Summary of Smart Grid: Benefits and Issues

Md. Golam Rahman, M. Fahad Bin Ramim Chowdhury, Md. Abdulla Al Mamun,
Md. Rakib Hasan, Sayeed Mahfuz

Abstract— Electricity has a staggering importance in our daily life and economic development. Efficient transmission and distribution of electricity is a fundamental requirement for every society. Shortfall in power generation due to increased power demand to meet up the industrial requirements is causing several social and economic difficulties. As things stand now, the current grid is struggling to keep up. Smart Grid, an upgrade of current system which is more reliable, efficient, affordable, secured and environment friendly, is the solution of this growing concern. It is believed that Smart Grid will take us towards energy independence and environmentally sustainable economic growth. In this paper some key features of Smart Grid has been discussed. The benefits and potential barriers to create a Smart Grid are alsoexplained.

Index Terms— AMI, challenge, demand response, distributed generation, eco-friendly, efficiency, electricity market, smart grid

1 Introduction

There are many definitions of Smart Grid and different people have different views to define it. The brief definition of Smart Grid, as proposed by the European Technology Platform, is- "A Smart Grid is an electricity network that can intelligently integrate the action of all users connected to it—generators, consumers and those that do both—in order to efficiently deliver sustainable, economic and secure electricity supplies" [15]. National Institute of Standard and Technology (NIST) defines it as- "A modernized grid that enables bidirectional flows of energy and uses two-way communication and control capabilities that will lead to an array of new functionalities and applications" [16]. According to US Department of Energy's modern grid initiative, "A Smart grid is the technology that incorporates advanced sensing technologies, control systems and integrated communications into the existing electricity grid"[17]. Basically it is the digital upgrade of current power grid by modernizing and digitalizing the generation, transmission and distribution of power and by introducing active participation of the consumer.

Smart Grid itself is a big idea. The total concept doesn't end with the modernizing the transmission or communication network. The idea of modernizing electricity network includes the ability to reduce power consumption at the consumer end during peak hours (Demand side management), enabling grid connection of distributed generation, incorporating grid energy storage for distributed energy, providing opportunity to integrate renewable energy and eliminating failures such as widespread power grid cascading failures. The increased efficiency and reliability of the smart grid is expected to save consumers money and help reduce CO_2 emissions by establishing an eco-friendly power network.

To get a better idea about what is Smart Grid and what it is not let's look at Table 1.

TABLE 1
COMPARISON BETWEEN EXISTING POWER GRID & SMART GRID

Features	Current Grid	Smart Grid
Communication	One way	Two way
Interaction with user side	Limited	Extensive
Instrument type	Electrical	Numerical
Flow control	Limited	Universal
Reliability	Prone to failure and cascading outages	Pro-active, real-time protection and islanding
Power restoration	Manual	Self healing
Topology	Radial	Network
Generation	Centralized	Distributed
Operation & Maintenance	Manual equipment checks, time-based maintenance	Remote monitoring, predictive and condition based maintenance
Metering	Electromechanical	Digital
Customer participation	Limited	Extensive

Source: [1] [2]

2 Driving Factors

The current climate demands change in the way electricity is supplied. The current social and economic situation is driving us towards Smart Grid. The driving factors are briefly described below.

2.1 Security of Supply

As the demand of energy is ever increasing we need secure supply of fuel. If we look at the oil price trend, since the Islamic revolution in Iran in 1979, the price is always increasing and fairly unstable. Another major problem is that all the fossil fuels are limited. Inside next 120 years all major sources of fossil fuel will be finished [3]. So depending on non renewable fossil fuel makes our economic growth vulnerable. Integrating more fossil fuel can solve the problem. Smart Grid provides ideal opportunity to integrate Renewable into the

- *Md. Golam Rahman. E-mail: schools.goals@yahoo.com*
- *M. Fahad Bin Ramim Chowdhury. E-mail: fahadramim@gmail.com*
- *Abdulla Al Mamun. E-mail: smnnew@gmail.com*
- *Md. Rakib Hasan. E-mail: Rizvej@hotmail.com*
- *Sayeed Mahmuz. E-mail: sayeedm2@gmail.com*

system.

2.2 Free Market Economy

We live in the age of free market economy. Free Market Economy allows different companies to invest and compete with each other. This competition will drive the price down which will benefit the consumers. This will also encourage the vendors to invest more for advancement in technology.

2.3 Environment

Typical fossil fuels cause the emission of gases like CO_2, SO_2 and other pollutants which are causing severe environmental damages. The U.S. CO_2 emissions from energy consumption alone totalled 1,340 million metric tons during the first quarter of 2012 [4], which contributes almost 41 percent of the CO_2 emissions from fossil fuels in the United States and 34 percent of all greenhouse gas emissions [5]. So we need fuels and technology which are green and eco friendly. Smart Grid provides ideal opportunity to achieve that.

