Recent Trends in Smart Grid Technology-A Review Paper

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Abstract: Smart Grid is now the buzzword in the power industry all over the world. It presents our planet with a revolutionary way of power transmission and distribution. It has even paved the way for many advanced forms of data prediction and handling. The existing grid has to be changed so that it can convey security to the grid. While on one hand, it provides, clean energy and planet-saving benefits and on the other hand, it also poses the complications of providing hi-tech elements of the operation. A lot of characteristics have made it conceivable to separate Smart Grid from the existing old grid. Features like Smart metering, Smart sensors, and Smart protection have been discussed in detail for an overall view of this technology. There are numerous difficulties and issues regarding the usage of Smart Grid which is also debated in the paper. The future investment opportunities and the expected growth has also been given an overview.

***Index Terms*: Smart Grid, Smart Meters, Smart Sensors, Smart Protection.**

I. INTRODUCTION

There was one time when the world generated power at the individual level, small amount, and scattered energy production.But with time, this scattered generation of electricity got unified with the evolvement of power grids, where generation, transmission, and distribution were connected together under the national grid. It was done specifically for proficient distribution and use of energy.Now with the new end need of present era, for proper distribution of this electrical energy, without stealing, corruption, over-exploitation of existing resources; Smart Grid like a savior has come into the frame. In a few words, Smart grid, is the integration of generators, consumers or both together under one unit with the proper objects to guarantee a monetarily proficient power framework with low losses and high efficiency.[1] In the paper, we have discussed the importance of Smart Grid and why it is necessary in today's world. The comparison between the old grid and Smart Grid is debated here. There are many features which make Smart Grid. Smart Meter is one of the most integral parts of Smart Grid. Its importance in the 21st century is being discussed. Moreover, Smart Meter characteristics are being told. Other important parts Smart Sensor and Smart protection are also being discussed below. Since Smart Grid is a new and recent technology, it has some disadvantages which are also being stated. The future scope for Smart Grid is bright.

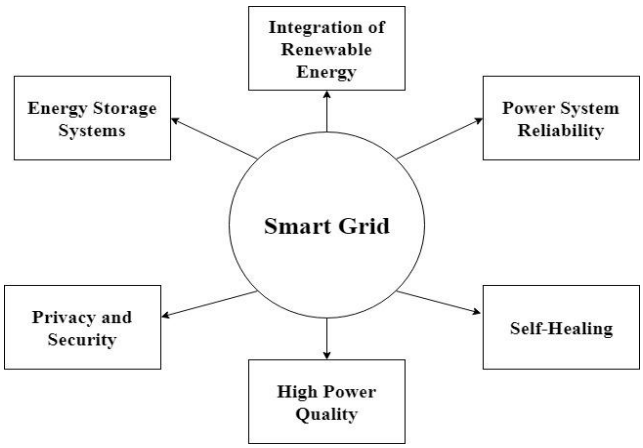

Fig. 1: The representation of the smart grid

II.FACTORS AFFECTING THE PERFORMANCE OF THE EXISTING GRID

Let us first see what exactly are the problems faced in the conventional grid so that we can better understand what smart grid is and how it solves most of the problems.

- The requirement for reducing the various losses
- Electricity demands have increased [2]
- The generation systems which are renewable can be put into a function by this.
- An effective measure of global warming
- Electric vehicles can be effectively used
- Improved customer services
- Solving the issues with the meter reading
- Lower grade efficiencies of old power generation systems
- Power network designed life in need of replacement
- Need for a reliable supply of electricity for more critical loads
- Transmission and Distribution lines at its limits
- Reduction in the life of the equipment and increasing incidence of faults

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- Voltage and frequency limits
- Uncertainty of RES

III. COMPARISON BETWEEN THE TRADITIONAL GRID AND SMART GRID

The traditional or old grid not only is electromechanical in nature but also lacks flexibility.[3]. The consumers are not able to get the required real-time data of the use of electricity at a specific time.[4] There was no privacy given to them. There was a one-way distribution of energy from the main plant. The problem with the centralized power grids is that they can be severely damaged at any time of failure, leaving consumers vulnerable to outages or blackouts. Stealing of electricity became easy which resulted in the loss of money for the utility companies. The consumers were not given a choice in the manner in which they get the power. Also, the demand for electricity was not met. Additionally, the improvement of sustainable renewable energy source isn't upheld by the traditional network. A lot more issues are present in the traditional grid which can be solved by the smart grid through improved communications technology.

