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SMART GRID TECHNOLOGY

P Vijaypaul, SK Reshma
DEPT. OF ELECTRICAL AND ELECTRONICS ENGINEERING
SAMSKRUTI COLLEGE OF ENGINEERING AND TECHNOLOGY
HYDERABAD, INDIA
vijaypaul.my@gmail.com

Abstract

Smart Grid refers to a range of energy policies designed to reduce peak energy load.
The electrical grid is expected to evolve to a new grid paradigm--smart grid, an enhancement of the 20th century electrical grid. The traditional electrical grids are generally used to carry power from a few central generators to a large number of users or customers. In contrast, the new emerging smart grid uses two-way flows of electricity and information to create an automated and distributed advanced energy delivery network.
A smart grid is an electrical grid that uses information and communications technology to gather and act on information, such as information about the behaviours of suppliers and consumers, in an automated fashion to improve the efficiency, reliability, economics, and sustainability of the production and distribution of electricity.

I. INTRODUCTION:

Origin of the term "smart grid":

The term smart grid has been in use since at least 2005, when it appeared in the article "Toward A Smart Grid" by Amin and Wollenberg. The term had been used previously and may date as far back as 1998. Various capabilities result from the deeply integrated use of digital technology with power grids, and integration of the new grid information flows into utility processes and systems is one of the key issues in the design of smart grids. Much of the modernization work that has been going on in electric grid modernization, especially substation and distribution automation, is now included in the general concept of the smart grid, but additional capabilities are evolving as well.

According to a newest survey on smart grid the research is mainly focused on three systems in smart grid.

1. The infrastructure system,
2. The management system, and
3. The protection system.

1. **The Infrastructure System** is the energy, information, and communication infrastructure underlying of the smart grid that supports

- Advanced electricity generation, delivery, and consumption;
- Advanced information metering, monitoring, and management; and
- Advanced communication technologies.

In the transition from the conventional power grid to smart grid, we will replace a physical infrastructure with a digital one. The needs and changes present the power industry with one of the biggest challenges it has ever faced.

2. The Management System is the subsystem in smart grid that provides advanced management and control services. Most of the existing works aim to improve energy efficiency, demand profile, utility, cost, and emission, based on the infrastructure by using optimization, machine learning, and game theory. Within the advanced infrastructure framework of smart grid, more and more new management services and applications are expected to emerge and eventually revolutionize consumers' daily lives.

3. The Protection System is the subsystem in smart grid that provides advanced grid reliability analysis, failure protection, and security and privacy protection services. We must note that the advanced infrastructure used in smart grid on one hand empowers us to realize more powerful mechanisms to defend against attacks and handle failures. For example, NIST pointed out that the major benefit provided by smart grid, the ability to get richer data to and from customer smart meters and other electric devices, is also its Achilles' heel from a privacy viewpoint. The obvious privacy concern is that the energy use information stored at the meter acts as an information rich side channel.

II. EARLY TECHNOLOGICAL INNOVATIONS

Smart grid technologies have emerged from earlier attempts at using electronic control, metering, and monitoring.

- In the 1980s,Automatic meter reading was used for monitoring loads from large customers, and evolved into the Advanced Metering Infrastructure. Whose meters could store how electricity was used at different times of the day.
- Smart meters add continuous communications so that monitoring can be done in real time, and can be used as a gateway to demand response-aware devices.
- Recent projects use *Broadband over Power Line (BPL)* communications, or wireless technologies such as mesh networking that is advocated as providing more reliable connections to disparate devices in the home.
- Monitoring and synchronization of wide area networks were revolutionized in the early 1990s when the Bonneville Power Administration expanded its smart grid research with prototype sensors that are capable of very rapid analysis of anomalies in electricity quality over very large geographic areas.

III. FEATURES OF THE SMART GRID

The smart grid represents the full suite of current and proposed responses to the challenges of electricity supply. There are numerous diverse range of factors which include.

- Reliability.
- Flexibility in network topology.
- Efficiency
- Sustainability
- Market-enabling

Reliability:

The smart grid will make use of technologies that improve fault detection and allow self-healing of the network without the intervention of technicians. This will ensure more reliable supply of electricity, and reduced vulnerability to natural disasters or attack.

Initial power lines in the grid were built using a radial model, referred to as a network structure. However, this created a new problem: if the current flow or related effects across the network exceed the limits of any particular network element, it could fail, and the current would be shunted to other network elements, which eventually may fail also, causing a **domino effect**. A technique to prevent this is load shedding by rolling blackout or voltage reduction.

Flexibility in network topology:

Classic grids were designed for one-way flow of electricity, but if a local sub-network generates more power than it is consuming, the reverse flow can raise safety and reliability issues. A smart grid aims to manage these situations.

Efficiency:

Numerous contributions to overall improvement of the efficiency of energy infrastructure is anticipated from the deployment of smart grid technology, in particular including **demand-side management**, for example turning off air conditioners during short-term spikes in electricity price. The overall effect is less redundancy in transmission and distribution lines, and greater utilization of generators, leading to lower power prices.

