Artificial intelligence–enabled Internet of Things technologies in modern energy grids

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Chapter Outline

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5.1 Introduction

Throughout time, state-of-the-art technologies are changing the industrial and energy environments. Specifically, in artificial intelligence (AI)-based technologies in the connectivity area, the most popular application is mainly Internet of Things (IoT) and its settings implementation. New AI-based methods help with the computation and analytical power needed in modern energy grids. Hence, we will delve into IoT knowledge to facilitate the process.

IoT process generally is categorized into (1) Internet technologies usage and smart objects interconnection, (2) Likewise internet services, aiding in technologies batch are required to find out the perceptions, such as radio-frequency identifications (RFID), sensors, switches, actuators, and machine-to-machine (M2M) connection devices, and (3) service and application layers influencing such technologies to trigger new grid's business opportunities. Since only one frequent Internet protocol (IP)-based digital network in the IoT is available, different networks such as home area network (HAN), wide area network, and neighborhood area network (NAN) are not necessarily used [1]. All the subdepartments in the industry retain help from an IP-based network by service providers in their applications layer. The recent approach is the communication networks' architecture incentive that reduces time and smoothens the path for capital investment reallocation. The first main smart grid (SG)'s deployment component is the smart meter that gives access to smart metering setup at dwelling units, profit-making sector, and industrial users [1].

In this chapter, a new approach for IoT technologies in SGs is discussed. This new approach looks at these technologies as an object that contains features, including infrastructure, components, challenges, future structure, and applications. There are some combinations of these features discussed in this chapter, such as the role of new IoT technologies in SGs and Energy Internet, which are AI-enabled IoT technologies.

5.1.1 Internet of Things basics in smart grids

Modern power networks are being introduced as SGs. Some key problems of the current electric power system are one-orientation information, spoiled energy, flourishing energy demand, and reliability. In modern power grids, it is vital to implement operations and analytics in a new way that stands on employing AI-based technologies on the IoT platform. There are many important tasks in these grids, including data gathering, data preprocessing, data processing, data analytics, and reaching results. Each of these tasks is considered in modern energy grids' tasks with regard to its challenges.

Computing integration and bidirectional communication potential with current power infrastructures happen in SG. All energy value chain levels are considered, which are not restricted to smart metering (SM). In addition, intelligent use of sensors, embedded computing, and digital communications make the electricity network discernible (measurement and visualization scope), controllable (manipulation and optimization scope), automated (adaptive and self-correcting), and fully integrated (full interoperability with current systems and being able to incorporate a wide energy source span) [2]. So, a complete SG requires IoT devices connectivity, automation, and real-time monitoring. A vast range of network functions throughout the generation, transmission, distribution, and power consumption are supported in SG systems by the IoT devices integration [2].

5.1.2 The relationships between Internet of Things and intelligent grids

An SG creates a cross-directional data platform for optimal monitoring of the system and efficient energy supply by AI technologies network. In an intelligent grid, end users are able to determine the demand by data collection via an IoT network. IoT helps with battery management and monitoring, causing the minimizing of the unnecessary waste demand by electricity supply [3].

The prospective view of IoT facilitated SGs is not determined with the virtual connection considering all utility providers to customers. The interconnection that contains smart phones data becomes possible with data-driven decision-making through collaboration comprising IoT reduction in application total cost of ownership. In the past, since no communication between the user and utility provider was available, a failing transformer had a poor supply. The smart meters and sensors used for data extraction provide complete information for triggering the process. This is the basics of a compressive work order generation. When a blackout happens, a notification by the power line sensor is sent to utility providers where the transformer action is being monitored. This instant action is accomplished more gently, making an efficient wireless system by IoT [4].

5.1.3 Internet of Things in power systems

IoT is mostly used in the distribution and consumption power sector. According to Fig. 5.1, in the third and fourth layers, IoT and the system's operator control the interactions with power distribution and consumption.

