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A BRIEF STUDY ON SMART GRID

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ABSTRACT

With the many manifestations of climate change and the ever-increasing need for energy, energy sustainability and environmental preservation have become global issues. Electricity consumption increases as cities and countries become more technologically sophisticated, reaching levels that may be unmanageable if left unchecked. The Smart Grid is a solution to the transition to more environmentally friendly technologies like distributed generation and microgrids. It is critical that the general public be aware of the issue, as well as prospective researchers and policymakers. This article provides an overview of the Smart Grid, including its basic characteristics, functions, and features. It explains the fundamentals of Smart Grid technology and how they connect to other technologies, as well as research efforts, difficulties, and concerns. It shows how these technologies created the current electrical grid and how it has continued to develop and enhance its role in better matching energy demand and supply. Smart Grid deployment and practices are also revealed in different places. Smart Grid efforts in different countries are aided by concrete energy legislation. Surprisingly, Smart Grid practices in various areas don't seem to suggest rivalry, but rather a cross-regional community with comparable goals and lessons to learn.

KEYWORDS: *Communication, Control, Network, Security, Smart Grid.*

1. INTRODUCTION

Smart Grids aren't something that just happened. They arose from a desire to upgrade the electrical system, make it more environmentally friendly, and enhance power distribution. Utility companies may utilize existing infrastructure instead of building new power plants and substations since Smart Grids are more autonomous and improve the efficacy and efficiency of electricity supply. Smart Grids enable renewable energy resources to be securely connected into the grid to augment the power supply with electricity generated and stored by consumers[1]–[3].

The goal of this article is to provide a high-level overview of the Smart Grid, including its features, functions, and characteristics. Its goal is to show how Smart System technologies have influenced today's energy grid. It looks at policies, pilots, and projects from around the world to see how far Smart Grid technology has advanced. It will also look for research activity, trends, problems, and opportunities. The more people who are aware of the Smart Grid, the better they will comprehend its importance, and the more willing they will be to make any necessary sacrifices. More information on Smart Grid achievements and problems promotes active involvement in efforts to enhance their capabilities and mitigate their drawbacks[4].

1.1 Smart grid:

A grid is a network of electrical wires that transmit energy to specific locations; smart denotes intelligence, neatness, trimness, style, or automation. One may get a sense of what the Smart Grid is like in certain ways. The term "smart grid" has no universally agreed-upon definition. It can be explained in both simple and complex ways. It was once merely a dream and a concept, but it is now one of the most widely discussed topics in modern electrical systems. Simply stated, a Smart Grid is a network that is aware of its surroundings. Electric electricity can only be transmitted or distributed via the conventional grid. This contemporary grid is capable of storing information, communicating with one another, and making choices. The Smart Grid replaces today's grid with one that is more cooperative, responsive, and organic[5]–[8].

1.2 Infrastructure:

A Smart Grid system's infrastructure and design are always in relation to predetermined goals and capabilities. The grid's resilience, self-healing capabilities, and integrability may all be improved by implementing a Smart Grid. The National Institute of Standards and Technology (NIST) has developed a conceptual model to aid in the design, specification, documentation, and organization of the Smart Grid's linked networks and equipment. Smart Grid actors and applications are divided into seven domains (with subdomains) by NIST. Furthermore, it classifies as actors devices (such as smart meters and solar energy generators), systems (such as control systems), programs, and stakeholders that make decisions and exchange information required for performing applications; applications are defined as tasks carried out by one or more actors within a domain (such as home automation, solar energy generation and energy storage and energy management). Actors with comparable goals are found in the same domain.

1.3 Smart Grid functionalities:

The Smart Grid proposes solutions and responses to the problem of insufficient electricity supply. The Energy Independence and Security Act (EISA) of 2007 lays the groundwork for grid modernisation. The following features of the Smart Grid are listed in the section:

1.4 Reliability, Security, and Efficiency of Grid:

Any power system needs a steady supply of electricity. It hinders the grid's ability to provide the services required by end users. Smart Grids provide self-healing and improved fault detection. It is becoming more difficult to analyze grid reliability as grids grow in size and complexity, but new analytical methods developed through research efforts have continued to strengthen the reliability foundation for modern networks. Bayesian networks may be used to predict grid service dependability using a data mining technique to identify grid system structure from raw historical system data. The effectiveness of hybrid generating is aided by remote monitoring and automated Smart Grid control for instable distribution[9]. The information network in Smart Grids allows for many features, and while it is vulnerable to attacks, it has been countered by promising solutions such as an intrusion detection system (IDS) or a wavelet-based steganographic technique that randomly hides household sensitive information inside normal readings.

