the utilization of fossil fuels and reduce greenhouse gas emissions [7].

10.6.2.1 Technologies Used in Smart Microgrid

There are several emerging technologies available to the smart microgrid construction and operation. At home, we can have smart meters that permit two-way exchange of costing data, utilization data, and electrical energy. There are programmable smart appliances, intelligent gadgets, and user-friendly home energy control systems that enable consumers to connect with the smart microgrid to automatically control each aspect of home energy utilization. Energy efficacy enhancements through further automation assist customers utilize less energy and also reduce monthly electricity bills [7]. At work, the advanced energy control systems help to make commercial buildings "smart". Latest warming and air-conditioning technologies that regulate the building ventilation rates automatically and in real time based on air quality, habitation, the cost of energy, can help improve efficiency. Latest electrical energy production systems can give energy to singular buildings and deliver energy to the whole grid [7].

Inside the electric energy distribution system, intelligent switches, relays, and sensors that supplant their obsolete and incompetent antecedents can enable the smart microgrid to oversee and distribute energy with greater productivity and dependability. Redundant plans give a backup source of energy when recurring storms, ice, and squirrels disrupt energy supply. Modernized controls that continually check for and even forecast potential instabilities can resolve at least some issues before clients encounter any disturbance in the service [7].

10.6.2.2 Project Examples of Smart Microgrids

Here, we present a few examples of smart microgrids based on new technologies.

US Army Forces, Fort Bragg, North Carolina, have developed a smart microgrid. To improve electrical energy supply and dependability while diminishing costs, Fort Bragg in the USA chose to construct one of the world's biggest microgrids. With direction from Honeywell, Fort Bragg incorporated an assortment of distributed production technologies that operate in combination with the military base's utility infrastructure. Covering in excess of 100 square miles, Fort Bragg claims its own electric distribution system that is capable to supervise different productions from a central energy management center. In spite of its size, the different production technologies are completely coordinated with the distribution network, information technology, and communication infrastructure. Because of its smart microgrid distribution system, Fort Bragg have improved its energy provision and dependability and diminished energy expenses [7].

Beach Cities Microgrid Project in San Diego, California, is likewise a smart microgrid. This project has united a portion of the country's greatest names in the power industry to study more about how a smart microgrid in the San Diego region would operate under real-world situations and eventually decrease peak loads by more than 15%. This attempt is driven by San Diego Gas and Electric in partnership with Horizon Energy Group, Advanced Control Systems, Motorola, IBM, Lockheed Martin, Pacific Northwest National Laboratory, and the University of San Diego. Together, they built up a system that includes various distributed production systems, for example, solar power in homes and businesses, biodiesel-fueled generators, distributed energy storage devices, and demand response technologies, for example, smart meters [7].

Perfect Power at Illinois Institute of Technology (IIT) in Chicago is building a smart microgrid. IIT has joined with the Galvin Electricity Initiative and the US Department of Energy (DOE) to build up a perfect power system that is a smart microgrid for the IIT main campus. In collaboration with S&C Electric, Endurant Energy, and ComEd, the university is building an electric energy system of interconnected smart microgrids in a loop configuration with a redundant electrical energy supply. The building of this system is in progress, and it will provide a chance to IIT to wipe out expensive outages, limit energy disturbances, moderate a consistently increasing demand, and control greenhouse gas emissions. It is anticipated that the smart microgrid will pay for itself as it is constructed over the next five years [7].

10.7 IIoT to Combat Challenges of Renewable Energy Sector

In this section, we elaborate on the inherent challenges and global future of the renewable energy sector.

10.7.1 Challenges of Renewable Energy

A number of challenges and concerns have already been mentioned in previous sections. Traditionally, a large portion of the concentration in the energy industry has been on diminishing energy consumption when market prices or demand is high, mainly to lessen costs and balance utility load. Such arrangements are intended to reduce the energy deficit. Nevertheless, when energy sources spike, and delivery beyond what the grid can deal with becomes problematic. Quick fluctuations in power load can cause damage to the grid and in addition influence consumers downstream. Regardless of whether a fluctuation goes unnoticed in normal home use, a solitary millisecond of instability can harm computing frameworks or other sensitive devices. Moreover, as we include unusual and variable energy generation to this framework, we have instability on one side from demand and on the other side instability from the expansion of renewable energy.

