

Characteristics, Challenges and Initiatives in Optimum Utilization of Smart Grids

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ABSTRACT: The basic concept of Smart Grid is to add monitoring, analysis, control, and communication capabilities to the national electrical delivery system to maximize the throughput of the system while reducing the energy consumption. The Smart Grid will allow utilities to move electricity around the system as efficiently and economically as possible. There are thousands of power plants that generate electricity using wind energy, nuclear energy, coal, hydro, natural gas, and a variety of other resources. These generating stations produce electricity at a certain electrical voltage. This voltage is then “stepped-up” (increased) to very high voltages, such as 500,000 volts, to increase the efficiency of power transmission over long distances. As per the need of industries and towns, the electrical voltage is “stepped-down” (decreased) in a utility substation to a lower voltage for distribution around your town or city. As this electrical power gets closer to your home, it is stepped-down by another transformer to the voltage you use in your home. It will also allow the homeowner and business to use electricity as economically as possible. You may want to keep your house set at 75 degrees F in the summertime when prices are low, but you may be willing to increase your thermostat to 78 degrees F if prices are high. Similarly, you may want to dry your clothes for 5 cents per kilowatt-hour at 9:00 pm instead of 15 cents per kilowatt-hour at 2:00 pm in the afternoon. You will have the choice and flexibility to manage your electrical use while minimizing your costs.

I. INTRODUCTION

A web of transmission lines, substations, transformers and more that convey electricity from the generating station to homes and businesses is an electric grid. In other words, any nexus of synchronized power providers and consumers that are connected by transmission and distribution lines is a grid. In India, in 1960s, individual State grids were interconnected to form 5 regional grids- Northern, Eastern, Western, North Eastern and Southern. These regional links were set up to allow transmission of excess electricity between States in each region.

Later on, in October 1991, the North Eastern and Eastern grids were interconnected. The Western Grid was linked with the aforementioned grids in March 2003. The Northern grid was interconnected in August 2006, forming a Central Grid synchronously connected operating at one frequency (Monacchi and Elmenreich, 2016). With the commissioning of the 765 kV Raichur-Solapur transmission line, the solely remaining regional grid, the Southern Grid, was synchronously linked to the Central Grid on 31 December 2013. Thus, the National Grid was established and making Indian power system as the largest operating synchronous grid in the World.

According to the Ministry of Power, averaging 26 per cent of total electricity production, and as high as 62 per cent in some states, India's transmission and distribution losses are amongst the highest in the world. These losses do not include non-technical losses like theft etc. There is also a pressing need to provide impel the development of low-carbon energy technologies in order to address the global challenges of energy security, climate change and economic growth. India is, thus, steadily venturing into renewable energy resources like wind and solar. With such uncertain and unpredictable energy sources feeding the grid, it is necessary to have a grid that is highly adaptive, in terms of supply and demand (Montazerolghaem, *et al*, 2017). After all a good electric supply is one of the key infrastructure requirements to support overall development. To move forward, we need a new kind of electric grid, one that is built from the bottom up to handle the grounds well of digital and computerized equipment and technology dependent on it—and one that can automate and manage the increasing complexity and needs of electricity in the 21st Century (Adil

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and Ko, 2016).

We need a digital technology that allows for two-way communication between the utility and its customers, which uses sensors along the transmission lines. This is what makes a grid smart. Like the Internet, the Smart Grid consists of controls, computers, automation, and new technologies and equipment working together. These technologies work with the electrical grid to respond digitally to our quickly changing electric demand.

Smart grid is a dynamic interactive, real-time infrastructure that responds to the challenges of designing and building the power system of the future, rather than being simply a marketing term. One can think of the Smart Grid as the internet brought to electric system. The smart grid represents the longer-term promise of a grid remarkable in its intelligence and impressive in its scope, although it is universally considered to be years and years from realization. One can expect the Smart Grid to spur the kind of transformation that the internet has already brought to the way we live, work, play and learn. A smart grid applies technologies, tools and techniques available now to bring knowledge to power – knowledge capable of making the grid work far more efficiently. Smart Grid is a nebulous term spanning various functionalities geared towards modernizing the electricity grid. At its core, a smart grid utilizes digital communications and control systems to monitor and control power flows, with the aim to make the power grid more resilient, efficient and cost effective (Block *et al.*, 2008).

Since 2005, a great deal has been accomplished to develop and communicate the concepts that define what we call the smart grid today. A number of studies have concluded that, when viewed at a high level, the benefits of a smart grid far outweigh its costs—that is, when all costs and all benefits applicable to all stakeholders are included. It is to be kept in mind, though, that the physical and institutional complexity of electricity systems makes it unlikely that the market alone will implement smart grids on the scale that is needed (Block *et al.*, 2008). Governments, the private sector, and consumer and environmental advocacy groups must work together to define electricity system needs and determine smart grid solutions.

