

# Smart Grid

By:

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## Introduction

Smart grid (smart power grids) is the intelligence of the grid, also known as "grid 2.0". Smart Grid is built on the basis of integrated, high-speed bi-directional communication network, through advanced sensing and measurement techniques, the application of state-of-the-art equipment and technology, advanced control methods and state-of-the-art decision support system technology to achieve reliable grid security, economical, efficient, environmentally friendly and use security goals, its main features include self-healing, motivation and including the user to defend against attacks, power quality to meet the users' needs in the 21st century to allow the access of the various forms of electricity generation, start the power market and asset optimization and efficient operation. The smart grid is an overview of the next generation power system, which is characterized by the use of communications and information technology in the generation, transmission and electricity and other sectors more.

Each branch of the Association of Electrical and Electronics Engineers (IEEE) in their respective areas of expertise through the organization to carry out various activities, publishing magazines and the development of standards to assist in advancing the revolutionary development of the smart grid. In the process of development of the modern power grid, countries combined with the specific circumstances of the electric power industry development through the different areas of research and practice, formed their own direction of development and technology roadmap, but also reflects a different understanding of the countries in the future grid development mode. In recent years, with a variety of advanced technology widely used in the power grid, intelligent has become the inevitable trend of development of the grid, the development of smart grid in the world to reach a consensus. Technology development and application point of view, the world, experts in various fields, scholars generally agree that the following view: the smart grid is a state-of-the-art sensor measurement technology, information and communication technology, analysis and decision technology, automatic control technology and energy power technology combined and highly integrated with the grid infrastructure and the formation of the new modern power grid.

## Definitions

The physical grid based on modern state-of-the-art sensor measurement technology, communication technology, information technology, computer technology and control technology and the physical grid high degree of integration and the formation of new grid.

- To fully meet user demand for electricity and to optimize the allocation of resources, to ensure the safety, reliability and economy of electricity supply, to meet the environmental constraints, to ensure power quality, to meet the electricity market development for the purpose to achieve reliable, economical and user , clean, power supply and interactive value-added services.

## Characteristics

In the United States on the definition of the smart grid, smart grid has seven characteristics:

- Self-healing: Self-healing is the healing powers of modern grid and grid failure to respond to quick fix to reduce outage time and economic losses.
- Interactive. In the modern power grid, commercial, industrial and residential energy consumers can see electricity prices, the ability to select the most appropriate power supply scheme and electricity.
- Safety. Safety is a modern power grid construction to consider thoroughly security.
- To provide power quality to adapt to the needs of the 21st century. Modern power quality problems, voltage drop, voltage spikes, disturbances and interruptions to the grid will not meet the needs of the data center, computer, electronic and automated production line.
- To adapt to all types of power and energy storage methods. Modern grid allows plug-and-play connection to any power supply, including renewable energy and energy storage devices.
- Market transactions. The modern grid support ongoing national transactions, allowing local and local innovation.
- Optimize network assets to improve operational efficiency. Modern grid system has been built with more energy; just building a little new infrastructure, spend less operation and maintenance costs.

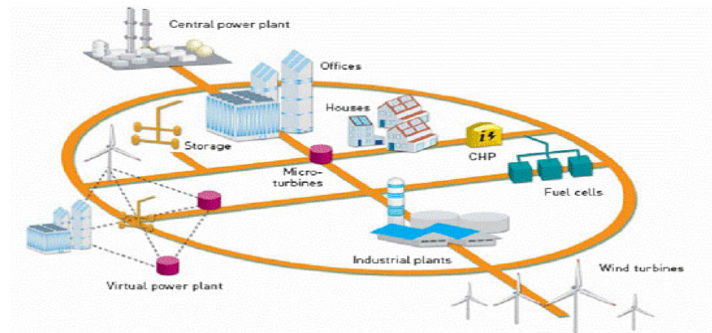


Figure 1: Milestones of Smart Grid Concept

The development of the smart grid concept three milestones:

1. The first is the 2006, the United States, IBM's "smart grid" solutions. IBM's smart grid is the solution to the safe operation of power grid, improve reliability, from its release in China - China Power development of new ideas "White Paper" smart grid innovation operations management can be seen, the solution includes the following aspects:
  - a. First, assets and equipment to improve the level of digital sensor connection;
  - b. second is the integration of data systems and data collection system;
  - c. Third, the ability to analyze based on master data, to optimize the operation and management. The program provides a broad framework, electricity generation, transmission, retail optimization of all aspects of management, depicts a blueprint for other companies to improve operational efficiency and reliability, reduce costs. The IBM marketing strategies.
2. The second energy plan after Obama took office, in addition to the announced program, the United States will also focus on focus on each year to spend \$ 120 billion circuit loss and breakdown maintenance grid system upgrading, the establishment of the United States across four time zones unified power grid; development of smart grid industry, to maximize the value and efficiency of the national grid, the progressive realization of solar energy, wind energy, geothermal energy, unified network management; comprehensively promote distributed energy management, creating the world's highest energy efficiency. As can be seen the U.S. government's smart grid has three purposes, one is the U.S. power grid equipment is relatively backward in urgent need of renovation to improve the reliability of the grid operators; smart grid construction quagmire the United States pulled out of the financial crisis; improve energy efficiency.
3. The third is the Chinese energy expert Wu Jiandong, "interactive grid. Interactive grid, English for the Interactive Smart Grid, which covers the meaning of it smart grid. Interactive grid is defined as: information model on the basis of the open and interconnected by loading system digital equipment and upgrade the power grid network management system, the whole process of the generation, transmission, power supply, electricity, customer sale of electricity grid hierarchical scheduling, integrated services and power industries intelligence, information technology, tiered interaction management is a collection of industry the efficiency of transformation of the revolution, technological revolution and management revolution will recycling the grid information loop, to build the new user feedback, to promote the power grid as a whole transformation into energy infrastructure, improve energy efficiency, reduce customer costs, reduce greenhouse gas emissions, create grid value maximization.

Interactive grid through the electronic terminal between users, between users and grid companies to form a network interaction and instant connectivity, to achieve the power data read real-time, high-speed, bi-directional overall effect, electricity, telecommunications, television, intelligent appliance control mixed-use development and the integrated battery charging user affluent and energy sold back; integration of data in the system, improve the integral role of the central power system, to achieve effective protection of critical loads, various power and client terminal with the grid seamless interconnection, which can optimize the management of the grid, the grid is upgraded to the new interactive operation mode, the formation of the new grid service functions, improve the entire grid reliability, availability, and overall efficiency. Interactive grid is both the next generation of the basic pattern of the global grid, the core of China Power Grid modern In fact; the interaction is the essence of alternative energy grid, compatible with the use and interaction of economic.

Technically, interactive grid should be the integration of the most advanced communications, IT, energy, new materials, sensors and other industry, but also with grid technology, network technology, communication technology, sensor technology, power electronics, energy storage technology synthesis, for the promotion of the new technological revolution has a direct effect. As a result, the smart grid with reliable, self-healing, economic, compatibility, integration and security features. I thought: interactive grid essence of the doctrine is made onset of the information revolution, standards and technical means to promote large-scale industrial revolution, the most important property - the grid system was innovation and upgrading, the interaction between consumers and grid managers.

