Electromagnetic Transient Simulation Model of UHVDC Transmission Based on PSASP Parameters

Feng Zhao¹, Jiali Lu²*, Tao Wu¹, Hanzhi Zhang¹, Jing Hao¹, Ran Li², Lili Hao³, Ziqiang Ran², Xinhao Wang², Huan Xie¹

¹Electric Power Research Institute, State Grid JIBEI Electric Power Company Limited. (North China Electric Power Research Institute Co., Ltd.), Xicheng District, Beijing 100045, China
²North China Electric Power University, Baoding, Hebei Province, 071003, China
³ Corresponding author: 9464678884@qq.com

Abstract. With the development of power system, the safe and reliable operation of power grid is the most important. It is impossible for the actual system to conduct experiments on every operation condition of the power grid, simulation software is used to simulate possible faults in the system and to build components or control systems to avoid serious faults. Compared with electromechanical transient, electromagnetic transient simulation software can simulate the actual working conditions more accurately. Based on the electro-mechanical transient PSASP simulation model and component parameters of an actual UHVDC transmission system, the electrical parameters are converted to RTDS, and the electromagnetic transient simulation model is built in this article. In order to keep the steady state of the two stable operating conditions, the power flow of each branch is calculated through the PSASP power flow calculation function module, and the output of the generator in RTDS is adjusted, so that the power flow on the line is basically the same as that of the generator. The short-circuit current of the outlet bus of the equivalent machine is calculated by the PSASP transient calculation, and the reactance of the generator in the RTDS is adjusted to allow the short-circuit current to be within the allowable range of the engineering error.

1. Introduction

The electromechanical transient simulation software is more suitable for the stability of the power system. The simulation step is generally ms level, and the electromagnetic transient simulation software is mainly used to study the change process of the instantaneous value of voltage and current in a very short time, and the simulation step is usually μs level[1]. With the construction of HVDC transmission lines, the grid gradually formed a system of "stiff and weak intersection". The DC transmission system contains a large number of power and electronic components, the electromechanical transient simulation software can not simulate its dynamic process, and the electromagnetic transient simulation and the similarities and differences of the model electrical parameters and the conversion process are analyzed in detail under the two simulation software, and the electromagnetic transient simulation software can accurately simulate the dynamic characteristics of AC / DC system [2,3].

In practice, the use of electromagnetic simulation software to build a model requires a lot of memory, and it is impossible to build a simulation model of the whole power grid. Generally, electromechanical transient simulation software such as BPA and PSASP are used to establish the whole system model. Therefore, the electrical parameters of electromechanical transient simulation
mod-els are usually converted to electromagnetic transi-ent si-mulation software. According to the relevant data in the PSASP integrated steady state program, the electromagnetic transient simulation model of Shandong power grid with dc feed is built under PSCAD/EMTDC environment in document [2]. Document [4] built electromagn-etic transient simulation software based on electromech-anical transient PSASP data, and analyzed the construct-ion process of DC system in detail. Document [5] used the electromechanical transient doubly fed wind turbine model to build an electromagnetic transient PSCAD si-mulation model. The steady-state performance of the two models is highly consistent. Document [6] detailed anal-ysis and construction of electromagnetic transient simul-ation model of multi DC transmission grid containing wind electric field, and compared with electromechanical transient PSASP to verify the validity of the model. Doc-ument [7] built the RTDS model of Guizhou power grid, compared the transient steady-state simulation structure with BPA, which proves the validity of the model, and further tests can be done. However, the electrical param-eters of the simulation model under electromechanical t-ransient are not analyzed in detail to the electromagnetic transient model. Document [8] based on the equivalent system model of BPA equivalent data and the southern power grid containing 800 kV UHVDC, the correspond-ing electromagnetic transient simulation model is built, the steps of RTDS construction and the principle of ele-ment selection are analyzed in detail, but it is simply analyzed from the DC system, and the difference of the parameters of other components is little involved.

