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Advantages and recent developments of smart energy grid

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Abstract
The commonly utilized smart grid technology helps to reduce losses and increase system stability. It promotes dependability, effectiveness, and efficient management of the electrical energy supply. Although it has been a popular issue for recent papers, academics still don't fully comprehend it. Since this subject requires a broad foundation, the goal of this review effort is to enlighten and assist beginning researchers. It is difficult for the current electric transmission and distribution networks to deliver resiliency in performance, dependability in service, and real-time data. While conventional networks lack the flexibility to interact with renewable energy generators or micro grids, smart grid is a potential network maneuver to stabilize the system whenever any disruptions break out employing distributed renewable energy producers. This thorough effort is done to map earlier contributions in a logical way, and it includes the requirements, features, and principles that are offered to help readers who are interested in the creation of smart grids.

Keywords: Power system renewable energy smart energy systems smart grid

1. Introduction

The smart energy system, a cutting-edge technical method of electricity networking, is primarily a new generation of smart power systems. It controls the distribution networks, transmission, and energy generation by integrating the power system with communication technology. As a result, a system that is appealing, communicative, and competent can handle the difficulties of power networking. It should be noted that utilities initially developed and managed traditional power networks to provide customers inside the same nation, as shown in Figure 1 below.

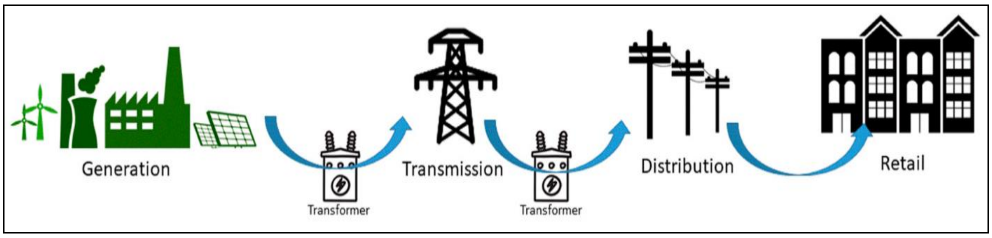

Fig 1: Traditional power flow in the conventional grid.

High levels of availability, flexibility, and efficiency are provided by smart grids. In order to build a two-way communication-based power system that allows operation and consumer to interact with each other to improve service reliability in comparison to the existing power system, an interdisciplinary integrated power grid is dependent on many elements such as digital sensing, smart metering, online monitoring, and automation instruments. Currently, the grid is being enhanced with several technologies to meet the evolving difficulties such energy storage, demand response, and generation due to rising two-directional power flows, as seen in Figure 2.