Up until now, the effect of renewable energy has been relatively undetectable to the framework. However, in certain regions, e.g., Germany, Hawaii, and California, the utilization is increasing at a fast rate. In such situations, it is hard to adjust these three factors: existing generation, the new generation from renewables, and the unpredictability of the demand. To keep up predictable energy distribution, a few utilities have needed to bring fossil fuel generators like coal power plants back online to compensate for a slacker generation. Otherwise, they need to leave windmills sitting idle when the grid is full. To unravel those difficulties, it is required to take a moderate and productive approach to store the excess energy and utilize later when needed [27].

10.7.2 Achieving Grid Stability

Rather than searching for an answer inside the grid infrastructure itself, there is another methodology discussed in [27]. Imagine a scenario in which it is possible to transform a device (that normally consumes electrical energy) into something that stores energy, and then, we have a way to balance out the grid and the whole energy distribution framework. Now, imagine the usefulness if such a device is embedded in a normal household appliance.

Such innovative ideas have led Steffes Corporation to the development of smart electric water heaters as discussed in [27]. Such moderately cheap devices represent between 20 and 40% of the residential demand or load on energy grids. To make a local and quick reacting storage asset for a distributed system of water heaters, Grid-Interactive Electric Thermal Storage (GETS) framework has been built with the help of Microsoft Partner, Mesh Systems, using Microsoft Azure Platform including Azure IoT Suite and Azure Service Fabric.

Steffes devices are orchestrated by a creative idea called the “Power Tower”, made conceivable by the Azure IoT suite, clarifies TJ Butler, Chief Software Architect at Mesh Systems. The Power Tower is a real-time mirror of every end unit in the cloud and has complicated logic, which facilitates blending and synchronization and utilizes bigger volumes of renewable energy. Microsoft Azure is a cloud platform developed by Microsoft [28].

By exploiting cloud technologies, Steffes devices can interface and control a large number of water heaters and at the same time make a virtual storage asset for utilities. These devices store energy at whatever time it is generated; which may be at night for wind generation or early afternoon for solar, so energy is accessible on demand. With Microsoft Azure, we take an everyday simple device and transform it into an adaptable instrument for overseeing demand, says Murphy of Steffes Corporation. As we get increasingly renewable energy, there is a need to influence load to pursue generation, as opposed to the traditional method for generation following the load. Steffes made water heaters with sensors that empower an organization to monitor up to 150 data points for every unit. In addition to remotely checking the data, the company can control every heater to quickly add or decrease load whenever necessary.

With such approaches as illustrated above, we can reduce the unpredictability and instability that go with renewable energy production resources while at the same time making more prominent the stability and resilience of the electrical grid and distribution framework, says Kelly of Steffes Corporation. This proves that when the normal water heaters meet the Internet of Things, it can transform the energy sector [27].

10.7.3 Global Future of Renewable Energy

The real-time control empowers to furnish grids with new frequency regulation services that are much more nimble than traditional strategies. To stabilize the grid, utilities companies normally need to throttle these giant machines here and there [27]. Yet, presently they can utilize devices and appliances that are omnipresent in people's houses, which they can aggregate and monitor in real time with second-by-second control. It is considerably more effective than attempting to regulate frequency with large upstream generators. Steffes Corporation has completed 24 separate trials running across over seven time zones.

Hawaii has started to set up the Steffes GETS system in the latest development called Kapolei Lofts that will incorporate 499 rental houses in Western Oahu. Other countries of the world are eagerly watching this venture. In addition to the fact that Hawaii has high daily demand, up to 33% of that demand is provided by unpredictable renewable energy, and they are focused on increasing this figure to 100%. California has focused on 50% and Germany to 45% renewable energy. So if individuals need to comprehend the way the situation is developing, they should examine the developments at Hawaii, California, and Germany.

In addition to furnishing energy companies with accurate control of its grids and distribution networks, Steffes Corporation hopes to cut the upfront expense of water heaters for customers. However, more significantly, it provides opportunities to more people to turn into stakeholders in renewable energy and enhance the global energy environment. This is something that an individual, family, or community can easily do to do their bit on climate change [27]. Consumers can accomplish something at an exceptionally great level to speed up the installation of renewable energy. By utilizing IoT technologies to associate normal consumer devices like water heaters, Steffes Corporation is enabling homeowners to help achieve the vision of sustainability [27]. With this example of IIoT-based water heater project, it is easy to understand the role of IIoT technologies to combat the inherent challenges of renewable energy sources and provision.

