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A Comprehensive Survey on Smart Grid Integration Based on IoT

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Abstract:
Smart Grid (SG) and Internet of Things (IoT) advancements have accelerated recently. This articlepresents a survey of SG environments that use Internet of Things (IoT). In addition to reducing power consumption, combining these two technologies simplifies the monitoring and control of electronic devices. There is a lot of discussion about software solutions and network and data security. Interdisciplinary researchers will benefit from this work, which provides new perspectives and knowledge.
Keywords: Smart Grid (SG), Internet of Things (IoT)

I. INTRODUCTION

There has been a tremendous growth in digital power distribution. To keep up with rising demand, existing power grids are being upgraded to smart grids. Sensors, smart meters as well as other devices collect data that can be used to analyse and understand it.IoT in SGs should be thought about when it comes to issues like mobility and latency [1]. This is because IoT can have an impact on these issues. Energy consumption, distribution, transmission, and generation can all benefit from smart grids and the IoT[2]. SG monitoring and control are now possible thanks to the IoT.
IoT-enabled electronics include smart plugs, home gateways, and smart metres. Consumers can get up-to-the-second updates on their energy usage and costs [3], which helps them conserve energy. Energy demand and distribution can be predicted by the producer. As a result, both parties' benefit from the system. Smart grids and their data flow are used by millions of people. The ability to expand this system is critical [4]. When it comes to this, cloud computing is the best option. Architectures acting as event progressing for load predicting and cyclic are used to generate the data that these systems use. Smart Grid IoT components use the internet to communicate [5]. These systems wireless nodes are constrained by resource and spectrum scarcity. A fog-based construction and a programming model for the smart grid were proposed by Pan Wang et al[6]. A smart electric car prototype is also used to test the paper's performance [7].

II. RELATED WORK

A. Internet of Things

Digital controllers, metres, and sensors are used to connect various system elements and objects via the IoT. Monitoring and remote control are possible thanks to this interconnection. As long as there is an internet connection available, this system can generate and collect data [8]. The IoT and energy were combined to create the Internet of Energy (IoE) [9]. Network, environmental, software, side-channel, cryptanalysis, and physical attacks can be used against the Internet of Things, according to a report by the Pew Research Center. It is necessary to use APIs and

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other technologies in order to implement the Internet of Things (IoT). It is possible to explore the IoT's challenges and opportunities through the use of enabling technologies, improving connectivity models, and realising transformative potential.

Figure 1: Internet of Things (IoT)

B. Smart Grid

Construction as well as smart groundwork can benefit from the energy efficiency provided by smart grids. Both the grid and the building can exchange data and current flow making it more dynamic and extensible. [10]. In a SG, digital communication is integrated with the distribution of electricity. Smart buildings are the building blocks of SG. The cost and risk of putting IoT in buildings is going up, but the benefits far outweigh the costs [11]. A variety of new devices and technologies are being developed to help buildings use less energy while still performing as intended [12]. By integrating IoT into conventional structures, it is possible to increase environmental safety, sustainability, comfort, and efficiency. Customers have more control and say over their own energy consumption with smart grids. Businesses can also benefit from monitoring their power consumption [13]. To ensure a reliable power supply and give consumers a say in the grid's operations, smart grids can also self-repair [14].

Figure 2: Smart Grid Architecture

C. Architectures of Smart Grid centred on IoT

The IoT can be put to use in smart grids in order to facilitate information exchange between all grid components. The IoT is critical to the evolution of SGs and smart cities. The IoT enables energy efficiency. Smart meters' superior sensing and connectivity make them ideal for the Internet of Things. Energy and billing can be optimised by studying large-scale consumption patterns. Smart grid privacy and security were improved by [15]. It's difficult to put these systems in place [16]. In the end, it all comes down to safety and privacy. Data acquisition, equipment monitoring, control messages, and notification transmission are all important to securing these functions. Security considerations, such as confidentiality and integrity, should be taken into account [17].Attacks like message content disclosure and traffic analysis must be countered actively and passively. The use of firewalls and encryption is being considered [18]. Flocking models, warning systems, JADE, and cryptographic keys are just a few of the solutions being investigated by researchers [19]. There are also things like combining key encryption and Intrusion Detection, as well as real-time inaccurate data injection detection and message delay reduction under jamming conditions.