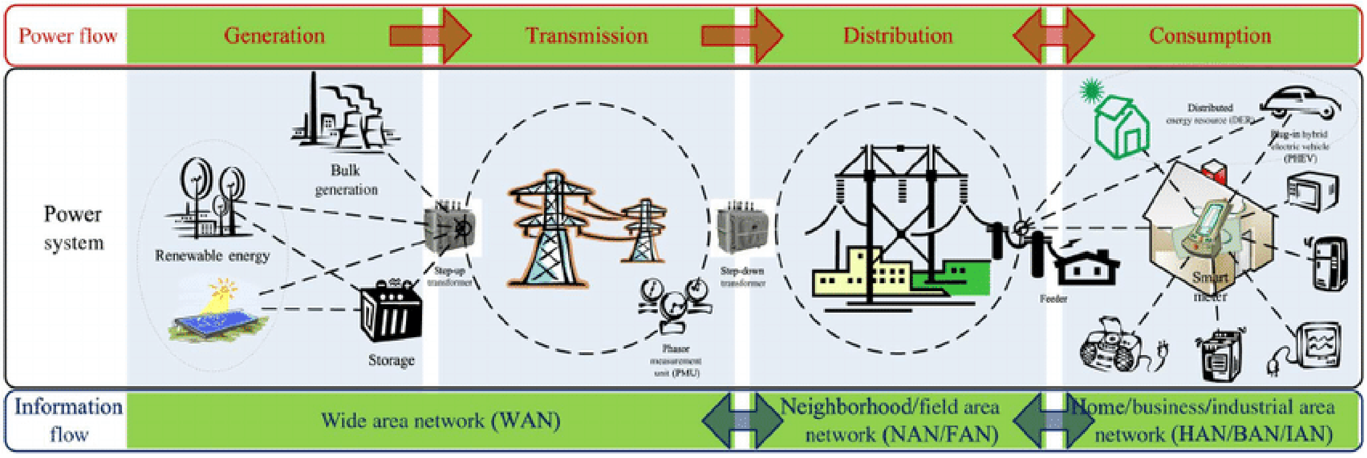

Fig 2: Smart energy grid emerging system

While there are several effective instances of smart grid networks, Telegestore, which was established in Italy in 2005, is the one used in this analysis. The 27 million consumers connected by the Telegestore initiative are the first grid to deploy smart meters. Additionally, it is stated to be the first smart grid in the world that serves the domestic scale. This intelligent power system allows for significant energy savings. Three crucial components—communication, information technology, and electricity—are united in a smart power grid. These components function in a certain way to provide utility and customer feedback exchange. The implementation of electrical energy transfer from the power provider to the consumer and vice versa. Consumers that own PV systems that produce more electrical energy than they use can sell the excess energy to the utility provider for a profit. Access to inexpensive energy resources is vital for sustainable development in order to meet basic necessities and support productive activities without jeopardizing the possibilities of future generations. The world economy is powered by traditional energy sources, yet 56.6% of greenhouse gases are released during the burning of fossil fuels.

Thus, attempts to incorporate renewable energy sources (wind and PV) into electricity systems are pushed by worries over greenhouse gas emissions that contribute to climate change. However, because it depends on wind or sunlight, the energy produced is unpredictable. As a result of the significant swings in their outputs, such systems are intermittent. It is also non-dispatchable because no external command may be modified to change its output. While traditional grids are variable, operating a power system with a significant proportion of renewable energy sources is a problem due to the fluctuation in renewable energy supply.

2. Literature Review

With its rapid speed of research and development, the electric grid is innovative. The smart grid is a focus of the USA and the Europe. In the US, with the help of a nationwide initiative called "Intelligent grid," which is being coordinated by the Department of Energy (DOE) and the Electric Power Research Institute (EPRI), the smart grid may be constructed. To increase the dependability of power systems, this initiative combines the power grid with computing systems. Additionally, DOE collaborates with commercial entities under the "grid smart" initiative. The project's goal is to provide standards for the power and communication systems. The created grids also need infrastructure for trials, smart engineering, good security, and market framework, as well as analytical and simulation tools.

The European Technology Platform (ETP) is committed to the idea that Europe's electricity grids must be affordable, highly adaptable to customer requirements, readily available, and dependable. To fulfill the standards, it is also necessary to employ a cost-effective method of manufacturing solutions to improve the customary. In order to successfully upgrade an outdated system to a new smart arrangement, technical standards and rules to integrate the power system and IT-based systems are required. International organizations have varied definitions of the smart power grid, although they all agree on its general structure. The National Institute of Standards and Technologies (NIST) views the smart grid as a network of distinct power systems that uses two-way communications and information technology, including computation, intelligence, and cybersecurity. Figure 3 illustrates how any smart grid is built and how it must be resilient by disruption predictive maintenance and self-healing responding to disturbances occur due to the high penetration of renewable generators in order to improve power quality and reliability, optimize facilities to avoid peak load challenges, and ensure power plants efficiency and capacity of power networks.