The Smart grid is an upgraded form of a conventional grid. It was able to problems that were arising in the old grid. It is a two-way communication of data between the suppliers and customers. It is capable of providing real-time information about the events, so the consumers are informed of their real consumption. Moreover, one can adjust the energy usage in the home, thus reducing consumption. Smart grid updates the old grid infrastructure, thus making sure that the power is delivered continuously. Detection of power theft becomes very easy. It decreases blackouts and failures as applications of smart grid smoothen the flow of power. There is two-way distribution as now the power can also go back to the grid with the help of consumers having access to renewable sources like a solar panel. The smart grid has automatic control and recovery and it facilitates the real-time troubleshooting. It reduces the carbon impact of the grid. Here, the consumers get priority. Accordingly, we can reason that Smart Grid has progressively maintainable future.

IV. FEATURES OF SMART GRID

The following are the features:

A. Smart metering:

The smart meter is a device which gives electricity consumption and sends this information back to the utility for other purposes. The consumers have greater control over their energy use. The smart meter has put a conclusion to the assessed bills as it will assist the suppliers with calculating the ideal bills. In the beginning, Automatic Meter Reading (AMR) systems were acquainted which lets the utilities to take the readings remotely [5]. From that point forward, electric providers put resources in Automatic Meter Infrastructure (AMI). It differs from AMR is that two-way communication is enabled with the meter [6].

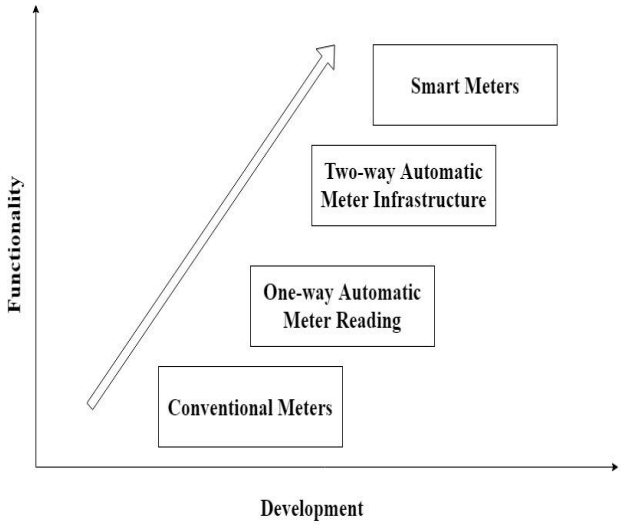

Fig.2: The representation of the evolution of smart meters.[7]

Two-way communications refer to the communication or interaction between electric suppliers and consumers with the help of either wire or wireless communications. It is one of the important features that differentiate smart meters from traditional meters. Smart meter usually measures Root Mean Square Current, Root Mean Square Voltage, Instantaneous Active Power, Instantaneous Reactive Power, Power Factor, etc. Apart from real-time information, historical and accumulative data, such as consumption, electricity cost, and CO_2 emissions can be recorded. Smart meters can also record information to help consumers to remember their energy usage. It can also detect the fault and diagnose it.[19] Moreover, the consumers have a decision of choice of selection of tariffs such as at different times of day and night. A smart meter can help in the detection of electricity theft and it enhances security. One of the most important features is that the smart meter enables demand-side management. Demand-side management refers to the management of consumers' behavioral change in energy consumption [8]. In simple ways, encouraging consumers to reduce energy consumption during peak hours. B. Smart sensors: Sensors are the devices that take a predefined action on sensing a particular kind of input. Sensor networks are used for monitoring purposes and as measuring units for the grids. These are required to provide quality of service, high security and also help in harsh environmental conditions. Smart sensors are the devices that can be integrated with smart grids so that the lack of energy and (or) failures in the system can be efficiently managed. Smart sensors are getting to be principle parts of the systems performing functions that previously could not be performed.[9] Sending systems consist of transducers, sensors, and actuators. These should have features that help them acquire data and process it in real time. That helps in making early decisions as well as safe delivery of electricity during extra demands. The early decisions help in raising alerts and giving warnings to make the system an improved one.

