Challenges in Implementing Smart Grid in Power Systems

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Abstract- Electricity, considered by most to be energy, is actually an energy currency. Power collected from a variety of sources, such as falling water, burning fuel, wind and solar is used to create electricity for delivery to customers. Electricity has proven to be a convenient and efficient means of delivering energy. Electricity is delivered at the speed of light and is consumed the instant it is created. There is no means to store electricity without converting it to another form of energy. As a result, the demand for power, driven by users, must match the supply of power from the available sources (e.g. generators and energy storage devices) at all times. As the Smart Grid continues to evolve, and demand-side management, which is available today, builds on its growing reputation as a cost-effective way for industrial users to manage energy usage and costs, buy-in from both residential and industrial consumers will become simpler. In this paper we have discussed use of ICT in Smart Grid, concept of Smart Grid, Goals and Objectives of Smart Grid, Characteristics of Smart Grid, Smart Grid Applications and Services, and Challenges in Smart Grid.

Keywords: - Electricity, ICT, Grid, Smart, power

I. INTRODUCTION

Smart Grid is a new electricity network, which highly integrates the advanced sensing, and measurement technologies, information and communication technologies (ICTs), analytical and decision-making technologies, automatic control technologies with energy and power technologies and infrastructure of electricity grids. Some important aspects of what 'smart' are as follows:

- ***Observability*:** It enables the status of electricity grid to be observed accurately and timely by using advanced sensing and measuring technologies;
- ***Controllability*:** It enables the effective control of the power system by observing the status of the electricity grid;
- ***Timely analysis and decision-making*:** It enables the improvement of intelligent decision-making process;
- ***Self-adapting and self-healing*:** It prevents power disturbance and breakdown via self-diagnosis and fault location.
- ***Renewable energy integration*:** It enables to integrate the renewable energy such as solar and wind, as well as the electricity from micro-grid and supports efficient and safe energy delivery services for electric vehicle, smart home and others.

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II. Goals and Objectives of Smart Grid

Efficient and reliable transmission and distribution of electricity is a fundamental requirement for providing societies and economies with essential energy resources. The utilities in the industrialized countries are today in a period of change and agitation. On one hand, large parts of the power grid infrastructure are reaching their designed end of life time, since a large portion of the equipment was installed in the 1960s. On the other hand, there is a strong political and regulatory push for more competition and lower energy prices, more energy efficiency and an increased use of renewable energy like solar, wind, biomasses and water.

In industrialized countries, the load demand has decreased or remained constant in the previous decade, whereas developing countries have shown a rapidly increasing load demand. Aging equipment, dispersed generation as well as load increase might lead to highly utilized equipment during peak load conditions. If the upgrade of the power grid should be reduced to a minimum, new ways of operating power systems need to be found and established.

In many countries, regulators and liberalization are forcing utilities to reduce costs for the transmission and distribution of electrical energy. Therefore, new methods (mainly based on the efforts of modern information and communication techniques) to operate power systems are required to guarantee a sustainable, secure and competitive energy supply.

The general goals of Smart Grid are to ensure a transparent, sustainable and environmental-friendly system operation that is **cost and energy efficient, secure and safe**. Objectives of developing the Smart Grid are quite different from country to country for their various demands and start points. However, the common objectives of a Smart Grid are clear and listed below:

- ***Robustness*:** The Smart Grid shall improve resilience to disruption to provide continuous and stable electricity flows, avoiding wide-area breakout accidents. It shall guarantee the normal and secure run of the electricity grid even under the instance of emergency issues, such as natural disasters, extreme weather and man-made breakage, and provides self-healing abilities;
- ***Secured operation*:** The Smart Grid shall enhance communication networks and information security of the electricity grid;
- ***Compatibility*:** The Smart Grid shall support the integration of renewable electricity such as solar and wind, has the capacity of distributed generation access and micro-grids, improve demand response functions, implement the effective two-way communication with consumers and satisfy various

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electricity demands of consumers;

- ***Economical energy usage*:** The Smart Grid shall have the capacity of more effective electricity markets and electricity trades, implement optimized configuration of resources, increase efficiency of the electricity grid, and reduce electricity grid wastage;
- ***Integrated system*:** The Smart Grid shall highly integrate and share information and data of an electricity grid, utilize the uniform platform and model to provide standardized and refined management;
- ***Optimization*:** The Smart Grid shall optimize assets, reduce costs and operate efficiently;
- ***Green energy*:** The Smart Grid shall solve problems of energy security, energy saving, carbon dioxide emission and etc.

