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Fault Simulation Analysis of HVDC Transmission

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Abstract: High voltage direct current transmission (HVDC) has the advantages of large transmission capacity, low cost, low losses, and strong asynchronous networking ability between power systems. Moreover, its high stability in transmitting electricity is conducive to long-distance and high-capacity power transmission. Moreover, high-voltage direct current transmission has advantages such as good economic efficiency, high-power long-distance transmission, and interconnection with different frequencies. In this context, the structure and control methods of high-voltage direct current transmission were studied. Finally, the HVDC was modeled using Simulink in Matlab, and based on this model, the system DC line fault simulation was conducted, resulting in corresponding simulation waveforms, which verified the effectiveness and correctness of the HVDC model.

1. Introduction

After more than a hundred years of development, high-voltage direct current transmission played a crucial role in the early stages of transmission technology. Due to the complexity of its commutation technology, it could not be compared with AC transmission technology in terms of transmission technology and economy in the early 20th century, resulting in slow development [1].

Since the 1950s, with the continuous expansion of power networks, there have been more and more large capacity long-distance Electric power transmission, and the requirements for grid connected synchronous operation in AC transmission technology have become increasingly high [2] Therefore, in certain technical and economic aspects, DC transmission technology is superior. Thus, High-voltage direct current transmission has been widely valued by the power sector of various countries, and it has also been developed rapidly [3].

In the past 20 years, with the development of power electronics technology, HVDC transmission has developed rapidly. Since the world's first thyristor converter station was built in Canada in 1972, thyristor technology has continued to progress, the capacity has increased, the reliability has improved, the price has gradually decreased, and the DC transmission has become more mature, which has become an important way of power transmission [4]. In particular, the development of new technologies such as optical fiber and computer makes the control, regulation and protection of HVDC system more perfect, and further improves the reliability of HVDC system execution [5].

2. Advantages and Disadvantages of HVDC Transmission Technology

2.1. Advantages of HVDC Technology

Compared with AC power transmission, DC transmission has the following advantages:

1) DC transmission can be transported on a large scale and over long distances, and its transmission capacity is large, and its power and direction can be quickly and effectively controlled during the transmission process [6].

2) Adding a DC transmission system to the power system will not increase the short-circuit current capacity of the original system, and its operational stability will not be affected [7].

3) DC transmission generally adopts a bipolar neutral grounding method, with only two conductors required for DC lines and three conductors required for three-phase AC lines. However, the power transmitted by the two is almost equal, resulting in low transmission cost and small footprint [8]. In addition, when the same cable insulation is used for DC, its allowable working voltage is twice higher than when used for AC, so when the voltage level is the same, the cost of DC transmission lines is lower than that of AC transmission lines [9].

4) DC cable lines do not have the problem of capacitive current in AC cable lines, nor do they have magnetic induction losses and dielectric losses. Basically, they only have core resistance losses, and the insulation voltage is relatively low;

5) During the DC transmission process, the failure of one pole does not affect the operation of the other pole, so the transmission power loss during the transmission process is small [10].

6) DC itself has modulation function, which can automatically adjust according to system requirements to achieve the required stability level.

7) The large power grids are interconnected through DC transmission (such as back-to-back mode), so that there is no mutual interference or impact between the two grids, and power support can be quickly carried out [11].

2.2. Disadvantages of HVDC Technology

Disadvantages of DC and AC power transmission technology:

1) The converter valve needs to consume more reactive power during operation, and the overload energy of the thyristor component is relatively low

2) When a DC transmission circuit is laid underground, its metal facilities will be corroded and it will also cause interference to communication.

3) It is difficult to extinguish the arc in direct current transmission.

4) The structure of the converter station in the DC transmission system is complex, and its cost is higher than that of the AC substation system with the same voltage and capacity.

