Planning and Operation of Smart Grid Technology With Integration of Renewable Resources

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Abstract- *Before we can begin to modernize today's grid, we first need a clear vision of the power system required for the future. Understanding that vision, we can create the alignment necessary to inspire passion, investment, and progress toward the Smart Grid for the 21st century. The Smart Grid is a necessary enabler for a prosperous society in the future. Energy supply has become one of the most challenging issues facing the world in the 21st Century. Growing populations, more homes and businesses and a myriad of new appliances have caused energy demand to skyrocket in every part of the country. Utilities across the globe are trying to figure out how to bring their networks into the 21st century and the digital age. This effort to make the power grid more intelligent is generally referred to as creating a "smart grid". The industry sees this transformation to a smart grid improving the methods of delivery as well as consumption.*

Keywords- Smart Grid, Renewable Energy, Transmission Line

I. INTRODUCTION

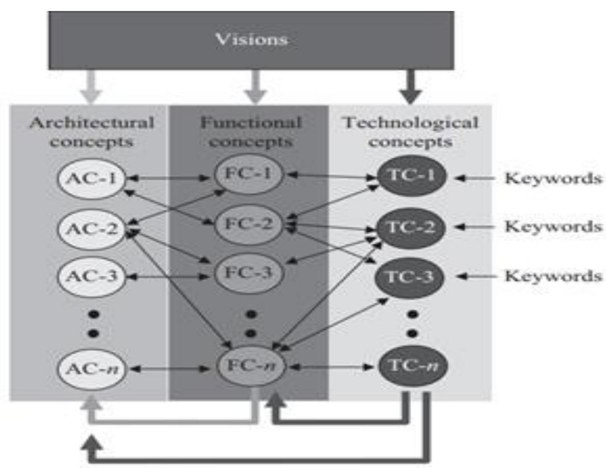
A SmartGrid is an electricity network that can intelligently integrate the actions of all users connected to it – generators, consumers and those that do both – in order to efficiently deliver sustainable, economic and secure electricity supplies. It uses digital technology to improve reliability, security,and efficiency (both economic and energy) of the electric system from large generation, through the delivery systems to electricity consumers and a growing number of distributed-generation and storage resources.

Similar to the definition of the Smart Grid, its characteristics have been identified by different organizations/authors using different approaches.

- Optimize asset utilization and operating efficiency.
- Accommodate all generation and storage options.
- Provide power quality for the range of needs in a digital economy.
- Anticipate and respond to system disturbances in a self-healing manner.
- Operate resiliently against physical and cyber-attacks and natural disasters.
- Enable active participation by consumers.
- Enable new products, services, and markets.

1.1 Smart Grid vision and its realization:

The proposed Smart Grid vision is based on a three-layered approach: architectural, functional, and technological concepts layers as shown in Figure 1.1.



I. Architectural concepts layer 1:

● Evolution of energy supply mix
● Enhancement of transmission networks
● Coexistence of electrical network configurations
● End-use as an active component
● Advancement of enabling technologies
● Control methodologies

II. Functional concepts layer 2:

● Communications networks
● Cyber-security 12 Smart Grid: concepts, technologies and evolution
● Markets and economics
● Operations, monitoring, and control
● Planning, analysis, and simulation

● Systems engineering
● Visualization and data management

III. Technological concepts layer 3 :

● Computer applications
● Cyber-security
● Distributed systems architectures
● Information science

II. THE EVALUATION PATH OF SMART GRID

2.1 Conventional electrical networks:

2.1.1 Infrastructure of conventional electrical networks

Conventional electrical supply network usually consists of generation, transmission, distribution, and consumer (load) systems. Generation system normally consists of a combination of large-scale centralized generation plants. A typical modern generating unit has rated value of over 1,000 MW. A transmission system is specifically designed to transfer bulk of power from generating plants to distribution systems at high- and extra-high voltage levels over long distances. Typical operating voltages of transmission systems include 765 kV, 500 kV, 400 kV, and 275 kV. Distribution systems, however, are specifically designed to receive electric power from transmission system to be distributed to load centers. It is therefore important to note that the role of a distribution network is passive, that is, its role is confined to transferring electricity from generation and transmission systems to load centers. The operating voltage of distribution networks includes 132 kV, 110 kV, 66 kV, 33 kV, 20 kV, and 11 kV.