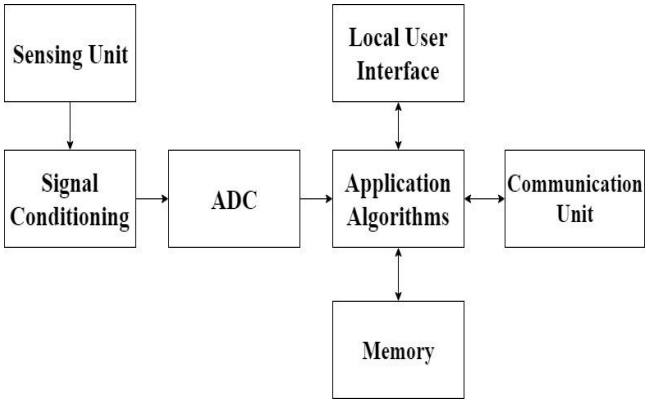

Fig.-3: Smart sensor building block

Along with data processing, smart sensors should also have facilities of storage and wireless communication. When integrated with a smart grid, these sensors should be mass deployed and thus be low in cost and maintenance along with being self-powered. Sensors provide real-time knowledge of quantities like Voltage, Current, Power Quality, Frequency, Sags in Transmission Lines, etc. These information's empower the grid with its required learning working conditions and aides in assuming responsibility for its generation, transmission, and distribution to help the overall operational efficiency.[10] Sensors with advanced data processing circuits have become a common feature and newer sensing technologies are being reported. For example- Locating Corona Discharge using TMR sensors (TMR= Tunneling Magnetoresistive). For safer operations, the locations of Corona Discharge are pretty essential. C.

Smart protection: Smart grid requires very different types of protection systems, elements, and schemes. Here, we talk about how the different elements, zones, and requirements of smart protection.

Elements of smart protection system are:

1. Telecommunication:

The telecommunication system has a very important role in the Smart Grid. Using telecommunications helps us to use more secure and selective protection functions. They have been mainly used in line differential schemes which is one of the main important applications of Smart Grid.

2. Adaptively:

It ought to likewise be versatile with the goal that the setup of the system and dynamic components are continually evolving. The arrangement of the radial feeders might be changed to accomplish minimum losses to avoid congestion situations. The protection systems must be aware of the open points and generation status of each generator. The latter provides information about the faults in the various current and voltage sources that are active in the network. [18-20]

3. Relay software and algorithms:

The necessities that are made reference to above states that the IEDs must utilize the required programming stage to empower simple correspondence and versatile utilization of several protection schemes. From the point of view to accomplish the required intelligent system is to properly apply the required corresponding the agent technology. Generally, the multi-systems of various agents work and communicates together to achieve a goal the desired goal. The agents are basically autonomous software entities that operate without human assistance, as a result, they are able to react to the changes in the required environment. One of the interesting features is that most of the time they remain proactive.

4. Protection zones:

There are various zones that are to be protected from various hazards. For protecting a Smart Grid a protective system along with a protective zone is required. The zone division is made taking into considerations all the possibilities of self-healing functions. For each protection zone, there may be one or more circuit breakers enabling the disconnection of a zone in any in zone fault system. If increasing the number of circuits breakers, the complexity also increases.

