

Smart Grid: New Era of Electricity Distribution Network

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Abstract. The Smart Grid concept is conceived as a means to optimize the operation and to improve the reliability of the electric delivery system. As environmental concerns and energy consumption continue to increase, utilities are looking at cost effective strategies for improved network operation and consumer consumption. Smart Grid is a collection of next generation power delivery concepts that includes new power delivery components, control and monitoring throughout the power grid and more informed customer options. A “smart grid” leverages digital technology to improve reliability, security, transparency, connectivity, interoperability, and efficiency. It enables information collection and communication throughout the system, from generation to transmission and distribution to end users. The Smart Grid can’t be reduced to a simple formula.

Keywords: Smart Grid, Self-healing, Power system, Commercial agreements, Electricity markets, Interconnectivity.

1. Introduction

“Smart grids,” as the name implies, are sophisticated, digitally enhanced power systems where the use of modern communications and control technologies (the former also known as ICT, or Information and Communications Technologies) allows much greater robustness, efficiency, and flexibility than today’s power systems. Designers also aim for smart grids to save money. Additional terms used include a “Self-healing grid,” which can repair itself in the event of any failure or attack. There is no single definition of a smart grid, nor is there any standard architecture or design for a Smart Grid. This makes things difficult for utilities, planners, and the government, but it also highlights the enormous potential and opportunities in this space. Smart Grids are best defined by functionality, especially since the underlying technologies for achieving these goals are still under evolution. We can list following objectives of a Smart Grid: 1. Enabling informed participation by customers, 2. accommodating all generation and storage options, 3. Enabling new products, services, and markets, 4. providing the power quality for the range of needs in the 21st century economy, 5. Optimizing asset utilization and operating efficiently, 6. Addressing disturbances through automated prevention, containment, and restoration, 7. Operating resilience against all hazards.

2. What Is Smart Grid?

2.1. Definition of Smart Grid

Based on physical power grid, smart grid is a new type power grid which highly integrates modern advanced information techniques, communication techniques, computer science and techniques with physical grids. It has many advantages, such as improving energy efficiency, reducing the impact to environment, enhancing the security and reliability of power supply and reducing the power loss of the electricity transmission network and so on.

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Fig. 1: Objectives of a Smart Grid.

2.2. The Characteristics of Smart Grid

Smart grid holds the promise that the power sector can go "green" by not simply reducing the use of dirty power generation methods but instead become a system that can take more aggressive measures to lower greenhouse gas emissions through efficient integration of renewable energy sources.

- **Secure and Reliable:** The power grid is still to maintain the power supply capacity to the users, rather than a large area power outage when big disturbances on the power grid, faults, natural disasters and extreme weather conditions, or man-made damage happen.
- **Efficient and Economical:** The power grid can improve the economic benefits through technological innovation, energy efficient management, orderly market competition and related policies. The power grid is in support of the electricity market and power transactions effectively to achieve the rational allocation of resources and reduce power losses and finally to improve the efficiency of energy.
- **Clean and Green:** A large-scale of renewable energy sources can be fed into the grid which will reduce the potential impact on the environment.
- **Optimization:** The optimal cost to provide qualified electricity to the community. Smart grid can optimize utilization of assets; reduce investment costs and operation and maintenance costs. Quality of power meets industry standards and consumer needs. Provide various level of power quality for the range of needs.
- **Interactive:** Interaction and real-time response to the power market and consumers, which improves service. Mature wholesale market operations in place, well integrated nationwide and integrated with reliability coordinators. Retail markets flourishing where appropriate.
- **Self-healing:** The power grid has capabilities such as real-time & on-line security assessment and analysis, powerful control system for early warning and prevention control automatic fault diagnosis, automatic fault isolation and system self-recovery capability. Self-Healing and adaptive to correct problems before they become emergencies.
- **Flexible and Compatible:** The power grid can support correct, reasonable integration of renewable energy sources and it is suitable for integration of distributed generation and micro power grid. Besides, it can improve and enhance the function of demand side management to achieve the efficient interaction capability with users.
- **Integrated:** Unified platform and models are used on the power grid. It can achieve a high degree of integration and information sharing of power grid, and to achieve standard, normative and refined management, which integrates the infrastructure, processes, devices, information and market structure so that energy can be generated, distributed, and consumed more efficiently and cost effectively.



Fig. 2: Characteristics of Smart Grid.

3. Components of Power Systems and Changes in a Smart Grid

Generation in most modern power systems is a mostly centralized affair, with a wide portfolio of generation technologies based on availability of primary fuels as well as costs. In the US and India, coal dominates generation. Larger and larger generating stations have been built over time, typically with economies of scale in mind.

