Smart Grid Scenario in India

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***Abstract*—Smart grid technologies can be defined as self-reliant systems that can find solutions to problems quickly in an available system that reduces the employees and targets sustainable, reliable, safe and quality electricity to all consumers. In this respect, different technological applications that can be seen from the perspective of researchers and investors. The Smart Grid, considered as the next generation power grid, uses two-way flows of electricity and information to create a widely distributed automatic energy delivery network. It also supports transmission and distribution system operators to follow the right path as they are transforming their classical grids to smart grids.**

***Keywords*—**Smart grid, power grid, survey, energy, information, communications, management, protection, security, privacy

I. INTRODUCTION

Traditionally, the term grid is use for an electrical energy system that may support all or some of the following four operations: electricity generation, electricity transmission, electricity distribution, and electricity control.

A smart grid (SG), also called smart electrical power grid, intelligent grid, future grid, inter grid, or intra grid, is an enhancement of the 21th century power grid. The modern power grids are generally use to carry power from a few central generators to a large number of users or customers. In the SG uses two-way flows of electricity and information to create an automated and distributed advanced energy delivery network.

By utilizing modern information technologies, the SG is capable of delivering power in more ways that are efficient and responding to wide ranging conditions and events. Mostly stated, the SG could respond to events that occur anywhere in the grid, such as power generation, transmission, distribution, and consumption, and adopt the corresponding strategies. For occurrence, once a medium voltage transforming failure event occurs in the distribution grid, the SG may automatically change the power flow and recover the power delivery service brief contrast between the existing grid and the Smart Grid.

More specifically, the SG that can be regard as an electric system that uses information, two-way, cyber-secure communication technologies, and computational intelligence in an integrated manner across electricity generation, transmission, substations, distribution and consumption to reach a system that is clean, safe, secure, reliable, resilient, efficient, and sustainable. This description covers the entire spectrum of the energy system from the generation to the endpoints of consumption of the electricity

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Smart Grid	**Existing Grid**
Digital	Electromechanical
Two way communication	One-way communication
Distributed generation	Centralized generation
Sensors all over	Few sensors
Self-monitoring	Manual monitoring
Self-healing	Manual restoration
Adaptive and islanding	Failures and blackouts
Prevalent control	Limited control
Many customer choices	Few customer choices

TABLE NO.I
A BRIEF COMPARISON BETWEEN THE EXISTING GRID AND THE SMART GRID

A. *Smart infrastructure system*

The smart infrastructure system is the energy, information, and communication infrastructure essential of the SG that supports
1)Advanced electricity generation, delivery, and consumption.
2)Advanced information metering, monitoring, and management.
3) Advanced communication technologies.

B. *Smart management system*

The smart management system is the system in SG that provides innovative management and control services.

C. *Smart protection system*

The smart protection system is the system in SG that offersinnovative grid reliability analysis, failure protection, and security and privacy protection services.

II. SMARTGRID

The initial concept of SG started with the idea of advanced metering infrastructure (AMI) with the aim of improving demand-side management and energy efficiency, and constructing self-healing reliable grid protection against malevolentharm and natural disasters. However, new requirements and demands group the electrical industries, research organizations, and governments to rethink and expand the initially perceived scope of SG. The U.S. Energy Independence and Security Act of 2007 directed the National Institute of Standards and Technology (NIST) to coordinate the research and development of a framework to achieve interoperability of SG systems and devices. Although a precise and comprehensive definition of SG has not be proposed yet, according to the report from NIST, the anticipated benefits and requirements of SG are the following:

1) Improving power reliability and quality.
2) Optimizing facility utilization and averting construction of back-up (peak load) power plants.
3) Increasing capacity and efficiency of existing electric power networks.
4) Improving flexibility to disturbance.
5) Supporting predictive maintenance and self-healing responses to system disturbances.
6) Facilitating expanded deployment of renewable energy sources.
7) Accommodating distributed power sources.
8) Automating maintenance and operation.
9) Dropping greenhouse gas emissions by enabling electric vehicles and new power sources.
10) Dropping oil consumption by reducing the need for inefficient generation during peak usage periods.
11) Presenting opportunities to improve grid security.
12) Allowing transition to plug-in electric vehicles and new energy storage options.
13) Developing consumer choice.
14) Authorizing new products, services, and markets.