Load adjustment;

The total load connected to the power grid can vary significantly over time. Although the total load is the sum of many individual choices of the clients, the overall load is not a stable, slow varying, average power consumption. Traditionally, to respond to a rapid increase in power consumption, faster than the start-up time of a large generator, some spare generators are put on a dissipative standby mode.

Using mathematical prediction algorithms it is possible to predict how many standby generators need to be used, to reach a certain failure rate. In the traditional grid, the failure rate can only be reduced at the cost of more standby generators.

Peak curtailment/levelling and time of use pricing;

According to proponents of smart grid plans, this will reduce the amount of spinning reserve that electric utilities have to keep on stand-by, as the load curve will level itself through a combination of "*invisible hand*" free-market capitalism and central control of a large number of devices by power management services that pay consumers a portion of the peak power saved by turning their devices off.

Sustainability:

The improved flexibility of the smart grid permits greater penetration of highly variable renewable energy sources such as power and wind power, even without the addition of energy storage. Rapid fluctuations in distributed generation, such as due to cloudy or gusty weather, present significant challenges to power engineers who need to ensure stable power levels through varying the output of the more controllable generators such as gas turbines and hydroelectric generators. Smart grid technology is a necessary condition for very large amounts of renewable electricity on the grid for this reason.

IV. TECHNOLOGY

The bulk of smart grid technologies are already used in other applications such as manufacturing and telecommunications and are being adapted for use in grid operations. In general, smart grid technology can be grouped into five key areas:

1. Integrated Communications.
2. Sensing and Measurement.
3. Smart Meters.
4. Phasor Measurement Units.
5. Advanced Components.

1.Integrated Communications:

In most cases, data is being collected via modem rather than direct network connection. Areas for improvement include: substation automation, demand response, distribution automation, supervisory control and data acquisition (SCADA), energy management systems, wireless mesh networks and other technologies, power-line carrier communications, and fibre-optics. Integrated communications will allow for real-time control, information and data exchange to optimize system reliability, asset utilization, and security.

2.Sensing And Measurement:

Core duties are evaluating congestion and grid stability, monitoring equipment health, energy theft prevention, and control strategies support. Technologies include: advanced microprocessor meters (smart meter) and meter reading equipment, wide-area monitoring systems, dynamic line rating (typically based on online readings by Distributed temperature sensing combined with Real time thermal rating (RTTR) systems), electromagnetic signature measurement/analysis, time-of-use and real-time pricing tools, advanced switches and cables, backscatter radio technology, and Digital protective relays.

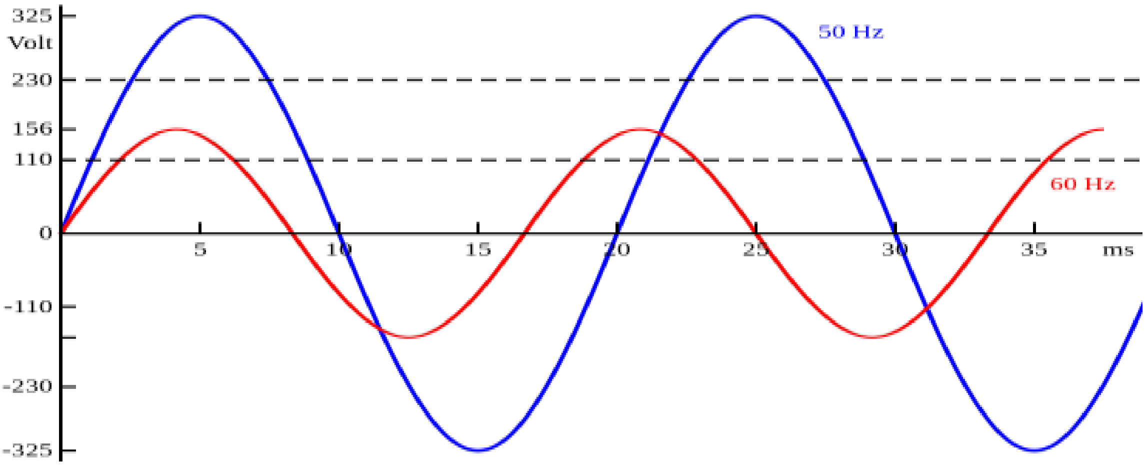
3. Smart Meters:

A smart grid replaces analog mechanical meters with digital meters that record usage in real time. Smart meters are similar to Advanced Metering Infrastructure meters and provide a communication path extending from generation plants to electrical outlets (smart socket) and other smart grid-enabled devices.