3. Basic Structure and Working Principle of HVDC Power Transmission

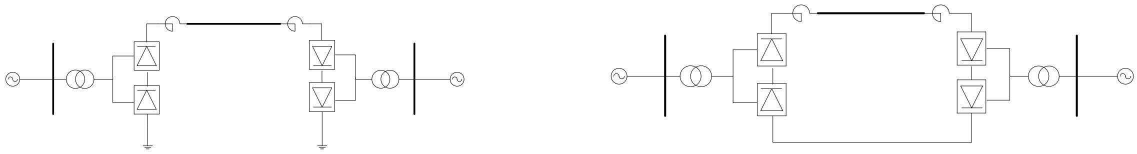
The High-voltage direct current transmission system mainly consists of two parts: the electrical system and the control system. The electrical system mainly consists of transformers, AC/DC filters, reactive compensation equipment, converters, reactors, AC/DC transmission lines and other components. The main function of the control system is to control the operation of the converter, the start and stop of DC transmission, the power flow, the recovery of transmission line faults, transmission capacity, and the normal operation of DC transmission.

3.1. Composition of DC Transmission System

The structure of DC Electric power transmission is mainly divided into two categories: two terminal and multi terminal. This paper mainly studies the two terminal DC system of unipolar system.

3.2. Unipolar System

Unipolar DC Electric power transmission can adopt positive or negative operation mode. Single pole DC overhead lines usually use negative polarity because the corona and electromagnetic interference of the positive electrode wire are greater than that of the negative electrode wire, and most lightning is negative polarity. Therefore, the probability of lightning flashover of the negative electrode wire is much lower than that of the positive electrode wire. The wiring methods for unipolar systems include unipolar earth loop (Figure 1 (a)) and unipolar metal loop (Figure 1 (b)).



(a) Unipolar earth loop mode (b) unipolar metal loop mode

Figure 1: Schematic diagram of unipolar system wiring.

(1) Unipolar earth loop mode

The unipolar earth loop method utilizes a single wire and the earth (or seawater) to form a DC side unipolar circuit. In this method, the operating current is the medium direct current transmission current through the earth or seawater. Due to the underground nature of DC transmission lines, excessive current can cause severe electrochemical corrosion of metal devices. Its advantages are simple structure and low cost; but there are drawbacks such as low reliability and inflexibility in operation.

(2) Unipolar metal loop mode

The single pole metal loop method utilizes two wires to form a single pole circuit on the DC side. In this method, there is no current flowing underground, so there is no electrochemical corrosion problem. The grounding of one end of the metal return line is to improve the safety and reliability of operation. This method is usually used in DC transmission projects that do not allow the use of land or seawater as the return line, or where it is difficult to choose a grounding electrode and the transmission distance is short.

3.3. The Structure and Working Principle of HVDC Transmission System

HVDC power transmission includes rectifier side, DC transmission line and inverter side three parts, the main equipment are: converter transformer, converter, filter, reactive power compensation, flat wave reactor. The basic structure is shown in Figure 2.

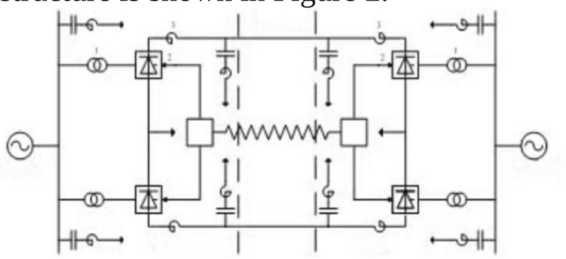


Figure 2: Basic structure of HVDC transmission system.

The AC output of AC system I is converted into direct current by the rectifier on the rectifier side, and the DC transmission line transmits the direct current to the inverter side. The inverter side converts the direct current into alternating current again through the inverter and sends it to the AC system II to complete AC. Direct current. Ac conversion. Rectifier and inverter are collectively referred to as converter, converter by adjusting the trigger Angle to change the on or off state of the thyristor in the converter to achieve AC-DC conversion, when the trigger Angle is less than the converter operates in the rectified state, the alternating current into direct current, when the trigger Angle is greater than the inverter state, the direct current into alternating current.

