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The Analysis of TV Primary Fuses Blown in the Distribution Network

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ABSTRACT

Accidents occur frequently in distribution network TV primary fuses blown, so it has a certain practical significance to study the main reason for the fuse blown and prevention measures. This article first introduces the causes of TV primary fuses blown are ferroresonance and low-frequency oscillation. Then it uses ATP-EMTP to establish the mathematical model of 10kV distribution system and based on the simulation analysis of three influence factors of TV primary fuses blown. Finally, it carries on the comprehensive comparison on the existing measures to prevent TV primary fuses blown.

Keywords: Electromagnetic voltage transformer, Primary fuses, Ferroresonance, ATP-EMTP

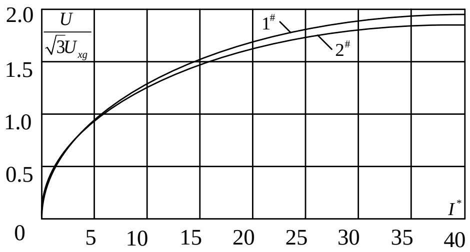
INTRODUCTION

In the ungrounded distribution network, Bus generally installed on the electromagnetic voltage transformer (TV), which provides voltage for the backup protection, outline protection and measurement of up one level. But when the single-phase earth fault is eliminated, no-load bus bar closing or severe changes in system load, frequently TV primary fuses blown accident will occur. It does affect the measured value of the electric energy meter, also easy to cause misoperation of relay protection device, seriously it still can not make the power grid safe, stable and reliable [1], therefore, it is very necessary to study the main reason for TV primary fuses blown and prevention measures, which has significant engineering value and practical significance.

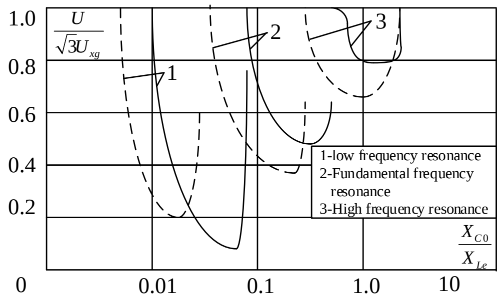
The Analysis on the Causes of TV Primary Fuses Blown

After years of scholars' research, they found that the cause of TV primary fuses blown is so many, such as the ferroresonance; Low-frequency oscillation (LFO); TV entrance capacitance current shock when the thunderstorm weather; Power grid harmonic; TV secondary windings short circuit, etc. [2]. Among them, that ferroresonance and LFO is the main reason for the TV primary fuses blown in medium voltage distribution network.

Ferroresonance. The TV nonlinear excitation characteristics is the root cause of ferroresonance. When the system is normal, TV excitation inductance will relatively enlarge. When the system appear stimulate disturbance, iron core tends to saturation. Due to TV nonlinear characteristics of excitation inductance, TV excitation inductance slash, which leads it to match line-to-ground capacitance and stray capacitance of other electrical equipment, then it will form the vibration circuit, eventually cause ferroresonance phenomenon. H·A·Peterson made the following conclusions through the comprehensive study on the simulation test of ferroresonance: with the increasing impedance ratio X_{C0}/X_{Le} (X_{C0} is line zero sequence capacitive reactance, X_{Le} is TV of impedance measurement under the rated line voltage), successively it generates high-frequency resonance and fundamental frequency resonance and resonance frequency [3-5]. Fig.1 shows that TV volt-ampere characteristics of excitation inductance are better, the iron core is saturated difficultly, the resonance range will more easily move to the right [6]. With the change of grid zero sequence capacitive，X_{C0}/X_{Le} will also change, loop maybe change a state of resonance into another one.



(a) Volt-ampere characteristic curve



(b) Resonance area

Fig.1 TV excitation inductance of volt-ampere characteristic curve and resonance area

Low-frequency Oscillation (LFO). In recent years, that cables instead of overhead lines is widely used in urban distribution network makes the system to line-to-ground capacitance increased significantly, which is far beyond the scope of ferroresonance. But the field operation shows that TV primary fuses blown does not reduce. This is because the system of capacitance is large, the single-phase earth fault eliminate disturbance and others inspired another electromagnetic oscillation, which is LFO. The oscillation frequency score is lower than frequency resonance, but it caused by TV primary windings current is much larger than the latter, whose level is amps in the initial stage, causing accidents such as TV primary fuses blown.