Interactive grid operation efficiency and social significance the interactive grid essence of the doctrine is to promote the industrial revolution, the most important assets - innovation and upgrading of the grid system, the establishment of standards and technical means of information revolution in the law-making large-scale consumers and grid management by the interaction between. The interactive grid benefits include: First, the smart grid can achieve two-way interactive Intelligent Transfer data, the implementation of dynamic floating price system; sensor for real-time monitoring of the operational status of the generation, transmission, distribution, supply and other key equipment and data integration, experience the peak period of the power supply, timely scheduling between different areas, to balance electricity supply gap, so as to achieve the optimal management of the entire power system operation; smart grid can be a new alternative energy access grid, such as solar energy, wind energy, geothermal energy, distributed energy management; Fourth, improved power efficiency, reduce energy consumption, improve the quality of power supply to solve the grid commercial operation; smart meters can be used as Internet routers, to promote the power sector based on its end-user communications, broadband services or dissemination of television signals.

To this end, the depth of the revolution of the IT industry and energy revolution will be the twin brother of the smart grid reform will promote the depth of diffusion of the global energy revolution. Through the construction of an interactive grid, the IT revolution will advance the innovation stage; will provide consumers with a better path to reduce energy consumption; cost savings for society as a whole, reduce greenhouse gas emissions and promote green economy dominated.

Wu Jiandong define a concept of "liberation of an era grasp a concept glow potential of an industry, defined the concept of grid information technology is to determine the basic premise of a national grid modernization" (Gelling's, 2009). China power grid upgrade route change should be defined as an interactive grid development is a global industry and information industry, a new industrial revolution, technological revolution and management revolution, China starting point, it should be developed as a basis for the strategic development of the grid modernization route. Historical development in 2005, Campbell invented a technology, use (Swarm of group behavior) principle, so that the building electrical co-ordination to reduce the electricity consumption of the building in the peak period. Campbell invention, a wireless controller, connected to the various electrical and building, and to achieve effective control. For example, an air conditioner to run for 15 minutes, the indoor temperature is maintained at 24 ° C; two air-conditioning may be guaranteed under the premise of the indoor temperature, outage 15 minutes. In this way, without sacrificing the premise of each individual, the entire building energy efficiency goals can be achieved. This technology gives electrical intelligence; improve the efficiency of energy use.

In 2006 the Council of the European Union's energy Green Paper "European Sustainable, competitive and secure energy strategy" (A European Strategy for Sustainable, Competitive and Secure Energy) stressed that smart grid technology is a key technology and development to ensure that the EU power quality direction. At this time, the smart grid is in the process of transmission and distribution automation technology. Mid-2006, a company called "dot" (Grid Point)'s, recently began selling a home circuit for monitoring the power consumption of electronic products, home appliances via the Internet communication technology to adjust power consumption. The electronic products with a part of the interaction can be seen as a smart grid infrastructure.

In 2006, the United States, IBM has worked with global power professional research institutions, power enterprises to develop a "smart grid" solution. This program metaphor for the power system of the central nervous system, the power company through the use of sensors, meter, digital control and analysis tools, automatic monitoring network, to optimize network performance, prevent power outages, restore power more quickly, consumer power management can be refined to each networked device. This can be seen as the most complete smart grid solutions, marks the official birth of the concept of smart grid.

In 2007, the East China Power Grid official launch of the smart grid feasibility study project, and plan the "three-step" strategy from 2008 to 2030, namely: in 2010, initially built grid dispatch center, fully completed by 2020 preliminary intelligence digital grid, completed in 2030 real smart grid with self-healing capabilities. The start of the project indicates that China has begun to enter the field of smart grid"(Brown, 2008).

In 2008, Boulder, Colorado (Boulder) has become the nation's first smart grid city, per household arrangements smart meters, one can intuitively understand the tariff at the time, some things, such as laundry, ironing and other arrangements in the low tariff period. The meter can also help people priority in the use of clean energy such as wind power and solar. The same time, the substation can be collected every household electricity consumption. Google and General Electric in September 2008 issued a joint statement announced that they are working together to develop clean energy business, the core is to build a national smart grid in the United States.

