ISSN: 2664-9640

Development and Function of UHV Transmission Technology

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Abstract

The paper introduces the development history of UHV technology in the world. The history of China's development of UHV technology is emphatically introduced. Because UHV transmission has its unique advantages and is in line with China's actual national conditions, China has built huge-scale UHV transmission projects, which has promoted China's economic and social development.

Keywords

UHV; transmission; AC; DC.

1. Introduction

China is a vast superpower. The north-south span is very large and has various complex terrains. These reasons directly determine the UHV transmission is very suitable for the actual situation of such a superpower as China. With the progress of society and economic development, the electricity demand is growing rapidly, and the traditional transmission methods are difficult to meet the needs. China ' s resource distribution is extremely uneven, and the energy in the western region is richer than that in the eastern region. But due to the harsh natural environment in the western region compared to the eastern region, the eastern population is very dense while the western population is relatively scarce, which makes it difficult to generate electricity and transmission in China. Faced with these objective factors, China attaches great importance to UHV transmission technology, and has vigorously developed UHV transmission technology since the end of the last century. According to the international voltage equivalence standard, AC UHV refers to the AC transmission voltage with voltage level greater than or equal to 1000 kV [1]. Under the premise that the electricity load continues to increase, the cycle from low voltage to high voltage is generally 10 years. The time for low-voltage grades is shorter than that for high-voltage grades, while high-voltage grades generally take about 20 years from research and development to operation, and it takes nearly 20 years to reach ultra-high voltage.

There are three purposes to develop UHV transmission in China. First, transport electricity from the west to areas where electricity is concentrated in the east. Second, merge China ' s power grid into a grid, and build a ' strong grid '. The advantage of large power grid is that the stability of the whole system is improved, and electric energy can be transmitted between regions, which improves regional interconnection. Thirdly, since the transmitted power is certain, and the larger the voltage is, the smaller the current in the conductor is. Thus, according to the Joule law, the power loss on the conductor is reduced, and the economic benefit is improved.

The fundamental purpose of UHV technology is to enhance the transmission capacity of the line and reduce the waste of electricity in the mid-distance transmission, and meet the specific environment between separate power systems connectivity. That is, connecting the whole country into a network. According to previous studies, the transmission capacity of UHV lines

can be multipled to that of ordinary voltage, so the selection of UHV transmission can greatly reduce the use of wire and other materials, save costs and improve economic benefits.

Until the end of 2021, China has built 15 UHV AC transmission lines and 13 DC transmission lines, and the power level transported by the lines ranks first in the world. Research on UHV transmission in China is increasing. China ' s investment in ultra-high voltage technology has also increased significantly, and ultra-high voltage technology has become one of the symbols of China.

2. Development of UHV Transmission in the World

From the development of the world power grid, the transmission network has a history of more than 100 years. However, in the process of transmission technology from low voltage to high voltage level, western countries have been leading, and China is nearly 20 years later than the first high voltage transmission network in developed countries.

The world ' s first research on UHV transmission started in the1960s, when the world ' s developed countries such as the United States, Japan and so on had begun the study of UHV transmission technology and practical experiments, which had achieved good results. In 1985, the former Soviet Union took the lead in conducting relevant research on UHV transmission technology. During this period, many developed countries were also conducting in-depth exploration of various UHV technologies. The former Soviet Union built the first UHV current section in 1988. The United States, Japan and Italy had built UHV AC test lines and conducted a large number of UHV AC transmission technology research and test. Research abroad mainly focuses on topics such as high-voltage insulation of UHV transmission technology, development of transmission equipment, ecology and environment.

In 1967, the ultra-high voltage AC test center was established in Pittsburgh, which was coordinated by the U. S. government. General Electric Corporation of the United States was one of the largest electrical companies in the United States at that time. In cooperation with the National Electric Power Association of the United States, the electrical performance of the test line with a voltage level of 1000 kV – 1500 kV and a length of 1 km and related power equipment were tested and debugged. AEP and BPA in the United States had planned to build 1500 – 1600 kV UHV transmission lines and 1200 kV UHV transmission lines in the 1990s. In 1976, AEP company built a 1km 1500kV test line near Chicago to promote the development of UHV transmission insulation, environmental protection and other related technologies [2]. Although the U. S. started ahead of the world average, the U. S. has not been in the first echelon in the field of UHV transmission technology.

