Smart Grid Technology

Vaibhav R. Kharat[1] Ganesh G.Mhatre[2]
[1]Research Scholar [2]Assistant Lecturer
[1,2]Department of Computer Engineering
[1]Yadavrao Tasgaonkar College of Engineering, Chandai, Karjat, 410201 [2]New Horizon Institute of Technology, Thane, 400601

Abstract— The Smart Grid is a combination of hardware, management and reporting software built atop an intelligent infrastructure. In the world of Smart Grid, consumers and utility companies alike have tools to manage, monitor and respond to energy issues. The flow of electricity from utility to consumers becomes a two way conversation, saving consumers money, energy, delivering more transparency in terms of end user use and reducing carbon emissions. However new requirements and demands drove the electricity industries, research organizations and governments to rethink and expand the initially perceived scope of Smart Grid. More specifically the Smart Grid can be regarded as an electric system that use information and computational intelligence in an integrated fashion across electricity generation, distribution and consumption to achieve a system that is clean, safe, secure, reliable, resilient, efficient and sustainable. This report addresses the area of Smart Grid as it is applicable to various fields of image processing. It also includes various benefits of using Smart Grid technology.

Key words: Smart Infrastructure System, Smart Grid Technology

I. Introduction

A smart grid puts information and communication technology into electricity generation, delivery, and consumption, making systems cleaner, safer, and more reliable and efficient. A smart grid integrates advanced sensing technologies, control methods, and integrated communications into the current electricity grid. , the term grid is used for an electricity system that may support all or some of the following four operations: electricity generation, electricity transmission, electricity distribution, and electricity control. In contrast, 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 efficient ways and responding to wide ranging conditions and events. Basically the existing grid has features like it is electromechanical in nature, one way communication, few sensors, manual monitoring and restoration, failures and blackouts and Few customer gets benefits whereas in smart grid it is digital in nature, Two-way communication, Self-monitored, Adaptive and islanding, many customer can have choice.

More specifically, the SG can be regarded as an electric system that uses information, two-way, cyber-secure communication technologies, and computational intelligence in an integrated fashion across electricity generation, transmission, substations, distribution and consumption to achieve a system that is clean, safe, secure, reliable, resilient, efficient, and sustainable.

A. Concept of Smart Grid

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 malicious sabotage and natural disasters. However, new requirements and demands drove the electricity 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, the anticipated benefits and requirements of SG are the following:

- Improving power reliability and quality.
- Enhancing capacity and efficiency of existing electric power networks.

II. Steps involved in smart grid

A. Providing Regulatory Incentives for Innovative Grid Investments:

Smart grids benefit everybody. For many regulated companies therefore, their current return on investment is lower than their cost of capital. Regulators should thus allow enough commercial space for investment in future technologies that can improve the networks.

B. Developing Market Models:

Smart grids will be a platform for new business models. A well-functioning division of work between regulated and commercial players, and well-functioning interaction between market players should be ensured, not least by defining the roles, responsibilities and interfaces among individuals.

C. Testing Through Demonstration Projects & Sharing Knowledge:

“Smart” technology is already available, but testing it through pilot and large-scale demonstration projects is needed in order to gain practical “in-the-field” experience. Projects ‘smartness’ level needs to be qualitatively and quantitatively assessed, taking into account potential energy savings, demand reduction, deployment of centralized generation and payback periods.

D. Rolling Out Smart Metering– Informed Customers:

A smart meter is an essential device that integrates data collection and communication within smart grids. Thus, many smart grid functionalities cannot be deployed without smart metering.. Using open standards, smart meters will enable dynamic pricing, in turn incentivizing customers’ involvement.

E. Monitoring and Controlling the Grid & Distributed Generation:

Remote monitoring and automatic fault detection at the level of medium and low voltage networks are currently the exception, but throughout the next decade, network operators will invest to make their grids smarter.

III. SMART GRID SYSTEM

A. Smart Infrastructure System

The smart infrastructure system is the energy, information, and communication infrastructure underlying the SG. It supports two-way flow of electricity and information. “Two-way flow of electricity” implies that the electric energy delivery is not unidirectional anymore. For example, in the traditional power grid, the electricity is generated by the generation plant, then moved by the transmission grid, the distribution grid, and finally delivered to users.

In an SG, electricity can also be put back into the grid by users. For example, users may be able to generate electricity using solar panels at homes and put it back into the grid, or electric vehicles may provide power to help balance loads by “peak shaving” (sending power back to the grid when demand is high). This backward flow is important. The micro grid can function, albeit at a reduced level, with the help of the energy fed back by the customers. In this survey, we further divide this smart infrastructure into three subsystems: the smart energy subsystem, the smart information subsystem, and the smart communication subsystem.

B. Smart Management System

The smart management system is the subsystem in SG that provides advanced management and control services and functionalities. The key reason why SG can revolutionize the grid is the explosion of functionality based on its smart infrastructure. With the development of new management applications and services that can leverage the technology and capability upgrades enabled by this advanced infrastructure, the grid will keep becoming “smarter.” The smart management system takes advantage of the smart infrastructure to pursue various advanced management objectives. Objectives are related to energy efficiency improvement, supply and demand balance, emission control, operation cost reduction, and utility maximization.

