OVERVIEW OF SMART GRID - CHALLENGES AND OPPORTUNITIES

Nguyen Van Dinh
Faculty of Information Technology,
Thanh Dong University
Hai Duong, Vietnam
dinhnv@thanhdong.edu.vn

Pham Thu Thuan
Faculty of Information Technology,
Thanh Dong University
Hai Duong, Vietnam
thuanpt@thanhdong.edu.vn

ABSTRACT

The constantly growing demand for electricity along with the diversification of power sources has required the development of modern power grid systems, with advanced management technologies. This article will help you learn about smart grid - a revolution in digital transformation in power transmission and distribution systems, a solution that is being widely developed around the world. The article focuses on the role of information and communications technology in smart grid control without going too deeply into the electrical components of the power system.

Keywords: *Smart grid, Smart meters system, Distributed smart control system, Information-Communication technology*.

1. INTRODUCTION TO SMART GRID

1.1. Some details about the history and context of smart grid's appearance

The traditional AC power grid was appeared in 1896, based on Nikola Tesla's design published in 1888. It is an electric power system consisting of components: Power plants, power transmission lines, and other components, such as transformer stations, electricity distribution stations, meters and electricity consumers.

The term smart grid has been officially used since 2005, when the article "Toward a smart grid: power delivery for the 21st century. IEEE power and energy magazine 3 (5), 34-41, 2005." by authors S. Masoud Amin and Bruce F. Wollengerg was published in IEEE magazine in 2005 [1]. In general, most of the definitions of the smart grid highlight the application of information processing and digital communication to the power grid, making the management of data flow and communication become the heart of the smart grid. Integrating information streams into the grid's processing systems is one of the key issues in smart grid design. Many definitions have been given for smart grids, some based on functional perspective, some based on technology or benefits, depending on countries and regions.

In Europe, a smart grid is understood as a power grid that can

integrate the operations of all components connected to the grid, including power plants, transmission systems, electricity customers... to efficient power supply. Smart grids use advanced products and services along with monitoring, control and communication technology, which can self-repair and adjust when problems occur [4, 5, 9].

In the United States, the smart grid is defined as modernizing traditional electricity transmission and distribution systems to maintain a reliable and resilient electrical infrastructure that is resilient to natural disasters. Smart grid relies on increased use of information technology and digital controls to improve grid reliability, security and efficiency. Smart grids have the potential to meet future demand growth, allowing proactive engagement with new customers, services, and markets [6, 7, 8].

IEEE briefly introduces the concept of smart grid: Smart grid is the next generation power system characterized by enhanced exploitation of information technology - communication (ICT) in electricity production, distribution and consumption [4].

Based on the above viewpoints, we will provide descriptions for smart power networks:

1.2. Descriptions of smart grid

- *About structure*: Smart grid is an electricity system that uses information and communications technology (ICT) in management and operation to optimize the transmission and distribution of electricity between producers and consumers user. Smart grids integrate electrical infrastructure with information and communication infrastructure.
- *About features*: Smart grid has the ability to independently monitor and distribute electricity to achieve maximum energy efficiency, flexibility and sustainability in operating and managing the power system..

Thus, it can be considered that the smart grid system consists of two layers: layer 1 is the traditional power system and above it is layer 2: information, communication, and measurement system, creating a distributed smart control system, this is the brain of the smart grid (see figure 1).

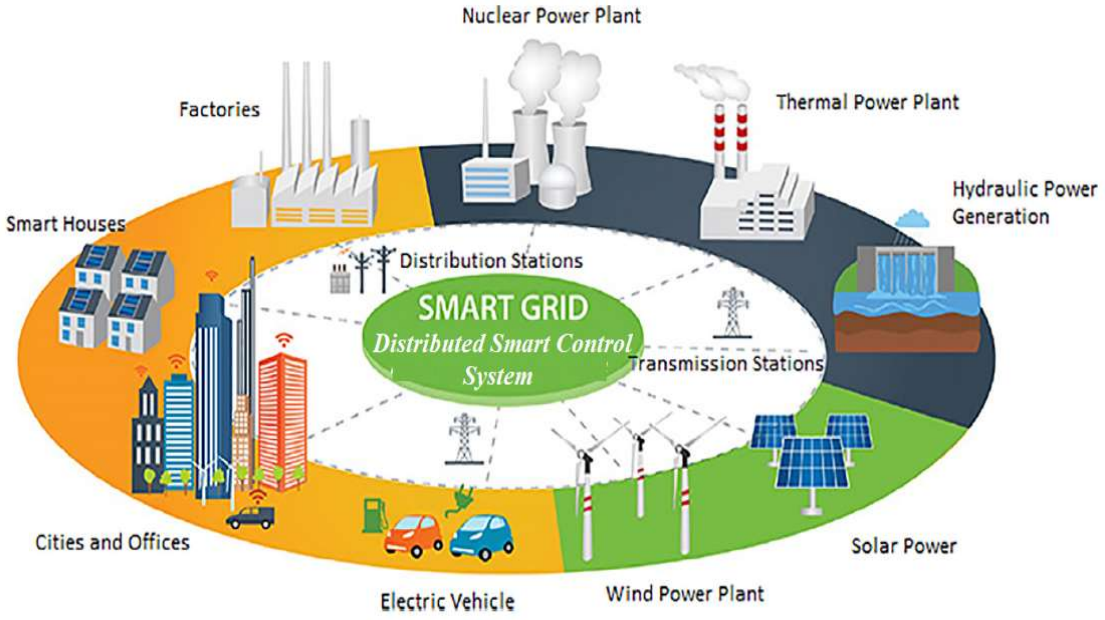

Fig. 1. *Smart grid diagram*

Figure 1 is a smart grid diagram: the outer ring is the traditional grid system including power supply, consumption and transmission systems (layer 1). The core is a distributed smart control system (layer 2).