The rectifier side and inverter side in Figure 2 include converter transformer l, converter 2, flat wave reactor 3 and control system 4 respectively. Converter transformer 1 provides converter 2 with the required commutation voltage to realize the pulsating current, and plays the role of mutual insulation between AC and DC systems, limiting fault current and buffering and suppressing lightning impulse overvoltage waves. Converter transformer is an important equipment for AC-DC network interconnection and DC transmission, and its operation performance plays a vital role in the stability of AC/DC Electric power transmission.

The control system at the rectifier side and inverter side is the core part of the High-voltage direct current system. The control system mainly controls the converter and transformer to achieve the required voltage and power, which also directly affects the safety and stability of the High-voltage direct current system. The control system can also timely adjust the trigger angle of the converter and the output voltage of the transformer when the High-voltage direct current transmission process fails, so as to ensure the safe and stable operation of the system and fault recovery. Therefore, in the simulation modeling process, its research is an essential part.

3.4. Thyristor-Based 12-Pulse Converter Unit

Converter station is the core part of HVDC transmission system, mainly including the following parts:

(1) Converter transformer: It is divided into rectifier side transformer and inverter side transformer, where the rectifier side transformer converts the AC voltage emitted by the power station into the voltage required by the rectifier, and the inverter side transformer converts the output voltage of the inverter into a system specific voltage.

(2) Converter: composed of thyristors, used for rectification or inverter. Converters generally use three-phase bridge (there are two types of single and double Bridges) circuit, each bridge has 6 bridge arms (that is, 6 pulse converters), such as Tianshan Bridge a ±500 kV HVDC system thyristor block rated voltage of 8 kV, with 78 blocks in series to form the valve body.

(3) Flat wave reactor: Stabilize the DC current and voltage, and slow down the current rise speed when disturbed.

(4) Filter: It is divided into AC filters and DC filters. AC filters mainly suppress AC harmonics generated by converters, while DC filters mainly suppress harmonics injected into DC lines during rectifier operation.

4. Establishment of HVDC Transmission Simulation Model

In Matlab/Simulink environment, the simulation module of power system block (PSB) is used to establish the simulation model of HVDC system and controller. Here, 12-pulse thyristor converter is used to realize the modeling of HVDC system, and the model is shown in Figure 3.