A power flow example is explained by Fig. 5.2, which is the complement of Fig. 5.1. A step-by-step power development process and IoT usage are shown in Fig. 5.2. Because of the urgent alert in the power system operation and control center in the moment of failure in transformers, IoT is a crucial problem in SGs. With the approach of power saving, SGs try to solve the power consumption problem with the help of IoT, since the process is monitored on a momentary basis in the data center. The outcome is efficient power saving with an active scheduling approach.

The modern SGs have interconnected elements with built-in preservation and intelligence. Because of the need in utilizing substitute energy resources, service providers are no longer dependent on the customers. IoT is completely adjusting the energy zone with the largest chain added value. Hence, inferential data analytics

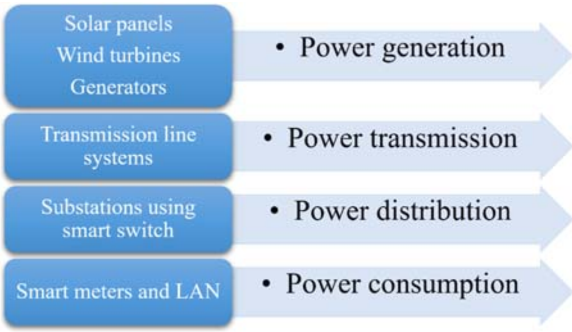

Figure 5.1 IoT in power systems. *IoT*, Internet of Things.

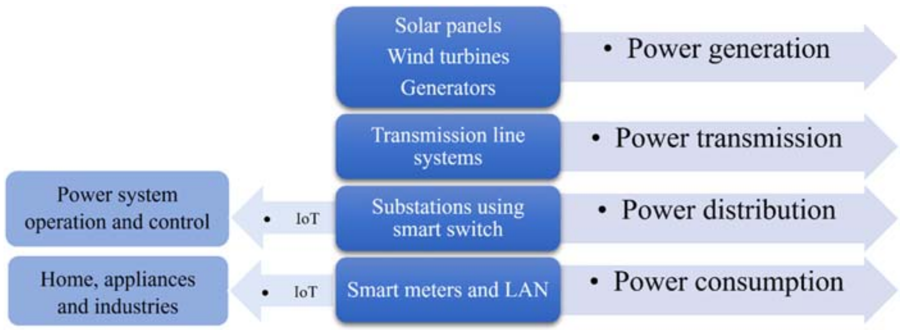

Figure 5.2 General power flow systems.

is suitable using for the collected dataset and the other real-time equipment results in pivotal insight toward settled business decisions that have become transcendent [4].

5.1.4 Smart grid roles and drawbacks in power systems

Smart grid (SG) is basically defined as a smart automated electric grid, including a batch of computers and services [5]. Based on the load type in use and energy systems network (ESN) type (e.g., residential, operational, monetary, and industrial), differences will be obvious in services. The present SG framework is associated with several structure scenarios, which change based on the operational range. Some of these operations such as energy-dependent smart cities output, energy-based residential operations computing systems, and energy conservation blueprints enabled by metering and tracing processes [5]. SG technologies and device utilization can substantially reduce renewable energy resources (RER) problems and allow SGs to effectively use the potential of RERs for clean energy production. Accomplishing complete SG is significant for the distributed energy resources (DER) efficiency. It is also important to provide electricity management (demand/supply) between renewable energy (RE) technologies and energy storage systems (ESSs) with attention to both electricity consumers and producers [6].

Despite SGs having many positive effects to help the industry in many ways, there are also drawbacks to triggering such a system. First, the overhead costs of an SG are extremely expensive and time-consuming and cause labor costs increasing; however, this will result in creating many jobs in the new market for electricity. Second, the privacy standards violation which is possible according to continuous data usage. This internet-based system usage could lead to security issues. Some of the problems are acquainted with the trend of SG technology installation.

One of the main SG's goals is promising peer's active attendance with mechanized bonds. Data-driven decisions are vital for a distributed energy distribution network that has a bidirectional electricity flow with the associated data. Besides residential, economic, and industrial loads, SG also helps with a combined operation for electric vehicle (EV) charging structures. As a matter of fact, SGs gather all the electrical system production, transmission, and consumption architecture together, so the overall system performance will be improved for the sake of customers and the IoT ecosystem. In general, the SG strengthens ESN operation and the context of generation, transmission, and distribution management and decision-making [7].

