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Smart Grid Communication

Mrs. ShubhangiSudhirLandge

Assistant Professor, shubhangi.landge1@gmail.com 7774077173

Abstract -This paper give an introduction to the smart grid communication. It describes a communication-oriented smart grid framework. It provides comprehensive understanding of the communications issues in the smart grid. Hence the framework given can be used properly to design a smart grid communication system. Italso introduces a three-entity, high-level, communication-oriented framework for the smart grid along with a closer look at each entity.

Keywords – Wide-area monitoring and control network (WAMCN), Local area network (LAN), smart meter (SM), local energy management (LEM), consumers network gateway(CNG), Smart grid, Control centers (CC

i. INTRODUCTION

The traditional electricity grid has four major components: power generation, power transmission, power distribution, and grid operation. Power generation usually consists of numerous types of generation plants, such as fossil-fuel power plants and nuclear power plants. The generated electricity is fed into the transmission network. It consists of High voltage and extra high voltage transmission lines and transmission substations. It delivers power over long distances. This electricity is handed over to the distribution subsystem and then dispatched to the customers. Power operation monitors and controls the flow of electricity and all grid components and is essential to the proper functioning and efficiency of the grid.

After serving for more than a century, existing electricity grids have found to be incapable of satisfying the desire for greater system reliability and increased usage of renewable energy sources so as to reduce emissions of the greenhouse gases that cause global warming. The amount of electricity generation and consumption should be exactly matched at any given instant in time. Otherwise, either the excess amount of electricity generated is wasted or power outages will occur due to insufficient energy supply. In the existing electricity grid, numerous schemes have been developed to balance generation and consumption. Because of the stochastic nature of renewable energy generation, however, none of the existing schemes will be adequate when there is a high percentage of renewable energy generation in the grid. Most existing electricity grids cannot tolerate more than 10% of renewable energy. Also there is a desire to involve customers in grid operations. Hence there is an urgent need to upgrade the existing grid. The future electricity grid is the "smart grid." This future smart grid will be capable of:

- Accommodating a high percentage of renewable energy generation.
- Providing high-quality and highly reliable electricity services to customers.
- Actively involving consumers in grid operations.

For successfully up gradation of to a smart grid, advanced communication technologies are essential. The benefits of these technologies are more accurate and timely dissemination of state information about the grid. Hence the grid operation programs can be carried out with precise and efficient real-time scheduling. It is necessary to reduce the problems brought due to volatility of renewable generation and fluctuations in customer demand.

This paper gives an introduction of the smart grid and describes a communication-oriented smart grid framework. It also introduces a three-entity, high-level, communication-oriented framework for the smart grid

ii. SMART GRID FRAMEWORK

The smart grid communication framework consists of three networks: the operation network, the business network, and the consumer network as shown in fig. 1. Each of these three networks represents a different set of communication networks serving for different functions. The operation network is used by power companies for maintaining the grid functionality. The business network is used by participants in the electricity market to efficiently regulate the market and to provide electricity services to consumers. The consumer network is used by each consumer for management of home energy and to enhance the electricity usage.

The operation network is the backbone of the smart grid communication system. The design of operational network requires a deep understanding of the existing power system. It involves collaboration with power system and communication engineers. The business network is the connection between the operation network and the consumer network. Its design requires knowledge of economics and government policies. It maximizes the efficiency of the electricity market. The consumer network is used for serving the end users. It also exploits the advantages retrieved by the other two entities.

The important merits of this network are that it captures the major differences between the communication systems used in traditional electricity grids and in smart grids.

