Research on Infinite Bus System Model in the Power System dynamic Simulation

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***Abstract*—The author analyses the infinite bus power source model used in the power system dynamic simulation lab, and make further study on the industry standard for the Dynamic Test of the Power System Protective Products, then introduced a design scheme for the infinite bus system dynamic model, based on which an infinite bus system model for different voltage levels is proposed. The experimental results show that the proposed model can well reflect the dynamic process of the prototype.**

Keywords-infinite bus system; dynamic simulation test; physical model

I. INTRODUCTION

The power system dynamic simulation is an important tool of power research. The power industry attaches great importance to the development and research of dynamic simulation. Despite the rapid development of modern digital simulation technology, simulation software and all kinds of simulation equipment, the technology fails to completely replace the physical simulation laboratory. As the dynamic simulation laboratory construction of electric power industry is just unfolding, China's network relay protection experiment finally passed experimental evaluation, the people's Republic of China issued the "test" electric power industry standard operation of relay protection products GB/T 26864-2011 power system, the dynamic simulation laboratory should be carried out in accordance with the construction of the latest version of the industry standard, to better reflect the dynamic characteristics of the prototype system[1] [2].

The following regulations were given by Power industry standards for the infinite bus power:

- Before the connection to the simulation system, the harmonic voltage of the high voltage side should be less than 1.5% of the rated value, and the maximum value of the two current in three-phase short circuit should reach the level of the prototype. The zero sequence current of single phase short circuit is less than 3 times current value, and the time constant of non-periodic component of short-circuit current is greater than 90ms, that is to say, the impedance angle of power transformer is more than 88.

- The three phases are balanced before the connection to the simulation system. The second value of the negative sequence voltage component in the rated voltage should be less than 0.5V, and the negative sequence current should be less than 4% of the current value of the analog circuit.

According to the above requirements, it can be seen that the design difficulties of infinite bus power supply model lie in the short-circuit capacity and time constant simulation.

II. SHORT CIRCUIT CAPACITY CALCULATION

For the simulation of systems of different voltage levels, the power supply is required to provide a different short-circuit capacity and the infinite bus power supply of the short circuit capacity has a maximum, minimum value.

According to the “power system relay protection product dynamic model test”, drafted based on power industry standard, the infinite bus power supply of 500kV system is 3000MVA~20000MVA and the short-circuit current of the system is 3464A~23095A, which is 1.39~9.24 times of the rated current transformer. In the industry standard, the 110kV system capacity of infinite bus power supply is defined as 1000MVA~10000MVA, and based on this the short-circuit current of the prototype system is calculated 5248A~52488A, which is 8.747~87.47 times 600A/5A of the current transformer [1] [3].

Through the analysis and calculation, the author puts forward that the 110kV system is more suitable for the short circuit current of 500MVA~3000MVA, and the short circuit current is 2624A~15746A, which is 4.37~26.2 times of the rated current of 600A/5A.

In order to save the investment and realize convenient use, the high pressure model system of the dynamic model laboratory generally adopts one voltage level to simulate the prototype of different voltage levels of the system, and the domestic model is commonly using 800V, 1000V, 1200V and 1500V models. The following is an example calculation of the model with rated voltage 1000V and rated current of 10a: according to the changes of prototype and model transformers, the different voltage simulation ratio, current simulation ratio, resistance simulation ratio and capacity simulation ratio under different voltage can be calculated out [4]. According to different simulation ratios, the short circuit simulation capacity and current under different voltage levels can be calculated out. (See Table I, II) [5].

Because the dynamic simulation model is designed for large short circuit current fault experiment, general domestic dynamic model of infinite bus power supply adopt a specialized power transformer and its capacity is 250kVA, variable ratio is 10kV/380V, wiring mode is Y/Y – 12;and short circuit impedance is 10.5%.

TABLE I. SHORT CIRCUIT CAPACITY OF INFINITE BUS POWER SUPPLY

Voltage Level		**750kV(1000kV)**	**500kV**	**220kV**	**110kV**
Prototype Short Circuit Capacity	Min	9000MVA	3000MVA	2000MVA	500MVA
	Max	60000MVA	20000MVA	10000MVA	3000MVA
Capacity Simulation Ratio		400000	125000	26400	6600
Model Short Circuit Capacity	Min	0.023MVA	0.024MVA	0.076MVA	0.076MVA
	Max	0.15MVA	0.16MVA	0.379MVA	0.455MVA

TABLE II. SHORT CIRCUIT CURRENT OF INFINITE BUS POWER SUPPLY

Voltage Level		**750 (1000kV)**		**500kV**		**220kV**		**110kV**	
TA Prototype TA First Rated Value		4000A		2500A		1200A		600A	
Prototype Short Circuit Current	Min	6928A	1.73Ie	3464A	1.39Ie	5249A	4.37Ie	2624A	4.37Ie
	Max	46189A	11.5Ie	23095A	9.24Ie	26244A	21.9Ie	15746A	26.2Ie
Current Simulation Ratio		400		250		120		60	
TA Model TA First Rated Value		10A		10A		10A		10A	
Model Short Circuit Current	Min	17.3A	1.73Ie	13.9A	1.39Ie	43.7A	4.37Ie	43.7A	4.37Ie
	Max	115A	11.5Ie	92.4A	9.24Ie	219A	21.9Ie	262A	26.2Ie

III. BUILD THE SIMULATION MODEL OF INFINITE SYSTEM

In order to make the infinite bus power provide the maximum short-circuit capacity and the power transformer impedance angle greater than 88 , the designed selected infinity step-up transformer capacity is 100kVA, variable ratio is 1000/380V, wiring mode is Y0/ Δ -11, and short-circuit impedance is 17%.