Conversion to SG fundamentals from traditional grids, including digital energy vision and its devices deployment, can be gradual and piecemeal. The related process will be started by running a small prototype project as a nanogrid, mini-grid, or microgrid remotely. The SG implementation drawback shows the interest of the provider and the consumer, bolstered by third-party regulatory restrictions and technological standards hindering SG solutions [8].

While designing SG, concerns such as ensuring reliability, resiliency, security, computational, and the SG operations' energy efficiency in the digitalization process become vital. Fast, modern computing methods and digital tools such as AI, IoT, big data analytics, machine learning (ML), deep learning (DL), cloud computing, and blockchain have been rationally applied in building administration, transportation, networking, and manufacturing to build sustainable and energy-efficient systems.

With new technologic devices and emerging algorithms, enabling data-driven decisions will help with the quotes below, which will be discussed in the chapter [8]:

- An introduction to DER, power electronics components, communication and cybersecurity issues in SG.
- The techniques associated with AI, such as fuzzy logic, knowledge-based systems, artificial neural networks, and their roles in distributed energy-based SGs.
- Energy Internet architecture, including the IoT components.
- The AI-based analysis has the potential to enhance SG services.
- The IoT and blockchain services, such as data collection, data storage, and digital transactions among the associates within ESN and its groups, are accomplished.
- Automated services to associates are achieved by the ESN's real-time extracted knowledge from data for monitoring, authenticity, accessibility, flexibility, strength, security, and viability purposes.

5.2 Communication infrastructure

After a brief knowledge of the different aspects of IoT in SGs, information about the infrastructures, including networks, electrical components, etc., needs to be investigated.

5.2.1 Smart grid internet infrastructure

The SG Architecture Model framework is introduced as an SG applications reference architecture and contains specifically five main interoperability layers, employment, functions, information, communications, and elements. Different aspects of SG and its services, operations, assets, and devices are addressed by one layer in the power grid's functionality support. Four interconnected sectors aggregate the communication infrastructure of SG, including the backbone network, the middle-mile network, the last-mile network, and the premises area network (PAN) [9]. Each of the sectors' functionality is discussed as follows:

- The backbone network supporting the link between the diverse subsystems and the public utility sites.
- The backhaul network conveys data flow to the advanced metering infrastructure (AMI) with mechanized distribution in architecture and public utilities operation control centers. The network explains an efficient evaluation focusing on its utilization and application [10].
- Moreover, the communication in SG networks progresses considering operational and sensorial data structure, which must be adjustable and consecutive. Hence, the network might be managed by operators and employ wireless technologies such as wireless fidelity (Wi-Fi), Worldwide Interoperability for Microwave Access, and mobile networks such as long-term evolution (LTE) and 5G [10].
- The last-mile network: Supporting by NAN, FAN, and AMI, which facilitates the smart energy meters' data gathering and their propagation to concentrators [10].
- The PAN: It is implemented by HANs, based on programmable logic controller (PLC) standards. The HAN adjusts several elements, such as lighting control, basement automation, thermostats, heating, ventilation and air conditioning, and plug-in hybrid electric vehicle/electric vehicle [10].

Cellular technology has been progressive with one goal, which is new industry enhancement. With the arrival of low-power wide-area network technologies, the IoT paradigm's integration in a an SG design is being discussed among the experts.

5.2.2 Power electronic components

The relationship between the power grid and DERs is an essential function in the SG system performance, which introduces the role of power electronics. Furthermore, boosting, regulation, and DC/DC or DC/AC transformation electricity, especially grid and RE integration, happens in this process. For interfacing to the grid, the distributed energy unregulated RE sources' voltage output and intermittency require power electronics [11].

