International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 06 Issue: 07 | July - 2022 Impact Factor: 7.185 ISSN: 2582-3930

A Comprehensive Study on IOT Based Smart Grid Technology

S.S.V Kanakaraju[1], Y Manikanta[2], K Sai Ram[3], Teki Vamsee Krishna[4]
[1,2,3,4] *Department of Electrical & Electronics Engineering,*
Sasi Institute of Technology & Engineering, Tadepalligudem, West Godavari

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Abstract- Small items and objects have been integrated, networked, and even linked to the Internet, as part of the Internet of Things, to be able to provide improved services for supervision and control. Along with intelligent embedded devices, the Capability to make intelligent decisions, will improve the efficiency of services in a variety of fields, including the smart grid. A smart grid is an electrical power system in which all of the electrical power system's operations are connected via a smart communication system. It comprises the primary energy generating sources, renewable energy resources, smart metres, and smart appliances. It comprises the primary energy generating sources, renewable energy resources, smart metres, and smart appliances. It makes use of communication technologies to increase fault detection, cut down on power waste, and boost the grid's self-healing abilities. Smart grids make extensive use of a variety of equipment for grid monitoring, analysis, and control, which are installed in huge numbers at power plants, distribution centres, and customers' homes. As a result, smart grids need to be connected, automated, and trackable. The Internet of Things (IoT) is used to do this. By incorporating Internet of Things devices (such as smart metres, sensors, and actuators), The Internet of Things assists smart grids by supplying connectivity, automation, and tracking for such gadgets. Throughout the energy generation, transmission, distribution, and consumption processes, systems assist with a variety of network activities. We present a detailed overview of smart grid Internet of Things systems in this study. The open concerns, difficulties, and future research prospects for Internet of Things of smart grid systems are also highlighted in this study.

Keywords- Smart Grid, IOT, Smart meters, IOT Architectures.

1. INTRODUCTION

The Internet of Things (IoT), made possible by the last advances in wireless, sensor, both embedded computing technology, is a fresh perspective aimed at providing enhanced, monitoring and control services that are effective. The Internet of things(Internet of Things) is a transdisciplinary infrastructure that will connect a large number of our everyday devices and things. The Internet of Things (IoT) opens up completely new world services, as well as a variety of applications increasing the efficiency of current ones.

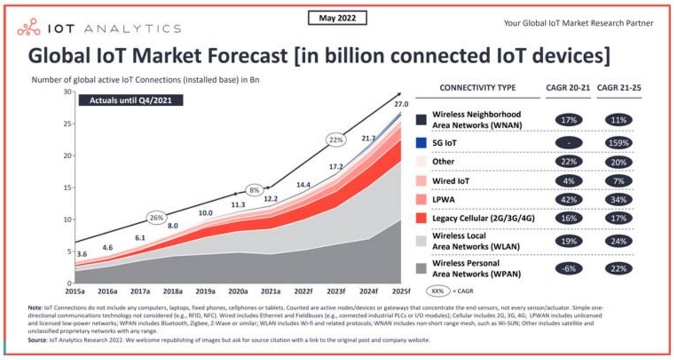

Fig 1: The estimated number of IoT devices across various industries, according to Gartner

Computers, laptops, landline phones, smartphones, and tablets are not included in the Internet of Things. Not every sensor/actuator is counted; only active nodes/devices or gateways that focus end-sensors are counted. Simple one-way communication technology is not taken into account (e.g,RFID,NFC). Ethernet and fieldbuses (e.g., connected industrial PLCs or I/O modules) are examples of wired technologies; cellular technologies include 2G, 3G, and 4G. WPAN covers Bluetooth, Zigbee, Z-wave, and similar protocols; WLAN contains Wi-fi and related protocols; WNAN includes non-short range mesh, such as Wi-SUN; and other includes satellite and unclassified proprietary networks of any range.

According to our latest State of IoT—Spring 2022 study, issued in May 2022, the chip scarcity continues to hinder the Internet of Things (IoT) industry recovery. In 2021, the number of worldwide IoT connections increased by 8% to 12.2 billion active endpoints, a far slower rate of increase than in prior years.