In January 25, 2009 The White House recently released "recovery plan scale Report announced: 3,000 miles of transmission lines to be laid or update and install smart meters to 40 million U.S. households - America is about to promote interactive grid as a whole revolution. In February 2 independent energy expert Wu Jiandong, "full implementation of interactive grid revolution to promote economic innovation and transformation," the article, clearly put forward the revolutionary transformation of the urgent need for China Power Grid "interactive grid".

In February 4, 2009, the Mediterranean island of Malta on Wednesday announced the agreement and IBM, the two sides agreed to establish a "smart utility system, digitization of the country's power grid and water supply systems. IBM and its partners will be replaced by the Malta 20000 meter interactive meter; Malta power plant will be able to real-time monitoring of electricity, and to develop different tariff incentives to conserve electricity users. This project valued at up to \$ 91 million (70 million euros), including the establishment of a sensor network in the grid. This sensor networks and transmission lines, power stations and other infrastructure to provide relevant data, so that the plant can more effectively carry out the distribution of electricity and potential problems are detected. IBM will provide software to collect and analyze data to help power plants to identify opportunities to reduce costs as well as the country's carbon-intensive power plant emissions.

"Google has begun testing the meter called Google Power Meter electricity monitoring software. This is a test version of the online dashboard; the equivalent of Google is becoming a common infrastructure of the information age"(Parikh, Kanabar, & Sidhu, 2010). February 28, 2009, as part of the intelligent power grid construction of the North China - North China Power Grid steady state, dynamic, transient Trinity security and defense, and the whole process of power generation control system in Beijing by the acceptance of the Expert Group. "The system the first time the previously decentralized energy management system, grid WAN dynamic monitoring system, on-line stability analysis of an early warning system is highly integrated scheduling without frequent switching between different systems and platforms, can be run on the grid panoramic monitoring and access to decision support"(Metke, & Ekl, 2010). In addition, the system by building a grid-connected power plant management assessment and quality of the ancillary services market analysis platform, can effectively improve the scheduling department for grid-based power plant management level of standardization and processes. U.S. Google into words to the U.S. Congress on March 3, 2009, requires the use of non-monopoly standards in the construction of a "smart grid (Smart Grid).

## **Strong smart grid - promote the progress of the 21st century energy**

### **Smart Grid conceptual framework**

National Institute of Standards and Technology Research Institute (NIST) Smart Grid conceptual model to build a smart grid framework, which set up seven areas: large-scale power generation, transmission, distribution, electricity, operators, market and service suppliers. This model shows the connecting various aspects of communication, the flow of energy and power, as well as various aspects of the relationship between. For each separate link is also constituted by a key feature of smart grid, through a bi-directional communication between the various elements, energy, and an electric power path connection. These connections are the future intelligent and dynamic foundation for the development of the grid.

NIST Smart Grid conceptual model can help the parties to understand the entire smart grid system elements, from power generation to the user (from the user to generate electricity), and study the relationship between the various elements of the smart grid.

"In IEEE, smart grid is deemed by different systems consisting of a large system, wherein each of NIST Smart Grid link could be extended to three smart grid base layers: (1) power and energy layer (2) communication layer (3) information technology and computer layer. (2) And (3) layer for power and energy layer provides basic facilities platform, so that the grid has become more "intelligent"(Potter, Archambault, & Westrick, 2009).

### **U.S. smart grid technologies and features**

United States Department of Energy data show Although the U.S. power grid reliability rate of 99.97%, but the United States still spends \$ 150 billion to make up for losses caused by the failure rate of 0.03%. Therefore it was suggested that even if invested trillions of dollars to upgrade the existing power grid into a smart grid, the remaining 0.03% failure rate is excluded, the cost can be recovered within 10 years.

#### **U.S. Smart Grid development status**

January 25, 2009, after Obama took office, the White House released the "economic recovery plan progress report, announced that within the next three years, 40 million U.S. households will install smart meters, while investing more than 40 billion dollars to promote the modernization of the grid.

