Improving the Performance of Power Transmission via Ultra High Voltage Direct Current (UHVDC)

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Abstract. To meet people's increasing demand for power, the power network system is developing. And the concept, essence and an energy interactive network plan of "Smart Grid" is proposed. However, some technical issues concerned in power network system appear. It is the key to improve the efficiency of transmission in the grid network. And the feasibility of applying Ultra High Voltage Direct Current (UHVDC) transmission to improve efficiency reliably is adequately expounded and proved. There are many countries using this method, especially China. Direct Current (DC) transmission is an important technology for high voltage, large capacity, and long distance transmission. Development and characteristics of UHVDC transmission and its development prospects in China are also introduced in this paper.

1 Introduction

The electric power industry is in the early stages of a complete transformation [1]. During the last few years, an increasing focus was put on the electricity supply and infrastructure. For one aspect, electricity usage increases significantly and becomes very fluctuating. Demand peaks should be changed gradually. Thus, due to the rapidly fluctuating demand, minimal grid requirements have increased. Another fluctuation in demand is a sharp decrease in generation efficiency [2]. For another aspect, the reduction in the CO_2 emissions and the introduction of generation based on renewable sources become hot topics today. However, these renewable resources are mainly given by the sun, water and wind power which are very variable and uncontrollable. The generation patterns may have some similarities with the electricity demand patterns. But those two kinds of patterns are in general far from being equal [3]. Furthermore, a large part of the existing electrical power infrastructures is worn out and should be replaced. As the electricity infrastructure needs to be upgraded and expanded, it is also important to enhance monitoring, control and communication capabilities [1]. These changes will challenge various axioms that underlie current practices in power system operation and control. Therefore, new strategies will be required to cope with the increasingly sophisticated nature of electricity generation and control patterns [4].

The view is that future power systems will highly dependent upon the intelligent power grid of the 21st century, namely the Smart Grid [1]. It includes wide-area monitoring, reliable and secure information networks, and distributed control. The concept of Smart Grid starts with the notion of advanced metering infrastructure. It is designed to improve demand-side management, energy efficiency. And a self-healing electrical grid is designed to improve supply reliability and respond to natural disasters or malicious sabotage. However, several developments have led to the expansion and help shape the new face of the initially perceived scope of Smart Grid [5]. In addition to enhancing efficiency, reliability and safety, the Smart Grid nowadays should enable the smooth integration of electric power's distributed generation, the practically real-time participation of energy producers and consumers into the energy market and the introduction of electrical vehicles [6]. The Smart Grid will also act as an intelligent agent creating economic value in the electricity market. It opens a wholesale electricity market, which supports the necessary changes in energy flows. The retail electricity market reflects the final level of the electricity supply chain. It focuses on the interaction between suppliers and consumers of electricity [7]. All the above new services or enhanced applications are necessary information and communication technology solutions. They are intended specifically for better utilization of electricity.

This paper is going to talk about the power transmission of Smart Grid technology. The first part is about the main aims of the Smart Grid. The second part will be the content of High Voltage Direct Current (HVDC) transmission. Directions of future academic research on Smart Grid will be included in the final part.

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2 Background:

2.1 The history of the Smart Grid development

As early as 2001, Italy electric power company installed and reconstructed 30 million smart meters, and established an intelligent metering network [8].

In 2005, Campbell invented a technology, using the principle of Swarm (group behavior) [8]. The electrical appliances in the building coordinated with each other and reduced the power consumption of the building in the peak period of electricity consumption. Campbell also invented a wireless controller which connected all electrical devices in the building, and achieved effective control [9].

In 2006, IBM of the United States proposed "Smart grid" solution which was mainly to solve the safety operation of the power grid and to improve the reliability. The program provides a large framework. It aimed to improve operational efficiency and reliability, and reduce the cost of the relevant enterprises through the optimal management of power production, transportation, retail and so on [10].