Transmission lies in the “middle” of the power system interconnecting generation with distribution systems. Transmission lines are typically long distance and high voltage. Since waste heat losses are proportional to the square of the current, which is inversely linked to the voltage, transmission is high voltage or extra high voltage – hundreds of kilovolts are common. Voltages are stepped up (or down) using power transformers, which are present at a number of stages of a power system.

Distribution is the last physical component of a power system, and is usually the retail end of the system (though retail can be separated from the physical distribution system). Distribution is also like transmission in the sense that this carries power towards consumption points, but there are two main differences. First, the voltages are lower (perhaps tens of kilovolts at most, before being converted to 120V or 220V for end-users), and second, the branching of lines is usually in the form of a tree structure. In transmission, different circuits interconnect, even forming loops for managing bulk power transfer. Distribution is mostly unidirectional power flow, going from the sub-station (where the power transformer separates it from transmission) to the consumer.

4. Designing a Smart Grid: Stages of Capabilities

Not only are the technologies within a smart grid evolving, even using today’s technologies there can be a number of designs for a smart grid based on business case, legacy needs, regulatory guidance, etc. Across this continuum, we can identify a number of capabilities, with some that are linear (like below) and some capabilities that can be deployed independent of others. Some of these functionalities are typically not even considered part of a smart grid, rather, are part of modern grid operations and management



5. Interconnectivity – a Key Requirement

Most designs typically end at the consumer premise, given utilities typically do not want to become involved with activities inside the consumer home or office. Here, the meter or alternative gateway becomes the interface and boundary. However, it’s unclear as to the best design for signaling appliances or devices directly. Some signals might need to be broadcast, while others customized. The good news is that the connectivity bandwidth is modest. One doesn’t need broadband for such applications.

It is worth clarifying any potential use of the Internet. The Internet is the public, global, interconnected network comprising of multiple smaller networks owned and operated by a number of entities. It has no owner or controller. Most ICT designs for a smart grid do not advocate directly using the public internet given security, control, and predictability concerns (the Internet as of today is designed for “best effort” data communications). “Broadband” is merely end-user high-speed connectivity to the public Internet. It can be used for many functionalities, but there are challenges when it comes to predictability, control, etc. given it ties back to the Internet.

6. Some Research Activities on Smart Grids

In the following some of the most important international researches on SMART GRID are described. The tasks of the IntelliGrid program, initiated by Electric Power Research Institution (EPRI), are the creation of the technical foundation for a SMART GRID that links electricity with communications and computer control to improve reliability and customer services. This program can provide methodologies for open standards and requirement-based technologies with the exploitation of advanced metering, distributed automation, demand response, and wide area measurement.

7. Design Challenges

There are a number of technical design issues for which there are no easy answers – each utility will be slightly different based on existing architecture, legacy equipment, topology, demographics, etc. Utilities often span different geographies, consumer mixes, etc., not to mention often incorporate assets decades apart in technology (sometimes made more complex through acquisitions or restructuring). What would work well in one case may not be optimal in another.

8. Status of Smart Grids

Various utilities around the world have taken steps towards deploying a smart grid. A number of nations also have regulations and legislation towards smart metering if not smart grids. Perhaps the largest deployment to date has been Enel, in Italy, where all 27+ million consumers have smart, bi-directionally communication, and controllable meters. However, with continuous improvements in technology, new deployments (e.g., Boulder, Colorado, or Southern California) are “smarter” in their capabilities. Smart grids remain a work in progress, and there are other projects ongoing around the world. In developing countries, smart grids have not been the focus of the utilities given the other challenges they face, including supply shortfall, theft, financial losses, etc. However, given their small base of present deployment, it is possible that they could leapfrog to smart grids, while at the same time using them as a means to improve their operating and financial sustainability.

9. Conclusion

In conclusion, the smart grid brings both benefits and design challenges to the utility, its customers, and the associated technologists. The electric power system is arguably the world’s largest machine, if one defines a machine as a series of interconnected parts that form a common system. Transient stability, I²R losses, communications, security, system architecture and modeling are all parts of the complex picture. Data communications is often the largest missing piece. The project needs to be done in well defined phases. The primary mission is still to keep the lights on. The data deluge must be managed. Knowledge capture is part of smart grid planning and results. The work is not all technical; there are strategy and change components for the employees. To accommodate a more flexible, dynamic, secure, and diverse system, the smart grid is an essential component on the path to the energy future of 2030.

10. References

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