III. Characteristics of Smart Grid

Smart Grid has the following fundamental characteristics:

- Use of information, computing, networking technologies to support the envisioned Smart Grid services: energy distribution management, energy trading, grid monitoring and management, distributed renewable energy integration, electric vehicles charging, distributed energy storage, and smart metering infrastructure;
- The Smart Grid services involve many parties across many domains, in particular active participation of customers is essential;
- Smart Grid requires new capabilities in each functional plane to achieve its goal of energy efficiency, reliability, and automation, such as new algorithms in the Services/Applications plane, security and QoS-awared two-way communications in the Communication plane, two-way transmission capability, storage techniques, and new intelligent sensors/controllers in the Energy plane;
- In order to support these services, the ICT systems must
    - provide wide range of applications such as home, building, and factory energy management systems, on demand meter readings, demand and response systems, electrical grid status monitoring, fault detection, isolation, and recovery;
    - manage wide variety of devices such as intelligent sensors, smart meters, smart appliances, and electric vehicles;
- The network infrastructure must provide reliable two-way communication and support various class of QoS, such as real-time and non-real-time, and different bandwidths and latency, loss, and security requirements;
- To ensure the interoperability of applications and devices, interoperable standards are required for communications, information representations and exchanges;
- Security of services, applications, devices in all domains, including the networks are of paramount importance to the stability and integrity of the Smart Grid.

IV. Smart Grid Applications and Services

The Smart Grid Services/Applications contains representative applications in conceptual domains which are listed below:

- ***Customer Domain***
    - This domain consists of several sub-domains: home, commercial/building, and industrial. Hence, the applications can be categorized into energy store, management and generation for home, building, and industrial, respectively.
    - Besides the basic functions within a building and home such as lighting and temperature control, energy management system (EMS) is a core application providing the capability for in-home/building display of customer usage, reading of meters, and integration with building management systems and the enterprise, and remote load control, monitoring and control of distributed generation, the EMS provides auditing/logging for system troubleshooting and security purposes as well.
- ***Operation Domain***
    - This domain consists of the applications for distributed network operation, including the Supervisory Control and Data Acquisition (SCADA) systems to monitor and control the status of devices in bulk generation, transmission, and distribution domains.
    - Operation domain also consists of the applications for general operations, including the asset management and meter data management (i.e., energy usage, energy generation, meter logs, and meter test results) to make energy data available to authorized parties.
- ***Service Provider***
    - This domain consists of applications such as customer and account management, and installation management. Customer management is to manage customer relationships by providing point-of-contact and resolution for customer issues and problems. Conversely, installation management is to install and maintain the premises equipment that interacts with the Smart Grid.
    - Service provider domain also consists of applications such as billing/ account management, home management, building management, and others. In particular, building management is to monitor and control building energy, and respond to Smart Grid signals while minimizing impact on building occupants. Home management is to monitor and control home energy and respond to Smart Grid signals while minimizing impact on home occupants. Billing

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management is to manage customer billing information. Account management is to manage the supplier and customer business accounts.

- ***Markets***
  - The main applications include the distributed energy resource aggregation, wholesaler and retailer marketing. To be specific, retailers sell power to end customers and may play aggregation role as a broker between customers and the market. Most of retailers are connected to a trading organization to allow participation in the wholesale market.
  - Other applications include dynamic pricing, trading, and market management. Traders are participants in markets and include aggregators for provision and consumption and curtailment, and other qualified parties.
- ***Bulk Generation***
  - The main applications in this domain include bulk generation plant control, measure, and traditional energy generation. In particular, the plant control permits the operations domain to manage the flow of power and ensures the reliability of the system. Measurement is used to provide visibility into the flow of power and know the condition of the systems in the field remotely.
  - Other applications include renewable energy generation and storage.
- ***Transmission and Distribution***
  - The main applications within these two domains include distributed energy generation (i.e., wind, solar, thermal), distributed storage, substation, and local distribution network monitoring and control. Substation management and control contains switching, protection and control equipment, i.e., sub-stations connecting generation (including peaking units) and storage with distribution. Substations may also connect two or more transmission lines.
  - Other applications include local network monitoring and control used to measure, record, and control with the intent of protecting and optimizing the operation of electricity transmission and distribution.

V. Challenges in Smart Grid

The utilities of the Smart Grid shall address the following challenges:

- High power system loading;
- Increasing distance between generation and load;
- Fluctuating renewable;
- New loads (hybrid/electric vehicles);
- Increased use of distributed energy resources;
- Cost pressure;
- Utility unbundling;
- Increased energy trading;
- Transparent consumption & pricing for the consumer;
- Significant regulatory push.

VI. Conclusion

The key market drivers behind Smart Grid solutions are:

- Need for more efficient use of energy;
- Increased usage of renewable energy resources;
- Sustainability;
- Competitive energy prices;
- Security of supply;
- Ageing infrastructure and workforce.

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