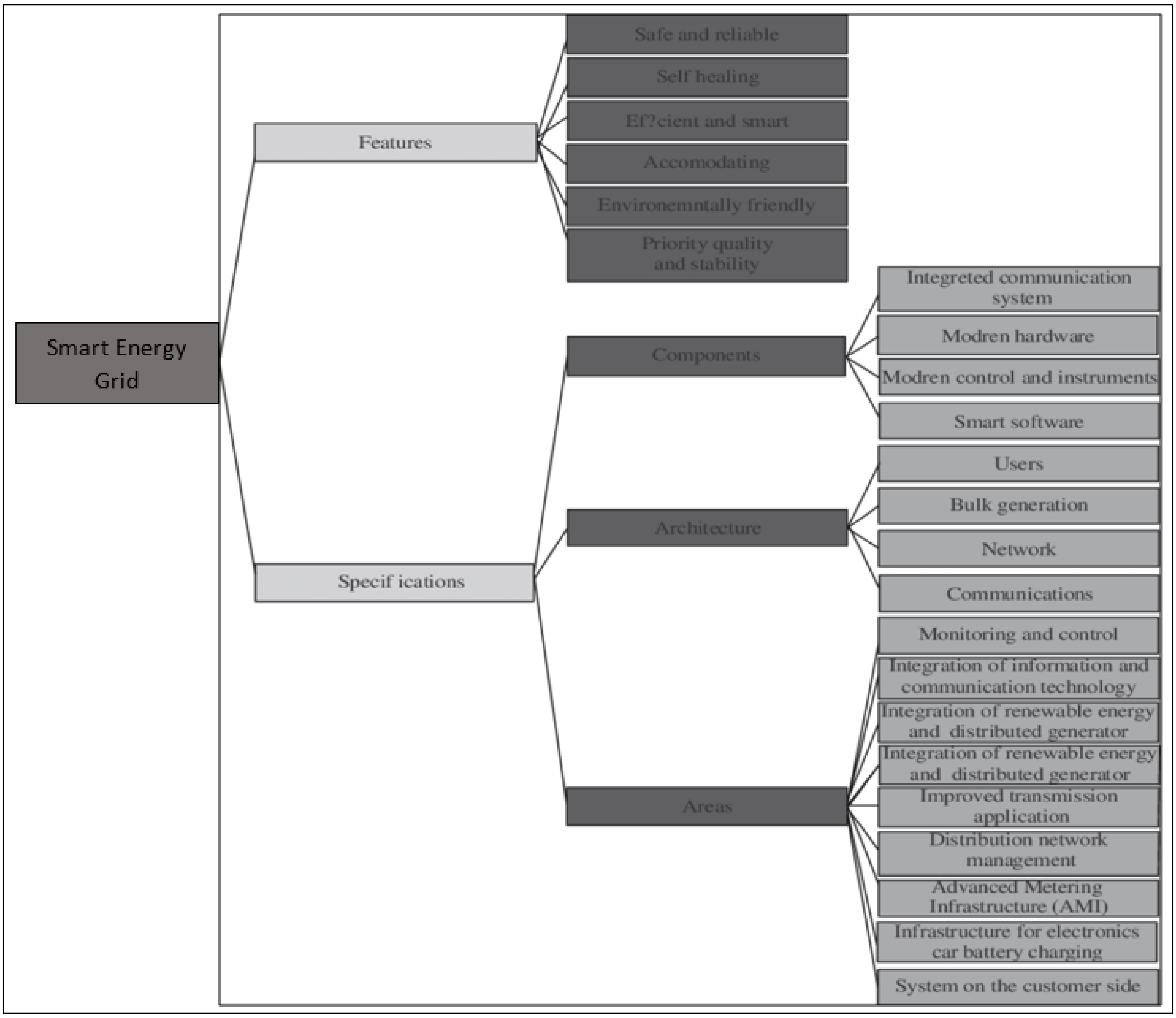

Fig 3: Taxonomy-of-literature-on-smart-energy-grid-implications-and-implementation

2.1 Motivation of Smart Energy

The excessive burning of fossil fuels has resulted in high CO2 levels and other greenhouse gas emissions, which have led to an increase in ecological damage on earth today. Nations are working hard to minimize it since it is a substantial contributor to climate change. Australian and American forest fires are a result of the high temperatures brought on by global warming. Other problems include unstable weather, floods, melting polar ice, and increasing sea levels. Power generation comes from the energy sector, which is the one that contributes the most to global warming. Therefore, industrialized nations work to lessen these consequences by accelerating research initiatives to enhance the production of renewable energy as a more environmentally benign source of energy. The development of the smart power grid idea has led to an increase in the trends for current renewable generators (PV, thermal, and wind).

2.2 Construction

Electric utilities are intelligently integrated into smart communications systems through smart grid networks, which makes distribution systems more active. The IT-based communication and security technologies employed in smart grids are subject to cyber warfare and hacking attempts as well as to any natural calamity. In order to defend against harmful interferences and cyberattacks, complex encryption technologies are utilized. In order to detect natural disturbances early, the weather monitors may also deliver weather information in real time. Security measures are also employed to offer vehicle maintenance, cutting down on the amount of time it takes to fix electricity systems.

2.3 Self-Healing Feature

According to data collected by grid sensors and information sent by the communication system, this phrase refers to the grid's capacity to anticipate and respond swiftly to technical faults that arise in the system. This allows for the detection of disturbances in distribution transformers and the automated isolation of faults by protection equipment using coded commands. Without having to wait for operator interference, the auto command can protect the network from additional harm and avoid blackouts in nearby locations.

