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High-voltage DC Transmission System Model Research Based on SIMULINK Software

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Abstract

In recent years China presents to send power from west to east, and positively develop ultra high voltage and DC transmissions. This paper introduces the DC modeling in high-voltage direct current transmission the general method; respectively analyzed the characteristics of three kinds of simulation model and scope of application. Deduce the mathematical model formula of the main part of DC system, describe the basic control principle. By SIMULINK software to use the detailed model of HVDC system simulation model is established. And in view of the common faults under transient conditions are simulated. Through the simulation results show that in the transient analysis to choose the model is suitable and reliable.

Keywords: *HVDC; Simulation; model; Transient*

1. Introduction

As China advance big strategic development of the power transportation from west to east, high-voltage direct current transmission is booming, such as HVDC, multi-terminal DC system and so on. [1] The computer simulation is an important means to study the dynamic characteristics of inter power grid and to verify the theoretical results. In the AC/DC hybrid transmission system, with DC power transmission capacity accounts for increasing of the proportion of the total transmission capacity, high voltage direct current transmission control system is more and more important. At the early stage of the study generally in the form of simulation, then the model is very important in the simulation. If model can more accurately reflect the characteristics of the system, so the results of simulation analysis are more reliable, and the control strategy is more correct. The Scale of power system and computing time are constrained, can't use transient simulation model in detail for all the devices in the DC transmission system. Especially the power grid contains several DC lines, the problem is particularly prominent. But if use the simplified system model of ignore the dynamic behavior and it will makes the reliability of analysis results lose guarantee. So the research how to choose the model has important practical significance.

Now which the simulation hybrid grid model of DC system is a bit too simple, although speed up the computation speed, but the influenced the credibility of results. Some model is relatively one-sided, not conducive to a wide range of applications. And are directly using a model, did not compare model targeted. The article [2] by using BPA power flow calculation software, adopt double side quasi steady state model of high-voltage direct current transmission, analyzing the

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interaction characteristics of AC/DC hybrid system. The article [3] is directly using PSCAD software studying high-voltage direct current transmission system by a detailed modeling of each component. And establish a system for the simulation different operation of DC system. Dynamic phasor model [4] is a common dc modeling method, it mainly by retaining system state variables corresponding to the time-varying Fourier series of important items and the simplification of the original system.

2. High-voltage DC Transmission Modeling Method and Model

2.1. Classification Model

In the stability calculation of system communication system network equations are generally represented with the positive sequence component, thus to dc system modeling with a basic restrictions. If the three phase fault occurring near the inverter, Inverter commutation failure problem may won't get the accurate simulation. So in all of the HVDC simulation are generally based on the following several assumptions: [5]

1) Converter bus voltage of the three-phase ac is symmetrical standard sine wave curve.

2) The operation of the inverter itself is completely symmetrical balance.

3) Dc current and dc voltage is stable and smooth lines.

4) Converter transformer is an ideal lossless, and excitation current is negligible.

To assumptions and conditions to build the model is the quasi steady state model based on the average. In electromechanical transient simulation, usually assume that after the above three basic hypotheses, but the first basic assumptions can't assume that it established forever. Because during the asymmetric fault occurs in ac system, on the ac bus voltage is not symmetrical. So the quasi steady state model is not applicable during asymmetric AC system fault.

In the power system stability simulation, are generally separate AC system and DC system solving independently. The role of DC system on the AC system was equivalent to a changing load or power supply. AC system is equivalent to an equivalent voltage source of DC system. DC system's influence on the AC system on dc control system model to describe. Through the DC system parameter changes reflect the impact on the AC system. DC model according to the detailed degree of the main part of the model can be divided into detailed model and response model and a simple model. Its main parts generally contain DC converter, DC circuit and DC control system.