10.8 Future of IIoT in the Energy Sector

In this section, we present some future directions by suggesting bonding between buildings and the energy grids, and more discussion on electrical energy generation.

10.8.1 Bond Between Buildings and the Grid

Our new energy future has many emerging opportunities but also has threats. As DER technologies and strategies, EVs, and IoT proceed to develop further, and the conventional grid develops to a smart grid, the bond between buildings and the grid will strengthen. Buildings will develop into dynamic partners in the electrical energy sector. Rather than passive loads on the distribution end of a grid that sends electrical energy one way, buildings will also produce electrical energy that would be distributed to neighboring loads or the bigger grid distribution network. Through on-site or EV batteries, buildings will offer crucial energy storage solutions for the advantage of their very own tasks and also for the bigger grid. In addition to producing earnings from conventional building inhabitance, building owners will have the chance to sell electricity and energy services. The job of utilities will probably move from an emphasis on selling electricity to selling grid infrastructure and energy services, in a general sense changing the conventional bond among utilities and their customers of buildings [1].

10.8.2 Market Exchange of Electrical Energy

The market exchange of electrical energy will likewise change, advancing with the smart grid to a transactive energy approach that empowers a free-market exchange of electrical energy and energy services between an assorted variety of suppliers, including utilities, building owners, and third parties. Our new energy future holds incredible guarantees, and building professionals will become essential partners who would understanding the opportunities and recognize and unravel the difficulties on route. Building professionals will be vital in shielding health and sustainability of the constructed environment and the general population it serves. Design, construction, commissioning, and preservation; and tasks and procedures will probably also be changing. There will likewise be extra businesses and whole industry sectors looking to grasp the opportunities.

The technology sector is now occupied with building automation and controls, and renewable production and energy storage. The electricity sector has been functioning at the issues identified with DERs and the smart grid for quite a long while. Data will most certainly be vital to our new energy future, and any company with an enthusiasm for “our” data is now pondering this future. These industries see the probabilities, and they are preparing for the future. Building professionals must be an element of the research, development, and policy changes; the conferences, meetings, and discussions to guarantee the advancement of our new energy future and ready to serve the customers better and support a sustainable world [1].

10.8.3 Decentralization of Energy Generation

Our new energy future uses decentralized energy generation where smart microgrid performs a critical role. With the expanded spotlight on pollution-free energy and efficacy as well as the requirement to create the smart grid business system, an increasing number of stakeholders are concentrating on smart microgrids as a practical and vital way to deal with an upgrade of the grid at the neighborhood level. Smart microgrids increase consumer participation in the energy sector using IoT-based devices [7]—these are like the smart grids.

To optimize the utilization of renewable energy sources, to enhance consumer participation infrastructure, and to guarantee coordination with IoT at the community level, the microgrid needs to get smarter. A smart microgrid permits a bidirectional flow of electrical energy and communication between electricity suppliers and buyers at the community level. So, to handle the issues of non-accessibility of individual renewable energy sources, IIoT performs an essential role by observing the energy usage, energy generation, and its incorporation, particularly for the smart microgrid. Customers and businesses in the USA pay around $150 billion per year in expenses because of the outages of power. The quality of reliability in smart microgrids can considerably diminish these expenses. It enables buyers to procure energy in real time and altogether bring down expenses at the same time as utilizing neighborhood production to hedge peak electricity expenses. Furthermore, the smart microgrid infrastructure incorporates outsider finance as well as futuristic upgrade plan for decreasing infrastructure enhancement expenses which are mainly paid by ratepayers. Likewise, smart microgrid reduces the cost of energy transmission as compared to traditional grid system [7].

In short, our new energy future includes smart building and smart microgrid as the key elements in the energy sector where IoT plays a crucial role in connecting them. In addition, DERs, energy storage, and EVs also perform an essential role of maintaining grid stability and reliability in the energy sector using IoT.