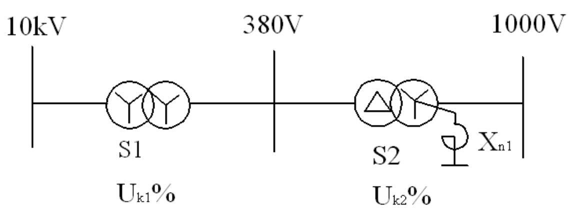

FIGURE I. WIRING MODE OF THE INFINITE BUS POWER SUPPLY WITH MAXIMUM SHORT-CIRCUIT CAPACITY

The maximum short-circuit capacity of the infinite model system wiring diagram is Figure I. and the calculation method is as follows:

Reference Voltage: $U_* = 1000V$

Short-circuit capacity of each transformer:

$$S_{1k} = \frac{S_1}{U_{k1}\%}; \quad S_{2k} = \frac{S_2}{U_{k2}\%}$$

Imputation equivalent impedance:

$$Z_{k1} = \frac{{U_*}^2}{S_{1k}}; \quad Z_{k2} = \frac{{U_*}^2}{S_{2k}}$$

Total impedance: $\sum Z_k = Z_{k1} + Z_{k2} = {U_*}^2 (\frac{1}{S_{1k}} + \frac{1}{S_{2k}})$

Total short circuit capacity:

$$S_{\Sigma k} = \frac{{U_*}^2}{\sum Z_k} = \frac{1}{\frac{1}{S_{1k}} + \frac{1}{S_{2k}}} = \frac{1}{\frac{U_{k1}\%}{S_1} + \frac{U_{k2}\%}{S_2}}$$

$$S_{\Sigma k} = \frac{{U_*}^2}{\sum Z_k} = \frac{1}{\frac{1}{S_{1k}} + \frac{1}{S_{2k}}} = \frac{1}{\frac{U_{k1}\%}{S_1} + \frac{U_{k2}\%}{S_2}}$$

Or: $S_{\Sigma k} = \frac{1}{\frac{10.5\%}{250} + \frac{17\%}{100}} = 471kVA = 0.47MVA$

Comply with the requirements of the maximum short-circuit capacity in the 110kV system (consider contact resistance).

In order to adjust the power supply voltage in the experiment, there is usually a tandem connection between the transformer and the inductive voltage regulator, as shown in Figure II.

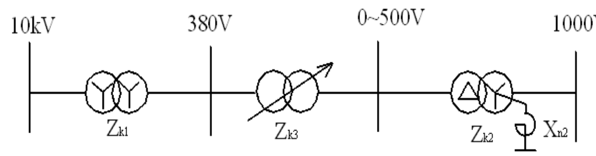

FIGURE II. THE WIRING MODE OF THE INDUCTIVE VOLTAGE REGULATOR

The capacity of the selected inductive voltage regulator is 100kVA and the pressure range is $380V/(0\sim 500V)$. The short-circuit pressure drop at the time of the experiment is $45V$, or $U_k = \frac{45}{380}\times 100\% = 11.8\%$. According to the above calculation method, the short circuit capacity is calculated:

$$S_{\Sigma k} = \frac{1}{\frac{10.5\%}{250}+\frac{11.8\%}{100}+\frac{17\%}{100}} = 303kVA = 0.303MVA$$

$$Z_{k1} = \frac{U_*^{\ 2}}{S_1}\cdot U_{k1}\% = 0.42\Omega\, , Z_{k3} = \frac{U_*^{\ 2}}{S_3}\cdot U_{k3}\% = 1.18\Omega\, ,$$

$$Z_{k2} = \frac{U_*^{\ 2}}{S_1}\cdot U_{k2}\% = 1.7\Omega$$

Electric power industry standard requires that the zero sequence current of single phase short circuit should be 3 times less than the three-phase short-circuit current, or $I_1^{(3)} > 3I_0$, so it is required that the neutral point of the transformer is connected with the zero sequence current so as to restrict zero sequence current. Calculated:

$$X_{n1} > 3Z_{k1} = 1.26\Omega\, ,$$

$$X_{n2} > 3(Z_{k1}+Z_{k3}) = 4.8\Omega$$

The selected series zero sequence impedance is $X_n = 5\Omega$; the intermediate tap value is 1.5, and the impedance angle is 80.

IV. CURRENT LIMITING REACTOR DESIGN

1 The power supply connection mode of the direct connection to the boost transformer (as shown in Figure I): the provided short circuit capacity is 0.47MVA. In order to gain 0.16MVA short-circuit capacity of the power supply, the current limiting reactor should be tandem connected [6].The total impedance of the non-series reactors is:

$$\sum Z_k = \frac{U_*^{\ 2}}{S_{\Sigma k}} = \frac{1000^2}{0.47MVA} = 2.128\Omega$$

Series reactance of 0.16MVA short circuit capacity:

$$\Delta Z_1 = \frac{1000^2}{0.16MVA} - 2.128 = 4.122\Omega$$

According to the above calculation method, we can calculate the reactance value of different short circuit capacity [7] [8].

2 The power supply connection mode of the inductive voltage regulator (as shown in Figure 2), the provided short circuit capacity is 0.303MVA. To reach the short circuit capacity of 0.16MVA, also it should be series connected to current limiting reactor.

V. CONCLUSION

To sum up, different simulation systems should be set up for different simulation objects. For the establishment of a minimum short-circuit capacity of the infinite system, a series short circuit method should be applied. And for the establishment of the maximum of the infinite system, the design adoption is a series connection to the reactor.

Experiments show that the model can correctly reflect the dynamic process, and the method has been successfully applied to many power system dynamic simulation laboratories with achieved good results [9] [10].

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