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Verification of New Generators Trip-off scheme for a Long Transmission System by EMTP

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Abstract: Long transmission lines will weaken the electric connection between power plants, which have several generators, and power systems, to which the power plant will provide power. In southeastern of china, there exits the same topological structure. The trip-off scheme of generators in power plant is very rigorous, albeit Fixed Compensation (FC) has been used to promote transient stability. After development in these years, the end-point power gird has been reinforced, so the old scheme should be modified. This paper employs Electromagnetic Transients Program (EMTP) as a simulation tool to verify the new scheme with field tests parameters, and hopes the conclusions can give operators some positive suggestions.

Key-words: Fixed Compensation, long distance transmission, Trip off, ATP/EMTP, Interface

1 Introduction

In southeast of china, there is such a system, which has Yangcheng-Huaiyin transmission lines over 760km with two FCs being settled respectively on two lines at the vicinity of Huaiyin station (Sanbao Bus). The compensation degree is 40 percent of line resistance. At the result of FCs, One 500kV line can be saved. YC-DM transmission lines, 262KM in length, consist of three lines and two of them are common-tower double-transmission lines. DM-SB transmission lines, 268KM in length, are set in common-tower double-transmission line mode. The representation of connection is shown below. The receiving system, Jiangsu Province power system, is with rather weak 500KV network structure and rather heavy load at Year 2003. Hence the power supplies are limited at Yangchen plant and the rigorous generators trip-off scheme is carried out for the sake of transient stability of Jiangsu Power system at Year 2003. With the developing during these years, the 500KV power network is enhanced obviously at Year 2005. New generators trip-off scheme should be used.

Although the technology of phase–transposed is used in such long common-tower double-transmission line, the imbalance of them is obvious. Besides the coupling exists among positive, negative and zeroth networks at each line, the coupling also exists among them between different lines. So, it is not accurate enough to simulate such lines as distribution lines in π model. Furthermore, the imbalance operation of such long common-tower double-transmission lines, can affect the safe operation of rotating equipments in power systems [1]. Hence, detail models should be used to consider the influence on the generators at Yangcheng plant by these lines. Paper [2] explores the impact of six-phase transmission line fault and their subsequent fault clearing and reclosing on the torsional torque induced in turbine-generator shafts. But In that paper, the two transmission lines are modeled as distributed parameters, untransposed lines.

Paper [3] verifies the necessary to model FCs in component level. The comparison results between transient stability program (TSP) and EMTP illustrate that TSP results are optimistic and may get erroneous stability limit at some certain conditions. Paper [4] describes a computationally efficient model for metal oxide varistors (MOVs) suitable for use in simulation studies of series compensated lines.

Software packages such as the Electromagnetic Transients Program (EMTP) have been developed for transient simulation of electrical power systems and are used whenever improved accuracy is required. These simulation programs are popular in the utility industry because they have been proven accurate and versatile.

Transient Analysis of Control Systems (TACS) is the basic interface in EMTP and used widely. But there is one-time step error between TACS and the main program. Paper [5] uses a technique, which can eliminate the time delay, without having to use a simultaneous EMTP and TACS solution. An autonomous general-purpose simulation program, which is named MODELS, is recently interfaced to two versions of the Electromagnetic Transients Program (EMTP). Paper [6] evaluates the usage of MODELS in the EMTP by stressing the differences in approach and use as compared to TACS. Another external interface method with MATLAB is introduced [7].

Nowadays, scientists are engaged in improving the performance of EMTP. Paper [8] shows a new method to combine TSP and EMTP to overcome the limitation of a single fixed size integration step. Another TSP/EMTP hybrid program which shows new techniques considering the effect of frequency deviation is introduced in paper [9].

In section 2 of this paper, the detail models of key equipments are presented. Section 3 presents the generators trip-off schemes of Year 2003 and Year 2005. The results and some future work are illuminated in section 4.

2 Components modeling in EMTP

In this section, several key components models in EMTP are introduced, including generators and their excitation systems. FCs and their protection schemes, common-tower double-line transmission line are also modeled.

2.1 Generators and their excitation systems

The generators are modeled by using Card 59 in EMTP. The d-q-0 models reference frame and 6-order Park models are used.

The control systems typically modeled in system studies include the excitation and speed control systems. Accurate modeling of these control systems has been the subject of significant research work, and typical controller models have been developed for a range of specific devices.

Excitation systems and PSS are modeled in TACS with parameters acquired by field tests and the prototype of the excitation and speed control systems of generators at Yangcheng plant is shown at Fig. 1. All transfer functions have been identified.