The DER's voltage output has two states: DC and AC, which comes into the calculations with variable frequency. Power electronics, such as high-voltage direct current, voltage source inverter, and boost converter, grant grids additional supplies with the goal of improving power excellence, reactive power service, and electric grid strength and balance. A smart inverter that merges RE and ESS technologies to the electric grid, has the ability to serve distinctive operations to make a power system performance more stable and reliable [12].

5.2.2.1 Volt-VAR control

The definition of Volt-VAR control is the responsive power injection for voltage regulation. Smart inverters have the ability to provide reactive power for the discussed goal at connection points for the SG voltage regulation. An Inverter special design and program cause its reactive power output to be dependent on the grid voltage.

A communication link is employed to utilize the power converter. It is another solution for the injection process by the grid operator command. In the interfacing meantime, the inverter is able to monitor variables, including current, voltage, frequency, and phase angles, with regard to control functions. This extracted information will further be used for data analytics and data-driven actions [13].

5.2.2.2 Ramp-rate control

Nontransmissible RE, such as solar and wind production outputs, fluctuates many times, even in a few minutes, which might cause confusion for the operators. A reduction in the up/down output power ramping rate is possible with a smart inverter associated with a built-in supercapacitor [14].

5.2.2.3 Frequency and voltage

If the RE production output parameters such as voltage and frequency are not within an acceptable range, the inverter is not able to release the output into the grid. However, there may be an exceptional temporary period of low/high voltage or frequency on the grid. If renewable sources have a further loss, the situation might aggravate these grid conditions [15].

5.2.3 Communication challenge and cyber-security

Assuring effective communication among the peers is an important matter in SGs. Also, protection should be implemented on the SG operations' database. On this subject, the communication role and assured cyber-security systems are discussed below.

5.2.3.1 Communication role in smart grid

The bidirectional information flow, electricity flow, and real-time communication between elements in the system is a vital problem in SGs. Communication importance comes up with two challenges; first, grid integration with DER, and second, aid in the reconstruction of the ESN topology according to the electric power adjustment need. Since SG is a large and complicated system, it needs a range of cutting-edge network technologies that can enable high-speed bidirectional intercommunication among elements, users, and operators in a specific time interval. Usually, these communications are wired (power line communication, fiber optics, and copper cables) optionally. Also, there are other wireless communications, such as Wi-Fi, cellular, and microwave. [16].

In the traditional grids' approach, engineers use power sensors as input for data collection and a consumer's terminal for the monitoring process, which takes place on a regular timetable basis. While in SGs, smart meters and sensors/devices receive real-time data and store all historical data by remote monitoring. All this extracted grid information is the output of an interaction platform connecting to a central processing unit with all considered points using wired/wireless communication technologies. This new real-time condition monitoring notices IoT power systems' operators about devices' health status by AI-based prediction, so they will be informed about the fault occurring ahead of time. This information includes variables such as notifications on possible outages with duration, energy consumption from the power meter, and available energy in determined time intervals. Additionally, users have the option to alter their power consumption patterns extracted from information available in the power databases in accordance with their power consumption rate and total cost. When IoT layers are completed in SG, this information and changing ability is accessible on an exchanging information platform [17].

5.2.3.2 Cyber-security role in smart grid

A need to prohibit misuse, suspicious destructive activities, and unauthorized access to an SG's bidirectional information flow is considered as a reason for cybersecurity in SG. Great consumption knowledge as an output of information analytics and consumers' commerce patterns are available within ESN. So, the data has to be protected from leakage, being hacked, and loss.

Inadequate cyber-security standards will expose the IoT system to a high-risk cyberattack, which compromises the IoT system and face our grid with stability challenges. Other problems such as fraud, information leakage, energy consumption, and collected data manipulation are outcomes of cyberattack. Cyber-security must be interpreted as accessibility, cohesion, creditability, and data accessibility schedule. Moreover, cyberattacks and information security violations detection in SGs will be solved by automatically sending signals to the peer. As a result, the peer will be helped in protecting the system cohesion [18].