2.4 Advancement in Technology

Smart Grid combines IT, power engineering, communication technology, material science etc. Recent advancements in these fields will encourage the growth of Smart Grid.

2.5 Higher Efficiency

Grid optimization is another key feature of Smart Grid. Geographic Information System (GIS) helps us to design the network efficiently which will ensure asset optimization. GIS is widely used to optimize maintenance schedules and daily fleet movements. Typical implementations can result in a savings of 10 to 30 percent in operational expenses through reduction in fuel use and staff time, improved customer service, and more efficient scheduling [6]. Advanced two way communication will also ensure greater efficiency.

2.6 Power Quality

Power quality determines the fitness of electrical power of the electrical devices. Poor Power Quality like voltage sag, transient voltage, flicker, spike, presence of harmonics etc. increase cost, down time and reduce competitiveness, life of device. So it's really important to provide clean power. Smart Grid can improve the Power Quality using back to back inverter and FACTS devices which satisfy our needs.

3 TECHNOLOGY

The technology areas – each consisting of sets of individual technologies – span the entire grid, from generation through transmission and distribution to various types of electricity consumers. Some of the technologies are actively being deployed and are considered mature in both their development and application, while others require further development and demonstration. A fully optimized electricity system will deploy all the technology areas described here. However, not all technology areas need to be installed to increase the "smartness" of the grid.

3.1 Advanced Metering Infrastructure (AMI)

Advanced metering infrastructure (AMI) refers to a system that collects, measures and analyses energy usage by enabling data to be sent back and forth over a two-way communications network connecting advanced meters ("smart meters") and the utility's control systems [7]. AMI provides utilities unprecedented system management capabilities, allowing for the first time the possibility of having consumers/end-users make informed, real-time choices about their energy usage (acting as a gateway technology to the "smart home"). Millions of smart meters are currently being deployed around the globe. There are two main components of any AMI system:

- The physical smart meter itself, which replaces older mechanical meters unable to communicate
- The communications network necessary to transport the data that the meter generates

3.2 Demand Response/Demand Side Management

Demand response is a relatively simple concept. Utilities incentivize electricity customers to reduce their consumption at critical, "peak" times, on demand [8]. Contracts, made in advance, specifically determine both how and when the utility (or an acting third-party intermediary) can reduce an end user's load.

Demand response is a win-win solution for utilities and customers. At times of peak energy demand, Demand Response is a cheaper, faster, cleaner and more reliable solution than adding a peaking power plant. While concerns for the environment are increasing in the U.S. and the EU, the fact that both the utility and the consumer save money will be key driver in the mass adoption of demand response programs.

3.3 Distributed Generation and Integration of Renewable Energy

The integration of renewable energy and distributed generation sources at mass scale is one of the most revolutionary aspects of a smarter grid. While many of the renewable energy solutions – such as wind and solar – have been around for decades, what has been lacking is the proper infrastructure to support their introduction in an impactful way. Smart Grid technologies will change this, as smarter grids attempt to fix the scale-management problem. The continued development of true "plug and play" interoperability will promote the same wide-spread deployment in renewables and distributed generation that occurred with personal computers and cell phones, bringing a profound transformation to electric generation in the coming decade [7].

3.4 Integrated Communication

Various types of communications media are used in today's electric grid, including copper wiring, optical fiber, power line carrier technologies, and wireless technologies. Using these

media, it is possible to deploy Substation Automation, an excellent first step in integrating grid communications. However, Substation Automation does not yet fully integrate with the other features that will modernize our power grid [9].

3.5 Phasor Measurement Units

Phasor Measurement Unit (PMU), also known as Synchrophasors give operators a time stamped snapshot of the power system using a common time source for synchronization. Time synchronization allows synchronized real-time measurements of multiple remote measurement points on the grid [1]. PMUs ensure voltage and current with high accuracy at a rate of 2.88 kHz. They can calculate real power, reactive power, frequency, and phase angle 12 times per 60 Hz cycle. The actual sampling rate used to achieve this output is 1.4 MHz [10]. Popularly referred to as the power system's "health meter", PMU sample voltage and current many times a second at a given location, providing an 'MRI' of the power system compared to the 'X-Ray' quality available from earlier Supervisory Control and Data Acquisition (SCADA) technology. Equipped with Smart Grid communications technologies, measurements taken are precisely time-synchronized and taken many times a second (i.e., 10-60 samples/second) offering dynamic visibility into the power system [11].