June 3, 2009, a meeting held in California, Intel developed the 2030 energy technology, information technology and power systems and end-user load interactive smart grid information interoperability guide the you "(IEEEP2030).In order to promote the integration of power engineering, communications and information technology, and it is hoped this standard to become a global standard.

December 4, 2009, General Electric (China) Co., Ltd. and Yangzhou Economic and Technological Development Zone signing ceremony were held in Yangzhou in Yangzhou Smart Grid Demonstration Center "smart grid technology has begun to enter the Chinese market.

Now, the United States has begun to install some families with communication function smart meters (Smart Meter), the goal is to family as a unit, at any time to monitor electricity consumption and management, transmission and distribution more effectively. "In the process of promoting the smart grid, the U.S. government to the National Institute of Standards and Technology Research Institute under the Ministry of Commerce (NITS) under the provisions of the Energy Independence and Security Act to assess all smart grid standards, measurement methods, techniques, and other support services"(Momoh, 2009).

### **U.S. smart grid technology features**

The smart grid in the United States, also known as unified smart grid is combined into a national network system will be based on decentralized smart grid. This system includes: the U.S. power grid intelligent unified smart grid, addressing the needs of distributed energy system, long distance, high and low voltage intelligent network links the customer's power; under the premise of protecting the environment and eco-system, construction of new the transmission grid, to optimize the transmission and distribution of renewable energy , improve grid reliability and cleanliness; This the system balanced integration is similar to solar power in Arizona and Ohio interstate industrial electricity demand for electricity, to achieve nationwide power optimization scheduling, monitoring and control, in order to achieve the overall U.S. electricity demand management, spanned by the United States of renewable energy balance.

"Another core of this system is to solve the solar energy, hydrogen energy, water, electricity and vehicle energy storage, which can help users to sell excess power, including the resolution of the battery system rich energy sold back to the grid"( Galli, Scaglione, & Wang, 2011). In fact, this system is based on renewable energy; optimize the management of U.S. power generation, transmission, distribution and electricity system. And the United States plan to consider the integration of Canada, Mexico and other power cooperation.

Development of smart grid in the United States focused on the distribution and consumption side, the promotion of renewable energy development, focusing on business model innovation and customer service to enhance. Four twin brothers are: high-temperature superconducting power grid, power storage technologies, renewable energy and Distributed Systems Integration (RDSI) and transmission reliability and safety control system, the nature of this grid development strategy is to develop and transition grid into the "next generation" system, the core of its strategy is to advance breakthrough in smart grid, after the construction of renewable energy and distributed systems integration (RDSI) and electric energy storage technologies, and ultimately to integrate the development of high-temperature superconducting power grid.

### **Five basic technology of the smart grid**

- First, the integrated communications and connectivity technologies, building real-time control and information updates, and each part of the grid both said "can" listen ".
- Second, the sensing and measurement technology, to support faster and more accurate feedback to achieve the electricity side of the remote control, real-time pricing management.
- Third, the advanced parts manufacturing technology products are used in superconducting power storage, grid diagnosis of the latest research.
- Fourth, state-of-the-art control technology for monitoring grid necessary components to achieve rapid diagnosis and rapid repair of emergencies. Fifth interface improved technology to support more powerful human decision-making functions, grid operators and managers of more foresight and forward-looking.

### **Progress in technological innovation**

University of Hawaii Distribution Management System the platform (DMS): The energy management platform developed by the University of Hawaii, which allow consumers to home energy management and power plants and distribution system has been upgraded. The platform will be a combination of advanced measurement system (AMI) to receive real-time client feedback (AMI is used to measure the collection, storage, analysis and use of information of users of electricity a complete network and systems); same time, it energy automation systems to achieve energy savings. In

addition, the platform of the dispersing power, storage, load the optimal allocation and management in the power distribution system, the distribution system to become an organic whole, and the entire power grid overall better integration. It is reported that the platform will use a substation in Maui, Hawaii.