2.4 Smart and Efficient

All components of the traditional power grid, such as generators, transmission, distribution, and consumers, are included in each sector of the smart grid. To offer technical parameter information in a smart grid, it was therefore necessary to be fitted with so-called advanced sensor infrastructures (ASI). The Smart system and the traditional system are compared in Table 1. In order to accommodate clients and tiny, dispersed producers, the present research on smart grids aims to expand the flexibility of integrating operational conventional power generation with distributed renewable generators. The environment may benefit more from a smart grid that is more effective and can include large-scale renewable energy sources. Current smart grid solutions, however, are concentrated on maintaining electricity quality. Technical problems therefore provide the least amount of harm to customers and electric energy utilities. The most frequent issues with smart grids include unstable voltage, shifting frequency, and harmonics. As a result, the power grid now includes a number of equipment such as data collectors, recording devices, automation, sensors, smart meters, real-time data displays, data management, and two-way communication applications.

Table 1: The general comparison between the current power system and the smart energy grid

No	Conventional power systems	Smart energy grid
1.	Centralized generation.	Distributed renewable generation with plug and play feature
2.	One-way communication	Two-way communication of energy resources interconnection
3.	Electromechanical system	Self-monitoring by many sensors and monitors
4.	Small number of sensors	Self-healing. Ability to detect and respond to faults
5.	Failures and blackouts need manual restoration.	Adaptive for islanding, using pervasive and extensive Control
6.	Manual monitoring Limited control	Greatly expanded control using data acquisition
7.	Cannot be integrated with PV systems	Can integrated with all sorts of renewable generators
8.	Vulnerable toward cyberattacks, vandalism, and natural effects	Resilient toward attacks, natural effects, and vandalism

However, when it comes to intersensor coordination and communication, the network becomes extremely complicated. A new network that was created by EPRI comprises active control, data management, and AMI. Other elements are employed to provide smart management at the consumer end, including internet networks, energy storage, hybrid automobiles, customer portals, and distributed generators. The electricity grid has an intelligent architecture implemented, as indicated in Figure 4, to ensure the greatest accessibility across a wide range. The power grid's network resilience is improved by the integrated data sensors and communication technologies amongst users. As a result, fiber optic cables or wireless networks are used to transmit the sensors' raw data for processing in order to perform further controlling operations. Some of the supporting components, including SCADA, are employed to evaluate, identify, and forecast the unpredictably occurring pattern of power flow. They operate quickly, dynamically, and in real time to guarantee the grid's stability.

