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A review of the concept of Smart Grid

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Abstract - *Smart Grid is the latest research area in the field of power systems. Smart grid technology involves smart meters, smart substation and distribution equipment. and smart generation. This uses the latest communication technologies based on IEC61850 standard. It is linked with modern world information technology and incorporates digitization. Moreover, Smart grid has self-healing and attack resisting property. This paper presents significance of smart grid and the concept of smart grid with its fundamental components has also been discussed. This paper reviews the contrasting features of smart grid.*

Key Words: Smart Grid, key issues, smart meters, smart substation, smart distribution, smart generation.

1. INTRODUCTION

An electrical grid is a large interconnected network which carries a huge amount of electrical energy and distributes it from the generating stations to the potential customers. It incorporates generating stations capable of producing electricity. Power stations are generally located far from the massively populated areas. The generated power is then stepped up by transformers for transmission. It is stepped down to a low voltage at a substation [1]. Power grid can be categorized into main three parts: generating station, transmission line and distribution system. A distribution system distributes the energy to all the end consumers from the transmission line. Generating stations and Distribution System are linked by the Transmission lines. Step up and step down transformers are installed in the transmission line for the purpose of decreasing and increasing the voltage up to the desired level. In order to minimize the transmission losses, voltage is magnified to a higher level by step-up transformer. At the end spot of transmission line, a step-down transformer decreases the voltage up to a possible level. This lowered voltage is then given out to the distribution system coupled by feeders, sub-stations, distribution transformers, lightning arrestor, utility lines etc. [2].

Though Conventional electrical grid system is efficient, reliable and has good control system, but as it is a well-known fact that technology needs to be updated to help it to be in pace with everyday modern scientific advancements and so, it becomes very important to look into the issues or limitations of the current power system and do research work to overcome those challenges so as to invent something more useful and productive. Some of key issues are discussed below:

- **Fuel Accessibility:** Although extra gas supply from Krishna-Godavari Basin has facilitated scarcity to some extent, but still domestic coal is facing supply constraints. It is a matter of concern as this issue is expected to grow further. This has caused Indian entities to import the fuel.

- **Coal Blocks:** The biggest challenge for the Indian Power Sector can be brought forward from the failure to obtain the scheduled target from the secured coal blocks. The main reasons behind this situation are accused to be land acquisition problem, delay in getting authorization and infrastructure issues.

  As coal is the main fuel used in the generation of power in India. Additional electricity production is likely to entail increscent amount of coal transportation within the nation by Indian Railways and sky rocketing unloading for imported coal at ports in India. Thus Capacity shortage is faced by India in both events.

- **Lack of equipment:** The basic elements of Boilers, Turbines and Generators are lacking, and also sufficient supply of Balance of Plant equipment, including coal-stock handling, ash handling plants etc., and additionally construction equipment have been on shortfall. For new project managers, it poses a challenge to choose a supplier who is reliable, and then monitor its progress and performance and to make sure sustainable quality supply [3].

- **Limited Transmission:** The present power system employs SCADA (Supervisory Control and data acquisition) system with confined bandwidth and comparatively slow transmission rates that often takes several seconds to respond to urgency.

High prices in case of electric power outage and interrupted power supply affecting power quality. Moreover, power demand varies many times during the day and to meet the required demands, cost also varies. Therefore, grid also requires maintaining sudden increment of supply resulting

in less efficiency, rising costs and high emissions. Thereafter the concept of Smart Grid has been brought forward to.

2. CONCEPT OF SMART GRID

A grid is considered as Smart Grid when utility grid is digitized by means of computers having two-way communication to the associated devices with the electrical utility. Automation technology is the key characteristic of Smart Grid that allows it to control and adjust all the connected equipments from the central area.

Simply, Smart Grid = Digitization + Power Grid

This implies that Smart Grid is the integration of IT (Information Technology) with existing grid to get better flexibility, reliability, resiliency, efficiency and also in order to provide the best services to consumers.

1. Functional Principal of Smart Grid System:

In traditional Power System, when a power failure takes place, or an outage is encountered on distribution side or consumer's place, then utility gets to know about it only after a complaint is obtained. But if the Smart Grid System is there, then utility can be informed at a faster pace with the help of smart automated devices attached to the smart network. It will have the capability to operate immediately according to the fault and it will have the ability to isolate the faulty part within few nanoseconds and create a detailed analysis to be repaired from the service men. In the urgency, it may re-route the power flow to give continuous uninterrupted supply.

It has been generally estimated that some special type of equipment tends to wear out within a long span of certain time and needs to be replaced with new devices after specific time. These devices are built of several different pieces and every piece gets substituted. On the other hand, Smart Grid technology is able to spot the soon to be worn out devices and can help in making a cost effective replacement strategy.

Moreover, having access to all the data of their power use, customers can plan their usage accordingly. Ultimately, it will bring transparency and eventually it will help them save money and power, and change their daily practices. Also, an efficient delivery operation is the biggest advantage of a Smart Grid system [2].