C. Smart Protection System

The smart protection system is the subsystem in SG that provides advanced grid reliability analysis, failure protection, and security and privacy protection services. By taking advantage of the smart infrastructure, the SG must not only realize a smarter management system, but also provide a smarter protection system.

IV. SMART INFRASTRUCTURE SYSTEM I-SMART SUBSYSTEM

Two-way flows of electricity and information lay the infrastructure foundation for the SG. The smart infrastructure can be subdivided into the smart energy subsystem, the smart information subsystem, and the smart communication subsystem, respectively.

Electricity is often generated at a few central power plants by electromechanical generators, primarily driven by the force of flowing water or heat engines fueled by chemical combustion or nuclear power. The transmission grid moves the power over long distances to substations. Upon arrival at a substation, the power will be stepped down from the transmission level voltage to a distribution level voltage. As the power exits the substation, it enters the distribution grid. Finally, upon arrival at the service location, the power is stepped down again from the distribution voltage to the required service voltage(s).In contrast with the traditional power grid, the electric energy generation and the flow pattern in an SG are more flexible.

A. Transmission Grid

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

Based 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 built on the existing electric transmission infrastructure.

However, the emergence of new technologies (e.g. new 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 built on the existing comprehensive automation technologies of substations. Major characteristics of a smart substation shall include digitalization, atomization, coordination, and self-healing. By supporting these features, a smart substation is able to respond rapidly and provide increased operator safety.

B. Distribution Grid

For the distribution grid, the most important problem is how to deliver power to serve the end users better. However, as many distributed generators will be integrated into the smart distributed grid, this, on one hand, 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. The first one is a circuit switching system based on alternating current (AC) power distribution, and the other is a direct current (DC) power dispatching system via power packets.

1) Distribution Atomization

Distribution Automation involves the section of the Smart Grid between the Smart Meter and the local community substation. Although some parts of many utilities' traditional grids have been automated to a limited degree for some time, Distribution Automation is a much more intensive and focused effort to computerize and/or automate grid operations. Specific Distribution Automation capabilities examined in this report include Integrated Volt/VAr Control (IVVC), fault location and isolation, and renewable generation integration

Industrial and residential loads are increasingly controlled through demand response. For example, during periods of peak electrical demand in the summer, the utility control centers may be able to raise the thermostats of houses enrolled in a load reduction program, to temporarily decrease electrical demand from a large number of customers without significantly affecting their comfort.

2) Demand Optimization

Demand Optimization is "a set of technologies that enable an electric utility to remotely monitor, coordinate, and operate distribution components in a real time mode from remote depends on Smart Metering::Automatic, Real Time, Consumer Communication & Load can be Controlled, utility of Consumer ,Demand Response Management System and In Home Technology enabling.

3) Micro Grid

Distributed generation promotes the development of a new grid paradigm, called micro grid, which is seen as one of the cornerstones of the future SG .The organic evolution of the SG is expected to come through the plug-and-play integration of micro grids. A micro grid is a localized grouping of electricity generations, energy storages, and loads. In the normal operation, it is connected to a traditional power grid (macro grid). The users 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 macro grid can be disconnected, with the micro grid functioning autonomously. 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 macro grid. This includes 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 affected by outages.

V. SMART INFRASTRUCTURE SYSTEM II-SMART SUBSYSTEM

A. Smart Energy Subsystem

The evolution 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 addressed from an information technology perspective, such as interoperability of data exchanges and integration with existing and future devices, systems, and applications. Therefore, a smart information subsystem is used to support information generation, modeling, integration, analysis, and optimization in the context of the SG.

1) Smart Metering

Smart metering is the most important mechanism used in the SG for obtaining information from end users' devices and appliances, while also controlling the behavior of the devices. Automatic metering infrastructure (AMI) systems, which are they built 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 transferring that data to a central database for billing, troubleshooting, and analyzing. AMI differs from traditional AMR in that it enables two-way communications with the meter. Smart meters, which support two-way communications between the meter and the central system, are similar in many aspects to AMI meters sometimes regarded 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 purposes. Also, a smart meter has the ability to disconnect-reconnect remotely and controls the user appliances and devices to manage loads and demands within the future "smart-buildings. From a consumer's perspective, smart metering offers a number of potential benefits. For example, end users able to estimate bills and thus manage their energy consumptions to reduce bills.

From a utility's perspective, 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.

2) Smart Monitoring and Measurement

An important function in the vision of SG is monitoring and measurement of grid status. We review the following two major monitoring and measurement approaches, namely sensors.

a) Sensors:

Sensors or sensor networks have already been used as a monitoring and measurement approach for different purposes. In order to detect mechanical failures in power grids such as conductor failures, tower collapses, hot spots, and extreme mechanical conditions sensor networks should be embedded into the power grid and help to assess the real-time mechanical and electrical conditions of transmission lines, obtain a complete determine appropriate control measures that could be automatically taken and/or suggested to the system operators once an extreme mechanical condition appears in a transmission line. Wireless sensor networks (WSNs) in particular, given their low cost, can provide a feasible and cost-effective sensing and communication platform for remote system monitoring and diagnosis.