In order to realize this new grid model, NIST provided a conceptual model (as shown in Fig. 1), which can be used as a reference for the various parts of the electric system where SG normalization work is taking place. This conceptual model divides the SG into seven domains. Each domain encompasses one or more SG actors, including devices, systems, or programs that make decisions and exchange information necessary for performing applications. The brief descriptions of the domains and actors given in Table 2. Refer to the appendix of the NIST report for more detailed descriptions. Note that NIST proposed this model from the perspectives of the different roles involved in the SG.

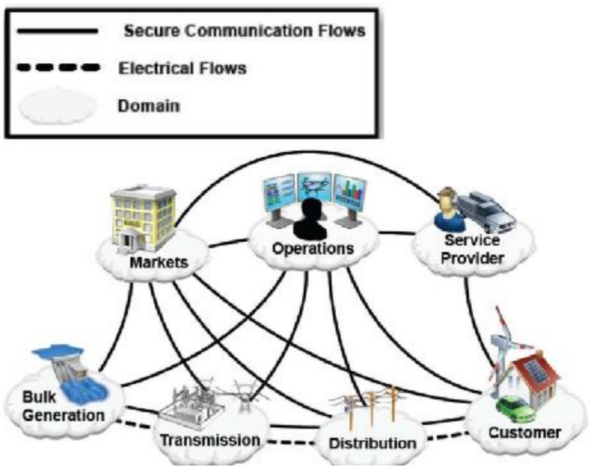

FIGURE NO I
THE NIST CONCEPTUAL MODEL FOR SG

In contrast, our survey, which looks at SG from a technical viewpoint, divides SG into three major systems: smart infrastructure, smart management and smart protection systems.

Domain	Actors in the Domain
Customers	The end users of electricity. May also generate, store, and manage the use of energy.
Markets	The operators and applicants in electricity markets.
Service Providers	The organizations providing services to electrical customers and utilities
Operations	The managers of the movement of electricity.
Bulk Generation	The generators of electricity in bulk quantities. May also store energy for later distribution.
Transmission	The carriers of bulk electricity over long distances. May also store and generate electricity.
Distribution	The distributors of electricity to and from customers. May also store and generate electricity.

TABLE NO II
DOMAINS AND ACTORS IN THE NIST SG CONCEPTUAL MODEL

A. Smart infrastructure system

The smart infrastructure system is the energy, information, and communication organizationcausal the SG. It supports two-way stream of electricity and information. "Two-way stream of electricity" implies that the electric energy delivery is not unidirectional anymore. For example, in the traditional power grid, the electricity is generate at the generating station, then transmitted through the transmission grid, the distribution grid, and finally delivered to users. In an SG, electricity can also be supplies back into the grid by users.

B. Smart management system

The smart management system is the system in SG that provides innovative management and control services and functionalities. The important reason why SG can develop the functionality based on its smart infrastructure. With the development of new management applications and services, the grid will keep becoming "smarter." The smart management system takes advantage of the smart infrastructure to pursue various advanced management objectives. So far, most of such objectives are relates to energy efficiency improvement, supply and demand balance, emission control, operation cost saving, and utility maximization.

C. Smart protection system

The smart protection system is the system in SG that provides innovative grid reliability analysis, privacy protection services, security and failure protection. By taking advantage of the smart infrastructure, the SG must not only recognize a smarter management system, but also provide a smarter protection system these can more effectively and efficiently support failure protectionmechanisms, address cyber security issues, and preserve privacy.

III. TRANSMISSIONGRID

The power transmission side, factors such as infrastructure challenges (growing load demands and quickly aging components) and advanced technologies (new materials, innovative power electronics, and communication technologies) drive the enlargement of smart transmission grids. As stated in, the smart transmission grid can be regrade as an integrated system that functionally consists of three interactive components: smart control centers, smart power transmission networks, and smart substations.

Established on the existing control centers, the future smart control centers enable many new features, such as analytical capabilities for analysis, monitoring, and visualization. The smart power transmission networks are conceptually builted on the existing electric transmission infrastructure. However, the emergence of new technologies (e.g. original materials, electronics, sensing, communication, computing, and signal processing) can help improve the power utilization, power quality, and system security and reliability, thus drive the development of a new framework architecture for transmission networks.