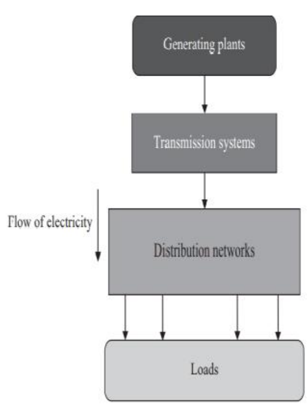


Figure 2.1 Principles of vertical structure of conventional power systems whereby the flow of electricity is unidirectional

2.1.2 Main characteristics of conventional electrical networks

The main characteristics of conventional electrical networks include:

(i) Conventional electrical network has vertical structure.
(ii) Power flow is unidirectional. This is particularly true for distribution networks.
(iii) The price of electricity is dictated by the utility to which the consumer is connected. In other words, consumers have no choice of opting from where they buy their electricity, that is, consumers are considered passive.

2.2 Comparison between Smart Grid and conventional electrical networks:

Table 2.1 Fundamental differences between the Smart Grid and conventional electrical networks

Feature/component	Conventional network	Smart Grid
Communications	None or one-way, typically not real-time	Two-way, real-time
Customer interaction	Limited	Extensive
Metering	Electromechanical	Digital (enabling real-time pricing and net metering)
Operation and maintenance	Manual equipment checks	Remote monitoring, predictive, time-based maintenance
Generation	Centralized	Centralized and distributed
Power flow control	Limited	Comprehensive, automated
Reliability	Prone to failures and cascading outages, essentially reactive	Automated, proactive protection, prevents outages before they start
Restoration following disturbance	Manual	Self-healing
Topology of distribution networks	Radial, generally one-way power flow	Network, multiple power flow pathways

III. SMART GRID INFRASTRUCTURE

3.1 Advanced metering infrastructure:

Development of AMI is considered as the milestone of modernizing conventional electric power system and its evolvement to the Smart Grid. A key benefit of AMI 32 Smart Grid: concepts, technologies and evolution is, it provides customers real-time (or near real-time) pricing of electricity and it also helps utilities to achieve necessary load reductions. In this section, a definition of the AMI will be given followed by discussing the components/technologies from which AMI consists of.

AMI therefore is an integration of several technologies that provides an intelligent connection between consumers and system operators. It facilitates the supply to consumers with the necessary information they need to make intelligent decisions, the ability to execute those decisions and a variety of choices leading to substantial benefits they do not enjoy under conventional electrical network environment.

Technologies involved in such integration include smart metering, home area networks, integrated communications, data management applications, and software interfaces with existing utility operations and asset management processes. The system resultant from the integration of these technologies enables AMI providing the required link between the grid, consumers and their loads, and generation and storage resources.

2.3.1 **Main components of AMI**

I. **Smart meters:**

Smart meters are typically digital programmable devices that record customer consumption of electric energy in intervals of an hour or less and communicate that information, daily or more frequent, back to the energy supplier for monitoring and billing purposes.

Other functions of smart meters include

(i) time-based pricing,
(ii) net metering,
(iii) loss of power and restoration notification,
(iv) remote turn on/turn off operations,
(v) load limiting for ‘‘bad pay’’ or demand response purposes,
(vi) energy prepayment,
(vii) power quality monitoring,
(viii) tamper and energy theft detection,
(ix) communications with other intelligent devices in the home