Simple model fully represented by an algebraic equation. Response model only considers the results of the control, without considering the control of the process. Detailed model system is expressed by the quasi steady state equation of dynamic characteristics. But detailed model needs to simplify the complex control loop to the DC system, decomposition and restructuring, and control parameter setting is quite complicated, so the difficulty of modeling is much more.

In the study of stability generally want to use the detail system model, because the detailed model is more close to actual. But because of the complexity and precision requirement is not necessarily very high, and so often use a simple model is enough. So in the AC/DC stability study, different situations and different problems use different model. Of course different model also has a bigger influence on the results. There will be a detailed model analysis under the common fault of DC system transient problems.

2.2. The Mathematical Model of Main Components

In the high-voltage direct current transmission system, to the realization of inverter AC/DC transformation and provides the control means of HVDC transmission power. A major part of the inverter is the valve bridge and converter transformer. Valve Bridge is composed of a set of high voltage switch array, and they will take three-phase ac voltage connected to the dc side, for obtaining the required power transformation. Converter transformer provides an interface between the ac system and dc system. The operation of the DC system can be deduced DC voltage equation of the rectifier:

$$U_{d0} = \frac{3\sqrt{2}}{\pi} BTE_{ac} \tag{1}$$

$$U_{dr} = U_{d0} \cos\alpha - \frac{3}{\pi} X_c I_d B \tag{2}$$

B is the number of bridge in series, T is Transformer turn ratio, E_{LL} is Converter transformer AC side voltage RMS, E_{ac} is line voltage RMS of converter transformer valve, $X_c = \omega L_c$ is each bridge commutation reactance.

Inverter DC voltage equation:

$$U_{di} = U_{d0} \cos\gamma - \frac{3}{\pi} X_c I_d B \tag{3}$$

$$U_{di} = U_{d0} \cos\beta + \frac{3}{\pi} X_c I_d B \tag{4}$$

In the column to write equations of dc transmission system, generally a pair of rectifier and inverter equation columns together, because rectifier and inverter control way is to cooperate with each other to determine the operation of the HVDC system.

2.3. The Control Principle of the DC System

Figure 1 (a), (b) represents a single link or bipolar link of a corresponding equivalent circuit and voltage distribution

The DC current from the rectifier flow to the inverter side:

$$I_d = \frac{U_{dor} \cos\alpha - U_{doi} \cos\gamma}{R_{cr} + R_L - R_{ci}} \tag{5}$$

Rectifier power terminal:

$$P_{dr} = U_{dr} I_d \tag{6}$$

The power of inverter terminal:

$$P_{di} = U_{di} I_d = P_{dr} - R_L I_d^2 \tag{7}$$

Lines in office a little of the dc voltage and current are available through the trigger Angle of gate/gate control or change of converter transformer tap to control the AC voltage.