3.6 Smart Home and Home Area Networks

The smart home represents the convergence of energy efficient, controllable appliances and real-time access to energy usage data. This integration of smart devices and smart grid enables customers to proactively manage energy use in ways that are convenient, cost effective, and good for the environment.

Home Area Networks (HAN) are a major part of Smart Grid. A network within the home that enables devices and major appliances to communicate with each other and dynamically respond to price signals sent from the utility, relaying whether or not electricity is currently expensive.

3.7 PHEV Smart Charging

One of the most discussed and anticipated "applications" of Smart Grid is the introduction of the plug-in hybrid electric vehicle (PHEV). PHEV's larger battery, relative to the previous generation (plug-less) hybrids, will allow for both the possibility of storing electricity, which might otherwise go unused (ideally from renewable, intermittent sources), and of feeding stored energy back into the electric grid, in periods of high demand, serving as a back-up source of power for the electric grid [7].

4 KEY FEATURES/ ADVANTAGES

The key features of Smart Grid are given bellow-

4.1 Self Healing

Smart Grid with the help of real time sensors like PMU can detect the health of the power. With the self healing ability Smart Grid can anticipate, detect and react to faults or outages using PMU and automatic control center. It also uses intelligent sensors which can start, stop or reroute power flow to avoid further problems.

4.2 Interactive

One of the main features of Smart Grid is bidirectional power flow. One can be a consumer and provider at the same time. Dynamic pricing will encourage users to use less power in the peak hours, which will reduce the peak demand. This behavior will ultimately lead to the unity Load Factor which is desirable.

4.3 Security

Smart Grid network and control system is designed such a way so that it is very strong against cyber attacks. Real time monitoring using PMU allows the operators to anticipate possible problems, so the preventive measures can be taken. Distributed generation and microgrid also ensures security of supply.

4.4 Asset Optimization

Using Geographic Information System (GIS), we can design efficient network using minimum transmission network and other equipments. It will enable condition and performance based maintenance. Smart grids will also improve efficiency through reduction in technical and non-technical line losses.

4.5 Distributed Generation

Distributed Generation (DG) means decentralized generating units in place of centralized network. The major benefits of distributed generation can be divided into two categories: economic and operational [12]. From an economic point of view, distributed generation provides power support when load increases during peak demand periods, thus reducing interruption that may lead to system outages. It also reduces the peril of investment, due to the flexibility of its capacity and installation placement. DG cuts operational costs when installed close to the customer load because it avoids upgrading or setting up a new transmission and distribution network, thereby providing a cost saving. The use of local renewable energy sources (RES) will help to reduce dependence on imported fossil fuels and decrease internationally escalating energy prices.

4.6 Market Empowerment

A smart grid involves consumers by engaging them as active participants in the electricity market. It will help empower utilities to match evolving consumer expectation and deliver greater visibility and choice in energy purchasing. It will generate demand, for cost-saving and energy-saving products. Smart grids will help educate the average consumer, foster innovation in new energy management services and reduce the costs and environmental impact of the delivery of electricity.

4.7 Environment Friendly

The energy conservation and improvements in end-use efficiency enabled by the smart grid can reduce significant

amount of CO_2 emission. The Pacific Northwest National Laboratory (PNNL) has issued a report in which carbon savings from introduction of smart grid technologies are estimated, looking ahead to the year 2030. PNNL located in Richland, Washington and operated by Batelle for the U.S. Department of Energy, puts direct carbon savings from equipment like smart meters at 12 percent, and indirect savings from things like stronger grid support for renewable electricity generation at 6 percent [13]. Environmental improvements can be obtained by managing the peak load through demand response rather than spinning reserves. Smart grid will reduce transmission and distribution loss besides controlling theft, ensuring better availability in rural areas and increasing reliability and quality of supply in urban areas. Reducing these losses would require an investment ranging from $20,000 (reactive power compensation, phase shifting transformer) to $75,000 (power electronics steering and control) per MW [14]. Smart grid system gives a continuous feedback on electricity use, which enables the consumers to adjust the usage in response to pricing and consumption and thereby reduce annual CO_2 emissions. Optimised use of existing generation, transmission and distribution through this system reduces the new infrastructure constructions.

5 KEY CHALLENGES FOR SMART GRID

Several challenges present themselves for smart grid development-

5.1 Financial Resources

Huge amount of capital investment is needed to initiate the journey of Smart Grid. So we need significant financial resources/ investments to create the necessary distributed network and other establishments.

5.2 Government Support

Financial resources are not the only obstacle to initiate Smart Grid. Political bodies of the country play an even bigger role. We need a willing government and effective energy policy for a successful implementation of Smart Grid.

5.3 Compatible Equipment

Some older equipment must be replaced as it is incompatible with smart grid technologies. This may present a problem for utilities, regulators as well as to the consumers.