The vision of the smart substation is builted on the existing comprehensive automation technologies of substations. Even if the basic configurations of high-voltage substations have not changed much over the years, the monitoring, measurement, and control equipment have undergone a sea change in recent years. Major characteristics of a smart substation shall include digitalization, autonomization, co-ordination, and self-healing. By supporting these features, a smart substation is

Able to answer rapidly and provide increased operator safety. In brief, with a common digitalized platform, in the smart transmission grid it is possible to permit more flexibility in control and operation, allow for embedded intelligence, and faster the flexibility and sustainability of the grid.

IV. DISTRIBUTION GRID

For the distribution grid, the most significant problem is how to supply power to serve the end users better. But, as many distributed generators will be integrated into the smart distributed grid, this will increase the system flexibility for power generation, and on the other hand, also makes the power flow control much more complicated, in turn, necessitating the investigation of smarter power distribution and delivery mechanisms.

V. ABOUTNEWGRIDMODEL

In this subdivision, we describe two of the most important new grid models, which benefit from smart energy subsystem technologies and further promote the development of SG. These two models are widely regarded as important components of the future SG. Note that these two models also take advantage of other SG technologies, as we will explain in the corresponding sections.

A. Micro grid:

Distributed generation promotes the development of a new grid model, called micro grid, which is seen as one of the foundations of the future SG. The gradual evolution of the SG is expect to come through the plug-and-play integration of micro grids. A micro grid is a localized alignment of electricity generations, energy storages, and loads. In the normal operation, it is connect to a traditional power grid. The customers in a micro grid can generate low voltage electricity using distributed generation, such as solar panels, wind turbines, and fuel cells. The single point of common coupling with the grid can be disconnect, with the micro grid functioning separately. This operation will result in an islanded micro grid, in which distributed generators continue to power the users in this micro grid without obtaining power from the electric utility located in the grid. Fig. 2: shows an example of the micro grid. Thus, the multiple distributed generators and the ability to isolate the micro grid from a larger network in disturbance will provide highly reliable electricity supply. This deliberate islanding of generations and loads has the potential to provide a higher local reliability than that provided by the power system as a whole. Note that although these users do not obtain the power from outside in the islanding mode, they may still exchange some information with the grid. For instance, they may want to know the status of the grid and decide whether they should reconnect to the grid and obtain power from the electric utility.

Lasseter also pointed out that using micro grids in the distribution system is straightforward and simplifies the implementation of many SG functions. This consist of improved reliability, high penetration of renewable sources, self-healing, active load control, and improved efficiencies. For example, in order to realize self-healing during outages, micro grids can switch to the islanding mode and as a result, the users in micro grids will not be affect by outages.

B. G2V and V2G:

The electric vehicle is a vehicle that uses one or more electric motors for impulsion. As a fossil fuels reduce and generally

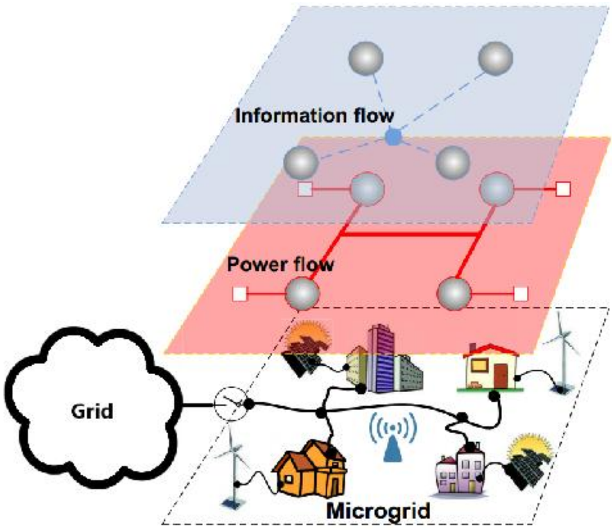

FIGURE NO II
AN EXAMPLE OF A MICRO GRID

The lower layer shows a physical structure of this micro grid, including four buildings, two wind generators, two solar panel generators, and one wireless access point (AP). These buildings and generators exchange power-usingpower lines. They exchange information via an AP-based wireless network. The blue (top) layer shows the information flow within this micro grid and the red (middle) layer shows the power flow. Get more costly, fully electric vehicles or plug-in hybrid electric vehicles will rise in popularity. In the following, we use EV to represent both fully electric vehicle and plugin hybrid electric vehicle. A wide use and deployment of EVs leads to two concepts, namely Grid-to-Vehicle (G2V) and Vehicle-to-Grid (V2G).