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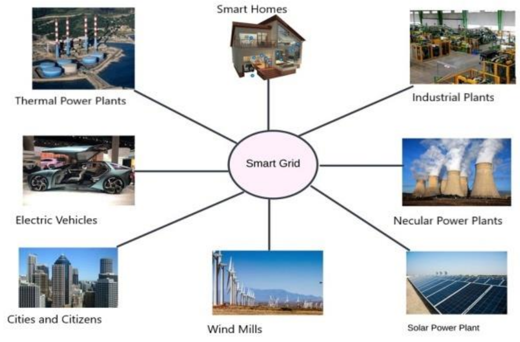
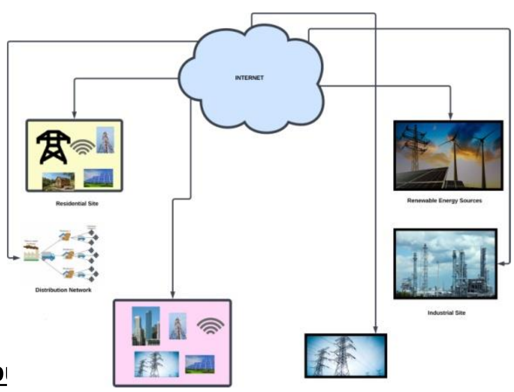


Figure 3: Smart Grid Architecture based on IoT [8]

III. APPLICATIONS

A. Smart Home

With IoT technology, the SG is making smart homes and devices, including smart Vs. home security systems, and washing machines and smart refrigerators (among others) [20]. Using IoT technology fire sensors, light control, and temperature quality monitoring as well as home security systems, smart freezers, smart TVs and automatic washer can all be implemented in Singapore[21][22]. In a smart home, sensors and actuators monitor and transmit data about their surroundings to the central control unit [23],[24]. Both control and monitor unit sallow users to control and monitor their electronic devices from anywhere at any time. Smart homes are considered as essential components of the SG because they enable agreeing communication between users and the grid, increase the level of service and integrated service capabilities, and effectively meet the customer potential needs. The use of smart home services is



essential to daily energy conservation. By switching on heaters and ACs before returning home, clients can quickly enjoy their favorite temperature [25]. In addition, users can save money on power by running energy intensive appliances like their washing machine at off-peak times. Surveillance data is also used by the control unit to identify questionable activities and inform users. The IoT is the sole technology that makes this possible [26]. One living area, three bedrooms that can sleep six to nine people, one kitchen, and one bathroom are all included in the system and test bed created by Viswanath. This system is an energy management system that uses dynamic pricing to keep track of how much energy is being used. As a result, peak-hour appliance use is avoided. Additionally, the authors created an Android app that allows users to access the system from a distance [27]. Using Reed Solomon Codes, found ways to improve smart home security by detecting and correcting flaws [28]. The sensor LAN protocol helps to operate multi-meter reading, smart gadgets, and data archive on energy utilization, load tracking and control operations, and user intercommunication with smart electronic devices are all examples of many applications in smart homes. Additional features provided by IoT technology include connecting a group of smart houses in the same neighborhood via a local area network (LAN) Thus; the findings of external surveillance cameras can be exchanged amongst smart homes in a smart community to detect any mishaps.

B. Advanced Metering Infrastructure

Historically, manual collection of data on power consumption at specific time intervals on-site was standard practise. As a result of this practise, there were bound to be inaccuracies in terms of accuracy and