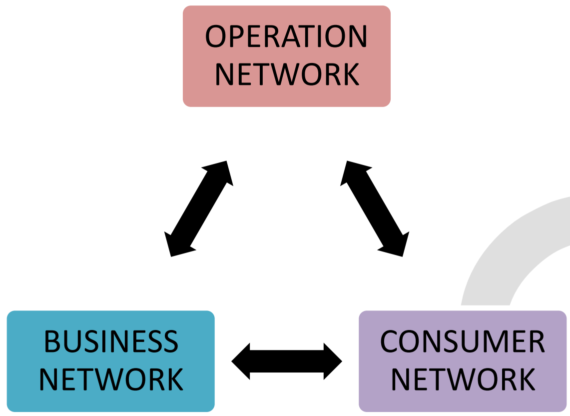

figure 1. A smart grid communication framework

iii. *COMMUNICATIONS WITHIN AND BETWEEN ENTITIES*

a. **Communications in the Operation Network**

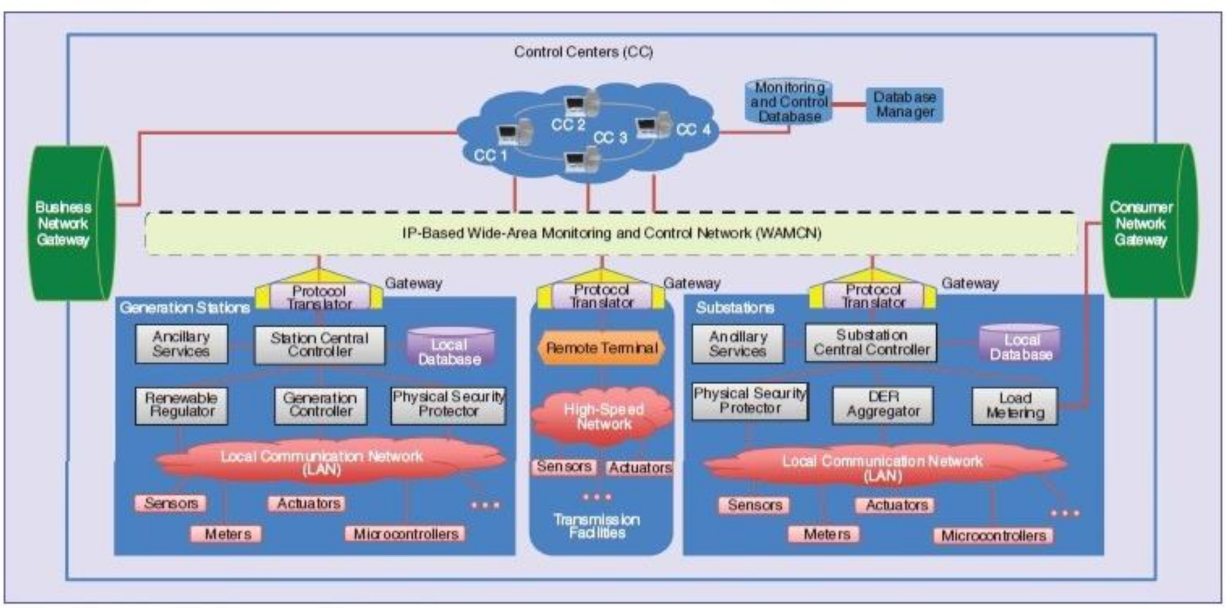

figure 2. The Operation network

The operation network consists of seven major components: the business network gateway (BNG), consumer network gateway (CNG), control centers (CC s), generation station (GS), substation (SS), transmission facilities (TFs), and wide-area monitoring and control network (WAMCN).

The BNG and CNG are the communication bridges. It connects the operation network with the other two entities. As the three entities are used by different parties and serves different purposes in the smart grid, when interentity communications are needed, the BNG and CNG serve as firewalls. It protects the operation network from external, malicious attacks.

CC s is the central control units of smart grid. The monitoring and control database (MCD B) is storing all grid operation information. This is accessed by CC s and maintained by database managers. In the traditional electricity grid, CC s follow a strict hierarchical design, with each grid area controlled by a single CC that in turn is controlled by upper-level CC s. A distributed CC design has strong advantages over the centralized one in increasing service availability. The distributed CC design is therefore taken as the future of control in the smart grid.

The GS component usually consists of a collection of large power generation stations, each of which may contain many sensors and actuators connected by a local-area network (LAN) and controlled by a local control unit. The local control unit in each GS communicates with CCs via the WAMCN, through a gateway. This second gateway, which complements the CNG and BNG, is used to prevent insider attacks initiated by someone who has managed to get into the WAMCN

The SS component is the collection of transmission and electricity distribution substations. It typically has a communication structure similar to that found in the GS component. Since distribution substations are close to consumers and are sometimes configured so as to have access to consumer datavia the CNG , the privacy of those data must be carefully protected. Other than that, the communication requirementsinside the SS and GS components are mostly the same.

The TF component consists of the assets involved in long-distance electricity transmission. These assets include transmission towers and underground cables. The TF component consists of some remote control terminals and a huge number of sensors and actuators located across a wide area. These terminals, sensors, and actuators are connected via a wide-area, high-speed network. Usually, data gathered by the TF component are concentrated by remote control terminals to avoid network congestion before being sent into the WAMCN and delivered as needed.