1.4 Deployment as well asIntegration of Distributed Resources and Generation:

Small sources of power known as distributed energy resources (DER) can assist in meeting regular power demand. The transition to Smart Grids is aided by DER such as storage and renewable energy. Renewable energy sources like distributed generators may assist alleviate the challenges of diminishing fossil fuel supplies and rising consumer demand. Thermal generating and electric cars may be included in distributed generation, which includes wind turbines, solar panels, and battery storage systems. However, combining these sources would necessitate the handling and processing of massive amounts of data.

1.5 Demand response and demand-side resources:

Demand response is defined as "changes in electric usage by demand-side resources from their normal consumption patterns in response to changes in the price of electricity over time, or to incentive payments designed to induce lower electricity use at times of high wholesale market prices or when system reliability is jeopardized," according to the Federal Energy Regulatory Commission. Consumers may participate in grid operations by reducing or shifting their energy consumption during peak times in exchange for financial incentives. One of the goals of the United States Department of Energy is to develop grid modernization technologies and techniques for demand response. Environmental, economic, and reliability concerns have prompted increased investment in demand-side resources, such as energy efficiency and load control programs.

1.6 Technologies:

This section explains Smart Grid technology and research, as well as where they are focused. It's difficult to cover everything due to the volume of articles accessible. This section, in general, provides an overview of what is being accomplished. In the preceding section on Smart Grid features, we highlighted some interesting research:

1.7 Control and communication:

Clean energy grid connected control methods and techniques are being used in the area of control for Smart Grids. Power electronics-based control, multi-agent system-based control, advanced fault management control, and virtual power plant (VPP) control technologies are all examples of these techniques. VPPs are systems made up of tiny dispersed generating units that come together to create a single virtual generating unit. Individual management of these units is possible additional big power plants can now be linked into the grid system utilizing hundreds of tiny energy conversion units thanks to advancements in power electronics and contemporary inverter management techniques (ECS). These conversion systems may run independently, linked to the grid, or separated from the grid. Small and medium power conversion topologies, as well as their control (mostly for PV systems), are available, and wind turbine design and control have been established[10].

1.8 Sensing and measurement:

Sensors are vital components of the Smart Grid. These small nodes act as detection stations for equipment and energy sources, allowing for remote monitoring. Synchrophasors, also known as phasor measurement units (PMUs), are high-speed sensors that give synchronized measurements of real-time voltage and current phasors. Advanced power systems monitoring, protection, and control applications rely on phasor measurements. PMUs record grid conditions with great accuracy and are 100 times faster than Supervisory Control and Data Acquisition (SCADA). Resilient communication for Smart Grid ubiquitous sensor network is another study involving sensors. In the Smart Grid, secure and dependable surveillance is provided by cognitive radio sensor networks. Cognitive radio sensor networks: smart communication for Smart Grids—a case study of Pakistan, and Quality-of-service differentiation in single-path and multi-path routing for wireless sensor network-based Smart Grid applications.

1.9 EVs, PHEVs and V2G:

EVs and V2G have many advantages. V2G is a system that allows electric cars, plug-in hybrid electric vehicles, and fuel cell electric vehicles to connect with the power grid to provide peak power, spinning reserve, renewable energy storage, and backup. V2G scheduling may significantly reduce the peaks and valleys in power demand profiles. The V2G idea has the potential to enhance the grid's efficiency, stability, and dependability. The cost of owning an electric vehicle is approximately half, while EVs have a minimal effect on the network in terms of distribution system losses and voltage control. The V2G capacity for synchronized charging and discharging of the EV fleet in a distribution feeder may be enhanced by real-time communication, smart metering, and home area networks (HANs). A case study in Portugal demonstrates that EV smart charging and PV production characteristics are quite similar. Charging is a critical component of V2G technology and work on charging and discharging has been active, with a large number of papers and conferences.

1.10 Security:

Smart Grid security is an outgrowth of Smart Grids' sophisticated networks, which are made up of millions of interconnected devices and organizations. Smart meters, intelligent devices in electricity supply and demand, components in insecure physical locations, outdated equipment that may be incompatible with current devices, device-to-device communication, unorganized communication among teams involved, IP-based components that are vulnerable to attacks, and the fact that there are many stakeholders are the most common vulnerabilities in Smart Grids. The International Electro technical Commission (IEC), the IEEE Power & Energy Society (PES), the National Institute of Standards and Technology (NIST), and the National Standard of the

People's Republic of China Smart Grid all contribute to the development of Smart Grid security standards. The need for a framework for evaluating Smart Grid security is critical. ChakibBekara studied the security problems and challenges faced by IoT-based Smart Grids and identified the most important security services to consider. The Internet of Things (IoT) is the next stage in the development of the Internet today, in which actual things are endowed with computing and communication capabilities. The feasibility and efficacy of a physical security layer built using a conceptual layering model are shown in preliminary simulation results from a research on cross-layer security framework.