Despite high demand for IoT solutions and favourable attitude in the IoT community and most IoT end markets, IoT Analytics believes the chip scarcity will have a long-term impact on the number of connected IoT devices to last until at least 2023. The ongoing COVID-19 epidemic, as well as general supply chain interruptions, are further obstacles for IoT industries. The Internet of Things industry is predicted to expand 18 percent to 14.4 billion active connections by 2022. As supply limitations relax and expansion increases, it is predicted that there will be around 27 billion linked IoT devices by 2025.

The actuals for IoT devices in 2021 and the current prediction for 2025 are both lower than originally projected. (For 2021, the prior expectation was 12.3 billion connected IoT

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devices; for 2025, the previous forecast was 27.1 billion linked IoT devices.)

Here's how IoT connections changed in 2021, where we are in 2022, and where we could be heading beyond 2022:

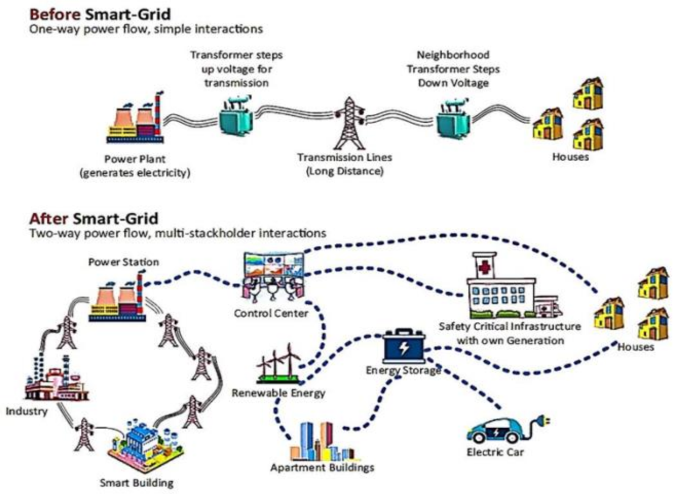

Fig .2: Environment of the smart-grid inside the national power system

2. CONTRIBUTIONS OF THIS SURVEY ARTICLES

We include all of the outstanding topics, obstacles, and future research prospects for IoT of smart grid systems in this study. The following is a summary of the survey's contributions:

- A taxonomic examination of the uses of IoT-assisted SG systems;
- A study of the interface of the Internet of Things and smart grids, or IoT-enabled smart grids.
- A thorough examination of existing IoT designs for SG systems;
- An in-depth look at the current security needs for IoT systems, smart grids, and IoT-enabled smart grids.
- A thorough examination of present and upcoming smart grid vulnerabilities, threats, adversaries, and security trends;
- A discussion of big data analytics and cloud in the context of SG systems in the Internet of Things;
- A description of the cyber kill-chain attack process, which is used to initiate assaults against vital infrastructure.
- A look at IoT and non-IoT communication technologies, as well as the threats they pose in smart cities.
- A look at IoT and non-IoT communication technologies in smart grids, as well as the threats they pose.
- A discussion of the open concerns, difficulties, and future research paths in IoT-enabled smart grid cybersecurity needs.

3. TECHNICAL CHALLENGES OF SMART GRID

1. Inadequacies in the network infrastructure

One of the most common significant obstacles to smart-grid network development. Rather of emphasising the individual elements of the generating the production process, and the dynamic networks that make up several pieces of a "smart" systems for distributing benefit from a more holistic approach. The objective of allowing existing grids to meet future clean energy and distributed generating demands may pose quite a few obstacles in terms of network design, construction, operation, and maintenance. Along with concentrating on smart grids, current Other difficulties with the grid's infrastructure need to be resolved. In many nations, for instance, many electrical portions are unequal linked to the national grid in order to best evacuate big wind farms or solar parks that would otherwise necessitate the installation of the complete infrastructure.