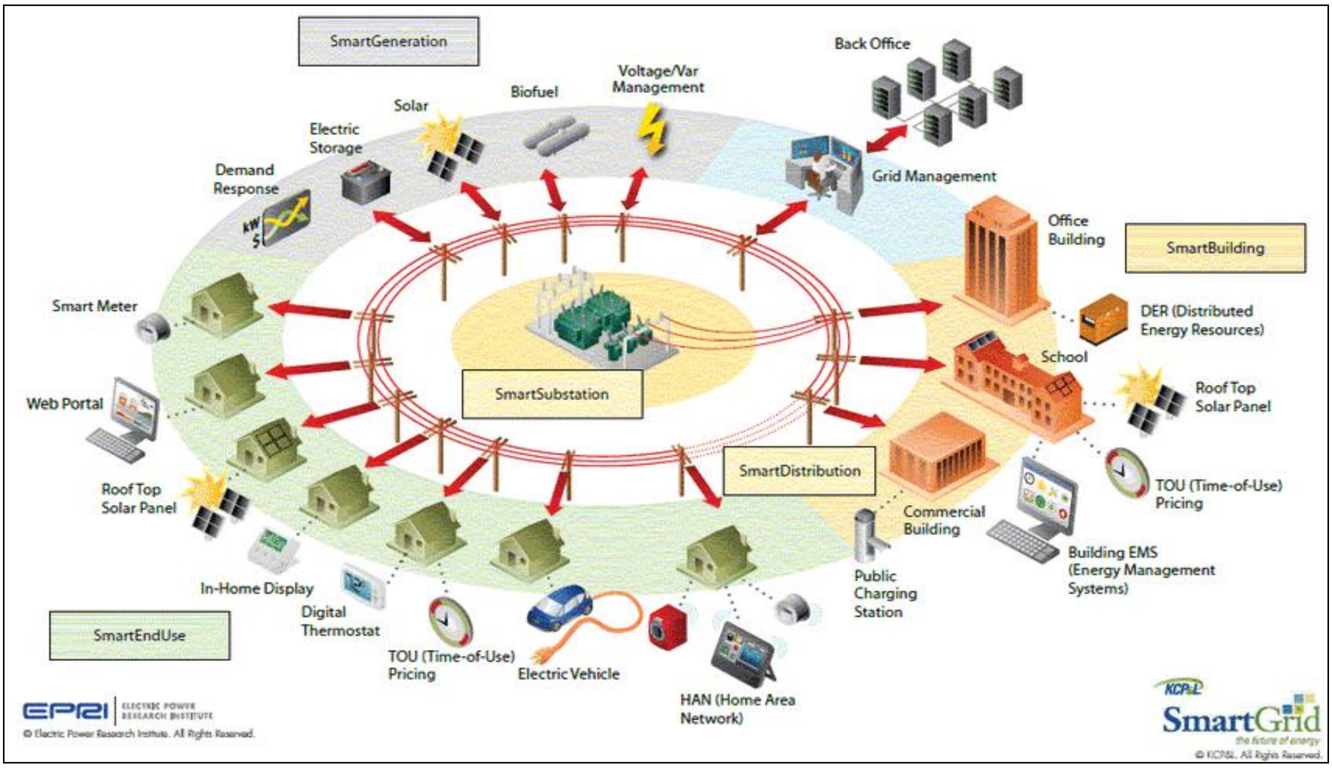

Fig 4: Smart grid model and scenario by EPRI

2.5 Interface and Auxiliary Systems

The distributed generators can ride through any disruption to restore the voltage stability in the whole grid thanks to the smart interface between the utilized and the system. The power grid's stability is anticipated to be aided by dispersed generation. A smart home also has feedback mechanisms to boost the effectiveness of harmonic and voltage restoration. In order to reduce harmonics and variable generating failures, distribution generation uses more power electronic equipment. The central automated control system of power grids is the energy management system (EMS). Users need an easy-to-integrate control architecture with simple controls to prevent blocking. Outage management system (OMS) can serve as the primary component of DMS in areas where power outages are frequent restrictions. A smart grid's interaction with geographic information systems (GIS) is essential since location is yet another significant failure factor. Additionally, advanced metering infrastructure (AMI) offers load limitation, remote measurement, power quality monitoring, and dynamic rates. Modern topologies incorporate automation for distribution.

3. Smart Grid Policy and Current Works

Smart grids include sophisticated operating systems that are intended to prevent blackouts and make it easier to integrate renewable producers into the distribution network. Figure 5 uses the smart grid as an example to show how communication and information technology are integrated. The need for a consistent, high-quality energy supply and the sharp rise in the world's energy consumption drive scientists to develop new energy-related technologies. The use of renewable energy, notably wind and solar, which may be linked to distribution networks, has been encouraged by policymakers and decision-makers. To design the processes for connecting Distribution Energy Resources (DER) to the distribution grid, technical standards were established. To design the processes for connecting Distribution Energy Resources (DER) to the distribution grid, technical standards were established. For instance, IEEE 1547, which essentially prohibited the DER from challenging the grid's protective coordination or causing any overvoltage.

Lower cost and more penetration at greater sizes have been made possible by the ongoing advancements in DER. However, it negatively affects voltage stability and transmission systems. The PRC-024 standard should be revised in order to take the DER restrictions into account, according to NERC's recommendations. In July 2016, the most recent version of PRC-024-2 became mandatory. Changing the inverter's voltage-time and frequency-time settings, allowing the voltage and frequency to ride through the fault, and giving the utility the option to let the inverter control the distribution voltage were all addressed in a 2014 revision of IEEE 1547-a that was published as a draft guidance.

This study focuses on increasing the system's dependability while using distributed energy resources, such that

a. It offers an active power decrease in the event of over-frequency.
b. It is capable of allowing the fault to pass through (FRT).
c. It offers reactive power and voltage assistance to the grid.
d. It enables DER penetration levels to be higher.

Due to strong voltage stability and self-healing from voltage and frequency fluctuation and faults, the aforementioned functionalities increase the grid's resilience and dependability. Long-term grid operation is feasible economically without many of the present grid voltage regulation systems.