The Establishment of ATP-EMTP Simulation Model

In this paper, the single-phase earth fault is used to excite the oscillation process to make the simulation effect obvious. Ferroresonance and LFO occur in zero sequence circuit, the capacitance and TV three-phase are symmetrical at that time. When the single-phase grounding fault occurs, voltage between phases will not change [7], so it can not be considered here. Simulation model is shown in Fig.2. If A phase occurs metallicity single phase fault and K simulate the grounding switch, Three-phase power supply is 110kV voltage grade, magnetic saturation transformer uses Y_N/Δ wiring variable ratio of 110/10kV. If the three-phase circuit parameters are symmetrical, each phase conductor to ground capacitance C_0=0.005μF/km, each phase conductor impedance Z_m=0.425+j1.433Ω; TV adopts the JDZX19-10G type as Tab.1.

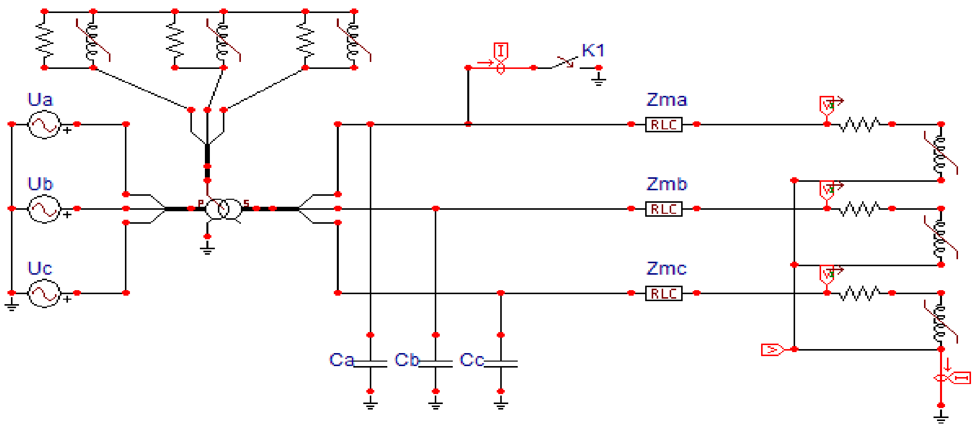


Fig.2 Simulation model

Tab.1 JDZX19-10G type of TV excitation characteristic parameters

Number	1	2	3	4	5	6	7	8
i /A	0.001	0.002	0.004	0.005	0.010	0.017	0.039	0.068
Ψ /Wb	4.50	9.00	18.01	25.97	36.01	39.84	45.02	47.72

The Influence Factors of TV Primary Fuses Blown

The Total Length of Bus Feeder Line. The total length of bus feeder line can be changed through the changing of the system capacitance value. Different resonance is simulated when the single-phase earth fault is eliminated, so as to explore the total length of bus line influence of TV primary windings current and the system resonance state. In this paper, the JDZX19-10G type of TV is simulated, the simulation results such as Tab.2. Three-phase voltage and current waveform of TV primary side for three modes of typical ferroresonance as Fig.3 and Fig.4. Three-phase voltage and current waveform of TV primary side for LFO as Fig.5. Tab.2 shows that high frequency resonance, fundamental frequency resonance and low frequency resonance occur in turn with the increase of 10 kV bus feeder line length when single-phase earth fault eliminate. When the feeder line length over the range of ferroresonance, LFO will happen.

The characteristics of the four modes of resonance state, respectively as follows：

1) High frequency resonance: three-phase voltage rise at the same time and over the line voltage, which can achieve the system normal phase voltage 4~6 times. The main harm is high overvoltage made in the system and the system insulation weaker areas threaten insulation.

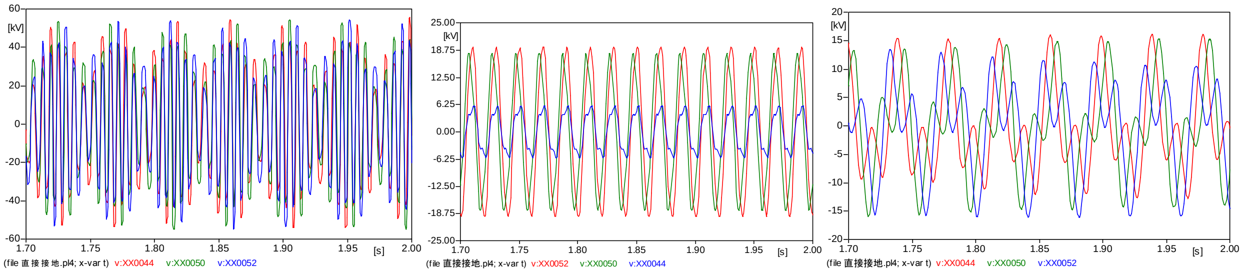
2) Fundamental frequency resonance: a phase voltage is reduced, the other two phase voltage rise more than line voltage, which is easy to appear virtual ground phenomenon.