2. Cyber Security

In the case of a serious breakdown of a major power system component, smart-grid security is essential for ensuring a stable and reliable power system operation. A significant blackout might occur due to a lack of sufficient "security measures," which could lead to a cascade failure. Smart-grid security challenges must be addressed with high priority in order to secure this important power system infrastructure and to maintain a stable and uninterrupted power supply to end-users. More crucially, because millions of electronic devices are networked across vital power facilities Through networks for communications (i.e., solutions based on IOT technology), cyber security has a direct influence on the dependability of such a vast infrastructure.

It is predicted that by addressing issues such as security needs network weaknesses, defences against attacks, and secure communication designs in the context of the smart grid, the entire system's safety, security, and dependability would be greatly improved. In this scenario, the cyber security subject must cover both incidental and planned attacks on the electric infrastructure, like from displeased workers, terrorism, business espionage The appropriate mechanism ought to implemented at both software and hardware levels in order to achieve this goal. Furthermore, because of the the significance of this area, cyber security risk-reduction techniques must be implemented both locally and on a larger scale, as well as the encouraging the greatest technologies' transfer practises, Norms and optional guidelines, as well as study in the fields of practical cryptography and microgrid Internet security.

3. Storage Concerns

Grid stability is especially important when using renewable energy sources. As a result, it's evident that energy storage systems will become more significant in the near future, because storage units take in excess electricity that isn't needed at the moment and then put it back into the grid when demand rises. This is also highlighted in several industry studies. According to Deutsche Bank, the German market for electrical storage devices is predicted to more than quadruple between 2012 and 2025, and by 2040, at the very least, 40 terawatt-hours (TWh) of power would need to be stored on a monthly basis, often over many months. It's worth noting that the 40TWh number is 1,000 times more than the storage capacity of Germany's pumped-storage plants today. Over the next 20 years, Germany alone will need to invest around 30 billion euros. Various technologies are used to manufacture these storage components. For example, surplus electricity from wind farms may be used to power hydrogen storage devices (which use electrolysis to create energy-rich hydrogen gas from water). A well-known energy storage system is the battery. Because they combine large storage capacity with rapid charge and discharge speeds, lithium-ion cells are presently the best batteries for securing distribution grids. If the grid experiences load volatility, such batteries can take in or out electricity in milliseconds, effectively balancing voltage and frequency changes. Compressed air is another option for storing energy. Pumping air into hollow chambers, such as salt domes, and compressing it to pressures of up to 100 bar is one method. A gas turbine is then powered by the compressed air.

4. Management of Data

Smart-grids provide effective connecting to and using all manufacturing methods, as well as automated and real-time network administration. This enables operators to better track use, increase dependability, and enhance existing services, resulting in cost reductions and energy efficiency both energy suppliers and customers. Due to the installation of smart metres and different sensors on the network, as well as the expansion of customer facilities, this idea results in a significant rise the amount of data that has to be processed. With the widespread implementation of the Smart-Grid idea, such a data flood problem becomes even more virulent. To demonstrate the severity of the situation, we may use a readily accessible smart metre that broadcasts 15 minute energy usage by the consumer, resulting in 96 million readings each day as opposed to a standard system's one metre reading every month. This demands the use of a smart grid., in addition to effective energy management, examine the handling of data strategy in order to meet the demands of high velocity, massive storage, and sophisticated data analytics.

Because of the nature, dispersion, and real-time limits of specific demands, smart-grids data necessitates extensive analytics. Big data approaches, in other words, are increasingly important for improved and effective data management in this type of application. Producing and running a smart grid will allow accomplish they items have never been able to do before, like greater understanding of consumer behaviour, downtime tracking, conservation, consumption, and demand and power outages, and so on, by properly evaluating this data.

5. Communication Issues

Although many recently created information and communication technologies have had a significant impact on other economic sectors, electric systems have mostly remained unchanged for decades. However, communication technologies that enable electric generating and distribution systems to integrate huge quantities of dispersed energy resources into the grid and deal with the intermittent nature of renewable energy have been in high demand in recent years. Wireless communication, for example, is critical to achieving all of the smart-aforementioned grid's objectives. More precisely, advances in wireless communication technology have enabled the implementation of a smart-grid with the capacity to transmit different essential information from and to power customers, resulting in extremely high utility efficiency. Although the wireless idea is not required (smart-grid infrastructure can alternatively use conventional links), wireless communications infrastructure often provides a larger degree of freedom for data collecting, distribution, and processing than traditional communication infrastructure. For example, recent advancements in Wireless Sensor Networks (WSNs) have enabled the realisation of integrated electric grid monitoring systems. WSNs can also be used for other purposes.