The defined basic protection zone types are:

- Radial
- Ring
- Mesh

Functional Requirements:

- The DGs can be integrated easily.
- It ought to have the capacity to adjust to change in the system conditions.
- System reliability is made higher by applying self-healing.
- Utilization of the full potential of advanced ICT technology.
- Enabling the use of essential framework advances that offer a cost-productive approach to enhance framework unwavering quality.

Smart protection system:

1. System reliability:

- The ability of parts to perform the required tasks for specified conditions and time intervals
- Local power generation reduces the chances of failure of cascading.
- An Ideal mix of the Smart Grid resources like renewable and demand responses increases the system reliability.

2. Failure Protection Mechanism:

- Major blackouts can be prevented by proper predictions.
- Identifying and locating the failure to avoid the various events related to events of cascading.
- The phasor diagram and information can be used for the line detection of output and identification of errors and other parameters.
- Self-healing can be effective if the power grid is divided into small sections.
- During post-fault conditions, distribution of decision-making authority, procedure, and knowledge to substations and other devices.

3. Microgrid Protection:

Protection of Microgrid especially when it is islanded is quite challenging. The first and foremost challenge is to detect the islanding of the microgrid.[11] The second biggest challenge is how to provide fault protection to the microgrid segments while operating it from the utility.

4. Security and Policy issues:

Cybersecurity is one of the greatest difficulties in Smart Grid. Vulnerabilities may enable an aggressor to get into the framework, take the client protection, access control programming and so forth. Smart meters are obvious prey for hackers, as

vulnerabilities can without much difficulty, can be gotten to and exploited. Unchecked distribution of estimation and monitoring units (e.g. sensors and PMUs) is the main cause for network vulnerabilities.

V. CHALLENGES OF SMART GRID

1. Changes in infrastructure:
• New communication infrastructure is needed to be constructed in order to have a smart grid.
• For phase measurement advanced sensor system is needed.
• To secure grid advanced software is to be developed.
• Highly sophisticated components like smart appliances smart meters, Flexible AC transmission system, etc. are supposed to be developed [18]
2. High-Security Required:
• Any new infrastructure added to the power grid, like smart metering is going to be costly, so high security is required for that.
• Theft of components is going to increase.
• Critical National infrastructure is responsible for tight security.[16]
3. Quality Power:
• For countries like India, which consumes one-fourth of the total, the big electrical network is needed.
• Existing grids are needed to be renovated and expanded.[12]
4. Uncertainty:
• Sustainable development is present demand and for that decarbonization is to be limited.
• A smart grid is one step in that direction, but the challenge is to establish it by 2050 all over the world.
5. Consumer Support:
• The main challenge of the Smart Grid is consumer unawareness.
• It is needed to promote the generation of distributed renewable energy generation.[13]

VI. SMART GRID VISION AND FUTURE RESEARCH

Smart grids are advanced, convenient and complex systems that have many technologies integrated into one single unit, consumer services and information exchange, and decision points.[20]That makes planning a smart grid's detailed development and deployment scenarios a little complex. Smart grid technologies are the center point of the Research and development departments all across the globe. But deployment needs to be discussed at the national, and to be more precise at the regional level, where locally distinct important factors such as the age of infrastructure, the rate of growth of demand, make up of generation, and regulatory and market specifications are varied highly. [10]

1. SELF-HEALING SMART GRID

Self-healing is the ability of a system to differentiate between normal and abnormal working, with the goal that it can apply the required settings as indicated by convention with the end goal to hold its typical instance of the activity. Hence, the objectives of self-healing smart grids can be condensed as follows:

- Fast and accurate detection of grid faults or failures due to real-time monitoring.
- Redistribution of grid resources to reduce the adverse effects of overcrowded resources
- Under any condition, the continuity of services is assured.
- Service restoration time can be minimized.