In G2V, EVs are often power by stored electricity originally from an external power source, and thus need to be charge after the batteries deplete. This technology is conceptually simple. However, from the perspective of the grid, one of the most important issues in G2V is that the charging operation leads to a significant new load on the existing distribution grids. Many works have studied the impact of EVs on the power grid.

In V2G, EVs deliver a new way to store and supply electric power. V2G-enabled EVs can communicate with the grid to deliver electricity into the grid, when they are park and connected to the grid. Note that as reported by Kempton et al. In the U.S, the car is drive only one hour a day on average. In other words, these cars are park most of the time doing nothing. There exist three major delivery setups:

A) A hybrid or fuel cell vehicle, which generates power from storable fuel, uses its generator to produce power for a utility at peak

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electrical usage time. This vehicle serve as a distributed generation system producing energy from conventional fossil fuels or hydrogen.

B) A battery-powered or plug-in hybrid vehicle uses its excess rechargeable battery capacity to supply power for a utility at peak electrical usage times. These vehicles can be recharge during off-peak hours at cheaper rates. These vehicles help as a distributed battery storage system to store power.

C) A solar vehicle use its excess charging capacity to provide power to the power grid when the battery is fully charged. These vehicles help as a distributed small renewable energy power system. Thus far, researchers have focused on the connection between batteries and the power grid, the validity of the V2G system, the feasible service, its environmental and economic benefits, its new markets, and system integration.

VI. SMART INFRASTRUCTURE

The development of SG relies on not only the advancement of power equipment technology, but also the improvement of sophisticated computer monitoring, analysis, optimization, and control from exclusively central utility locations to the distribution and transmission grids. Many of the concerns of distributed automation should be address from an information technology perception, such as interoperability of data exchanges and integration with existing and future devices, systems, and applications. Therefore, a smart information subsystem is use to support information generation, modeling, integration, analysis, and optimization in the context of the SG. In this segment, we concentrate on the smart information subsystem. We first explore the information metering and measurement, which generates information from end entities (e.g. smarter meters, sensors, and phasor measurement units) in an SG. This information is often use for billing, grid status monitoring, and user appliance control. We then explore the information management, including data modeling, information analysis, integration, and optimization. We finally outline some future research directions and challenges.

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A. Information Metering and Measurement

Learning in information metering and measurement can be classify into smart metering, and smart monitoring and measurement as shown in Fig. 3. In the following, we describe this classification in detail.

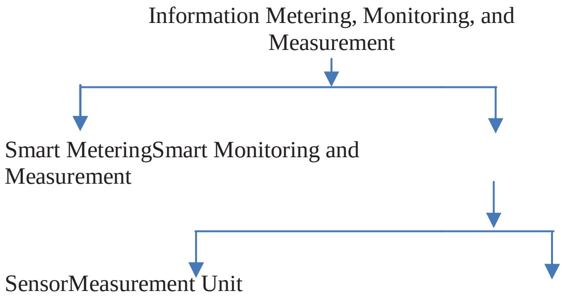

FIGURE NO III

CLASSIFICATION OF THE WORK ON THE INFORMATION METERING AND MEASUREMENT

1. Smart Metering:

Smart metering is the most significant instrument used in the SG for obtaining information from end users' devices and appliances, while also controlling the performance of the devices. Automatic metering infrastructure(AMI) systems, which are themselvesbuilds upon automatic meter reading(AMR) systems, are widely regarded as a logical strategy to realize SG. AMR is the technology of automatically collecting diagnostic, consumption, and status data from energy metering devices and transferring that data to a central database for billing, troubleshooting, and analyzing. AMI differs from traditional AMR in that it permits two-way communications with the meter. Therefore, nearly all of this information is available in real time and on demand, allowing for improved system operations and management of customer power demand. Smart meters, which support two-way communications between the meter and the central system, are similar in many parts to AMI meters, or sometimes are regrade as part of the AMI. A smart meter is usually an electrical meter that records consumption in intervals of an hour or less and sends that information at least daily back to the utility for monitoring and billing devotions. In addition, a smart meter has the ability to disconnect-reconnect remotely and control the user appliances and devices to manage loads and demands within the future "smart-buildings".

From a consumer's view, smart metering offers a number of potential benefits. For sample, end users are able to estimate bills and thus manage their energy consumptions to reduce bills. From a utility's perception, they can use smart meters to realize real-time pricing, which tries to encourage users to reduce their demands in peak load periods, or to optimize power flows according to the information sent from demand sides.