2.2 Fixed Compensation (FC) and its protection

2.2.1 FC Model

The prototype of FC is shown as Fig.2, including capacitors, MOV, air gap and bypass breaker. The model is described in single–phase.

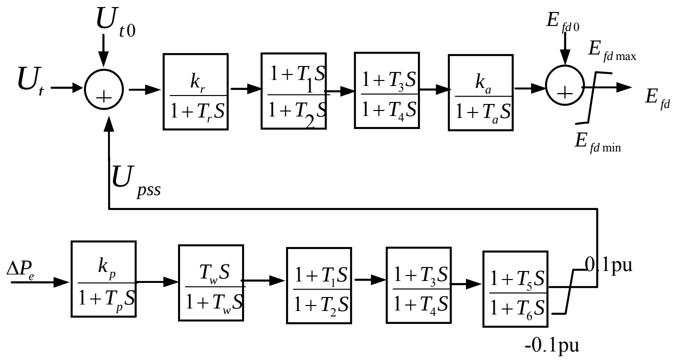

Fig. 1 Prototype of the excitation and speed control systems of generators at Yangcheng plant

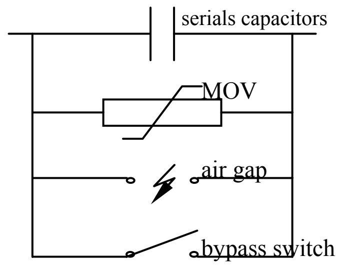

Fig.2 FC prototype

The capacitor in single-phase is 106.4μf. MOV is a nonlinear resistance, which is described by V-A characteristic. Its protection level is 2.2 multiple rated current.

2.2.2 MOV protection Scheme

In order to avoid the MOV destroyed for over-load, there are over-load protection and fault protection module in this equipment. Here, according to the real operating condition, fast by-pass the capacitor sets when the internal fault happens at the lines with serial compensators and the over-load protection of MOV are taken into consideration. These protections have two start styles:

1) The current flowing through MOV is more than 9KA;
2) Absorbing energy speed of MOV is more than 3427.21 KJ/MS/per phase

Fig.3 demonstrates the action process. Where the I_{MOV} is the current flowing through the MOV, and the P_{MOV} is the power at MOV. The I_D and P_D are their set values respectively.

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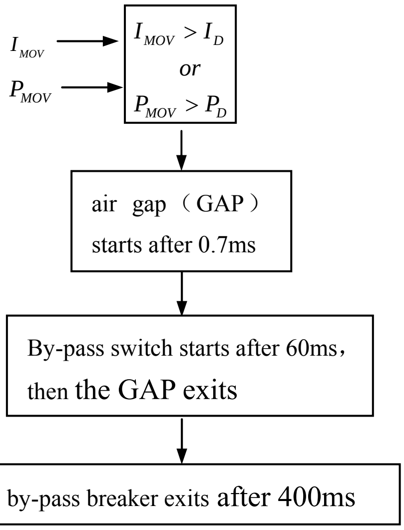

Fig.3 action process of serial compensator protection

2.2.3 Transmission Line, Tower and Transpose

Except for YC-DM-SB transmission lines, all the other transmission lines use distribution parameter model, written by Card –1, -2, -3 in ATP/EMTP.

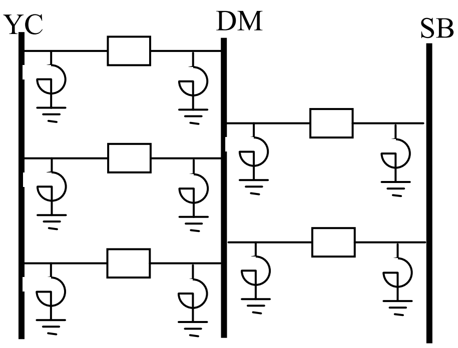

Fig.4 YC-DM_SB lines

The YC-DM-SB lines are shown as Fig.4. LCC model in ATP/EMTP is used here to simulate the common-tower double-transmission lines in detail. LCC model is a subprogram of ATP/EMTP, it calculates the line parameters according to the tower parameters. So, by real parameters from measurements, the detail parameters are obtained, which considers all conditions that may affect the line parameters. Furthermore, the phase-changes are considered in simulation. A typical tower placement is shown as Fig.5.