5.4 Consumer Education

Consumer education and participation is an important component of the successful implementation of the Smart Grid. A significant portion of the Smart Meter benefits rely upon consumer engagement. So the consumers have to be educated and intelligent to get the maximum benefit.

5.5 Cost Assessment

Costs could be higher than projected because the standards and protocols needed to design and operate an advanced metering infrastructure are still in a state of flux. Thus, investments made now, before the standards are settled, have a higher risk of obsolescence.

5.6 Cyber Security and Data Privacy

Digital communication networks and more granular and frequent information on consumption patterns raise concerns in cyber-insecurity and potential for misuse of private data.

5.7 Capacity to Absorb Advanced Technology

Smart Grid uses hi-tech devices all over the network. Technology is never at a standstill, in fact it is moving as fast as ever. So the Smart Grid has to be able to absorb modern and advanced technology.

5.8 Strengthening the Grid

The Smart grid, although a revolutionary being, has to have some weak spots, which should be of our utmost concern. The companies and manpower working behind the setup of the grid, has to deal with some unexpected occurrences and hazards the grid has to overcome. These are—

- Attacks of cyber thieves
- Weak Base
- Inefficient Control System
- Corrosion
- Smart Meter Authentication
- Blackouts

5.9 Compatible Equipments

The smart grid is a very complex and sophisticated system. To cover the controlling program of the whole grid system, a lot of equipments are required, which are compatible with the system.

6 CONCLUSION

The whole discussion, we tried to introduce and discuss some key features of Smart Power Grid. It is still in a primary stage. The whole power community is busy with researching and developing smart power grid system which is no longer a theme of future. The new technology associated with smart grids offers the opportunity to improve the quality and reliability of the power experienced by the consumers. However, it will also introduce a number of new challenges. But these new challenges should definitely not be used as arguments against the development of smart grids as Smart Grid will play the most vital role in turning the conventional and aged power system to an intelligent and modern grid of the 21st century and lead us towards energy independence.

ACKNOWLEDGMENT

The author would like to express his appreciation to Md. Maruf Hossain, Chowdhury Akram Hossain and Taskin Jamal for providing valuable inputs and support for writing this paper. The author is, of course, responsible for the contents.

REFERENCES

[1] James Momoh, 'Smart Grid- Fundamental of Design and Analysis', IEEE Press, March 2012

[2] Smart Energy Grid, Energy & Power Magazine, Volume 9 Issue 19, March 16, 2012. Available online: http://www.ep-bd.com

[3] BP Statistical Review of World Energy, June 2011. Available online: bp.com/statisticalreview

[4] Betsy Byrum, 'This Week in Environmental News 8-3'. Available online: http://blog.ebiconsulting.com/public/item/276702

[5] Alan W. Hodges and Mohammad Rahmani, 'Fuel Sources and Carbon Dioxide Emissions by Electric Power Plants in the United States'. Available online: http://edis.ifas.ufl.edu/fe796

[6] Kevin Morrow, 'GIS Integration Strategy for SAP Enterprise and Asset Management', February 2012

[7] David J. Leeds, 'The Smart Grid in 2010: Market Segments, Applications and Industrial Players', GTM Research, July 2009

[8] U.S. Department of Energy, 'Benefits of Demand Response in Electricity Markets and Recommendations for Achieving Them', February 2006

[9] Integrated Communications, Conducted by the National Energy Technology Laboratory for the U.S. Department of Energy Office of Electricity Delivery and Energy Reliability, February 2007

[10] Paul C. Krause, Oleg Wasynczuk, and Scott D. Sudhoff, 'Analysis of Electric Machinery and Drive Systems', Second Edition

[11] The Smart Grid: An Introduction, prepared for the U.S. Department of Energy by Litos Strategic Communication

[12] W. El-khattam, and M. M. A. Salama, 'Distributed Generation Technologies, definitions and benefits', Electric Power Systems Research, vol. 71, 2004

[13] Pacific Northwest National Laboratory, 'The Smart Grid: An Estimation of the Energy and CO2 Benefits', January 2010

[14] Peter Vaessen, 'Smart Grid power loss reduction: the costs and effects on availability'. Available online: http://smartgridsherpa.com/blog/smart-grid-power-loss-reduction-the-costs-and-effects-on-availability

[15] European Technology Platform Smart Grid, 'Strategic research agenda for Europe's electricity networks for the future', European Commission, Directorate General for Research, Directorate Energy, 2007.

[16] Smart Grid: A Beginner's Guide. Available online: http://www.nist.gov/smartgrid/beginnersguide.cfm

[17] Saifur Rahman, 'Smart Grid and its Role in Reducing Peak Demand and Improving Electricity Delivery'. Page- 19