"Illinois Institute of Technology "perfect energy system "project:" perfect energy system to meet the needs of every consumer power systems, it is very flexible"( Gelling's, 2009).The project will design a micro-grid system, grid timely response to different situations, while increasing the reliability of the grid, to reduce the demand for electricity. The researchers said that the system can be used in any metropolis, and the consumers truly become a part of the electricity market.

"Super circuit" West Virginia: West Virginia, Allegheny Power Company (Allegheny Energy) "super circuit" will be state-of-the-art monitoring, control and protection technologies together, thereby enhancing the reliable supply line and security. The grid will integrate bio-diesel power generation, energy storage, and AMI and communication network, rapid predict, identify and help resolve network problems.

San Diego coastal city micro smart grid "project: the performance of the micro smart grid is unique, can the power grid and power plant in the event of a large-scale grid failure to achieve precise isolation and precise combined with the defect is fixed, the power output is almost No impact. In San Diego, the coastal city micro smart grid "project will prove to be a variety of distributed energy combined with advanced control and communication method is effective. The goal of the project is to improve reliability and reduce peak load with the distribution feeder and substation grid components. "Whether it is the power generation consumers at home use of solar power, electricity storage can AMI connected to the substation, and the peak load is not more than 50,000 kilowatts"(Moslehi, & Kumar, 2010).

In addition, the city of Fort Collins, Colorado, and the city's public utilities department also supports a number of clean energy plan, the one involved in the user area of five renewable energy such as solar and wind power nearly 30 together. The plan and other distributed power supply system to support the city called Fort ZED zero energy districts.

#### THE PROMOTION OF SMART GRID VISION TO 2050

The smart grid is the integration of a number of technical, consumer interaction and decision-making points of complex systems. This complexity makes it difficult to define detailed

"The world in the development of smart grid technology, so the majority of R & D and demonstration can be placed in a global context theory, but to promote the need to be discussed at the district level, at this level, a number of important factors, such as infrastructure ages, the growth in demand, Power generation structure, regulatory and market structure differences"(Tsoukalas, & Gao, 2008).

#### Regional analysis and promotion

Driven by economic, security or environmental factors and the countries in the use of smart grid technologies will choose their own priorities. Where possible the case, it is necessary to quantify the costs and benefits of the different methods in order to assess the impact of potential promotion of smart grid. In any district assessment needs to consider the following regional characteristics:

- Current and planned supply structure, including fossil energy, nuclear energy and renewable energy generation.
- The current and future needs, the needs of the industry structure, such as manufacturing, extensive residential load, or the promotion of electric vehicles.
- Existing and planned new transmission and distribution network status.
- The ability to interconnect and adjacent areas.
- Regulatory and market structure.
- Climatic conditions and resource availability.

#### Quantitative assessment of peak demand and the impact of the smart grid

The interaction between the promotion of smart grid behind the motivational factors or drivers and drivers needs to be understood based on local or regional electric power system. This roadmap expanded to four regions on the basis of the "Energy Technology Perspectives 2010" scenario, to develop a more detailed land.

#### Conclusion

The benefits of Smart Grids are Widely Acknowledged. Smart Grids can manage live interaction and communication Among Consumers, Households or companies, other grid users and energy suppliers. It opens up possibilities for Unprecedented Consumers to directly control and manage their individual consumption patterns, supplier providing, in turn, strong incentives for efficient energy use if combined with time-dependent electricity prices. Improved and more Targeted management of the grid Translates into a grid that is more secure and cheaper to operate. Smart Grids Will Be the backbone of the future decarbonizes power system. They will enable the integration of vast Amounts of Both on-shore and off-shore renewable energy and electric vehicles while maintaining maintenance availability for conventional power generation and power system adequacy. Finally, the deployment of Smart Grids provides an opportunity to boost the future competitive and worldwide technological leadership of EU technology providers such as the electrical and electronic engineering industry, consisting mostly of SMEs.

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