The former Soviet Union began building 1150 kV UHV AC transmission lines in 1981 and put into operation in 1985. In the 1980s, the Soviet Union built a total of 1500 km UHV AC transmission lines, but all lines have reduced the voltage to 500 kV for operation. At present, UHV transmission lines in Russia are about 2500km long.

In 1988, Japan began to build UHV AC transmission lines with a voltage of 1000 kV, and in 1992 and 1993, respectively, built 138 km long Xiqun Madongshanli UHV transmission lines and 49 km long Baiqi transmission lines. At present, due to the actual situation of the two lines, both lines are reduced to 500 kV. Due to its small territory, Japan adopts the same-pole double-circuit erection method during construction, but these lines have been operated with reduced voltage.

From the end of the 20th century to the beginning of the 21st century, investment of UHV transmission technology decreased due to the economic crisis in developed countries. At the same time, due to the national economic downturn, power consumption continued to slump, resulting in UHV transmission technology research and development gradually stagnant.

ISSN: 2664-9640

3. Development of UHV transmission in China

China ' s research on UHV transmission technology began after 1986, China ' s first million volts high voltage transmission line segment was established in Wuhan. After that, the first million volt high voltage transmission line in China was established in Wuhan. Subsequently, a series of UHV technical achievements began to emerge, which laid a solid foundation for the subsequent development of UHV transmission in China. At present, China has been at the forefront of the world in the research on UHV transmission.

By the end of 2021, the State Grid Corporation had built the world ' s advanced UHV transmission project of ' 15 AC 13 DC ', with trans-provincial and trans-regional transmission capacity exceeding 230 million kW.

(1) UHV AC Transmission Project :

1000 kV Southeast Shanxi - Nanyang - Jingmen UHV AC Transmission Project
1000 kV Huainan-North Zhejiang-Shanghai UHV AC Transmission Project
1000 kV North Zhejiang - Fuzhou UHV AC Transmission Project
1000 kV Ximeng - Shandong UHV AC Transmission Project
1000 kV Mengxi-Tianjin South UHV AC Transmission Project
1000 kV Huainan - Nanjing - Shanghai UHV AC Transmission Project
1000 kV Shengli - Ximeng UHV AC Transmission Project
1000 kV Yuheng-Weifang UHV AC Transmission Project
1000 kV Xiongan - Shijiazhuang UHV AC Transmission Project
UHV AC Transmission Project of 1000 kV Sutong GIL Integrated Pipe Gallery
1000 kV Weifang - Linyi - Zaozhuang - Heze - Shijiazhuang UHV AC Transmission Project
1000 kV Zhangbei - Xiongan UHV AC Transmission Project
1000 kV Mengxi-Jinzhong UHV AC Transmission Project
1000 kV Zhumadian-Nanyang UHV AC Transmission Project
1000 kV Nanchang - Changsha UHV AC Transmission Project
UHVDC Transmission Project :
± 800 kV Xiangjiaba-Shanghai UHVDC Transmission Project
± 800 kV Jinping-Sunan UHVDC Transmission Project
± 800 kV Hami South-Zhengzhou UHVDC Transmission Project
± 800 kV Xiluodu-Zhexi UHVDC Transmission Project
± 800 kV Ningdong-Zhejiang UHVDC Transmission Project
± 800 kV Jiuquan - Hunan UHVDC Transmission Project
± 800 kV Jinbei-Jiangsu UHVDC Transmission Project
± 800 kV Ximeng-Taizhou UHVDC Transmission Project
± 800 kV Shanghaimiao-Shandong UHVDC Transmission Project
± 800 kV Zalut-Qingzhou UHVDC Transmission Project
±1100 kV Zhundong-South Anhui UHVDC transmission project
± 800 kV Qinghai-Henan UHVDC Transmission Project
±800 kV Yazhong-Jiangxi UHVDC project

In addition, in 2021, the State Grid realized : Shanbei-Hubei UHVDC project starts power transmission ; the Fujian-Guangdong interconnection project, the Baihetan-Jiangsu and Baihetan-Zhejiang UHVDC projects, and the Nanyang-Jingmen-Changsha, Jingmen-Wuhan and Changtan UHVDC power plants are under construction .