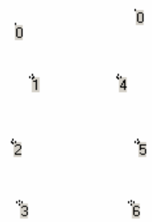

Fig.5 configuration of a typical tower

3 Simulation and Results

3.1 Test system

The test system is the Subei subarea of Jiangsu Province transmission networks, that is, the network of 220kV and above of Subei region, shown as Fig.6(a) and Fig.6(b). All detailed models are written in ATP/EMTP. The parameters of the power supply system were acquired by professional filed tests, including 316 transmission lines, 47 transformers and 35 generators and part of their excitation systems. The remaining power network is expressed as equivalent impedances plus an infinite voltage source connecting to WN and DS bus.

The compendious Jiangsu province power network at 500KV is shown as follows. Fig.6(a)1 is the power network configuration of Year 2003, while Fig.6(b) is of Year 2005.

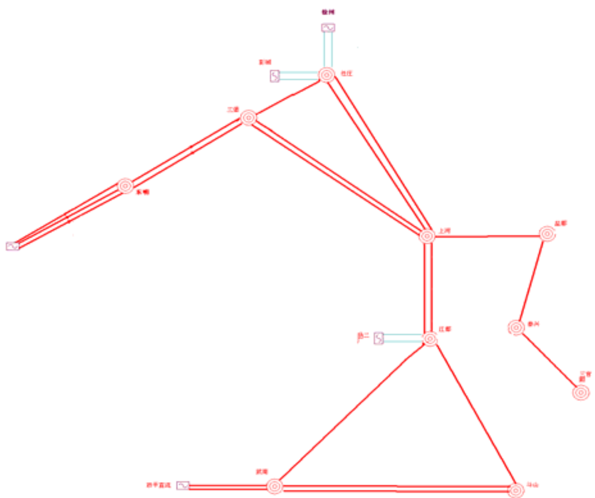

Fig. 6(a) Subei 220KV and above network sketch at year 2003

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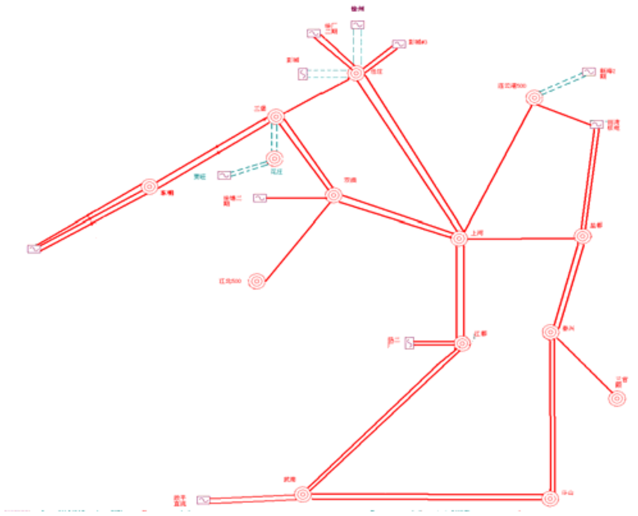

dashed： 220KV solid line：500KV

Fig.6(b) Subel 220KV and above network sketch at year 2005

Comparing Fig.6(a) with Fig.6(b), the electric power network of 2005 is more robust. First, several bulk plants are connected into 500KV network and go into work. Secondly, 500KV river-passing lines add from 3 to 4 and the double-circuit network structure is formed. At last, 500KV/220KV electromagnetic coupling circuits are disjoined while they exist at Year 2003.

3.2 Fault Simulation

The following fault types are taken into account.

1) Permanent Single-phase to ground fault. The actions are to trip off the fault phase after 0.1 second, then to reclose this phase after 1 second. If reclosing is not success, then open three phases after 0.1 second.
2) Permanent three-phase to ground fault. The actions are to trip off three- phase lines after 0.1 second, then to reclose this line after 1 second. If reclosing is not success, then open three phases after 0.1 second.
3) Permanent phase- to -phase fault. The action is to cut three phases after 0.1 second, then to reclose this line after 1 second. If reclosing is not success, then open three phases after 0.1 second.
4) Permanent fault between the different lines and different phases of Common-tower double-transmission lines. The actions are to cut the fault phases after 0.1 second, then to reclose the lines after 1 second. If reclosing is not success, then open three phases after 0.1 second.

Here, all fault simulations are realized by switches.

3.3 Comparisons and analysis of two schemes

Due to the stability limit of Jiangsu Electric Power system, power supply is 300MW per generator from Yangcheng plant at Year 2003. While the value is 350MW per generator, the rated supply, at Year 2005. Since these changes happen, the old generators trip-off scheme of Yangcheng Plant is not appropriate any more. So, A new generators trip-off scheme should be proposed. The results are shown at table 2.