5.2.4 Internet of Things components

The data preprocessing transmission for the SGs are categorized into an information and implementation database. The output results consist of smart meter results readings, utility statements, power consumption rates, power flow patterns, and customers' geographical information system (GIS) in SG. The SG's performance data contains a condenser bank, fault positions, IoT network's ongoing variables levels, and energy storage statistics [19]. The central and incidental technologies employ distinctive intelligent devices mentioned below:

5.2.4.1 Advanced sensing and intelligent measurement system

SM arises with the data gathering process on energy prices and resource usage rates. This includes the electricity consuming time and quantity. System security, SG integration with upcoming technologies, and state-of-the-art protective support in SGs all allow the customer to alleviate grid congestion. Grid stability improvement through early faults detection occurs through advance monitoring and analysis, helps in operating system isolation, and prevents power outages [19].

5.2.4.2 Mechanized monitoring and control

Real-time energy tracking for power device status display is a great SG feature, which takes place by optimization power system modules, device operators, and user recognition. These technologies extract data and supply a visual system status presentation for the decision-making process and help to enhance power distribution scope and authenticity [20].

5.2.4.3 Renewable resources consuming prediction

There is a need for an accurate forecast according to the intermittent nature of REs, specifically wind and solar. Advanced precise energy accessibility computations can lessen negative effects on the SG's required spinning reserves. Furthermore, it will contain exploratory knowledge on utilities, load, and other vital computational SG factors. A dynamic nature in all power system type levels, while equalizing the generating variables process, interprets forecasting by stabilizing the grid [21].

5.2.4.4 Information and communication technology

What is typical in current power system base includes all significant power system operational facilities (power generation, transmission, and primary distribution substation) connecting to the control unit center. However, extended communication taking place throughout power delivery networks ends in offering express bidirectional information flows. This forms the SG into a dynamic state for real-time communication. SGs employ information and communication technologies according to the power system status with attention to the up-down nature of a generation. Its goal is to perform more effectively for consumer appliances. Hence, electric power maintenance, grid dependability and productivity, cost-benefit analysis, and environmental protection will be improved [22].

5.2.4.5 Power distribution industrialization

Distribution automation (DA) is a method for mechanized control for power distribution networks' efficiency maximization, so the SG will be more steady and well-performed. As an important SG element, it enables the distribution geographical location readjustment to integrate RE mutability, power increasing, and two-way power flows. The DA facilitates voltage and power factors sensing and monitoring at some determined points on the power distribution circuit. In case of deviation detection from the determined feasible range, it causes voltage regulating devices automated control. So, the reflexive power and voltage injection to be regulated to the present value is allowed. In the moment of fault, the fault's real-time moments can be identified and located faster and more accurately by operators, even at remote locations. So, the time wasted on manual fault tracking will be reduced, and consumers/users do not see the troubleshooting time as a problem anymore [23].

5.3 Key features in energy internet

With the socioeconomic growth influence in mind, it is a noticeable practice to determine linked uncertainties affecting the energy demand/supply patterns. So, satisfactory, reliable, flexible, equal, and secured energy supplies exploration is preferred the most. Concerning environmental protection, and other clean energy standards in the energy supplies, efficient and viable energy resources are commanded to make socioeconomic growth secure. Considering DER, particularly RE and ESS trend, the conventional electric grid, has been given high priority in most infrastructures. The main cause of the DER employment importance rising and ESS is the increasing need for a decarbonized energy zone in the near future [24].

5.3.1 Internet of Energy

The Internet of Energy (IoE) is defined as the IoT development into distributed energy systems containing SG elements, including distributed sources, data warehouse systems, smart meters, and equipment, such as circuit breakers, digital relays, and transformers [25]. It initiates the inner-connection and peer-to-peer (P2P) transaction of energy and continues it. The most significant aim of IoE is to gather and summon data from distinctive grid edge elements throughout the accessible framework to all other grid control contributors clearly and promptly.