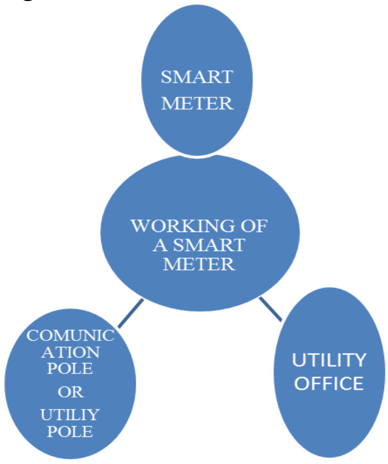

Fig. 1: Smart metering.

VI. SMART MANAGEMENT AND PROTECTION SYSTEM

A. *Smart Management System*

1) Management Objectives

Within the framework of SG, many management goals, which are difficult and possibly infeasible to realize in conventional power grids, become possible and easy. So far, the works for smart management mainly focus on the following three objectives:

- Energy efficiency and demand profile improvement;
- Utility and cost optimization, and price stabilization;
- Emission control.

2) Management Methods and Tools

In order to solve management objectives, researchers have adopted various methods and tools. Thus far, researchers Machine learning focuses on the design and development of algorithms that allow control systems to evolve behaviors based on empirical data. Although the power pattern of the renewable energy source is not known in advance, they proved that when the time horizon is sufficiently large, on average the upper bound on the gap between the expected profit obtained at each time slot by using the optimal renewable energy source and that by following their strategies is arbitrarily small.

B. *Smart Protection System*

The smart protection system in SG must address not only inadvertent compromises of the grid infrastructure due to user errors, equipment failures, and natural disasters, but also deliberate cyber-attacks, such as from disgruntled employees, industrial spies, and terrorists.

1) System Reliability and Failure Protection

Reliability is the ability of a component or system to perform required functions under stated conditions for a stated period of time. System reliability is an important topic in power grid research and design

a) System Reliability

It is expected that distributed generation (DG) will be widely used in SG. While using some fluctuant and intermittent renewable may compromise the stability of the grid as loads is being served locally within a micro grid. Thus, the reliability of the SG can be enhanced.

b) Failure Protection Mechanism

Failure prediction and prevention play important roles in the smart protection system since they attempt to prevent failures from happening.

2) Security and Privacy

Security is a never-ending game of wits, pitting attackers versus asset owners. SG security is no exception to this paradigm. Cyber security is regarded as one of the biggest challenges.

a) Security in Smart Metering:
One of the security issues comes from the newly deployed smart meters. Smart meters are extremely attractive targets for malicious hackers, since vulnerabilities can easily be monetized. Hackers who compromise a smart meter can immediately manipulate their energy costs or fabricate generated energy meter readings to make money.
b) Privacy in Smart Metering:
Smart meters also have unintended consequences for customer privacy. NIST pointed out that “the major benefit provided by the smart grid

VII. Conclusion

Due to the potential importance of SG, this survey comprehensively explores the technologies used in SG. We have surveyed the major SG projects/programs/trials and three major technical systems in SG: the smart infrastructure system, the smart management system, and the smart protection system. There is no doubt that the emergence of SG will lead to a more environmentally sound future, better power supply services, and eventually revolutionize our daily lives. However, we still have a long way to go before this vision comes true.

Acknowledgment

After the completion of this work, words are not enough to express my feelings about all those who helped me to reach my goal. It’s a great pleasure and moment of immense satisfaction for me to express my profound gratitude to my Guide, Prof. Mrs. G.G Mhatre.

References

[1] Xi Fang, Student Member, IEEE, Satyajayant Misra, Member, IEEE, Guoliang Xue, Fellow, IEEE and Dejun Yang, Student Member, IEEE,2011
[2] The Impact of Control Technology, T. Samad and A.M. Annaswamy (eds.), 2011
[3] Introduction to Smart Grid by Department of Electrical & Computer Engineering Texas Tech University Spring 2012Maharashtra
[4] S. Massoud Amin and Bruce F. Wollenberg, “Toward a Smart Grid,” IEEE Power and Energy. Magazine, September/October 2005.
[5] M. Pipattanasomporn and S. Rahman, “Intelligent Distributed Autonomous Power Systems (IDAPS) and their Impact on Critical Electrical Loads,” IEEE IWCIP 2005.
[6] R. Li, J. Li, G. Poulton, and G. James, “Agent-Based Optimization Systems for Electrical Load Management,” OPTMAS 2008.
[7] J. Li, G. Poulton, and G. James, “Agent-based distributed energy management,” In Proc. 20th Australian Joint Conference on Artificial Intelligence, pages 569–578. Gold Coast, Australia, 2007.
[8] http://www.smartgrid.gov/, November 2010.
[9] “GRID 2030: A National Vision for Electricity’s Second 100 Years”, United States Department of Energy, Office of Electric Transmission and Distribution, July 2003.
[10] “What the Smart Grid Means to America’s Future”, Technology Providers – One of the Six Smart Grid Stakeholder Books, 2009.