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timeliness. The Internet of Things enables AMI and remote metre reading systems based on WSN, as well as [20] PLC and optical PLC (OPLC) via the use of public or private communication networks. The SG's primary function is to collect highly reliable real-time electricity consumption data, process it, and then provide real-time control, enumeration, and energy consumption review as a result of this data collection [25],.. AMI metres are enriched automated versions of conventional electric metres which are used outside the home. They are gaining popularity. Outside of measuring electricity utilization, AMI metres also transfer energy and pricing information from service companies to consumer assumptions, enabling bidirectional transmission via the Internet of Things. Customers can adjust their energy consumption in this manner in response to energy and pricing information acknowledged via AMI, allowing them to cost-effective as a result of the information. The timeliness, efficiency, and accuracy of data on power consumption all act a crucial role in the performance of this structure. Thus, Internet of Things technology may be able to assist users in saving money by adjusting their electricity consumption behaviour in response to a consumption analysis and [21]. Numerous European Commission directives require each member state to incorporate smart metering structures into their domestic regulation in order to empower customer to participate actively in the electric power and gas supply retails [23] . Consumers can participate actively in the electricity and gas supply markets through smart metering structures. In accordance with these European Commission directives, France began its AMI mount in March 2010 with the launch of the "Linky" smart metering pilot project [24]. The French grid operator, Electricite Reseau Distribution France (ERDF), is responsible for the distribution of 28 million smart metres (the Linky) across the country. 35 million Linky meters have been installed across France to date at a cost of approximately $.5 billion euros. According to current measures, the Linky smart metre installation will cost between 150 and 200 euros, or between 1-2 euros per month per household over a ten-year period. The estimated annual savings are around 50 euros on average, which is significantly less than the cost of installation. The European Commission's Joint Research Centre (JRC). [29]recently published information on benchmarking the deployment of smart metres in EU member states, with an emphasis on the electricity power sector. The information was intended for all member states of the European Union. This report analyses each EU member state's mount idea in detail and compares them with cross-country index and metrics in order to draw conclusions. Additionally, this report highlights instructions studied and best practises from EU member states that have successfully implemented smart metres (also referred to as AMI). Readers are directed to the report [30] for complete information.

C. SMART PATROL

Previously, power generation, transmission, and distribution were patrolled primarily by humans currently; robots do the majority of the work. However, because of a variety of human and natural circumstances, patrolling quality and quantity are not always as high as they should be. Additionally, it is frequently difficult for electricity personnel to monitor unattended substation equipment. By deploying Smart patrol, IoT technology could assist in resolving this

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issue [31]. The smart patrol is comprised of WSN and RFID tags which are connected along IoT technology to power substation. WSN and RFID tags are used to locate power equipment and enhance patrol quality, in addition to enhance the stability, efficiency, and reliability of a power system and its supply. Smart patrols can be used for a various purpose, including monitoring the environment, monitoring equipment, and determining the proper way to perform things.

D. TRANSMISSION TOWER PROTECTION

Transmission tower protection has been signed as an IoT-assisted solution to protect towers against physical damage caused by theft, natural disasters, faulty construction, and tree growth under the foundations [32]. Protecting transmission towers is an essential element of the process of distributing electricity. Thieves, vandals, and careless people are the most common culprits in the destruction of transmission towers. If there is a natural disaster or the consequences of global warming, transmission towers could fall. Transmission towers and high-voltage transmission lines are sometimes required to traverse significant infrastructure projects like highways and high-speed trains. When operating near high-voltage transmission towers, construction companies often don't realise the dangers they face, which can lead devastating catastrophes. As well as posing a significant risk to their crew, these large construction machines have the potential to damage transmission wires and towers. When a building contractor fails to notify the proper power transmission departments, transmission towers may be exposed to unnecessary danger since the power transmission personnel are unable to verify and monitor the entire transmission infrastructure. Transmission tower protection is now provided primarily by manual patrols by members of the security team. On the other hand, high-voltage transmission lines and towers, on the other hand, are difficult to patrol manually because of the limited workforce, the division of responsibilities, and the level of understanding of people [33]. Furthermore, certain transmission towers are difficult to access and keep control over because of their location. Consequently, it is impossible to ensure the quality of the patrols. A lack of surveillance and rising security concerns are a result of this. One to ten weeks is the typical patrol time. Despite the fact that transmission towers are equipped with cameras and infrared alarms to keep an eye out for theft and other potential damage, the precision and stability of these devices are still lacking [32]

E. Online monitoring of Power Transmission Lines

Online monitoring of power transmission lines is one of the online applications of the most important things in Singapore, especially in disaster prevention and mitigation. In recent years, natural disasters have highlighted the challenges associated with high power transmission lines in terms of safety, reliability, and stability [34]. Historically, monitoring high power transmission lines is done by hand. Real-time online monitoring of transmission lines is now possible through sensor flow sensors, air vibrations, conductor temperature, micrometeorology, and icing [32]. This new online transmission line monitoring system consists of two components: a monitoring system and a data collection system. In the first phase of the project, sensors are inserted into the power transmission lines between the transmission towers to monitor line condition.[35]. In the second part of the program, sensors are installed in the transmission towers to monitor the condition of the towers and their surroundings [32].