6. Stability Concerns

In the smart-grid setting, the involvement of various energy sources raises worries about stability. This is due to the fact that the majority of producers rely on renewable energy sources to satisfy daily load demands. Many technological issues have arisen as a result of the differences between renewable energy-based technologies and conventional power plants, including operational stability concerns that necessitate real-time coordinated control systems for both conventional and renewable energy sources. Lower voltage stability due to lower power-sharing support, low-frequency power oscillations, lower angular stability due to lower overall system inertia, worsening of the smart-grid transient profile during micro-grid islanding, and inability to serve as system reserve are some of the most common stability issues

7. Energy Management and Electric Vehicle

The energy management method in most smart grids is based on price. Dynamic pricing is a concept with a lot of potential in the field of energy because it might be thought of as a tool for demand-side management allows for changing costs at various levels of demand while also assisting Peak loads are shifted to off-peak hours by manufacturers to postpone investment choices.

The units the smart grid setting are divided the third categories: Items that are price-elastic and are affected by pricing. Controlled loads, regulated renewable energy sources (such as biomass power plants) (electric heaters, for example), and other units fall under this category. Units that are price inelastic and cannot be modified by pricing. Uncontrolled Heavy and unpredictable renewable energy generating energy sources like wind and solar power plants are included in this category. Prices have an impact on electric cars, but they also have limitations on energy and mobility, as well as storage dynamics. These characteristics are favoured in order to significantly bring about the stabilisation of variable renewable energy.

4. INFORMATION PROCESSING IN SMART GRID

The smart grid's main idea is to employ new using communication technology to gather data from the electrical grid, then extract the data needed to boost the effectiveness of the grid and dependability. Customers' energy use is often gathered by smart metres and communicated to utility providers as part of the collected data. The extract information must be acted upon by various stakeholders in the smart grid, including utility providers and customers.

1-Utility Supplier: Utility suppliers keep an eye on the grid's health, forecast customer demand, estimate renewable energy sources, and create the requisite generating energy with traditional power plants. The dynamic and real-time pricing must be updated by the providers in accordance with demand and supply. Aside from that providers handle and accounting billing for clients depending on how they behave pricing and power use with time. systems for managing information (IMS) and other utility provider Private clouds can be used to host services.

2-Customers: Among the clients are smart homes, buildings, industries, and cities, among others. The price of energy is dynamic in the smart grid, and consumers must control the demand properly to adapt the ability system dynamism and status pricing in order to reduce their cost. A home energy management system's decisions include scheduling household appliances, redistributing the load at peak hours, and sharing energy with other clients (for example, when a single consumer excess renewable energy) (HEMS). A household automation (HAS) can include user choices, HEMS, and varying prices to reduce power bills while retaining home appliance functionality.

3-Cloud Service; Customers use cloud service providers for management systems such as HEMS (home energy management system), HAS (home energy management system), and Demand Management system in a cloud-centric architecture (DMS). Customers may also meet some of their own demand with renewable energy sources like solar panels in a smart house. As a result, based on historical and weather-related data, smarter supply forecasting techniques may develop tailored and specialised to models forecast potential for renewable energy. The Figure:3 the link between three smart grid entities: consumers, utility Supply chain partners, cloud service providers, and information exchange between them, is depicted in the diagram. This design is significantly reliant on third-party cloud computing and information management services.