2. Smart Monitoring and Measurement:

Asignificant function in the visualization of SG is monitoring. The smart meter collects the power consumption information of the dishwasher, TV, and the refrigerator, and sends the control commands to them if necessary. The data generated by the smart meters in altered buildings is transmits to a data aggregator. This aggregator could be an access point or gateway. This data can be further route to the electric utility or the distribution substation. Note that the smart communication subsystem, defined in Section, is responsible for the information transmission. In addition, measurement of grid status. We analysis the following two major monitoring and measurement approaches, namely sensors and phasor measurement units.

- *Sensors*:

Sensors or sensor networks have nowused as a monitoring and measurement approach for different purposes. In order to detect mechanical failures in power grids such as conductor failures, tower falls, hot spots and extreme mechanical conditions.

- *Smart communication system:*

The third part in the smart infrastructure arrangement is the smart communication system. This system is responsible for communication connectivity and information transmission among systems, devices, and applications in the context of the SG. In this segment, we first give an overview of the smart communication subsystem in SG. We describe how to manage end-to-end communications in this heterogeneous communication system, where various communication technologies, network structures, and devices may be used. We lastly outline some future research and research challenges.

VII. Summary And Future Research:

In this segment, we have reviewed the work on the smart protection system in SG. Although recognition of reliable system operation, resistance to attacks and failures, and preservation of privacy are the principle characteristics in the SG vision, realizing these objectives poses many challenges. We summarize the important challenges and the possible research directions worth exploring in the following.

A. *Interoperability between cryptographic systems:*

As many different communication protocols and technologies will be use in SG, and each of them may have their own cryptography requirements and security needs, realizing interoperability between cryptographic systems is not a minor problem. Before cryptography can be use, we need a method of securely issuing and exchanging cryptographic keys. One possible solution is to design, as advised in, a public key infrastructure approach, which can mimic the layered approach used in communication models. A complete solution based on this initial idea.

B. *Clash between privacy preservation and information availability:*

It recommend defining several privacy preservation levels similar to those in access control, each of which describes anacceptable amount of information leak. In each level, based on the accessible information, we can define the management objectives. For example, one privacy policy may allow full information exchange within a group of users. Therefore, this group of users can optimize their profits using their shared information. Other mechanisms using progressive encryption techniques may also be applicable.

C. *Effect of increased system complexity and expanded communication paths:*

The progressive infrastructure used in SG is a double-edged sword. On one hand, it lays the foundation for the future innovativegrid, which can serve us better. On the other hand, increased system complexity and expanded communication paths can easily lead to an increase in vulnerability to cyber-attacks and system failures.

Therefore, the influence of system failures and attacks can be restricted to a limited level as much as possible. This is essentially similar to the concept of micro grid. We must note that "autonomy" does not mean absolutely no connection among these sub-grids and electric utilities. The result of the existence of such connections is that failures or attacks cannot be completely isolated. Thus, a complete solution needs to consider both autonomy and interconnectivity.

D. *Influence of increasing energy consumption and asset utilization:*

The modern grid is working at the "edge" of its reliable operation in more locations and more often because of increasing energy consumption and especially the methodology of increasing asset utilization (as much as possible). This inevitably increases system reliability risk. In order to improve system reliability, we first need to develop effective approaches to compute the margins in advance for reliable operation of the system. Second, we need real time monitoring methods for dynamically observe the margins. In addition, as stated before, maximizing the asset utilization could reduce the margins and hence increase the risk of system failure. We have to balance the utilization maximization and the risk increase.

E. *Complicated decision-making process:*

In direction to process failures in SG, we usually have to solve much more complex decision problems, but within shorter time. Considering that, a commercial SG may have tens of millions of nodules, realizing this is challenging. A possible solution is trying to use more distributed decision-making systems. That is to say, a large number of failure controllers could be place in the SG. Each of them takes can decrease the complexity of the decision making process and thus reduce the failure response time. However, a locally optimal decision is not continuous globally optimal. We need to consider how to balance the response time and the value of the local decision.

VIII. Conclusion

Smart Grid is regrade by the integration of communication networks and IT infrastructure with the power and energy level. It requires continuous integration of different types of majority energy sources, distributed energy sources, transmission and distribution systems, communication systems, and measurement systems. Modular integration approach and open architecture need to be implement. Dealing the large amount of information and confirming its security will be a big challenge. Cyber-security and cloud computing applications are bound to get increased importance. Experts from various domains need to be involved.

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