IV. IMPLEMENTATION CHALLENGES OF SGS BASED ON THE IOTS

A. Stability and Communication in a Network

As a result, smart grids redistribute excess power to areas in need. System performance has improved. It's useful in a wide range of other situations, too. It is imperative that systems communicate with one another [36]. The Internet of Things necessitates high-speed connectivity. The optimality of power redistribution is reduced when there is a lack of connectivity in the system. Smart grid components must be able to communicate quickly and reliably with each other. The lack of tools for real-time data analysis makes it difficult to collect large amounts of data [37]. Furthermore, data collection and the activation of event logging hardware are difficult during major disasters. As the system in smart cities is implemented, data flows in large quantities, necessitating the use of cloud storage [38].

B. Cost

Compared to wired networks, wireless networks can be set up more quickly and easily. Failures of the smart grid must be addressed immediately. Implementation costs may go up because of this factor [39]. However more expensive, SGs and the IoTs can save energy by redirecting as soon as power outage are detected. In many countries, smart metres are installed in real time. The major sources of electromagnetic interferences in SG applications are distribution of power and transmission [40]. As a result, the chips and equipment used in the module must be able to withstand both low and high temperatures, vibration, and electromagnetic fields.

C. Information Security

There are several security flaws in smart grids and IoT. In this article, we'll look at some of the most common problems that people have when using the internet. Securing SG scentered on the IoTs can be made easier with tools for deep packet inspection and information management. These strategies can address specific errors and protect data strands. Damage and failure can occur in a wired network[25]. Data packets can be intercepted and decrypted on wireless networks, despite the use of strong encryption techniques. Cybercriminals are drawn to smart environments with cameras and sensors. An organization's ability to protect itself and its data is essential. As a result of technologies such as block chain [41], this can be ensured. Poor system design can lead to bugs and flaws. Because of power constraints, complex security measures are difficult to integrate into IoT and smart metre systems. Smart metre control from afar, invasions of consumer privacy, tampering with energy transactions and grid instability, and the monitoring of data for fictitious purposes are just a few examples.

D. Data Blending

The practise of integrating data from multiple origins is known as data blending. SG systems with IoT-aided devices have restricted resources since the IoT devices themselves are resource constrained. Their battery life, computing power, bandwidth, and storage capacity are all severely limited. IoT dev would not work well if they had to transfer all of their collected data to a gateway, which would require a specific amount of power and data transfer capacity. There are numerous advantages to using data fusion technology, such as reducing energy and bandwidth consumption by filtering and aggregating only the most relevant data from multiple IoT sensors [42]. According to the authors, new topics like smart aggregation for identifying meaningful data are expected to have an impact on future IoT-assisted SG systems

E. Energy Acquisition

Any IoT-enabled smart grid (SG) gadgets and sensors run on electronic batteries. There are a lot of sensors, camcorder, and foundation nodes on transmission lines and convey ance towers that are powered by batteries in the majority of situations for the online monitoring of electricity distribution networks [42]. Singapore and other countries have substantial challenges in integrating IoT technology because of the power consumption of these devices. In order to do this, it is necessary to build effective power storage for the IoT gadgets, as well as power producing gadgets that combine energy harvesting with energy conversion[43],[43]. When properly cared for today's batteries have a useful life expectancy of over ten years[44] . But there are limits on how much electricity may be used by individual devices.

F. Huge data handling

The increased processing and archiving of huge amounts of data that will be generated as a result of the lot integration with SG will inevitably raise the load IoT communication networks. Examples of this type of data include energy usage, customer modern metering records, load demand, power line problems, and others. Data rates and high band width, like those supplied by LTE, can increase data transmission capacity, but at the risk of generating bottlenecks elsewhere. Utility companies need to develop systems that can store, manage, and interpret the data acquired more effectively and efficiently [43].