10.8.4 Benefits of New Energy Future

It is essential to highlight that there are numerous potential positive advantages of changes coming to the electrical energy sector and buildings. Expansion of DERs can improve flexibility for buildings and communities, and also the grid. These enhancements offer an incredible guarantee in diminishing carbon emissions and different pollutants to help meet policy objectives and to increase environmental quality. They likewise offer more conceivable outcomes for lessening energy costs. Moreover, with better communication and information exchange through IoT and the smart grid or smart microgrid, there are chances to all the more likely liaison between the design, construction, and operations. This information-rich environment will encourage feedback from a whole integrated design group, and also authorizing and activity groups; and thus giving more chances to keep up design purpose. Our new energy future guarantees to open up new practice areas and open doors for building professionals [1].

10.9 Discussion and Conclusion

Expanding requirements for electricity, increased consumption of coal for electricity generation, growth in population, and utilization of renewable energy with its storage requirements are the fundamental reasons behind the changes coming to the electricity sector. Coal contributes to emissions that are destructive to the environment and human health. So, to lessen these emissions, utilization of renewable energy and requirements of its storage are rising. In this context, government agencies are dealing with the advancement of energy infrastructures known as the "smart grid" and "smart microgrid".

In the present scenario, sensor technology, big data, and data analytics are getting much attention in order to optimize operations, such as efficiently balancing supply and demand as customers connect to a smart microgrid. Usage of smart devices is also increasing; however, their connectivity depends on the speed and reliability of the Internet. Such usage in the industry has resulted in the development of what is called "Industrial Internet of things (IIoT)." Advances in the IIoT help to maximize operational efficiency, optimize business operation, and protect the system. It provides applications like predictive maintenance, remote monitoring, worker safety, and advanced distributed control. So the main objective of this study has been to analyze the IIoT-based renewable energy sector with a view to reducing the use of fossil fuel, increasing the use of cleaner energy resources and better utilization of the energy.

The key contribution of this chapter includes detailed discussion of the concept, history and applications of IIoT; changes coming to the energy sector; introduction of renewable energy and IoT in the energy sector; challenges of renewable energy sector and solutions to the challenges using IIoT; and future of IIoT in the energy industry. This chapter also includes a detailed discussion of smart microgrid which is mainly based on renewable energy and IIoT concept. It determines the role of IoT in smart grid and smart microgrid. Hopefully, the chapter helps us to understand how efficiently the IIoT-based energy system using renewable energy will work for improving the future in terms of better utilization of renewable energy resources as well as limiting the carbon emission. The chapter also includes open research directions in the energy sector and provides several examples of IIoT-based projects in the energy sector.

The overall conclusion of this chapter is that IoT performs a crucial role in the future energy sector for maximizing the operational efficiency, optimizing the business operation, protecting the generation and supply systems, helping with predictive maintenance, worker safety, and advanced distributed control. In order to tackle the problems of non-availability of individual renewable energy sources, IIoT also plays a crucial role by monitoring the energy usage, energy generation, and its integration, especially for the smart microgrid.

10.10 Open Research Directions

IIoT in the energy sector is the underlying technology; in this respect, there are many open research directions. There are relatively few published prototypes for the collaboration of renewable and non-renewable energy sources. There are few published prototypes for connecting home apparatuses to the Internet especially for monitoring. There is therefore an urgent need for joining different IoT information frameworks with various sensor input systems in order to increase and promote smart working of connected gadgets. There are very few effortlessly accessible open source simulation tools or the test beds that can allow to empower execution assessment of the IoT-aided SG frameworks [15]. There is a need to comprehend the characteristics of various IoT applications as well as their service requirements in more detail. There is also a need to build practical energy consumption models through the IoT environment, e.g., WSN network [29].

Some of the key challenges of IoT are privacy of data, data analytics, participatory sensing mechanisms, GIS-based visualization, and cloud computing. Moreover, there are some WSN challenges incorporating energy efficacy, architecture, security, protocols, and quality of service [30]. These areas require more detailed research. In addition, there is a need to line up ZEBs with the necessities of the electricity sector [1]. For the future, there is an urgent requirement to develop a methodology for utilizing modern database technologies with considerably more embedded intelligence for even quicker data handling and calculation. This is mainly required in the case of large-scale grid integration with renewable energy sources, especially for solar power plants [22]. These are some of the directions where future research is required to be conducted.

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