The first official definition of Smart Grid was provided by the Energy Independence and Security Act of 2007 (EISA-2007), which was approved by the US Congress in January 2007 and signed to law by President George W. Bush in December 2007 [11].

"Interactive smart grid", proposed by Chinese energy expert Wu Jiandong，covers the meaning of Smart Grid. Interactive Smart Grid is based on Internet and open information model. We can achieve power transmission and power supply in the whole process of intelligent information technology and hierarchical interactive management [12].

2.2 The strategies of smart grid in different countries

The Smart Grid in the world construction process has been started, and many countries have established the Smart Grid construction goal, course of action and investment plan. Combined with the supervision mechanism, current situation of power grid infrastructure and targets of Smart Grid, different countries have their own different strategies [13].

The Smart Grid construction in United States concentrates on the upgrading and updating of power network infrastructure. The main strategies aim to maximize the use of information technology to achieve the replacement of artificial substitution [8]. Super Smart Grid of the European Union (EU) mainly aims at large scale utilization of distributed generation and renewable energies. Meanwhile, promoting the transformation of the entire electricity industry development model is another target to achieve [8]. European countries develop their own Smart Grid researches and pilot projects with their own advantages and characteristics of the electric power technology development. New Smart Grid's construction plan in Britain is to build Intelligent City. Germany started "E-Energy" demonstration project. France and Italy focus on the development of distribution network intelligent meter and interaction [14]. Denmark focuses on the development of wind power generation and its control technology [15]. Australia implement advanced metering infrastructure to better manage the power consumption [13]. The core of Japanese Smart Grid is to build a grid suitable for large-scale promotion and development of solar power so as to solve the stability of energy resources and achieve energy visualization management [16]. Research focus of Korea Smart Grid is on intelligent green city construction. Korea also intends to increase the proportion of green energy in total energy use [13]. China concentrates on carrying out the research and practice work of the power grid modern construction and operation management technology. China is also organizing researches which are focused on access of new energy, Ultra-High Vacuum (UHV) transmission and large power grid operation control and soon. The work is done to develop international advanced and leading scientific power grid technology [13].

3 AC and DC in grid transmission

3.1 The advantage of AC transmission

For Alternating Current (AC) transmission, the voltage level which is of 220kV or below is generally considered as high voltage. The voltage of 330kV to 750kV is called UHV, 1000kV and above is called Extra-High Voltage (EHV) [17].

The reliability of 1,000kV large capacity and long distance AC transmission system is obviously higher than that of the 800kV DC transmission system [18]. And High Voltage Alternating Current (HVAC) transmission can have a transfer point in the process of transmission. It can form a powerful power network. With the network, we can transmit power and decide the way of wiring according to the distributed power point and distributed load point [19].

3.2 The advantage of DC transmission

There is something slightly different in Direct Current (DC) transmission. The general name of voltage which is over 100kV is high pressure. 500kV and 600kV are still called high pressure, which are generally not called UHV. However, the voltage which is over 600kV is called UHV [17]. And 800kV is determined as the appropriate voltage of the Ultra High Voltage Direct Current (UHVDC) transmission in China [20].

There are many advantages in DC transmission technology. 1) the watt level and direction of power transmission can be controlled and adjusted quickly; 2) the access of DC transmission system will not increase the short circuit capacity of the original power system; 3) the stability level of the system can be improved by using DC modulation; 4) when a pole of direct current does not work, the other can continue to run and utilize its overload capacity to reduce the loss of power under the monopole malfunction; 5) the width of the DC overhead

line corridor is about half the width of the same voltage grade AC line corridor [21]; and 6) the cost of the unit length of the DC transmission line is significantly lower than that of the AC line [22].

3.3 UHVDC

UHVDC transmission does not need complex system design. It only needs positive and negative Wireways [20]. In addition to all the advantages of DC transmission, it has more superiorities. Obviously, the transmission voltage is very large in UHVDC. And it has large transport capacity. The power transmission capacity of UHVDC power transmission project is up to 5GW to 6.4GW. Besides, it is capable to transmit power in a super long distance, which is up to 1500km, and even more than 2000km [23].