3) Low frequency resonance: with three-phase voltage increasing, the voltage is generally not more than 2 times of the phase voltage. The risk of low frequency resonance is the largest in the ferroresonance.

4) LFO: voltage and current will decay after a certain period of time. Current can be ampere level oscillation in the initial stage.The greater the capacitance of system is, the lower the oscillation frequency and the greater the degree of primary windings currents will be.

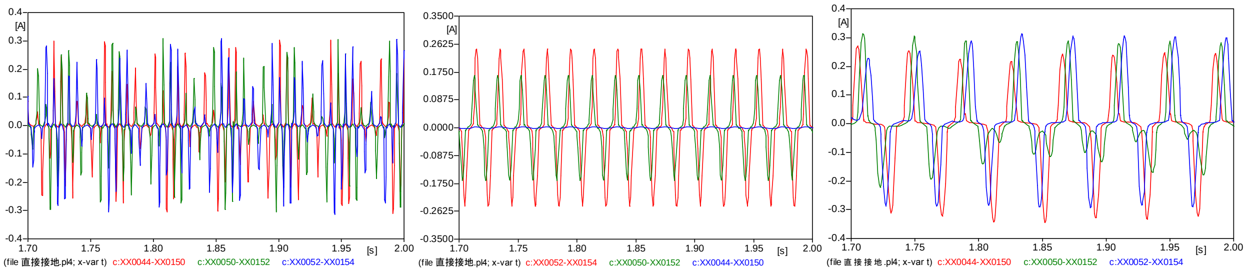
Tab.2 Resonance state of the different total length of 10 kV bus feeder line

Capacitance /μF	Feeder line length /km	Resonant state
0.002	0.4	High frequency resonance
0.01~0.02	2~4	Fundamental frequency resonance
0.03~0.1	6~20	Low Frequency resonance
0.15~10.0	30~2000	LFO



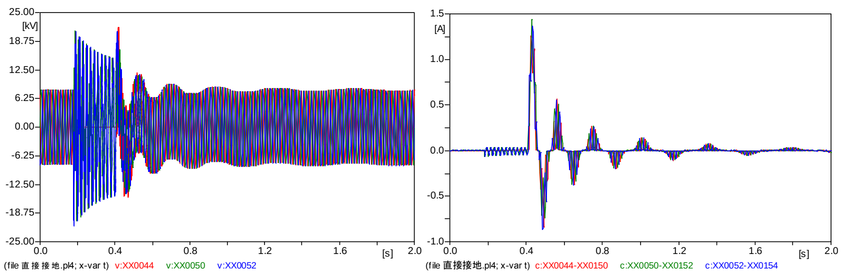
(a) High frequency (b) Fundamental frequency (c) Low frequency

Fig.3 TV primary voltage waveforms when ferroresonance occur



(a) High frequency (b) Fundamental frequency (c) Low frequency

Fig.4 TV primary current waveforms when ferroresonance occur



(a) Three-phase voltage (b) Three-phase current

Fig.5 TV primary voltage and current waveforms when LFO occur

TV Excitation Characteristic. Using two sets of TV with different excitation parameters comparing, we can explore the influence of TV excitation characteristic on the TV primary side current and resonant state of the system. Two curves of TV excitation characteristic is shown in Fig.6, and TV1's linearity is obviously better. ATP-EMTP simulated on two sets of TV, each TV primary windings current maximum peak and its system resonance state is shown in Tab.3. Under the different of system capacitance, the primary windings current of TV2 is always less in Tab.3. Especially during the LFO, three-phase over-current of TV2 is about a half of TV1. For poor TV1 excitation characteristic, its primary fuses is very easy to fuse and cause an accident. As can be seen from both of system resonance state, TV2 ferroresonance area is less and not easy to happen.