Effective power framework rebuilding is a necessary advancement to build up a self-healing SG.[14] The future situation, which has extremely high utilization and reaches of inexhaustible assets and fuels and responsive demands, fluctuation and vulnerability will influence grid activity and healing technologies.[18]

Upgrading our current zonal grids into a self-healing grid will mean introducing a few advances and coordinating by utilizing strategies improved for what's to come. The most suitable smart grid framework comprises of microgrids. They are small (hence 'micro'), for the most part, independent power frameworks, and a smarter, stronger high-voltage smart power grid, which acts as the spine to the national or even worldwide network. [41,43,44]

2. In Power Flow Optimization

Due o the rising demand, rapid depletion of fossil fuels, the climate change and the skyrocketing cost of energy the power industry is highly burdened and is trying to cater to huge loads.[15] In the near future, the rate of such factors is predicted only to increase. It will be a national and domestic goal to exploit renewable resources.[17] Private and government offices around the globe will cooperate to think of standards and gauges on power quality and data correspondence system to organize smart grid parts.

Future Scenario

The national outcomes give direction to the kinds of pathways that every nation may pursue as they create smart grid networks. China has the chance to employ smart grid advances to more readily plan and structure the new framework that is being constructed, accordingly decreasing the negative effects on peak demand from the organization of EVs/PHEVs. The extra examination is likewise expected to consider particular framework properties. Practical factors of developing nations were not considered in this modeling and should be added to provide insights into developing regions which are the second and third world countries.

Smart Grid is the combination of Information Technology (IT), communication technology and electrical framework, a national smart grid would update the flow low proficiency grids to suit the need of data stream, conservation of energy, better dependability and changing units of generation by sustainable sources, assisting the planet and the nation.

It is a system for power transmission and circulation frameworks that utilize two-way modernized communications, hi-tech sensors and pioneering technology to enhance the effectiveness, quality, and power distribution safety and usage. It is actually a way to advance the power grid to be used in a way that is highly interactive, adaptable and effective.

Arranged set up of Smart Grid may guarantee continuous power to purchasers to a bigger degree, even in remote areas of India, while reducing energy wastage. Smart Grid will build effective usage and power dependability while permitting clients to oversee and track, utilization and costs using real-time information given by SCADA.[16] It affects all segments of the power framework, namely, transmission and distribution. For an unorganized and chaotic third world nation like India, it will most definitely take a couple of years to understand the full effect of Smart Grid when a utility control room technician can install, manage and maintain an electric meter in homes. The innovation can enable us to decrease power transmission and distribution losses to 5-10 percent yearly. Without Smart Grid, all nations, including India won't have the capability to fulfill the expanding interest for power and upkeep.

Other fields where smart grids are planned to be integrated into

- Optimizing asset utilization programmers
- Transmission and distribution planning
- Condition based maintenance
- Telecommunications and Networking
- Design and construction
- Resource management
- Engineering and AI
- Customer services
- Cloud-based control

VII. CONCLUSION

The smart grid has not only provided our Earth with life-sustaining solutions for power generation, transmission, and distribution but has also opened up new venues for advanced level data management and handling. Although the sophisticated system requirements require massive capital and investment, the pros clearly outweigh the cons. Especially for the 1st world countries where enhancement of every sector is the only way to reach golden age, the smart grid is their new best friend. It will help us to reduce the carbon footprint. The future of smart grids is nowhere near bleak and only grows every day. The opportunities are endless and are only waiting for humans to exploit them in a planet-friendly and sustainable manner. Thus, in the paper, we can easily see that the Smart Grid is an advanced form of the traditional grid. The implementation of the Smart Grid should be done quickly by the government of India in all the cities. But firstly, there should be awareness programmers' undertaken by not only the governments but also the local bodies and non-profit organizations among the common people. The Smart Meters is still in the early stages. Many state governments of India like Uttar Pradesh, Bihar, etc. have already started rolling out the Smart Meters and the other states should learn from them and do the same. The installation of Smart Meter will not only reduce the revenue loss but also the consumer will be able to see his or her energy consumption. Smart Sensors will be able to detect faults at a faster rate not only in transmission lines but also in the various electrical equipment. Smart protection will also play an important role. Though there are many challenges one must know that these are short-term and if Smart Grid is implemented it will result in greater success.

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