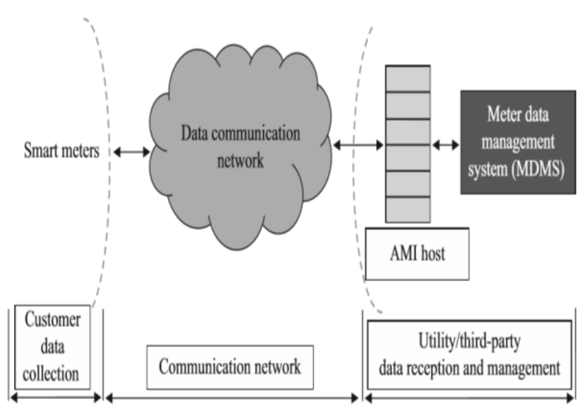


Figure2.2 Three main components of AMI

II. **Communication network :**

Communication network is the second important component of an AMI system. The aim of the communications network employed by AMI is to continuously support the interaction between the energy supplier, the consumer, and the controllable electrical load. Under such environment, open bidirectional communication standards must be employed but at the same time it must be highly secured. With bidirectional communications, utilities can monitor real-time consumption by end-users. It also enables end-users to actively participate in system operation by facilitating receiving price information or control signals from utilities.

There are different media that can be considered to provide part or all of communication architecture:

- Power line carrier (PLC)
- Broadband over power lines (BPL)
- Copper or optical fiber
- Wireless (radio frequency), either centralized or a distributed mesh
- Internet
- Combinations of the above

III. **Data reception and management system :**

The meter data transferred over the communication network are received at utility/third party site by the AMI host system, which is then sent to the meter data management system (MDMS).

MDMS plays an important role in realizing the full potential functions of AMI, particularly when implemented prior to a large-scale residential AMI installation . The major functions of MDMS system include (i) automating and streamlining the complex process of collecting meter data from multiple meter data collection technologies, (ii) evaluating the quality of the collected data and generating estimates where errors and gaps exist, and (iii) delivering the collected data in a format that suits utility billing systems.

In the context of AMI system, smart meters are usually located at customer premises outside residential buildings while MDMS are located at the utility side. Therefore, smart meters and MDMS communicate with each other within a neighborhood through neighborhood area network (NAN) .. In addition to the above three main components, home area networks (HANs) and operational gateways are also considered as constituents of an AMI system.

IV. COMPOSITION OF SMART GRID

From technical perspective point of view the Smart Grid is considered to consist of the following three major systems:

(i) Smart infrastructure system
(ii) Smart management and control system
(iii)Smart protection system

(i) **Smart infrastructure system**:

The smart infrastructure system consists of (i) electrical energy subsystem, whose function is to generate electricity, transmit it, and distribute it to load centers, (ii) information subsystem, whose function is to support advancedinformation metering, monitoring, and management systems and (iii) communication infrastructure subsystem, whose function is to perform communication and information transmission between various subsystems, devices, and applications from which Smart Grid consists of. Under Smart Grid environment, the smart infrastructure system supports two-way flow of electricity and information. Unlike conventional power system networks, in addition to central generating plants, the electricity may be generated at distribution voltage level by customers or otherwise and fed back to the grid. For example, customers may generate electricity using solar panels at homes and feed it back to the grid. Electric vehicles may also be used to help in ‘‘peak shaving,’’ a process whereby electric power is fed back to the grid to balance loads during peak demand periods.

(ii) **Smart management and control system**:

The smart management and control system of the Smart Grid provides advanced management and control services. The main objective of this system is to improve energy efficiency, ensure supply and demand balance, ensure greenhouse gas emission control, reduce operation cost, and maximize utility profit.

(iii) **Smart protection system**:

The smart protection system of the Smart Grid provides advanced grid reliability analysis, failure protection, and security and privacy protection services. The function of this system does not confine only to the protection of the grid from unintentional faults due to users, errors, equipment failures, and natural disasters, but it also includes protecting the grid from deliberate cyber-attacks that can be committed, for example, by disgruntled employees, industrial spies, and terrorists.

V. CONCLUSION

A smart grid is an electricity network that uses digital and other advanced technologies, such as cyber-secure communication technologies, automated and computer control systems, in an integrated fashion to be able to monitor and intelligently and securely manage the transport of electricity from all generation sources both traditional and renewable to economically meet the varying electricity demands of end-users. The motives behind the development of the Smart Grid concept have also been identified. Such motives include (i) aging of conventional electrical networks, (ii) political and environmental factors, (iii) economical factors, and (iv) motivation and inclusion of customers connected to Smart Grid.AMI is viewed as an important tool for providing the essential link required between the grid, consumers and their loads, and generation and storage resources.

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22 Smart Grid: concepts, technologies and evolution
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