4. Phasor Measurement Units:

High speed sensors called *PMUs* distributed throughout their network can be used to monitor power quality and in some cases respond automatically to them. Phasors are representations of the waveforms of alternating current, which ideally in real-time, are identical everywhere on the network and conform to the most desirable shape. In the 1980s, it was realized that the clock pulses from *global positioning system (GPS)* satellites could be used for very precise time measurements in the grid. With large numbers of PMUs the ability to compare shapes from alternating current readings everywhere on the grid.

A *wide-area measurement system* (WAMS) is a network of PMUS that can provide real-time monitoring on a regional and national scale.



5. Advanced Components:

Innovations in superconductivity, fault tolerance, storage, power electronics, and diagnostics components are changing fundamental abilities and characteristics of grids. Technologies within these broad R&D categories include: flexible alternating current transmission system devices, high voltage direct current, first and second generation superconducting wire, high temperature superconducting cable, distributed energy generation and storage devices, composite conductors, and "intelligent" appliances.

V. ADVANCED CONTROL

Power system automation enables rapid diagnosis of and precise solutions to specific grid disruptions or outages. These technologies rely on and contribute to each of the other four key areas. Three technology categories for advanced control methods are: distributed intelligent agents (control systems), analytical tools (software algorithms and high-speed computers), and operational applications (SCADA, substation automation, demand response, etc.). Using artificial intelligence programming techniques, Fujian power grid in China created a wide area protection system that is rapidly able to accurately calculate a control strategy and execute it. The Voltage Stability Monitoring & Control (VSMC) software uses a sensitivity-based successive linear programming method to reliably determine the optimal control solution.

VI. SMART GRID MODELLING

Many different concepts have been used to model intelligent power grids. They are generally studied within the framework of complex systems. In a recent brainstorming session, the power grid was considered within the context of optimal control, ecology, human cognition, glassy dynamics, information theory, microphysics of clouds, and many others. Here is a selection of the types of analyses that have appeared in recent years.

- Protection systems that verify and supervise themselves on the concept of a substation based smart protection and hybrid Inspection Unit.
- **Kuramoto oscillators** are a well-studied system. The goal is to keep the system in balance, or to maintain phase synchronization (also known as phase locking).The model has also been used to describe the synchronization patterns in the blinking of fireflies.
- **Random fuse networks** have been studied in *percolation theory*. The current density might be too low in some areas, and too strong in others. For instance, high-speed computer analysis can predict blown fuses and correct for them, or analyze patterns that might lead to a power outage. It is difficult for humans to predict the long term patterns in complex networks, so fuse or diode networks are used instead.
- **Markov processes** is as wind power continues to gain popularity, it becomes a necessary ingredient in realistic power grid studies. Off-line storage, wind variability, supply, demand, pricing, and other factor scan be modeled as a mathematical game. Markov processes have been used to model and study this type of system.

VII. ECONOMICS

General Economics Developments:

As customers can choose their electricity suppliers, depending on their different tariff methods, the focus of transportation costs will be increased. Reduction of maintenance and replacements costs will stimulate more advanced control.

A smart grid precisely limits electrical power down to the residential level, network small-scale distributed energy generation and storage devices, communicate information on operating status and needs, collect information on prices and grid conditions, and move the grid beyond central control to a collaborative network.

Deployments And Attempted Deployments:

The earliest, and still largest, example of a smart grid is the Italian system installed by Enel S.p.A. of Italy. Completed in 2005, the Telegestore project was highly unusual in the utility world because the company designed and manufactured their own meters, acted as their own system integrator, and developed their own system software. The Telegestore project is widely regarded as the first commercial scale use of smart grid technology to the home, and delivers annual savings of 500 million euro at a project cost of 2.1 billion euro.

Inov Grid is an innovative project in Évora, Portugal that aims to equip the electricity grid with information and devices to automate grid management, improve service quality, reduce operating costs, promote energy efficiency and environmental sustainability, and increase the penetration of renewable energies and electric vehicles.

Open ADR Implementations:

Certain deployments utilize the Open ADR standard for load shedding and demand reduction during higher demand periods. Open ADR is an open-source smart grid communications standard used for demand response applications. It is typically used to send information and signals to cause electrical power-using devices to be turned off during periods of higher demand.

United Kingdom:

The Open ADR standard was demonstrated in *Bracknell, England*, where *peak* use in commercial buildings was reduced by 45 percent

United States:

In 2009, the US Department of Energy awarded an $11 million grant to Southern California Edison and Honeywell for a demand response using the Open ADR standard program that automatically turns down energy use during peak hours for participating industrial customers.

VIII. CONCLUSION

- The next several years will be telling in the development of the Smart Grid. The pace of challenges to the existing grid continues unabated, with increased renewable linking onto and existing infrastructure continuing to age.
- In the short term, grid optimization efforts, with benefits that are divorced from consumer behavior, are likely to increase. The overall pace of smart grid technology deployment continues to be restrained by lack of generally accepted standards.
- The latter becomes increasingly important as utilities turn to over-the-air communication systems, such as RF and cellular, to transmit data. Advances in either of these areas would provide a much needed boost to the market.

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