2. Components of Smart Grid System:

The definition of Smart Grid can be taken as an electrical network with smart equipments installed with it that follows as a combination of existing electricity network and smart internet/digital communication technology. A smart electrical network can provide electricity by means of multiple and widespread distributed sources, for example from Solar Systems, Wind Power Systems, and most probably even from Hybrid electric vehicles [4]. Typical components of Smart Grid System are:

- Smart Power Meter
- Smart Substations
- Smart Distribution
- Smart Generation

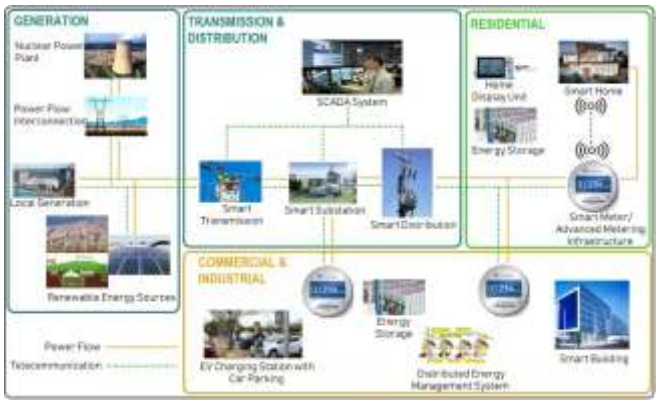

Figure-1. Overview of Smart Grid System

[Source: Elprocus.com]

These advancements generally classified into the following leading technology areas are as discussed below:

1) Smart Meter:

Figure-2. Smart Meters [Source: Google Images]

A smart meter is a new type of intelligent gas and power meter which is able to transmit meter reading digitally quickly to electricity supplier for more error-free electricity bills. These have in home display panels, which can help to utilize the energy in a much better way.

The technology used in Smart Meter is a secure national communication network that sends one's actual electricity usage to the supplier automatically and wirelessly. In this way, households will not have to be dependent on the

approximated energy bills or they will have to give their own daily usage readings [5].

2) Smart Substation:

The future grid requires smart networks grouped together by intelligent substations. The present world has digitalized to support new era and electricity industry is included in it.

Figure-3. Intelligent Substations (China)

Smart Substation is being integrated by China as stated by the State Grid China Corp. The project undertakes the latest software and power technology in order to ensure safety, control over long distances, automation, supervising and diagnostics for these substations, as well as also to cause both a decrease in their operating costs and footprint. (Courtesy of ABB)

Various complexities propel towards the complete computerization of power substation. As the consumer desire for more electric power is escalating due to various advanced devices, thereby requirement of more improved power quality has augmented and also, in case of fault, it must be attended within a blink of eye to clear it. This is where we expect modern smart technology.

Adding further, IoT (Internet of things) is a new term trending in the field of digitization on the customer side metering. IoT can be defined as a network of buildings, devices, electric vehicles, etc. and all other things which has the possibility to be integrated with sensors, interconnected by signals, supervised and regulated by computerized systems.

Figure-4. Digital Substation (Australia)

Queensland's first smart substation project by Australian company Powerlink was commissioned in 2011. This project included a series of six digital substations with process bus and nonconventional instrument transformer technology. The second and third substations were commissioned in 2013 and 2014, respectively. (Courtesy of ABB)

3) Digital Substation:

Technical specialists emphasis on the framework, hierarchies or building infrastructures to define a digital substation. Regardless whatever practices have been followed, the general terms used in intelligent substations include interconnection elements, communication, control and security function, and a process part. The most prominent ingredient is the communication technology as claimed by the experts. It is kind of multipoint system with high speed two-way communication. Further, control and safety comes at secondary level, which is linked with the primary level. The implanted sensors in the transmission line permits the system operator to keep an eye on the capacity of individual transmission line just as the live rating. Likewise, the monitoring system of Distribution part has been developed to a level where it has been able to spot the faults instantly and isolate the defective portion in small sections without disturbing a large group of locality and a fewer blackouts [6].

- **First Digital Substation in India:**

"Digital substations can contribute to India's energy needs", said Pitamber Shivnani, President of Power Grids, ABB India.

ABB India is going to install a 110 kV digital substation in kerala in India's largest information technology park 'Technopark'. [7]. [Source: Economic Times]

4) **Smart Distribution**:

Whether Micro-grid or Advanced Distribution Network, in order to achieve smooth operation, it is crucial to have these two fundamental properties – self-healing and Distribution Grid. Self-healing property of the Smart Grid makes it more

important to install it as self-healing refers to the characteristic that Smart Distribution Grid must have the ability to find the system's state, diagnose and wipe out the possible defect so as to avoid any blackout. Some main technologies in the way of Smart Distribution System are:

A. Supervisory Control and Data Acquisition (SCADA)

B. Power Electronic Technology

C. Advanced Metering Infrastructure (AMI)

D. Advanced Distribution Automation (ADA) System

A. Supervisory Control and Data Acquisition (SCADA):

An automation system called as DAS (Distribution Automation System) allows supervision, coordination and operation of Distribution equipment over long distances in real time. The essential parts of DAS include SCADA, GIS (Geographic Information System) and DSM (Demand Side Management). But SCADA is the most indispensable one. It gathers information from diverse points and displays all the fed parameters to the system operator. It also performs the security functions such as giving alarm, supervising the status and computing the required parameters etc.