ISSN: 2664-9640

4. Characteristics of UHVDC transmission

In the initial stage of UHV technology development in China, AC transmission is mainly studied, because the voltage of AC power can easily rise to KV through the transformer to achieve high voltage transmission. With the development of the times, especially the maturity of power electronics technology, the rectifier and inverter technology is becoming more and more perfect, so that AC and DC can be switched at will with people's wishes. In this way, DC transmission can be realized by first increasing the AC voltage and then converting it to DC. The technology was born in Sweden, researchers began to study ± 750KV wire transmission technology in the1960s. China ' s research on UHVDC transmission technology is marked by the formulation of the main circuit of voltage average distribution and the series transmission scheme of 12-pulse converter per pole. This scheme comprehensively analyzes various factors, selects the best components, and comprehensively compares each stage of converter, thereby improving the stability of transmission voltage.

4.1. Advantages of UHVDC transmission

(1) Economy. Compared with AC transmission, the biggest advantage of DC transmission is good economic benefits. Duo to AC transmission requires three-phase transmission, DC transmission only has positive and negative electrodes. This makes AC transmission more one-phase conductors than DC transmission. If the earth is used as a loop, a wire can be used to save a lot of wire metal. In UHV transmission projects, the conductor cost accounts for the vast majority of the project cost. At the same time, AC transmission has skin effect, that is, AC transmission only on the surface of the wire, and there is no current in the middle of the wire, which will cause the utilization rate of AC wire is low. Moreover, since DC transmission has no reactive power loss of inductance and capacitance, the loss of DC transmission is smaller than that of AC transmission.

(2) Safety. In terms of security, under the same voltage with effective value, the maximum value of AC is 2 times that of effective value, while DC is still the value of effective value, so the insulation is relatively easy. In addition, the HVDC system is more stable than the AC system, because there is no reactance in the DC transmission, and the transmission capacity and distance of the DC transmission can be synchronized.

(3) There is no capacitive current generated during the steady-state operation of DC transmission lines, and reactive power compensation equipment is not required in the line part. Moreover, flexible DC transmission does not need commutation power supply, which can be used for the access of various loads and power sources.

4.2. The shortage of UHVDC transmission technology

UHVDC transmission technology has the following shortcomings : First, the security risks of the technology to human body remain to be studied ; second, UHVDC transmission technology involves many technologies. In the case of continuous development of international electrical technology, UHVDC transmission technology also needs to follow the pace of the times in technical upgrading ; third, most of the equipment and technology used in UHV DC transmission technology in China are introduced from abroad, and the technical backwardness needs to be improved [5].

5. Development prospect of UHV AC transmission

China has a large land area, and the energy and economic development regions are unbalanced. Primary energy is abundant in the central, western and southwestern regions, but the electricity consumption in East China is larger. China has built two long-distance power transmission projects, namely "West-East Power Transmission" and "North-South Power

Transmission". At this stage, the problem of line corridors is becoming more and more important, corridor resources are becoming more and more limited, and the required costs are also increasing. The corridor width of the 1000kV UHV line is only 1/3 of that of the 500kV line with the same transmission capacity. The UHV AC transmission improves the utilization rate of the corridor, which not only improves economic benefits, but also saves land resources. Compared with the existing voltage level, UHV transmission technology can greatly save the floor space of line corridors and substations.

1000 kV AC UHV is much better than 500 kV AC grid economically. The transmission power of AC UHV is 4 – 5 times that of 500 kV, and the investment of 1000 kV unit transmission power is only 3 % of that of 500 kV. Taking Jinsha River hydropower transmission to East China as an example, the UHV ratio of 500 kV can save 13 billion yuan in investment costs. In addition, the loss and line area are saved by 70% and 60% respectively compared with 500kv AC.

6. Conclusion

UHV power transmission has increasingly become an international business card for China. UHV power transmission is a great cause that conforms to the specific national conditions of China's contemporary development and benefits the country and the people. The development of UHV power transmission is an important factor for China's economic take-off, which is in line with the environmental protection concept of "lucid waters and lush mountains are invaluable assets". UHVDC transmission is also an inevitable trend of long-distance transmission in the future.

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