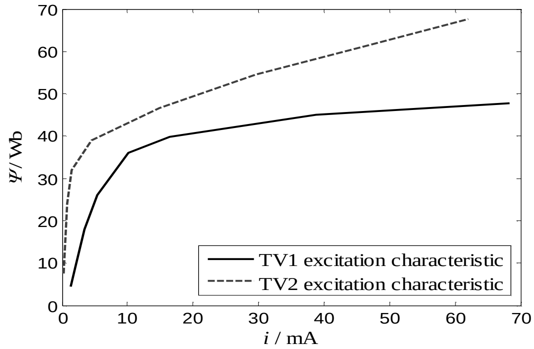


Fig.6 Excitation characteristic of TV1 and TV2

Tab.3 The contrast of TV1 and TV2 primary windings current peak

C /μF	TV1				TV2			
	i_A/A	i_B/A	i_c/A	Resonant state	i_A/A	i_B/A	i_c/A	Resonant state
0.002	0.349	0.343	0.319	High frequency	0.0004	0.028	0.030	Fundamental frequency
0.02	0.005	0.201	0.301	Fundamental frequency	0.115	0.112	0.119	Low frequency
0.1	0.462	0.384	0.522	Low frequency	0.220	0.153	0.188	LFO
2.0	1.263	1.443	1.361	LFO	0.675	0.697	0.701	LFO

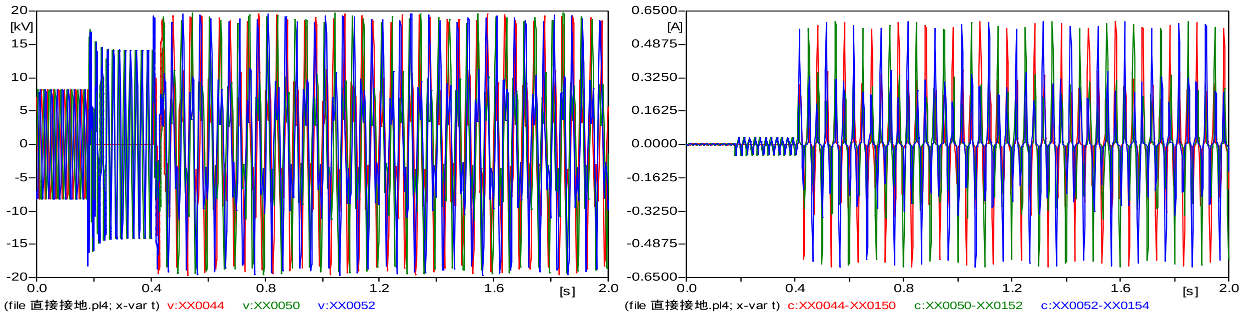


Fig.7 TV primary voltage and current waveforms when DC resistance is 100Ω (L = 20 km)

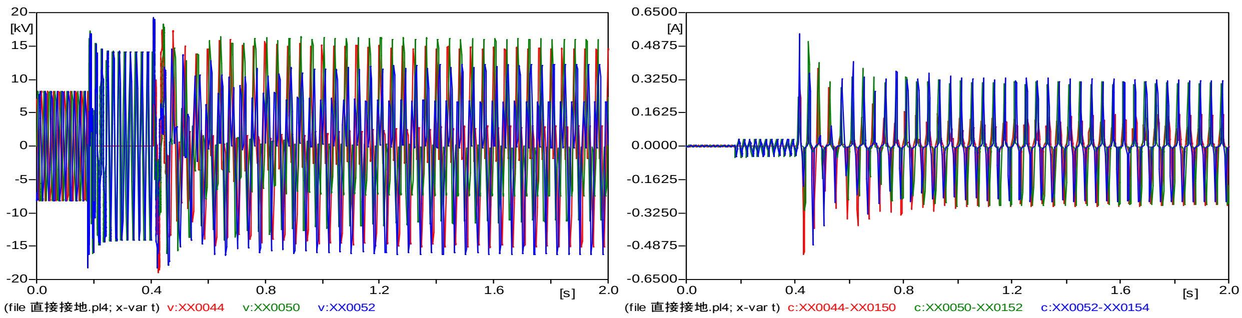


Fig.8 TV primary voltage and current waveforms when DC resistance is 1000Ω (L = 20 km)

The Primary DC Resistance of TV. The primary DC resistance of TV can also affect ferroresonance and LFO when single-phase earth fault is eliminated. In this paper, the simulation of the different DC resistance make the influence of the TV primary voltage and current. When the feeder line length is fairly short, with the increase of DC resistance, TV primary voltage and current amplitude is reduced, but the resonance condition is not easy to damage. When the feeder line length is longer, with the increase of DC resistance, TV primary current amplitude is reduced. Voltage and current amplitude decay obviously. So the increasing of damping in zero sequence circuit is beneficial to prevent TV primary fuses blown, harmonic elimination device currently widely used is according to this principle.