B. Power Electronic Technology:

In order to convert and control the power, Power Electronic Technology is used which provides more flexibility and controllability to the Smart Distribution Grid. Its applicability finds its place in large scale power generation via renewable energy sources and energy storage. In addition to, Power Electronic Converters aid to connect renewable generations (like fuel cells, photovoltaic cells, wind turbines and energy storage devices etc.) with the grid.

C. Advanced Metering Infrastructure (AMI):

AMI incorporates smart meters, communication system and metering data management system. For obvious reasons, something common sounds between AMI and SCADA. It is complex structure which can gather, save and scrutinize the data of the end customers. AMI can be categorized into four parts: smart meters, communication system, metering data management system (MDMS) and home area network (HAN). What is more, new applications need to be yet invented to get it interfaced with smart distribution technology in consideration of totally utilizing the AMI data.

D. Advanced Distribution Automation (ADA) System:

The automation at the Distribution Side can be classified into automation at substation, feeder, and customer level. An abundance of technologies highly lean on ADA System such as Remote Metering, Load Management, Integrated Volt-VAR Control, Automatic Load Shedding, Network Reconfiguration, AM/FM (Automated Mapping and Facilities Management) and Survey of loads and Energy Accounting. The Electricity Board might give permission in the coming future for load shifting and produce and do storage of electricity in the context of Smart Electric System based on real-time cost of power in order to boost the efficiency of power system. Hence, the customer may also be the seller of power to the grid in the event of inflated rates. The incentives received by selling the power back to utility will encourage the consumer-marketer interaction to enhance the grid utilization. Distribution System can be managed by the operators by using this effective tool ADAS [8].

3. Smart Generation (Decentralized Generation)

Decentralized Generation involves the generation and distribution of energy. Various technologies are available to generate electrical energy, for example, wind turbines, solar cells, geothermal energy, hydro energy etc., including many others. Smart Generation incorporates onsite electricity production. This engineering technique has many advantages over the centralized power generation, due to the fact that it will remove the extra cost of transmission and distribution over large distances. These Micro-grids can produce power in the range of 1-100MW. At local level, the generation of electricity is carried out according to the site specific sources of energy, which is basically small scale generation unit called as micro-grid generally serves only to the particular locality. It can work both in grid-connected mode and isolated mode as per the need. Second level constitutes a Distributed generation, in which end-user consumer may have installed the same technology at much smaller level. These can supply electric power in case of any requirement or urgency to the grid [9].

3. COMPARISON BETWEEN TODAY'S GRID AND SMART GRID

Table-1. Comparison between today's grid and smart grid [8]

Existing Grid	Major Characteristic	Modern Grid
It reacts to stop more harm to system and the emphasize lies on the safety of assets following system faults.	Self-Healing Property	It has the capability to automatically spot and react to the problem occurred instantly whether in transmission or distribution. Prevention is the main attentive point and it lessens consumer impact.

Consumers are unaware of their real-time energy usage and no participation of consumers is involved with the power system.	Encourages & involves the consumer	Customers are well informed and involved. Active participation enables maximum power saving and utilization. .
Vulnerable to malicious acts of terror and natural disasters.	Resists Attack	Resilient to attack and natural disasters with rapid restoration capabilities.
Rather than Power Quality, this system is more focused on blackout issues. Not so quick in response in resolving PQ issues.	Provides Power Quality for 1st Century needs	Power Quality is in accordance with the industry standards and customer requirements and demands. PQ issues identified and resolved prior to manifestation. Different levels of PQ at different prices possible.
Relatively small number of large generating plants. Various types of difficulties arise in interconnection of DER.	All generation and storage options considered.	Very large number of varied distributed generation and storage devices could be established to serve the large generating plants. "Plug-and-play" convenience. Considerably more focus on access to renewables.
Limited whole sale markets still working to find the best operating models. Not well integrated with each other. Transmission congestion separates buyers and sellers.	Enables Markets	Mature wholesale market operations in place; well amalgamated countrywide and consolidated with reliability coordinators. Retail Market booming where appropriate. Very less transmission congestion and constraints.
Minimal integration of restricted functional data with Asset management processes and technologies. Isolated business processes. Maintenance on time basis.	Optimizes assets and works efficiently	Greatly augmented detection and measurement of grid conditions. Grid technologies profoundly integrated with asset management processes to manage assets and costs most effectively. Maintenance on condition basis.

3. CONCLUSION

In a nutshell, the basic theory of smart grid is to improve reliability, economics, and efficiency. Increasing demand of energy is looking forward to more significant development in the sector of power systems and Smart Grid has come up as a solution to all those drawbacks of current existing grid structure by enabling all clean technologies including renewables and electric vehicles. Though many pilot schemes have been initiated, but electrical companies are not that active to promote Smart Grid. The comparison of existing and smart grid suggests researching more to implement successfully.

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