5.3.2 Modern methods for computation

According to computational techniques growth, especially in data analytics, some trending ML and DL methods have been applied in various applications and businesses. The DL is being used for feature engineering and big data management (especially when it is real-time) where ML methods fail. DL also contains large advanced neural networks consisting of several layers, including processing units, activation functions, and enhancing training methods to learn functional patterns from a great dataset.

In the SG applications, according to current and combined new technologies assembled together for the ESN monitoring in a more accurate way, approved data analytics and business intelligence methods are applied. There has been appropriate usage of traditional and basic data mining tools in the industries until now. Their goal has been to achieve better results in the field of exact electricity demand estimation. These tools have also been applied for other goals such as energy creation forecasting patterns according to peer behavior in the ESN [26].

Among the mentioned methods in Fig. 5.3, the two methods, convolutional neural network (CNN) and recurrent neural network (RNN), are frequently applied in SGs' applications. For the GIS distribution data analysis and interpretation, the CNN method is suitable. Moreover, RNN is good for handling the sequential and time-series data efficiently. According to Fig. 5.4, which is showing the DL schematic in the SG application, considering SG as massive data analytics, load prediction, and load equalizing circumstances application, it would be useful and effective to employ DL algorithms with the goal of achieving more accurate results.

Discussing about IoT and the IoE, the IoT gateways are emerging the "data gathering, dispatch, and analysis" SGs' networks. For example, an IoT gateway device triggers the dataset to be routed across the IoT network with a two-way interaction structure (i.e., device-to-gateway and gateway-to-cloud).

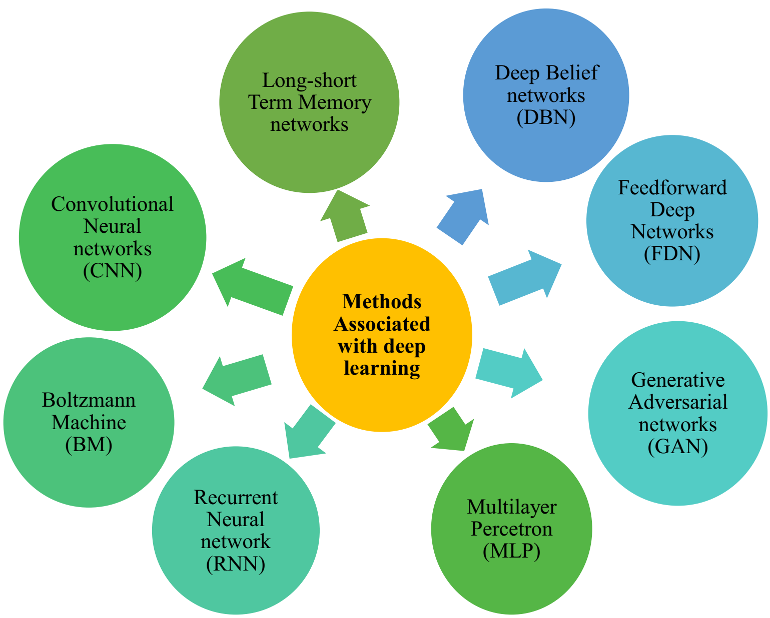

Figure 5.3 Applied deep learning methods.

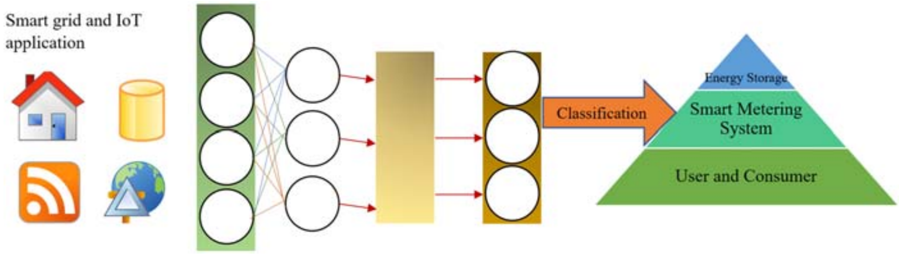

Figure 5.4 A deep learning schema for energy control and management use cases in SGs. *SGs*, Smart grids.