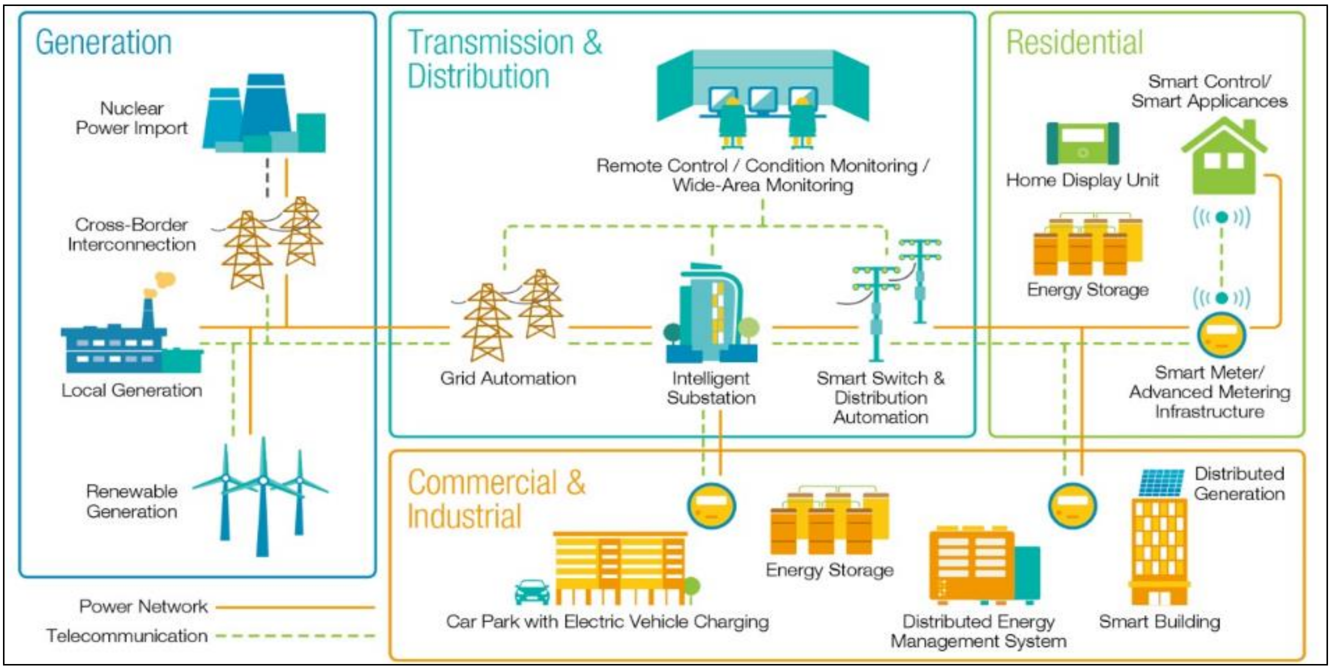

Fig 5: The technologies combine the smart grid structure

In addition, many smart meter projects require that the meters submit the data that the AMI receives to the data meter management system (MDMS) [48]. MDMS controls the data and does the analysis to give the utilities with information. The following services are available to consumers through AMI communication between utilities and meters: The price of a distant customer and use time, being able to track, save, and report client energy use for any necessary timeframe, using a thorough produced load profile, improve the energy diagnostic, employing a metering feature that sends a signal when the meter is out and when the power is restored to locate a remote powered place, joining and disconnecting remotely, the capacity to identify fraud and loss activities, allowing retail energy service providers to manage revenue more effectively.

4. Conclusion

The distribution system and energy flow are no longer unidirectional thanks to the smart energy grid, a unique electric power system that represents a significant advancement of the conventional electric grid. Additionally, the consumer side can play a very limited role in grid stabilization. The resilience of the system depends on both the supply and demand sides working together. In order to shed light on this popular issue in the halls of electrical research institutions, this review study presents the advantages, components, historical, and future advancements of the smart grid. A number of benefits of smart grids have been explored, including their self-healing, intelligence, adaptability, environmental friendliness, and quality and stability aspects. The requirements have been examined from a wide range of aspects, including: architecture, components, and locations. Control and monitoring, integration with information and communication technologies, integration with distributed renewable generators, and distribution management are the topics covered. Customers can help restore stability and manage their energy use thanks to the smart grid.

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