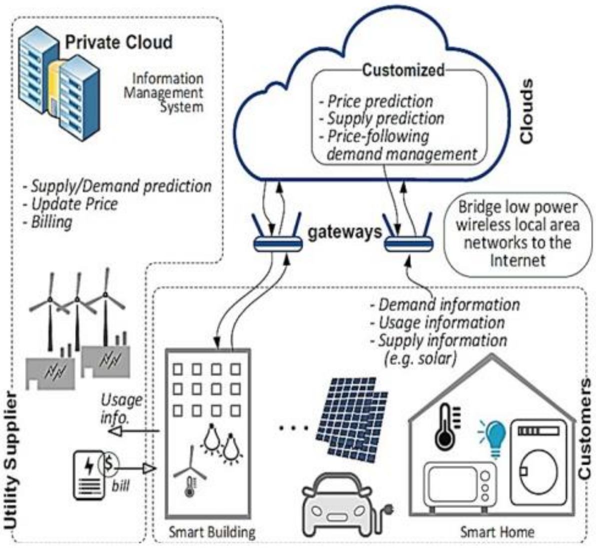

Fig3: Customers, utility providers, and cloud service providers are the three parties involved in the smart grid.

5. INTERNET OF THINGS AND SMART GRID

As shown in Fig. 2, the SG totally transforms the production, transmission, distribution, and consumption of energy in four sub-systems. Home Area Network (HAN), Neighbourhood Area Network (NAN), and Wide Area Network (WAN) are the three different types of networks that make it up (WAN).

1-HAN is the first layer; it controls the on-demand power needs of users and includes smart gadgets, household appliances, electric cars, and renewable energy sources (such as solar panels). HAN links electrical appliances with smart metres and is used in residential units, industrial facilities, and commercial buildings.

2-NAN The second layer of an SG is made up of smart metres from several HANs. NAN enables power distribution systems to communicate with distribution substations and field electrical equipment. It gathers and sends service and metering data from several HANs to data collectors that connect NANs to a WAN.

3-WAN It acts as a communication backbone for utility control, distributed grid equipment, NANs, and network gateways centres, and substations and is the third layer of an SG. It makes it easier for power transmission networks, bulk generating systems, renewable energy sources, and control centres to communicate. Figure 4: The architecture of the smart grid (SG) comprises power systems, power flow, and information flow. The SG is made up of three different types of networks (a wide area network (WAN), a neighbourhood area network (NAN), and a home area network) as well as four core subsystems (power production, transmission, distribution, and use) (HAN). While information travels through networks, electricity travels through subsystems.

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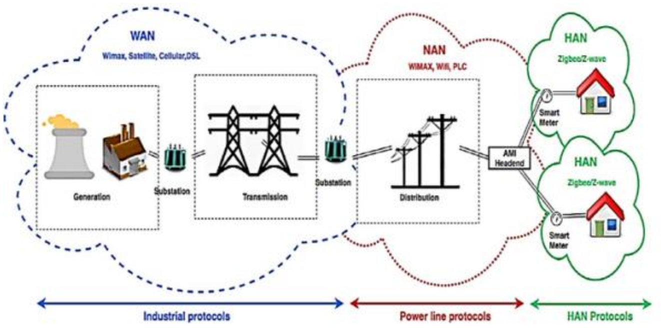


Fig 4: Illustration of the smart grid architecture

6. ARCHITECUTURES FOR IOT SG SYSTEMS

1) Perception Layer

This layer makes it possible to achieve the major goals of sensing and collecting data in IoT-assisted SG systems utilising a range of sensors. In order to gather data in an SG, it is made up of many types of IoT sensing devices, such as RFID tags, cameras, WSN, GPS, and M2M devices. A perception control sub-layer and a communication extension sub-layer are the two sub-layers.

2) Network Layer

The converged network generated by several communications networks and the Internet makes up the network layer. Because of its established technology, the network layer has gained widespread acceptance. Its job is to translate the data acquired by IoT devices in the perception layer into communications protocols. It then sends the mapped data to the application layer through the appropriate telecommunication network.

3) Application Layer

The application layer combines IoT technology with industry experience to enable a wide range of IoT SG applications to be realised. Its job is to process data from the network layer and monitor and debug IoT devices and the SG environment in real time using that data. It shows how IoT-assisted SG systems may be used in a variety of ways in Figure 3. It consists of application infrastructure/middleware, as well as content, web services, and directory services-related servers.