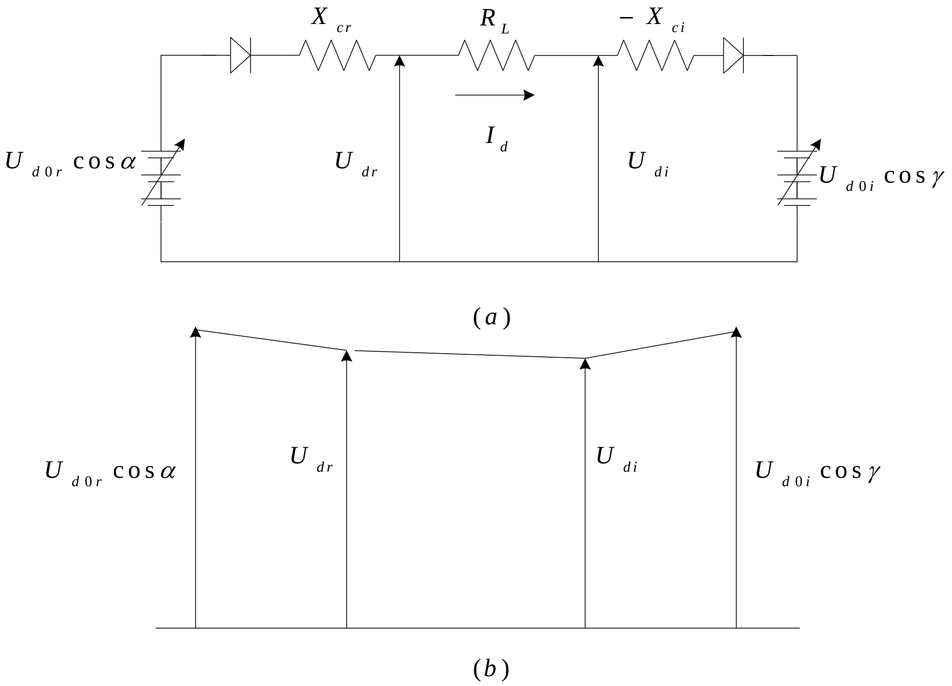

Figure 1. High Voltage Dc System Transmission Link (A) the Equivalent Circuit; (B) the Voltage Distribution

3. Detailed Model of the HVDC Transient Simulation

The typical build twelve pulse HVDC power transmission systems, DC line connect two different voltage levels of power grid. Converter stations are installed reactive power compensation and the AC filter device. The whole simulation system is shown in Figure 2.

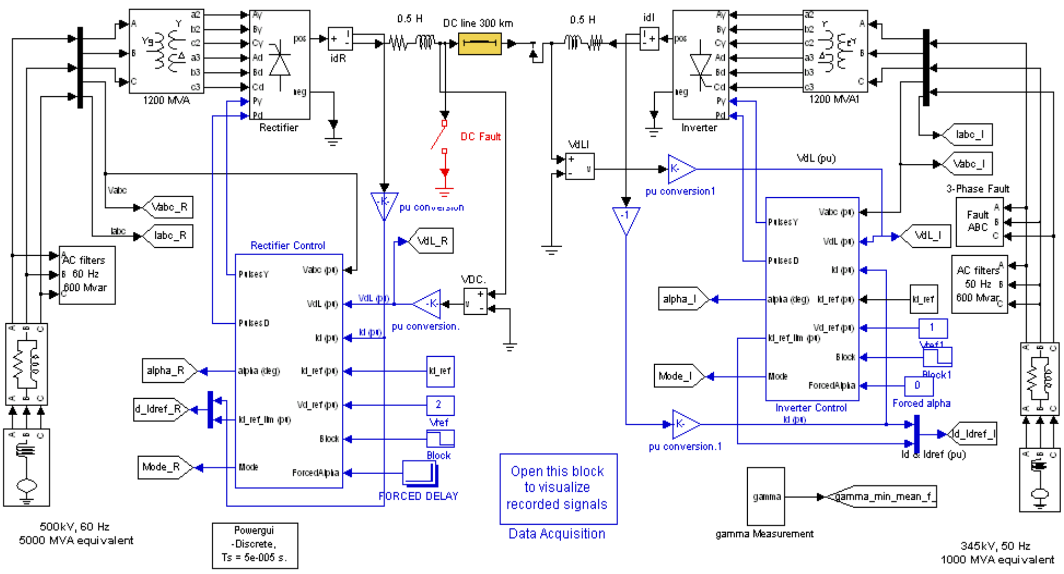

Figure 2. Twelve Pulse HVDC Power Transmission System

Control system is for constant current and constant voltage control of the rectifier side. Consider the triggering Angle of maximum and minimum limits. Inverter side and rectifier side is the same, considering the inverter control characteristics of the dynamic behavior of the low voltage current limiting. Used in the simulation model of six pulses Converter Bridge is with two diodes in general bridge. So can observe the on and off each bridge arm and even each diode opened and shut off. Rectifier and inverter control system is the same.