5.4 Internet of Things challenges in energy systems

Improving the electricity power networks needs allowing IoT to access that brings up some issues. Besides database and power sources, the IoT network must be addressed from the electricity business perspective. The reason is that IoT technologies create commercial chances in the electricity industry; however, it poses a risk in the implementation and control process, such as authenticity, surveillance, and identification process. These challenges are being discussed among experts as an important bottleneck in the irregular and ever-changing IoT regions.

In SGs' IoT, considering heterogeneous networks and systems, the network should give prominence to the resilience to support all data types, according to their service quality demands. Different IoT devices generate datasets without complying with any standard, so the data are often depicted in different compositions and configurations [27].

Reference architecture is one of the solutions to address these challenges that play a vital role in the building block representation. These architectures are defined as abstract architectures combined with knowledge and practice in a specific range of application domains. In fact, this incorporation contains development facilitating, order, interoperability, and software systems evolution. Another topic is developing solutions adaptability, which is able to be retained by reorganizing and innovating in design-based solutions conforming to reference architecture. Among the most used and reputable solutions, the trending open IoT platform is considered as a pioneer by being the reference architecture and IoT merger. This platform is designed by guidelines presentation and explanations of detailed automation with regard to required software and hardware [28].

In continue, all challenges categorized by their application are discussed with respect to SGs' experiences all around the world.

5.4.1 Internet of Things attacks

The security challenges and problems encircling the IoT, take place as a threat emerging consequence due to invalid entrances. Critical data flow in the IoT architecture (i.e., clinical health data, GIS data) and not efficient communication routes facilitate the interconnection of sensors/equipment through a wide range of protocols and standards [29].

Most of the IoT attacks are in the field of proof of concepts weaponization which exploits with destructive charges against popular weaknesses. Many vulnerabilities are left unknown because of differences in IoT systems performance or cost-benefit analysis challenges. As a matter of fact, the proper security controls on IoT devices are an expensive process but demand limited energy resources.

The most threatening IoT attacks are categorized in the following subsets:

- Malware: A destructive software hijacking the sensors' functionality of sensors and expanding in the IoT base. Its target is to gain operational intelligence, which can influence critical equipment connected to IoT devices such as smart meters to be exploited. With IoT devices integration in the SG, many malwares have the ability to damage both the clients and the grid supplier.
- Botnet: An infected device network that spreads across the world. It is controlled in the remote state by a master following the client-server framework.

In the conclusion of reviewing these attacks, there are other issues that come up with the Narrowband 5G approval and the IoT devices topology. A brief review of issues and IoT attacks are discussed below:

- Physical layer attacks on 5G: With the existence of several issues and attacks of this type, the physical channel is vulnerable, which is the path for the device's interconnection [30].
- Selectively jamming primary and secondary synchronization signal (PSS/SSS): Similar to the LTE standard, the 5G also consists of the PSS and the SSS which can be interrupted by a jammer transmitting fake signals [31].
- Sniffing and spoofing vulnerability of the physical broadcast channel (PBCH): The PBCH is utilized by the system information block messages, which cover information about the power thresholds. The information being carried is transmitting unencrypted, leaving it vulnerable to malicious activities [32].

5.5 Future research potentials

Current IoT systems have many advantages highlighted in previous sections for providing energy-efficient solutions in the energy sector. About IoT deployment in the energy domain, new solutions and trends are required to improve the IoT performance and overcome the associated challenges. In the following, we present the blockchain technology and green-IoT (G-IoT) as two approaches to tackle some of the challenges.

5.5.1 Blockchain for Internet of Things

Considering current IoT systems essentially rely on centralized cloud systems, a large number of IoT devices and machines need to be connected in most IoT applications, which is hard to synchronize. In addition, according to the centralized and server-client nature of IoT, all connected objects are easy to be hacked and compromised. In looking for a solution for these security concerns and privacy issues for users, blockchain will be a good choice.