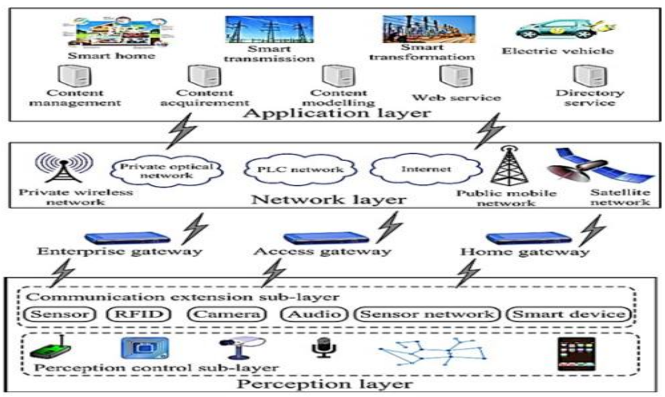
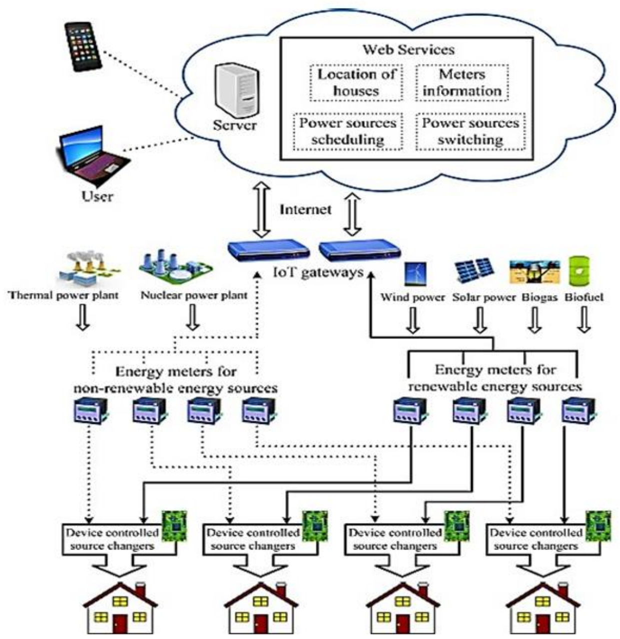


Fig 5: A perception layer, a network layer, and an application layer make up the three layers of the IOT SG system's architecture.

7. WEB ENABLED SMART METER ARCHITECTURES

A web of things-based architecture for IoT SG systems. The web of things consists of a collection of online services that are delivered on top of IoT devices, with the web browser serving as an interface to these web services. Non-renewable and renewable energy sources are the two categories of energy sources. Thermal power facilities (which burn coal or oil and emit carbon dioxide into the atmosphere) and nuclear power plants are examples of non-renewable energy sources

Individual digital energy metres are connected to the energy sources in this architecture. These computerised energy metres are in charge of gathering information on household energy consumption. Meter readings from nonrenewable and renewable energy metres are collected by distinct IoT gateways that interface with these metres on a regular basis. The server receives frequent updates from IoT gateways, and the server adds web services to these Internet of Things devices. The locations of households connected via the SG, as well as metre information, are among the web services available. Furthermore, online services are offered for each home to schedule power sources and control energy sources by remotely switching source controllers via IoT devices. A user can access these services simply connecting to the Internet via any device. Each household's energy sources are changed utilising source changers that are managed by Internet of Things (IoT) devices; these IoT devices change the energy sources when the server gets commands from the user.



Fid 6: Web-enabled SG architecture built on top of IoT devices with web services.

8. CONCLUSION

The Smart grid is the grid of the future that addresses issues with existing power grids such unidirectional information and energy flow, energy wastage, rising energy consumption, dependability, and security. The Internet of Things (IoT) technology offers connection at all times and in all places. It contributes to smart grid by offering smart devices or IoT devices (such as sensors, actuators, and smart metres) for the monitoring, analysis, and control of the grid, as well as connection, automation, and tracking of such equipment. This brings about the IoT smart grid system, which supports and enhances a number of network operations at power generation, transmission, distribution, and consumption. In addition, we reviewed recent developments in cyber attacks that target the weak spots in smart grids and IoT architecture in general.

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