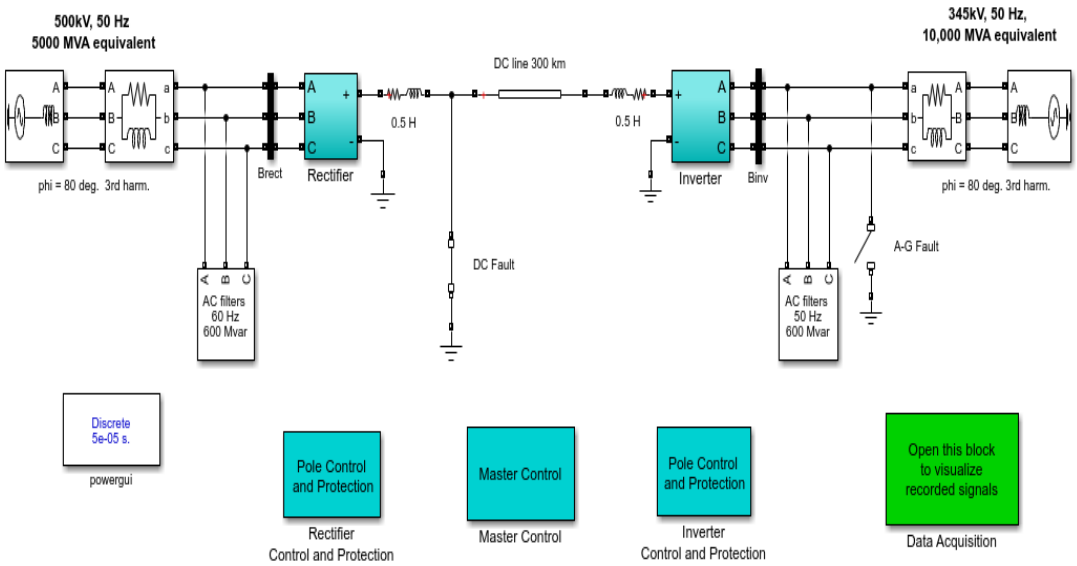


Figure 3: System simulation model diagram.

Its simulation waveform is shown in Figure 4 and Figure 5.

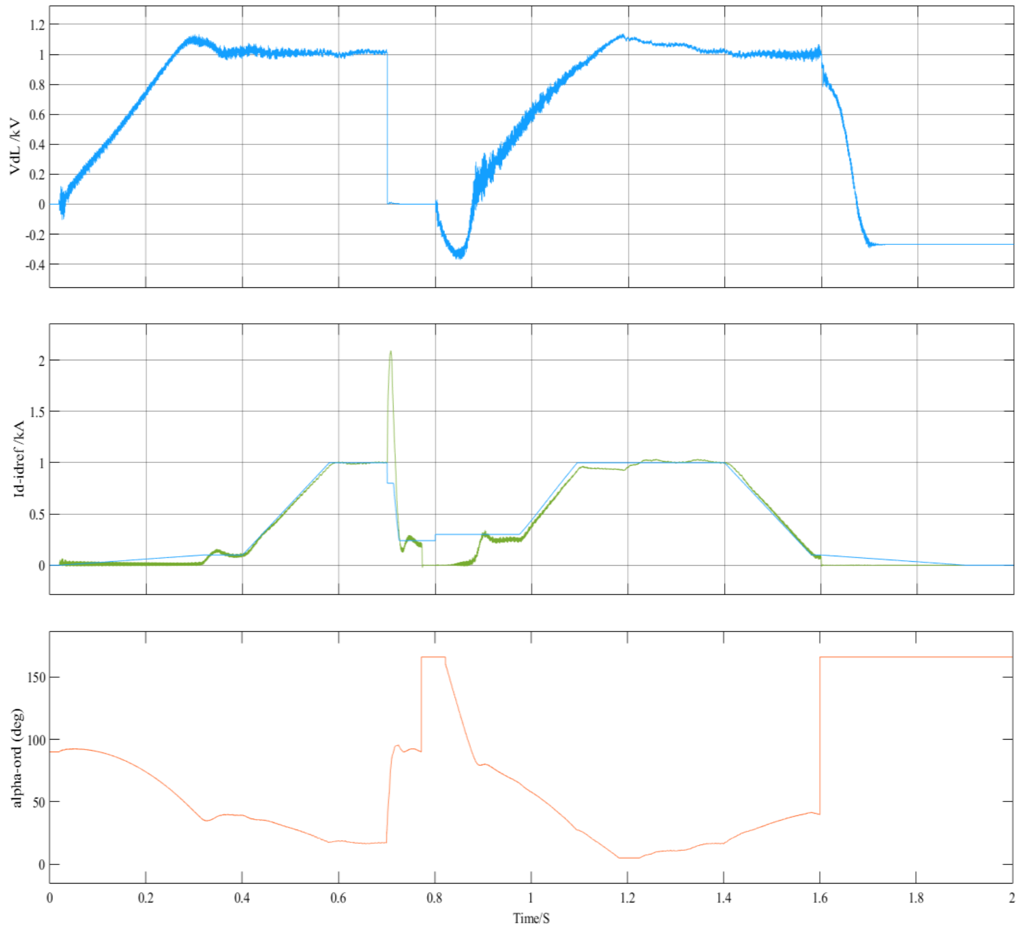


Figure 4: Rectifier side fault voltage, current and trigger delay Angle waveform on the rectifier side.