Thus, the components of the power system in the smart grid practically do not change, but all elements of the system have "*smart chips*" and communication channels to be able to exchange and communicate with each other and control each other. Such a power system is considered a smart grid. All Smart grid's devices interact with each other, forming a unified smart power supply system. A smart grid is a type of grid whose goal is to intelligently predict and respond to the behavior and actions of all components connected to the grid: electricity suppliers, consumers and units that both supply and consume electricity. Smatr grid aims to efficiently provide reliable, economical and sustainable electricity services.

1.3. The benefits of a smart grid

Smart grids bring enormous benefits to both consumers, power companies and all society.

- *For customers*: smart grid helps them monitor the power consumption of devices at different times in almost real time, thereby proactively selecting devices and adjusting using behavior. Customers can also choose to use new services with many price options, helping to proactively balance their finances and needs.
- *For power companies*: Smart grid will help them improve power supply reliability and power transmission efficiency, while reducing costs through improving operational and

management efficiency. Labor and operating costs are also minimized by the application of smart meters and technologies that allow data collection, monitoring and control of devices on the power grid through telecommunications networks (RF, mobile...).

- *For society*: Stable and effective electricity supply for agencies, businesses and the majority of people will be a solid foundation for economic development and social security. A smart grid capable of integrating with renewable energy, supporting electric vehicles such as electric cars, electric motorbikes… will also contribute to reducing emissions that cause environmental pollution.

2. BASIC CHARACTERISTICS AND FUNCTIONS OF A SMART GRID

2.1. Advanced features of Smart grid

- Two-way operation, real-time interaction, with information exchange between all elements of the grid, from generators to user terminals.
- Covers the entire power system from power plants and power networks to the final consumer.
- Ensuring the supply-demand balance is continuously controlled. Smart grid elements will continuously exchange information with each other about electricity parameters: planned electricity consumption and actual consumption.
- Smart grid has the ability to protect itself against major external threats (natural disasters, cyber attacks) and self-recover after disruptions and incidents.
- Smart grid will promote the emergence of new markets, new participants and new services such as the renewable energy market, CO2 emission quota exchange market... For example: The European Union's *emissions trading scheme* (ETS), is the world's first and largest emissions rights trading market. In 2022, the EU ETS is worth about EUR 751 billion, up 10% from 2021, and accounting for about 87% of the total value of the global carbon market [2].

2.2. Basic functions of smart grid

A smart grid system must have the following basic functions:

- Self-recover in case of emergency incidents: The electrical system and its components must continuously maintain their required technical condition by identifying, analyzing incidents to prevent all emergency damages.
- Able to promote positive behavior of end consumers: Provides consumers with the ability to independently vary the quantity and quality of electricity

received, based on a balance between their needs and power system capabilities.

- Ensuring reliability and power quality: Moving from a system-based approach to a customer-based approach to ensure and maintain high quality of electricity. Reliability and power quality vary across different price segments.
- Diversify power generation and storage sources: Based on real-time supply and demand information, the smart grid will optimize the integration of power plants and renewable energy sources such as solar power, wind power, power from sea surface energy, power storage systems...
- Expanding the electricity market: Expanding the ability for end consumers to access the electricity generation market, electricity trading and distribution maket.

Thus, with the above functions, the smart grid system provides more flexible management capabilities, allowing for faster detection and repair of problems, optimizing power supply at the same time as meet user needs.

2.3. Smart systems and basic technologies of smart grids

To perform the above functions, a smart grid must have smart systems that apply new technologies to manage and operate the power grid.

- *Smart meter system* (SMS): first of all, there are smart meters and smart sensors. By a system of smart metering devices, the smart grid allows recording and analyzing energy consumption data in a more detailed and accurate way, helping to optimize energy management and source integration electricity develops in the power grid. Smart metering devices will provide detailed information on electricity consumption data, detect electricity fraud, and save costs and commercial losses.
- *Distributed smart control system* (DSCS): is a distributed control system (DCS) in which smart devices, smart sensors are used in smart grids. DCS is a control system of a production system in which control elements are distributed across all components of the production system and connected to a distributed database (DDB) to exchange control data. A distributed database is a database based on computer network technology: local data is collected and stored at stations, integrated via computer networks, managed and exploited as a single facility. Centralized data, suitable for data management in distributed components of the power

network. DSDS allows to predict equipment failure conditions across the grid, to minimize power outages due to incidents and prevent intentional attacks on the system, both physical and communications.