There are three kinds of volt ampere characteristics of HVDC system. Determination of current control and ignition angle's minimum limit is on the rectifying side and control of extinguishing angle control is on the inverter side. The voltage control is decided by the inverter side. The control of the rectifying side remains unchanged while the inverter side implements the control of dynamic trigger angle. The control characteristics of UHVDC system basically belong to pole control [24].

4 AC--DC transformation

Compared with AC transmission, DC transmission has many advantages and it is widely used in practice. Therefore, we are going to introduce some conversion method between AC and DC.

4.1 UHV converter station

UHV converter station is composed of basic commutation units. The basic converter unit mainly includes converter transformer, converter, control and protection devices, and AC/DC filters. The layout of the converter station depends on the connection mode between the converter transformer and the converter valve [21]. The station is set in order to convert alternating current into direct current or convert direct current into alternating current. And it also helps to meet the requirements of the power system for safety, stability and the quality of power.

4.2 Capacitor Commutated Converter (CCC)

CCC technology connects the fixed capacitor in series to the traditional commutation system's converter transformer and commutator. The reactive power consumption can be compensated by series-wound capacitor. And the reactive power consumption basically does not change with the amount of the active power transmitted, thus reducing the reactive power compensation. Capacitor Commutation Converter can significantly improve the stability of AC and DC systems, increase the anti-interference ability, reduce the probability of commutation failure, and suppress the DC short-circuit current [25-27].

4.3 control and protection

The core of the DC project is the control and protection. Due to the high energy of UHV direct current transmission, higher requirements for DC control and protection are put forward. In order to avoid the commutation failure caused by multiloop direct current, the DC additional control should be taken good use of to improve the stability and the flexibility of the system. In addition, due to the series-wound 12 pulsation of UHVDC transmission commutation valves, the corresponding control and protection should be studied in depth [24].

5 Conclusion

Today's power system is dramatically changing. The awareness of global warming and the environmental impact of burning fossil fuels are increasing, oil and gas prices are soaring and security of supply is becoming a major global concern. In this environment, energy policy is shifting towards a more sustainable power system [28].And electrical energy becomes more and more important nowadays.

5.1 The development of DC technology in China

The research work on DC transmission technology in China started in 50s. And China's geographical conditions are very suitable for the development of HVDC transmission. At present, a number of DC transmission lines have been put into operation in China. The work of these DC transmission projects indicates that the DC transmission technology in China has been greatly improved and developed. Besides the interconnection of Smart Grid promotes the development of HVDC [29]. Under the condition of reliable operation of the system, the direction of the development is to continuously improve the operation voltage, increase transmission power, reduce system losses and develop its fast controllability in order to improve the power system's stability [30].

5.2 transmission technology

In this paper, the background and motivation of Smart Grid are presented. It is talked that AC and DC in grid transmission and their advantages separately. In China, DC power transmission is widely used. DC transmission can improve the system's stability, reduce the power loss and achieve long distance transmission. And UHVDC transmission technology has been developed for many years and makes the long distance transmission more reliable. The implementation of the converter station helps to achieve the conversion from AC to DC.

5.3 prospects for development

UHVDC transmission technology conforms to the development rule of the power industry and the development direction of the power grid technology [31]. It has a broad application prospect in China. China's 'west to east transmission' strategy requires that the transmission projects have greater power transmission capacity and higher transmission efficiency. UHVDC transmission is one of the key technologies to meet this requirement [17]. According to the national conditions of China and other countries' research experience of UHVDC, we set up a test base for UHVDC [32].

DC transmission will take a very important position in the development of China's power grid. China should focus on the development of DC transmission technology and UHVDC transmission technology. Combining China's exclusive power grid structure, the corresponding control and protection technology and system stability technology are studied to improve the reliability of the DC transmission. DC power transmission technology is bound to drive the development of modern power system. We should do well in the research, planning and construction of DC transmission. This is the need of the development of China's power grid [33].

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