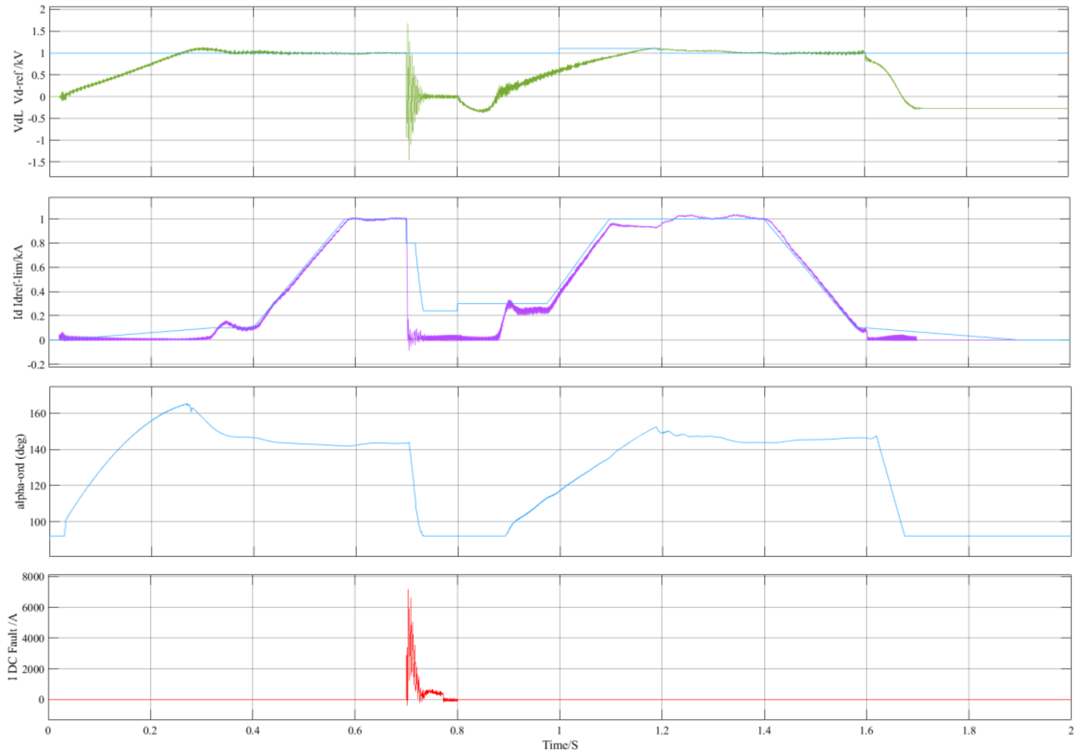


Figure 5: Waveform of voltage, current and trigger delay Angle on the inverter side.

When a DC line malfunctions, the current on the rectifier side instantly increases to 2.1kA at 0.7s, and the voltage drops to -0.4kV. The current of the inverter side circuit increases to 7.5kA, and the voltage drops to 0V. From Figures 5 and 6, it can be seen that the output voltage and current in the circuit contain a large amount of harmonics. When the DC voltage is 0.73s, VDCOL acts, reducing the reference current to 0.3kA. At this point, the delay trigger pulse angle on the rectifier side increases to 162 °, and the delay trigger pulse angle of the inverter decreases to 95 °. The voltage gradually recovers after 0.85s, and the fault is cleared when it reaches 1.1s, and the DC Electric power transmission returns to normal.

5. Summary

Through in-depth study of HVDC, this paper analyzes the advantages and disadvantages of HVDC and the changes of voltage and current of rectifier output and inverter input when HVDC line short-circuit fault occurs in the transmission process. By using matlab software to build HVDC transmission simulation model, the simulation results show that when HVDC line fault occurs, the voltage decreases. If the current increases, the rectifier and inverter will be damaged if not treated in time.

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