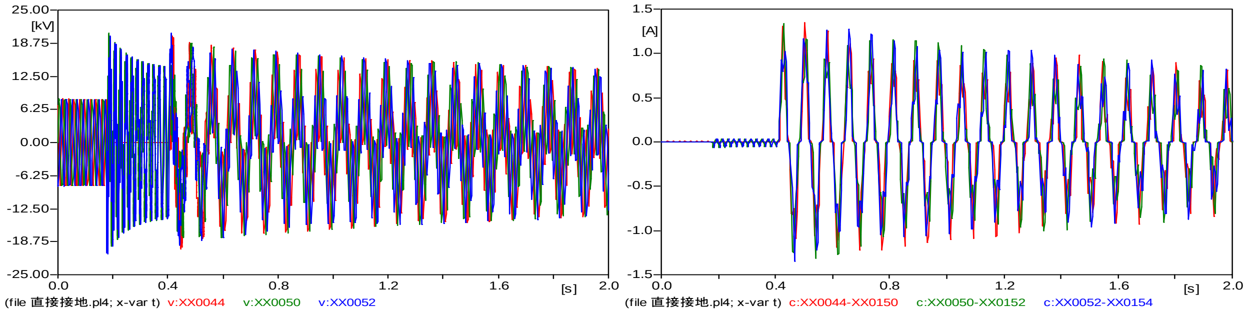


Fig.9 TV primary voltage and current waveforms when DC resistance is 100Ω (L = 200 km)

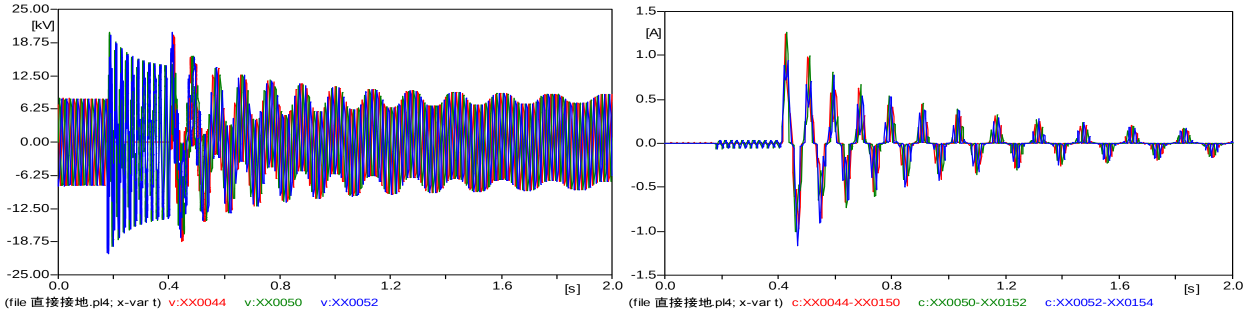


Fig.10 TV primary voltage and current waveforms when DC resistance is 1000Ω (L = 200 km)

The Prevention Measures of TV Primary Fuses Blown

The prevention generally has two aspects: one is changing the parameters of inductance and capacitance to destroy the resonance condition, another is the restraining resonance energy consumption by the damping [8-9]. To thoroughly solve this problems, a better excitation characteristic of TV is certainly the most fundamental. In addition, the system neutral point grounded by arc suppression coil or low resistance have good suppression on it. But it is a comprehensive project with more investment and more economic, and the price is too big if only to prevent TV primary fuses blown [10], which shall not be commonly use. Therefore, on the basis of the existing distribution network structure, some measures adopted to prevent the TV primary fuses blown is realistic, which is less additional impact of equipment and less investment.