Figure 3 is the simulation results for the rectifier side of HVDC line fault and recovery. System is set in 0.5 seconds to ground fault occurs, the current of DC circuit increase rapidly to 2.3 pu; DC voltage corresponding to zero rapidly. There are DC lines and current flows through the failure cases. At 0.55 seconds, DC system protection device action, forced triggering Angle of 165 degrees. The rectifier in the inverter state, the energy stored in the DC system added to the communication network. In the next a zero, current shut off. Protection device begins to release Angle in 0.6 s, system fault basic for 0.3 s back to normal.

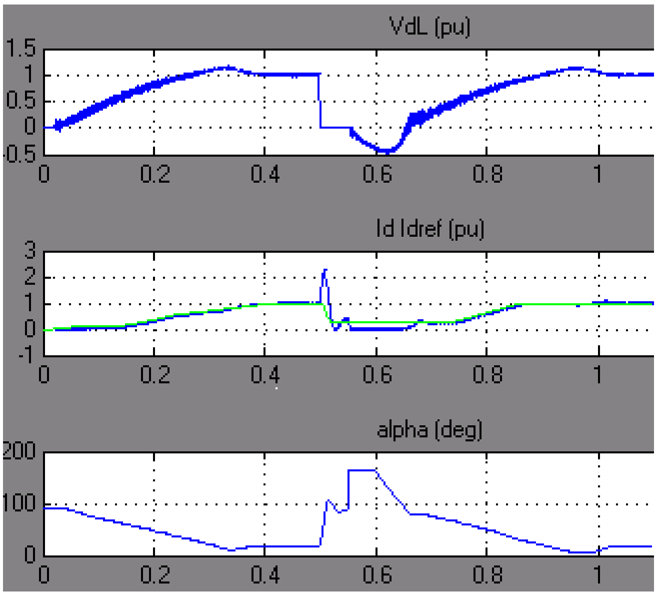

Figure 3. Side of Rectifier Dc Line to Ground Fault Simulation Results

Because the transient process has on the time response and the dynamic characteristic parameters, so it has a detailed model to simulate the dynamic behavior of the dc system control system, and reasonable simulation results are obtained. In each simulation, should according to the research purpose, in an acceptable error range, choose the right model. It can integrated time, accuracy and equivalence.

4. Conclusion

The simulation model for the high-voltage direct current transmission system in this paper analyzed and studied, as summarized below:

(1) This paper discusses the significance of high-voltage direct current transmission model research, the present condition of the mathematical model for the study. The classification of the high-voltage direct current transmission simulation model are analyzed, illustrates the characteristics and applicable conditions of all kinds of models.

(2) The main part of DC system is derived mathematical model equation, such as voltage and current of rectifier and inverter equation, and analyses the basic control principle.

(3) Through the SIMULINK software simulation for high-voltage direct current transmission system by using the detailed model, get the simulation results of Common faults, such as rectifier DC line to ground fault occurred and recovery voltage current situation.

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References

[1] X. Liang, P. Zhang and Y. Chang, "Recent Advances in High-Voltage Direct-Current Power Transmission and Its Developing Potential", Power System Technology, vol.36,no. 4, **(2012)**, pp.1-9.

[2] C. Zheng, C. Sheng, X. Guo and S. Ma, "Analysis on Practicable Steady State Model of HVDC Power Transmission and Corresponding Power Flow Algorithm", Power System Technology,vol.35,no.3, **(2011)**, pp.57-62.

[3] X. Zheng, N. Tai, G. Yang and Q. Tu, "Modeling and Simulation of UHVDC System", Electric Power Automation Equipment, vol.32, no.7, **(2012)**, pp.10-14.

[4] Q. Qi, L. Jiao and Z. Yan, "Modeling And Simulation of HVDC With Dynamic Phasors", Proeeedings of the CSEE,vol. 23, no.12, **(2003)**, pp.28-32.

[5] Z. Xu, "AC/DC Power System Dynamic Behavior Analysis", Mechanical Industry Press, Beijing, **(2005)**.

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