The main contents of this paper are as follows: the elect-rical parameters of the electromechanical transient simu-lation model of a UHVDC transmission system are conv-erted to the electromagnetic transient simulation softwa-re RTDS, and the similarities and differences of the mo-del electrical parameters and the conversion process are analyzed in detail under the two simulation softwares, and the electromagnetic transient model is built. In order to simulate the dynamic characteristics of AC and DC transmis-sion system accurately, and the applicability of t-he electromechanical transient simulation and the short-circuit current is calculated by the transient stability fun-ction of PSASP, and adjust the reactance parameter of the equivalent generator in the RTDS, and so on, so the short circuit current can be calculated within the allowa-ble range of the engineering error electromagnetic transient simulation software under different working condit-ions, the short circuit current of the line power flow and the equivalent generator outlet bus must be adjusted to the allowable range of the error in the two simulation software.

2. Construction of UHVDC transmission systems

2.1. Electrical data conversion
The electrical parameters of the simulation model of the power system integrated program PSASP and the real time digital simulation platform RTDS are not the same values of the reference value or the equivalent element. Therefore, it is necessary to transform the electrical para-meters of the two environments. The following is a detail-ed analysis of the electrical parameter conversion proce-ss:

2.1.1. Transmission line
The circuit parameters calculated in RTDS environment are basically consistent with the electromechanical trans-ient PSASP, only different from the ground admittance parameter. The parameters of transmission lines in RT-DS are shown in Fig.1, the capacitance is in the form of PI-type equivalent circuit in PSAP, while the reactance of the whole AC line is in the form of RTDS. The PSA-SP simulation software can not take into account the electromagnetic transient process of the transmission line, and the electromagnetic transient simulation software can simulate the dynamic process of the transmission line. As shown in Fig.2, the transmission line and its calc-ulation module are built on the dft interface. Note that t-he transmission line elements are consistent with the n-aming and root directory of the calculation module.
2.1.2. Transformer

In PSASP and RTDS, the electrical parameters related to transformer elements, such as winding group, variable r-ation, frequency and other electrical parameters are basi-cally the same. The transformer leakage reactance and l-ow capacitance and low resistance are different in form.

a. The difference of the leakage reactance representation of the electromechanical transient PSAPS and the electromag-netic transient RTDS is that the former is the leaka-ge reactance $x_1$, the $X_2$, the $X_3$, and the later leakage re-actance $X_{12}$, $x_{13}$ and $x_{23}$ between the three windings, and the mutual conversion relation is:

$$x_{12} = \frac{(x_1 + x_2 - x_3)}{2} \quad (1)$$
$$x_{13} = \frac{(x_1 + x_3 - x_2)}{2} \quad (2)$$
$$x_{23} = \frac{(x_2 + x_3 - x_1)}{2} \quad (3)$$

b. The low capacity resistance of the main transformer l-ow voltage side in PSASP and RTDS is expressed in the form of unitary values, the PSASP input capacity is the base value, and the RTDS takes the capacity of the transformers as the reference value, and the conversion relati-on between them is $X_{RTDS} = X_{psasp} \cdot S_{cap} / S_{capacity}$.

2.1.3. Reactive power compensator

The reactive power compensation device is installed on the commutating busbar. The type, group and capacity of the AC filter and shunt capacitor are shown in Table 1. In addition to the different models of the BP11/13 type reactive power compensation devices in PSASP and RT-DS, the rest of the reactive power compensation devices are basically the same.

| Rectifier station | Inverter station |
|-------------------|------------------|
| type | group | capacity | type | group | capacity |
| BP11/13 | 4 | 245*4 | HP12/24 | 8 | 245*8 |
2.2. Construction of electromagnetic transient model of transmission end AC system

In order to further analyze the coordination function of the transmission system to the DC system, 6 generators with corresponding parameters are built on the RTDS simulation software according to the generator parameters of the AC system of the actual UHVDC project. AC transmission lines, transformers, high resistance and so on are in accordance with the actual parameters, on the basis of the conversion process of part of the electrical parameters analyzed in section 2.1.1-2.1.3 above, a detailed transmission system is set up. As shown in Fig.3, the dashed lines in the figure are UHVDC transmission lines.