II. BENEFITS

Although, most stakeholders will enjoy some benefits of a smart grid, the biggest winner will be society as a whole. The smart grid is expected to provide benefits to society in the following areas:

- Smart grid improvements convert system events into instantly-retrievable digital information, thus facilitating the real time trouble shooting. With such improved efficiency come reduced producer costs.
- Smart grid allows direct communication with end-user equipment to reduce consumption during the peak periods, lowering the need for costly standby power plants.
- It overhauls aging equipment
- It equips the grid to meet increasing demand
- It decreases brownouts, blackouts, and surges
- It helps to monitor and adjust energy use through smart meters and home energy management systems

III. POWER SOVEREIGNTY

Smart grid makes renewable power feasible, by ensuring that this energy can be stored safely and distributed where and when it's needed. Moreover, it could take our nation's position at the forefront of the world's transition toward a clean energy future.

IV. PRINCIPAL CHARACTERISTICS

Consumer choices and increased interaction with the grid bring tangible benefits to both the grid and the environment, while reducing the cost of delivered electricity. It accommodates all generation and storage options and diverse resources with “plug-and-play” connections multiply the options for electrical generation and storage, including new opportunities for more efficient, cleaner power production. Besides, the grid's open-access market reveals waste and inefficiency and helps drive them out of the system while offering new consumer choices such as green power

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products and a new generation of electric vehicles. Reduced transmission congestion also leads to more efficient electricity markets. Digital-grade power quality for those who need it avoids production and productivity losses, especially in digital-device environments (Gungor, 2013). Moreover, desired functionality at minimum cost guides operations and allows fuller utilization of assets. More targeted and efficient grid maintenance programs result in fewer equipment failures and safer operations. The smart grid will perform continuous self-assessments to detect, analyze, respond to, and as needed, restore grid components or network sections. The grid deters or withstands physical or cyber attack and improves public safety (Gao, *et al.*, 2012).

The exploitation of technology solutions that achieve these characteristics will improve how the smart grid is planned, designed, operated, and maintained. These improvements in each of the key value areas presented above lead to specific benefits that are enjoyed by all.

V. SMART GRID IMPLEMENTATION

Smart grids are complex systems that incorporate a number of technologies, consumer interactions and decision points. The following technology solutions are generally considered when a smart grid implementation plan is developed (Haase, *et al.*, 2011).

- **Advanced Metering Infrastructure (AMI):**

Advanced metering infrastructure (AMI) is architecture for automated, two-way communication between a smart utility meter with an IP address and a utility company. The goal of an AMI is to provide utility companies with real-time data about power consumption and allow customers to make informed choices about energy usage based on the price at the time of use.

- **Customer Side Systems (CS):**

Customer technologies, such as in-home displays and programmable communicating thermostats, combined with AMI enables utilities to offer time-based rate programs and incentives that encourage customers to reduce peak demand and manage energy consumption and costs.

- **Demand Response (DR):**

Demand response is a strategy used by electric utility companies to reduce or shift energy consumption from peak hours of the day, when the demand for electricity is the greatest to leaner demand periods. It involves allowing customers to choose non-essential loads, which can be shed by the customers themselves or by the utility, at peak times. It is a pre-arranged agreement between the Utility or intermediate agencies like aggregators with the consumer with specific conditions of load, price and time intervals.

- **Distribution Management System/Distribution Automation (DMS):**

A Distribution Management System (DMS) is a collection of applications designed to monitor & control the entire distribution network efficiently and reliably. It acts as a decision support system to assist the control room and field operating personnel with the monitoring and control of the electric distribution system.

- **Transmission Enhancement Applications (TA):**

Transmission Enhancement Applications exploit the time periods in which the offered load of a particular type is less than its minimum allocated bandwidth by allowing the difference to be available to other generic load.

- **Asset/System Optimization (AO):**

AO is a set of activity created to make sure that the operational performance is maximized relative to the cost. This is made possible by owning the most attractive assets, which include capital, natural resources, workforce skills, and so on which has the potential to deliver maximum returns. The major aim of optimization is to achieve the best possible performance from the grid.

- **Distributed Energy Resources (DER):**

Distributed energy resources (DER) are smaller power sources that can be aggregated to provide power necessary to meet regular demand. As the electricity grid continues to modernize, DER such as storage and advanced renewable technologies can help facilitate the transition to a smarter grid.

- **Information and Communications Integration (ICT):**

Information and Communications Integration stresses the role of unified communications and the integration

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of telecommunications, computers as well as necessary enterprise software, middleware, storage, and audio-visual systems, which enable users to access, store, transmit, and manipulate information.

VI. SMART GRID CHALLENGES

- **Lack of awareness:**

The main problem with taking on smart grids seems to be a lack of awareness of mature standards by people involved in designing Smart Grid systems at a high level and a lack of clear best practices and regulatory guidelines for applying them.