1.11 Integration of Renewable:

While numerous renewable energy studies have been performed to investigate additional sources of clean energy, integrating renewable energy sources into the power system is one of the difficulties in the modernization and smartening of the electric grid. Some systems are already overburdened, making it harder to get electricity from wind farms into the grid for consumption. Renewable energy sources are inherently variable and intermittent. Electricity has always gone in one direction, from a power plant to a consumer. Electricity must enter the system from various places as a result of the extra sources coming from alternative sources. To integrate wind, solar, and other alternative energy sources into the distribution system and transport them to their destinations, grid automation, two-way power flow, and sophisticated controls are required. New devices in Smart Grid systems must be able to interact with current equipment, and coordinated efforts are required to adapt solar photovoltaic and wind energy. There are additional computer tools for evaluating the integration of renewable energy into energy systems. In terms of applications, matching technology, and the goals they achieve, these energy instruments are varied. Feasibility and viability assessments are commonplace all around the globe. These may be used to help build different grid-connected renewable energy systems for particular areas.

1.12 Issues as well as challenges in Smart Grids:

Despite the apparent progress made in the creation of Smart Grids, their technology, and systems, problems and obstacles remain, and ultimate achievement remains a long way off. The following problems and challenges may be investigated further:

- V2G: battery wear, limited electric vehicle adoption, new battery technologies.
- Cost and benefit, expertise, and institutional inertia are all barriers to adoption.
- Expenses, customer engagement, data security, and privacy
- IoT-based Smart Grid security problems and difficulties
- The layout of the route.
- Standards compliance and interoperability
- AMI vulnerabilities, physical security, and cyber security
- Smart Grid simulators and co-simulators: capable of simulating just basic situations, such as time synchronization and data transfer.

- There is a scarcity of scalable, interoperable context-aware middleware platforms.
- Issues with interoperability with intelligent devices, as well as technical standards for data recording and transmission.

2. DISCUSSION

A smart grid is an electrical network that allows for a two-way flow of power and data, as well as the detection, reaction, and prevention of changes in consumption and other problems, using digital communications technology. Smart grids are self-healing and allow energy consumers to have an active role in the system. The Smart Grid idea has progressed from a pipe dream to a goal that is progressively becoming a reality. Devices and systems have become increasingly capable of supporting the development of a more intelligent grid as technology has advanced.

The Smart Grid is part of an Internet of Things architecture that may be used to remotely monitor and control anything from lights to traffic signals, traffic congestion, parking spots, road alerts, and early detection of things like power outages caused by earthquakes and severe weather. Time series forecasting in Smart Grids, dependability and power quality studies, power flow optimization, battery systems, cloud computing, and realistic large-scale renewable energy source integration are all areas where study is possible. Smart Grids have a bright future since new technologies will be utilized to create them.

3. CONCLUSION

The Smart Grid idea has progressed from a pipe dream to a goal that is progressively becoming a reality. Devices and systems have become increasingly capable of supporting the development of a more intelligent grid as technology has advanced. Smart Grid efforts throughout the country are aided by concrete energy policy. Smart Grid activities in various areas seldom imply rivalry, but rather a cross-regional community with comparable goals and lessons to learn.

The Smart Infrastructure was born out of the necessity to upgrade the electric grid, according to this study. The traditional grid eventually grew limiting and required additional features. Smart Grids' functions and features have been discovered. The article outlined the fundamentals of Smart Grid technology and associated technologies, as well as the research efforts, difficulties, and concerns that surround them. Time series forecasting in Smart Grids, dependability and power quality studies, power flow optimization, battery systems, cloud computing, and realistic large-scale renewable energy source integration are all areas where study is possible. Even the problems and obstacles found, such as V2G battery wear, data protection, physical and cyber security, simulator limits, and distribution system automation, may serve as excellent starting points for future study. When starting on this complicated system, the Smart Grid's fundamental concept is insufficient. Even using existing experiences and technology as a guide, pursuing a Smart Grid requires a long-term commitment of time, money, and ongoing research and testing. The Smart Grid can be more successful in achieving energy sustainability and environmental conservation and preservation if more effort is put into Smart Grid research. Although the Smart Grid's precise future is impossible to foresee, recent developments show a dynamic fusion of sectors, mechanics, and communities.

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