The WAMCN is the backbone of the operation network and is used to transfer huge volumes of data among the GS, TF, SS, and CC components. In designing the WAMCN, the following requirements must be met:

- High availability: Since the unavailability of the WAMCN means the loss of most communication services, it is crucial that backup schemes for this network be properly provisioned.
- High security: Although gateways such as the CNG and BNG are installed in the operation network, the routers and switches inside the WAMCN still need to be able to resist insider attacks.
- Quality of service: Since different types of data are needed by different parties and different applications, the WAMCN needs to be able to prioritize data transmissions according to needs.
- Compatibility: During the process of upgrading the existing grid to the smart grid, it is possible that multiple legacy protocols that are incompatible with each other will be used simultaneously in the operation network. Protocol translators in the GS, TF, and SS components can help alleviate such problems. The WAMCN must employ globally accepted protocol such as the Internet Protocol (IP) to truly accommodate such compatibility requirements.

b. Communications in the Consumer Network

The consumer network is made up of six major components: the BNG and operation network gateway (ONG), the smart meter (SM) component, the home electronics (HE) component, local energy management (LEM),a smart controller (SC), and a LAN.

The BNG and ONG here serve as the primary protectors of the information inside the consumer network against intrusions by outsiders. Since data protection requirements at the consumer end are usually less stringent than those in the operation and business networks, designing these two gateways is a simpler task. The only major concern is the protection of consumer privacy. The BNG and ONG in the consumer network should be designed in such a way that consumers are aware of the types of information being requested by other parties and are capable of deciding whether or not the requested information should be released.

The SM is the electricity meter, with a built-in communications module and processor. It receives real-time electricity price data from the business network and sends consumer consumption profile data to the operation network. The price information received by SM is used by other components in the consumer network to perform various functions, and the environmental data collected by the sensors on those appliances, the power level of these appliances may be automatically adjusted to reduce overall electricity costs. An extra gateway is proposed to control access to the HE component, for security reasons. This gateway provides security functions, such as an authenticity check, to protect the appliances from being controlled by unauthorized parties.

LEM is present on the consumer network to accommodate distributed energy generation, such as small-scale wind generation or solar panels, and larger energy storage devices such as electric vehicles at a consumer's premises. With these distributed generation and storage assets, a consumer can actively participate in the electricity market by selling stored electricity when the price is high and purchasing extra electricity when the price is low. LEM is under the control of the SC, and the decision is made largely based on the current electricity price shown by the SM, which is in turn based on the current electricity demand-supply relationship in the market and the operational status of the grid. The SC is the central controller on the consumer network and is therefore considered its most important component. Since the functionality of the SC relies heavily on the LAN, the LAN is seen as essential to the consumer network. Two of its most important general communication requirements can be summarized as follows:

- Authenticity: Since consumers' premises usually are close to each other, undesirable consequences may be caused if a command issued by the SC in one consumer's home is accepted by the appliances inside another consumer's home. As a result, it is necessary that the LAN in the consumer network be able to encrypt messages in such a way that only authenticated devices can decrypt the contents and only authenticated commands are executed. This functionality may be aided by the HE gateway.
- Integrity: LAN in this context does not require high reliability or low latency but it must be ensured that the integrity of messages is strictly guaranteed. For instance, it must be ensured that the HE component will only execute commands issued by the SC if they are guaranteed to have been correctly received.