Blockchain proposes a decentralized platform with no need for a third party's intervention that requires every IoT node to seek the same goal as others. In the form of a block, verified transactions are stored and linked to the previous ones in a way information can never be erased. Additionally, every single transaction history at every node can be recorded, and everyone has access to them. As a result, any blockchain member becomes aware of any changes in each block instantly. Also, with attention to the distributed nature of blockchain, a great number of IoT devices can be synchronized easily. A secure distributed database is provided by P2P networks, so decentralized and private-by-design IoT can guarantee the privacy in need.

In modern energy grids, processed and streaming data is commonly exchanged without limit within the network. Hence, consumers/operators have direct access to power consumption results data without any third-party presence. By simply trading energy between neighbors, a high level of energy costs can be in centralized grids. Another positive point is considered as an area monitoring statistic, which enables the energy flow to be controlled remotely by the power distribution. In this regard, IoT systems help with the equipment fault diagnosis and maintenance process within the SG by blockchain implementation [33].

Despite beneficial cloud and fog computing platforms, there are three obstacles to efficient blockchain technology employment in an IoT-based SG, including computational supply shortage, insufficient bandwidth, and energy retainment.

5.5.2 Green Internet of Things

IoT devices' energy consumption, particularly in large-scale technology deployment of a large scope, is a vital challenge in the coming years. A great quantity of power is necessary to run all of the connected devices to the Internet. A carbon-free and effective communication internet is required to solve these problems, which caused the G-IoT presence. The vital elements in this field are energy measurement characteristics during the life cycle, such as scheme, generation, deployment, and final exposure.

Different IoT technologies, including RFID tags are applications of the G-IoT cycle. For reducing the number of materials used in each RFID tag, the size of RFID tags should be reduced. Another example is green M2M communications, enabling power transmission adjustment to the least amount by deploying algorithmic and distributed computing techniques and getting help from more efficient communication protocols [34].

These are three practical ways for energy management in G-IoT. The first is to get the wireless sensor network nodes in the rest mode and perform just when it is necessary. Second, signal optimization methods, such as synthesis optimization or cooperative connection, are applicable for the nodes' energy consumption reduction. Third, efficient routing methods, such as clustering approaches or multipath routing methods, provide efficient explanations [35].

The modern sustainable power system introduces a more possible strategy for the future SG market share planning according to IoE modern trends. There are some issues with this process, for example, adaptability, connectivity, and most crucial, IoE functions trustworthy among households and consumers. The newly IoE decentralized concept for SG effective management and monitoring is most likely to become ever-present by 2030. The goal in this regard is the overall SG cost minimization, including the investment cost and the operational cost, due to CO_2 emissions restrictions and the operational limitations, Internet devices, and modern carbon-free facilities, which are inconvenient according to new power consumption patterns. While SG power efficiency increases, demand/supply control platforms improvements, and developed interplatforms matching (matter of software) will become possible [36].

5.6 Conclusion

In the new smart era, large-scale usage of IoT technologies in energy systems distributionally and useful energy consumption need integrated IoT structures. Hence, the socioeconomic-environmental, sociological, and economic energy systems' influences will be minimized by helping the energy grid sector change completely from a centralized and clustered supply chain to a decentralized, smart, and optimized IoT enabled system.

In this chapter, the main achievements are the mentioned challenges and pros versus cons discussions instructing a new approach for IoT technologies in SGs. The proposed structure comes with infrastructure, components, challenges, future structures, and applications.

In addition, the modern IoT-based grid management system's advantages were explained, including energy efficiency increase and RE integration. Distinct IoT system components, such as communication facilities and sensors, with attention to their role in the power grid, were also described. Temperature, speed, infrared, humidity, light, and proximity sensors, alongside computing facilities and information analytics platforms, were investigated in detail. Information analytics and data visualization methods were used for several smart functions in the power grids.

Moreover, some IoT application challenges, including object identification issues, big data systems administration, connectivity challenges, systems subsets coordination, safety and availability, IoT grid power requirements, standardization, and system design, were discussed. Trending solutions such as blockchain and G-IoT were also mentioned for these issues.

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