- *Smart decision support system* (SDSS): This system includes information integration interfaces and decision support methods. Based on the information of the smart measurement system and smart control system to make decisions for demand management, distributed generation system management.
- *Smart communication system* (SCS): This system manages a distributed database, with computers storing data located at different stations of the Smart grid, but integrated into a unified database, allowing elements of the smart grid system to connect and interact with each other. This system helps increase speed and accuracy in load forecasting, forecasting the need to develop distributed power sources, recommending additional power generation, energy storage or demand reduction.
- Some basic technologies have been applied in smart grid systems:

  - Energy storage technology

  - Superconductivity technology

  - Current limiting devices

  - Digital substation technology

  - Direct current transmission technology

  - Controlled AC power technology

  - Control and protection technologies from external influences.

  - Technologies for monitoring and diagnostics of electrical networks

  - Adaptive automated and automatic control technology

  - Distributed database technology

3. CHALLENGES AND OPPORTUNITIES

3.1. Challenges in investment and infrastructure

Smart grid deployment requires huge investment in infrastructure and technology, especially upgrading the existing power transmission system to be able to manage, collect and process information on a timely, helping the power system optimize transmission and balance supply- demand between generation sources and consumption places. A 2013 report from the International Energy Agency showed that 2012 global investment in new technology for smart grid reached nearly 14 billion USD, a four-fold increase compared to 2008; and increased to more than 25 billion USD in 2018. It is estimated that, worldwide, several trillion USD will be invested in the next

few decades to fully build smart power grids [3].

Particularly in Vietnam, Power Plan VIII for the period 2021-2030, estimates the total investment capital to develop power sources and transmission grids equivalent to 134.7 billion USD, which is a huge challenge in terms of investment and infrastructure [10].

3.2. Cyber security challenges

Expanding the application of information technology in the energy sector means increasing the level of cybersecurity risks. Information about the operation of the smart grid system is stored at all stations of the distributed database system, thís creates many challenges for the management and operation of this database. Information security and intrusion prevention of smart grid systems have become an important challenge that needs to be resolved. This also provides opportunities for information technology experts to contribute to the development of smart grid systems.

3.3. Opportunities

By investing in smart grids, we can lay the foundation for a clean energy future. Modern power grids will be more efficient, making better use of renewable energy sources.

Smart grid opens up opportunities to develop new technology applications such as energy storage systems, electric vehicles, energy management systems in smart buildings and smart cities.

The information and communication network of the smart grid is interconnected in a distributed system, which also promotes the development of distributed database technology and communication technologies.

The smart grid itself is still continuing to be researched and developed. Many new smart grid technologies have not yet been put into practical application and still need research. Those are opportunities for IT professionals.

CONCLUSION

The development of Smart Grid is different in each country. Developed countries are interested in improving distribution network efficiency, reducing CO2 emissions, integrating electricity generation from renewable energy sources and improving customer service. Other developing countries focus mainly on managing electricity output during peak periods effectively, reducing power loss. Depending on its purpose, each country will choose different technology solutions.

In Vietnam, Power Plan VIII was approved under decision No. 500/QD-TTg, dated May 15, 2023, setting the goal: *"firmly ensuring national energy security, meeting the requirements economic and social development,*

industrialization and modernization of the country. Along with that, successfully implementing a fair energy transition associated with modernizing production, building smart grid, management advanced power system, in line with the world's trend of green transformation, emission reduction, and scientific - technological development. At the same time, forming an overall energy industrial ecosystem based on renewable energy, new energy" [10].

In recent years, Vietnam has also begun to deploy the application of information technology in national power grid management, in order to gradually build a smart grid in Vietnam according to Power Plan 8, with many challenges and opportunity.

Seize opportunities and overcome all challenges to make many contributions and success in building a smart grid system in Vietnam.

REFERENCES

[1] SM *Amin*, BF Wollenberg. *Toward a smart grid: power delivery for the 21st century.* IEEE power and energy magazine *3* (5), 34-41, (2005).

[2] https://nhandan.vn/thi-truong-mua-ban-quyen-phat-thai-lon-nhat-the-gioi-hoat-dong-nhu-the-nao-post769770.html. (2022)

[3] NIST (2014), *NIST Framework and Roadmap for Smart grid*. Interoperability Standards, Release 3.0.

[4] M. Shabanzadeh and M. p. Moghaddam, (2013). *What is the Smart grid? Definitions, Perspectives, and Ultimate Goals*. 28th International Power System Conference, Teheran, Iran.

[5] http://www.electropedia.org/iev/iev.nsf/display?openform&ievref=617-04-13 (2011)

[6] https://www.540technologies.com/why-540-technologies/power-a-system-on-the-brink (2023)

[7] https://www.smartgrid.gov/the_smart_grid/smart_grid.html

[8] U.S. Department of Energy. *Smart grid* / Department of Energy.

[9] Smart grids European Technology Platform | www.smartgrids.eu.

[10] https://nangluongvietnam.vn/phe-duyet-quy-hoach-dien-viii-phan-tich-mot-so-noi-dung-moi-quan-trong-va-can-thiet-30756.html. (May 2023)