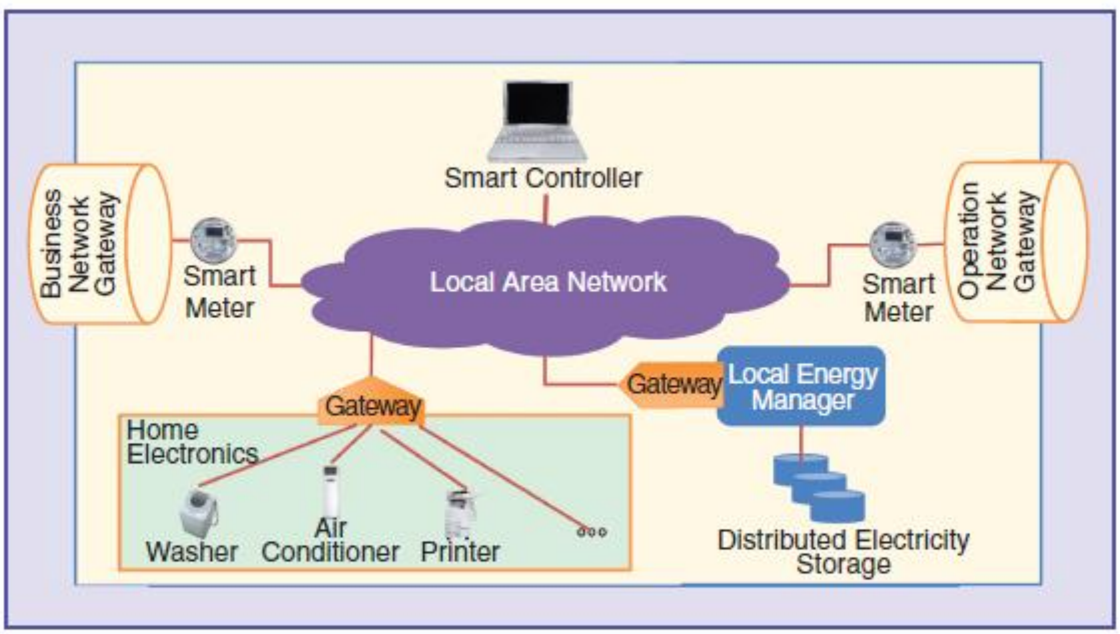

Figure3. The Consumer network

c. Communications in the Business Network

The business network does not possess dedicated communication architecture. It includes numerous new participants and players in the electricity market that communicate with each other using an IP based virtual private network (VPN). As shown in Figure 4, the electricity market regulator, smart meter service provider, demand responder, and electricity market participants are the major players in the business network. There are also parties that communicate with the consumer and operation networks to obtain smart meter data and smart grid operation data via the CNG and ONG, respectively.

Communications within the business network are mostly for commercial use, and hence economy and security are of the utmost concern. This will not be a big issue once an IP based network is used, however. Since IP has been under development for decades, players in the business network will not have much difficulty finding their desired applications and services from the market.

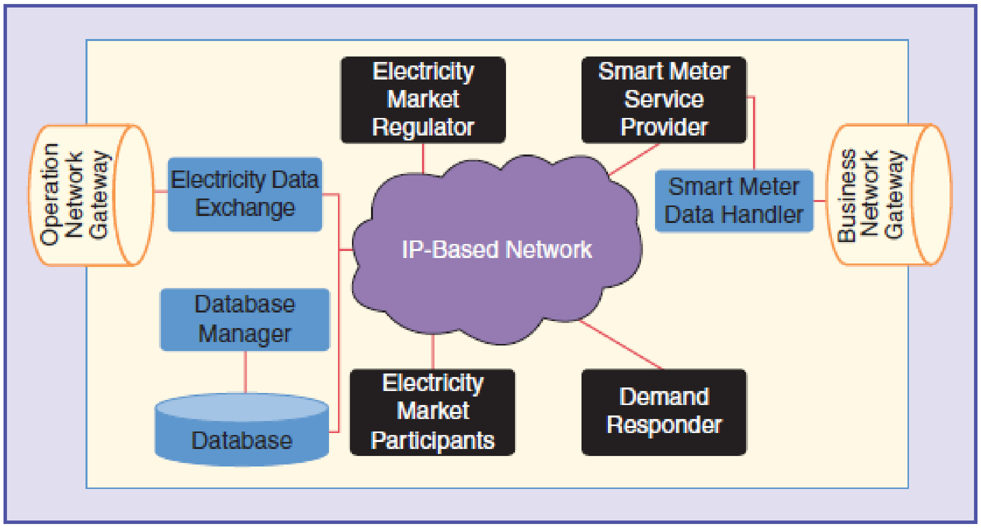

figure 4. The Business Network

iv. INTERENTITY COMMUNICATIONS

Interentity communications are very important for the proper functioning of the entire communication system in the smart grid. Communications between the operation and business networks require high reliability and security. Those between the operation and consumer networks require high security but relatively lower reliability. However for communications between the business and consumer networks only moderate levels of reliability, data availability, and security are required.

v. CONCLUSION

In designing the communication systems within the operation network, compatibility with existing technologies is of the utmost concern. Designing the consumer and business networks requires innovation to enhance the user experience but carries limited compatibility restrictions. In the traditional electricity grid, the most important communication system is supervisory control and data acquisition (SCADA), used by system operators to monitor the operational status of the entire system and to issue commands to particular components remotely. SCADA may be too slow to respond properly to urgent events. Instead of this a high speed system offering similar functionalities called a wide-area measurement system (WAMS) can be used in the smart grid. But as SCADA has been in existence for decades, it is neither economic nor feasible to simply throw it out and use new technologies. As a result, the coexistence of SCADA and new advanced systems such as WAMS is seen as the true future in smart grid communications.

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