G. Resource Restrictions

In an IoT-assisted SG system, different of IoT gadgets and smart objects have resource restrictions, particularly those set up in large numbers. They are unable to perform complex security algorithms on a regular basis because of their finite processing and storage capabilities. Because of this constraint, traditional security methods (PKI and public key cryptography) become more difficult to implement [45].For this reason, when designing security solutions for SG-assisted IoT systems, it is must to ensure that the finite resources of IoT devices can handle the proposed security solution [46].

H. Scalability

Many IoT gadgets and smart devices reequipped over vast sectors that can include only a few cities in the country for the IoT-assisted SG systems. Because of this, it is extremely difficult to scale the system.

I. Congestion

Packet loss and latency, two of the most important performance indicators for SG, can be caused by congestion, Congestion can cause the control center to miss, or delay an input from a NAN gateway, which can affect the center's ability to make critical decisions, resulting in decreased performance of a failure to meet the needs of the s. Due to congestion and memory saturation, it is possible that one or more messages from enormous number of IoT gadgets will be dropped by the HAN gateway at the same time. After the HAN gateway's acknowledgement interval has expired, IoT devices are forced to retransmit packets to HAN, resulting in longer delays. Because some smart grid (SG) applications are time-dependent, it is critical to keep transmission delays to a minimum in IoT-assisted 5G systems [47]. It is necessary for many SG-assisted IoT systems to receive several messages from various IoT devices at the same time, but this must be done without casing substantial delays or packet loss. In order to ensure that the total messages from diverse IoT gadgets to everyone HAN gateway is maintained at a minimum, careful network architecture and the right number of nodes and gateways are required [48]

J. Privacy

It is feasible that s meters and other home equipment will provide information about consumers' routines, even if they are at home or on vacation, and whether they are consuming electricity[49]. Although this information which isused for marketing purposes, it can also be used for criminal activities such as burglary if it gets into the wrong hands. Utilities must ensure that such personal customer data is not gathered without the user's agreement and is used exclusively for the purple for which it was collected [50]. To ensure privacy and security, [51]introduced separate ug access point to data-safe SG programs supported by IoT. Under this construction, consumers have full refined gain from users' data, while distributors and energy resources get only integrated mathematical data and he or she only has strong access to consumer data. In [40]. We talk about more privacy risks for SG-assisted IoT systems, as well as other privacy issues.

K. Authentication and Authorization

Before a smart meter may be used to bill a customer, the energy provider must validate it. The identification of the IoT gadgets in SG is also checked in pursuance to prevent illegal system use. Validate users and devices are the only ones who should have access to the appropriate credentials to accomplish tasks and have access to the relevant resources. For example, only a field agent may configure a smart meter, and they must be authorized and granted the proper privileges to do so [45].

L. Communication interoperability

Networks that bring together a wide range of power generation sources and energy distribution networks are called "networks." A non-physical communication medium is required for each component of these systems. This includes the makers of the types of devices that are utilized to communicate Communication design for IoT-added Smart Grid systems must allow for the coexistence of many communication technologies and standards. A communication architecture that follows these lines can be found in [52], [53], and [54]. For example, Bluetooth or Ultra-wideband (UWB) may be used to connect smart meters to their end devices. BothWi-Fi and ZigBee are two technologies that can be consumed to link smartmeters in a home automation network (HAN). It is possible to link smart meters to the central system usingwirelessmobile technology (such as 4GG, UMTS, and GPRS). Anintegrated need for smart metersunderscores the importance of collaborating in building communications smart metering devices and systems.

V. CONCLUSION

A wide range of hardware and software solutions for the IoT and smart grid are being discussed in detail. Discussed are smart cities and home management. There are many issues that need to be addressed, like privacy and security, and other stability of communications, and costs, in the system. The Smart Grid (SG) and Internet of Things (IoT) systems are examined. There is an explanation of the relevant systems. There is an increase in the efficiency of power utilisation, distribution, transmission, and generation.

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Installation of power equipment can be monitored, home consumption can be adjusted, electric vehicles can be stored and charged, power supply and demand can be managed, equipment maintenance can be performed, and malfunctions can be detected using the system. There will be more work on issues such as energy accumulation, intercommunication, handling, congestion large amounts of data, standardisation, safe-guard management, id spoofing, scalingand many more.

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