- **Not a match made in heaven**

Many Smart Grid project managers are trying to use standards together that were developed by different SDOs (Standards Development Organizations). Often standards may look like they match but because they deal with concepts at many different levels and from different viewpoints they actually do not. And even when elements were carefully chosen to artificially fit together, chances are that 10 or 20 years down the road that fit will have eroded. This is largely due to the fact that each SDO develops its standards with different interests and criteria, updating and reviewing it based on different protocols. Those may be linked to an industry or interest group that has regional or national relevance only (Momoh, 2009).

- **Technical challenges:**

The electrical network is composed of a high number of very distributed nodes that are tightly coupled and operating in real time. Since all the parts of this network have organically grown over many years, even decades, figuring out where intelligence needs to be added is very complex. System engineering is a mature industrial discipline, but its level of complexity here is unprecedented. In the first place, the electrical system is in continuous operation. At the same time, it is evolving constantly while incorporating a huge legacy. Different stakeholders are responsible for different parts of the system. Independently, each may make different choices about evolution and use. It is necessary to manage the integration of new equipment that has a lower life span than traditional network assets. Three to five years for consumer electronics and telecommunications, compared to 40 plus years for lines, cables, and transformers. The Smart Grid thus faces a technical challenge that goes way beyond the simple addition of an Information Technology infrastructure on top of an electro-technical infrastructure. Each device that is connected to a Smart Grid is, at the same time, an electro-technical device and an intelligent node. Today's "connection" standards need to address both aspects concurrently (Farhangi, 2013).

- **Standards and interoperability:**

The major challenge is to integrate interchangeable parts from a variety of different providers worldwide. There is a huge need for interoperability standards that will allow utilities to buy pieces of equipment from any vendor knowing that they will work with each other and with existing equipment at every level. We are not simply talking about interfaces – one plug fitting with another – we need interoperability at all levels in a given system. They not only need to speak the same language they also have to understand each other have "thought" processes. Instead of imposing detailed technical specifications at a global level we have to focus on key interfaces. This is how efficient standards for interoperability are creating a huge area of freedom and innovation for the benefit of manufacturers and the utilities (Fang, et al., 2012)

VII. DEMONSTRATION AND DEPLOYMENT EFFORTS

Most current smart grid pilot projects focus on network enhancement efforts such as local balancing, demand-side management (through smart meters) and distributed generation. Demonstration projects have so far been undertaken on a restricted scale and have been hindered by limited customer participation and a lack of a credible aggregator business model. Data (and security) challenges are likely to increase as existing pilots expand to larger-scale projects. Non-network solutions such as ICTs are being used in a growing number of smart grid projects, bringing a greater dependence on IT and data management systems to enable network operation. Although significant effort and financial resources are already being invested in smart grids, the scale of demonstration and deployment co-ordination

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needs to be increased (Palensky and Dietrich, 2011). Several organizations have created, are creating or are calling for the creation of an inventory or database of detailed case studies to gather the lessons learned from such projects, particularly in the areas of policy, standards and regulation, finance and business models, technology development, consumer engagement and workforce training (Momoh, 2009).

Some national smart grid demonstration and deployment efforts:

China:

China's State Grid Corporation outlined plans in 2010 for a pilot smart grid programme that maps out deployment to 2030. Smart grids investments will reach at least USD 96 billion by 2020.

United States:

USD 4.5 billion was allocated to grid modernization under the American Recovery Reinvestment Act of 2009, including: USD 3.48 billion for the quick integration of proven technologies into existing electric grids and USD 435 million for regional smart grid demonstrations.

Australia:

The Australian government announced the AUD 100 million "Smart Grid, Smart City" initiative in 2009 to deliver a commercial-scale smart grid demonstration project. Additional efforts in the area of renewable energy deployments are resulting in further study on smart grids.

Japan:

The Federation of Electric Power Companies of Japan is developing a smart grid that incorporates solar power generation by 2020 with government investment of over USD 100 million. The Japanese government has announced a national smart metering initiative and large utilities have announced smart grid programmes (Choi and Lee, 2010).

South Korea:

The Korean government has launched a USD 65 million pilot programme on Jeju Island in partnership with industry. The pilot consists of a fully integrated smart grid system for 6 000 households, wind farms and four distribution lines (Fusco *et al*, 2016). Korea has announced plans to implement smart grids nationwide by 2030.

VIII. CONCLUSION

Smart Grid builds on many of the technologies already used by electric utilities but adds communication and control capabilities that will optimize the operation of the entire electrical grid. Smart Grid is also positioned to take advantage of new technologies, such as plug-in hybrid electric vehicles, various forms of distributed generation, solar energy, smart metering, lighting management systems, distribution automation, and many more.

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