2.3. Construction of UHVDC transmission line

The parameters of UHVDC transmission system are as follows: the rated transmission power is 10000MW, the rated current is 6.25kA. The rated trigger angle is 15 degrees, the rated gamma angle is 17 degrees, and the total length is 1618km. The connection mode of bipolar double 12 pulsating converter is used and the neutral points of two poles are all grounded through a section of transmission line, and each side converter valve group is connected with two 12 pulsating commutation units per pole, such as the equivalent model of UHVDC transmission system in Fig.4. The UHVDC transmission line built in this section is the dashed line of the bus 7 to the bus 8. The receiving end is connected to a certain power grid and the equivalent machine is equivalent.

![Diagram of transmission system](image1)

![Diagram of equivalent model](image2)
voltage and current, respectively; $Q_{cj}$ is the AC filter and reactive power compensator ($j=1, 2$, $j=1$ represents the rectifying side; $j=2$ represents the inverter side).

3. Regulation flow distribution

Power flow calculation is a basic electrical calculation in power system analysis. Through the flow calculation, the steady state operation mode of the system can be determined, and the running state of the whole system is determined according to the given operating conditions and network structure[9]. When the electromagnetic transient simulation model is built, the power flow on the line is different from the electromechanical transient simulation model. The adjustment measures should be taken to ensure the consistency of the initial power flow of the two kinds of simulation software. When the system is in a special running state, the distribution of PSASP power flow is calculated. The RTDS is adjusted to the same running state and the output of the generator is adjusted, so that the initial power flow is basically the same as that in the PSASP environment. The initial power flow distribution of PSASP and RTD is shown in Table 2.

| Busbar node | PSASP       | RTDS       |
|-------------|-------------|------------|
| 1-2         | 385+j610    | 381+j598   |
| 2-3         | 385+j627    | 381+j615   |
| 3-4         | 379+j673    | 376+j655   |
| 5-6         | 475+j56     | 468+j54    |

It can be seen from the above table that the real time digital simulation software RTDS adopts some adjustment measures. The initial tide on the transmission line is basically the same as that in the electromechanical transient simulation software.

4. Regulation short circuit current

The calculation of three-phase short circuit current is the calculation and analysis work that must be carried out in the planning, design and operation of power system. The formula for calculating short circuit current is Equation (4) [11]. On the premise that the initial power flow is basically consistent in the upper section, the short circuit current of the generator bus terminal is calculated by using the transient stability function in the PSASP, and the error is kept in the permitted range by adjusting the reactance of the generator in the RTDS. As shown in Table 3, the short-circuit current between PSASP and RTDS is compared.

$$I_k = \frac{U_k}{(\sqrt{3}Z_k)}$$

In the formula, $U_k$ is the equivalent voltage source reference voltage and $Z_k$ is short circuit impedance.

|                | PSASP | RTDS | error |
|----------------|-------|------|-------|
| Rectifier      | 7.1   | 7.36 | 3.66% |
| Inverter       | 22.824| 22.3 | 2.29% |

It can be seen from Table 3 that the short-circuit current error in RTDS is within the allowable range according to the actual error range of the short-circuit current. Therefore, it can be considered that the strength of the two receiving systems of the simulation software is consistent.

5. Conclusion

a. By converting the electrical parameters of the electron-mechanical transient PSASP simulation software of a real UHVDC transmission system to the electromagnetic transient simulation software RTDS, combined with the actual network structure, the data conversion process and the similarities
and differences of the electrical modules and parameters under the two simulation software are analyzed in detail, and the electromagnetic transient simulation model is built in the RTDS platform.

b. In order to maintain the same initial steady-state operating point of the simulation models under the two simulation software, the power flow of each branch is calculated based on PSASP, adjusting the active power of an equivalent generator and so on in the RTDS to make the initial power flow of the two kinds of simulation model basically the same. The short-circuit current is calculated by the transient stability function of PSASP, and adjusts the data conversion process and the similarities and differences of the electrical modules and parameters under the two simulation software are analyzed in detail, and the electromagnetic transient simulation model is built in the RTDS platform. The reactance parameter of the equivalent generator in the RTDS, and so on, so the short-circuit current can be calculated within the allowable range of the engineering error.

c. The accuracy of electromechanical transient and electromagnetic transient simulation software under different operation conditions will be further analyzed.

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