Firstly, the generation of Yangcheng plant is not limited any more at Year 2005 while it has to decrease 1/7 rating generation for the sake of the stability of Jiangsu power network. Secondly, there is no generator trip-off at Year 2003 and Year 2005 at case 1, 2, 3, 5, 9 and 10, 11.

At case 4, the result of transient stability at year 2005 is more serious than that at year 2003. For it is the permanent phase-phase fault between different lines and different phases of YC-DM common-tower double-transmission lines at YC bus vicinity and these lines trip off after relosing fails, the power supply at Year 2005 more than at Year 2003 by the YC plant can not transport. At case 6, when the permanent phase-phase fault between different lines and different phases of SB-SH common-tower double-transmission lines at SB bus vicinity occurs, the Jiangsu power system can keep stability without trip off any generator although the line reaches its thermal stability limit at Year 2005, while it has to trip off a generator after 0.2 second. As shown on Fig.6(b), the most power flow through SB-SH common-tower double-transmission lines while little power flow through SB-RZ line at normal condition. When the fault shown as case 6 happens, the bulk power flow through SB-RZ line and induces its thermal over limit. Because the river-bypassing lines added from 3 to 4, the transient stability problems are improved at Year 2005 when network operation modes and fault types are relative of them, as shown in case 7, 8, 9. At case 12 and 13, with the enhancing of Jiangsu power system, Although two FCs are in repair and exit, generators at Yangcheng plant need not trip off any generator in the condition that the power supply per generator is limited at 330MW at Year 2005. Whereas a generator has to trip off although their generation is 300MW per generator at Year 2003. All in all, At most of operation modes, the transient stability of Jiangsu network is improved and less chances to trip off the generators of Yangcheng plant at Year 2005 .

Table 2 Results comparison between Year 2003 and Year2005 under different operation modes

Operation modes	NO.	Fault conditions	Calculation results	
			2003 year	2005 year
Normal	1	Type 3 of YC-DM #1line at YC bus vicinity	No trip-off	No trip-off
	2	Type 1 of DM-SB #1 line at DM bus vicinity	No trip-off	No trip-off
	3	Type 2 at YC, DM and SB buses	No trip-off	No trip-off
	4	Type 4 of YC-DM common-tower double-transmission lines at YC bus vicinity	The Power system can keep stable when trip off one generator at 0.1 second after fault. However, the voltage sag and the active power vibration are serious;	The Power system can keep stable when trip off one generator at 0.1 second after fault. However, the voltage sag is serious, and the active power vibrates worse than that of Year 2003
	5	Type 3 at SB-SH line	No trip off	No trip off
	6	Type 4 of SB-SH common-tower double-transmission lines at SB bus vicinity	Trip off one generator 0.2 second after reclose fails	The power system can keep stable without tripping off any generator. However, the line reaches its thermal stability limit, the voltage vibrates highly. It becomes better if tripping off one generator at 0.2 second after fault
	7	Type 2 of TX-TZ line at TX bus vicinity	Trip off one generator at 0.2 second after fault	No trip off
	8	Type 2 of JD-WN line at JD bus vicinity	Trip off one generator at 0.2 second after fault	No trip off
SH-JD #1 line in repair	9	Type 3 of YC-DM #1 line at YC bus vicinity	No trip off	No trip off
JD-WD line in repair	10	Type 2 of YC-DM #1 line at YC bus vicinity	No trip off	No trip off
FC at DM-SB #1 line in repair	11	Type 2 of DM-SB #2 line at DM bus vicinity	Trip off one generator at 0.2 second after fault	Trip off one generator at 0.2 second after fault
	12	Type 2 of JD-WN line at JD bus vicinity	Trip off one generator at 0.2 second after fault	No trip off
FCs at DM-SB #1#2 lines in repair	13	Type 2 of DM-SB #1 line at DM bus vicinity	Trip off one generator at 0.2 second after fault	The power supply is limited at 330MW, No trip off
	14	Type 2 of JD-WN line at JD bus vicinity	Trip off one generator at 0.2 second after fault	The power supply is limited at 330MW, No trip off

✧ Old scheme(year 2003) 300MW per generator; New scheme(year 2005) 350MW pre generator
✧ Fault types are shown at section 3.2

4 Conclusions and further work

This paper has made an experiment successfully with the EMTP for bulk power system simulation. The detailed models of generators, transmission lines and FCs are used, with these excitation systems modeling in TACS module. All the component parameters were acquired by special field tests. The validation of new trip-off scheme for power plant generators is obtained. The results can help utility operators make positive and efficient planning. The furture work should include replacing FC by TCSC to improve system transient stability, torsional torque and subsynchronous resonance research as the new bulk generators will be used at YangCheng plant.

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