TV Primary Neutral Point Gounded by Harmonic Elimination. Harmonic elimination is the nonlinear resistance and this measure is so far the most commonly use to prevent TV primary fuses blown. The principle is similar to the linear resistance, which has the effect of energy consumption and increase the damping. Using nonlinear resistance make harmonic elimination, the heat capacity is larger and the damping effect is better. However, harmonic elimination access will lead to the zero sequence voltage output of TV secondary reduced, which affects the sensitivity of the grounding indicating device. This paper adopts the LXQ(D)Ⅱ.10 type of harmonic elimination to simulate, TV primary voltage and current waveforms is shown in Fig.11. It can be seen the suppression effect of harmonic elimination is great. Over-current amplitude decrease from 1.45A to 0.55A, and rapidly decay.

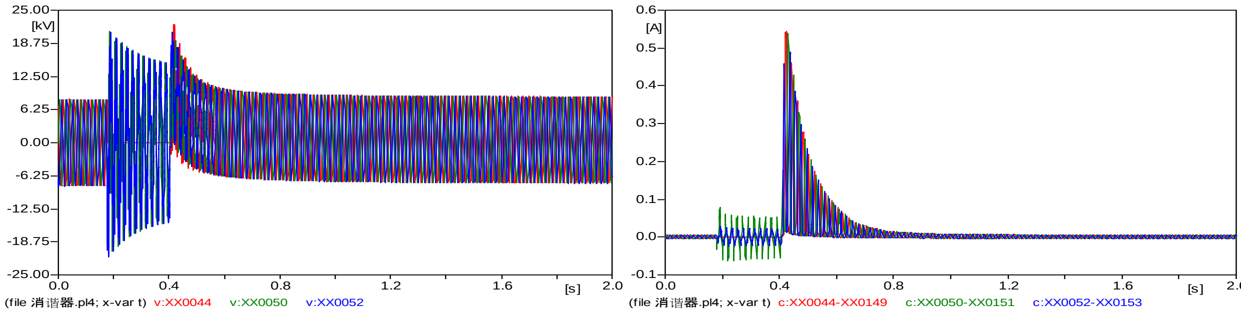


Fig.11 TV primary voltage and current waveforms (L= 400km)

TV Primary Neutral Point Grounded by Single Phase TV. This connection is equivalent to improve the excitation characteristics of TV core, so the core is not easy to appear saturated and the grounding instructions have enough sensitivity. In the same grid, if you have multiple sets of TV, it will be effective according to the connection mode for each one, and TV neutral point to earth voltage will be also raised. After single phase TV access, TV primary voltage and current waveforms is shown in Fig.12. In the larger capacitive current system, this measure can not avoid the resonance, and has larger oscillation. Over-current amplitude decrease from 1.45A to 0.95A, and generally this measure is not better than harmonic elimination.

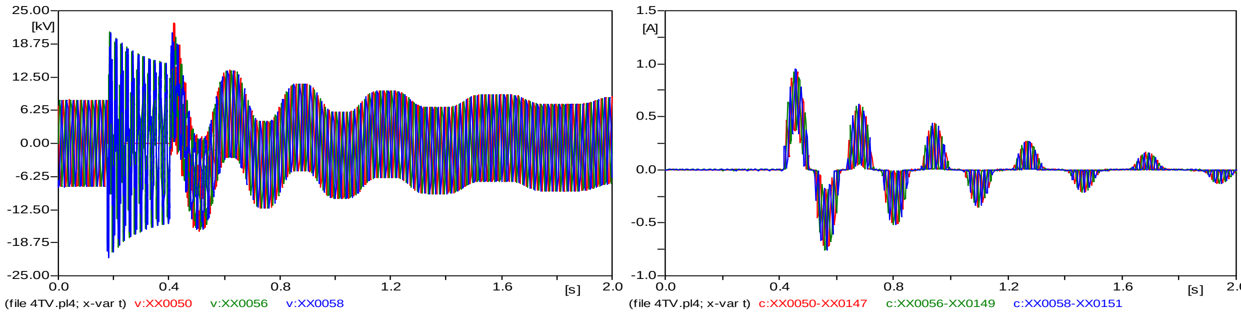


Fig.12 TV primary voltage and current waveforms (L= 400km)

The Damping Resistance in the Broken Corner of TV Secondary Delta Connection. The damping resistance can consume resonance energy of zero sequence circuit in the broken corner of TV secondary delta connection, equivalent to parallel resistor on the primary side of the coil. When durative single-phase earth fault happens, the zero sequence voltage in the broken corner of TV secondary delta connection will be 100V. The resistance value is very small, so it will produce very large circulation, easily burned TV windings. When damping resistor is too small, on the one hand, resistance may be burning itself due to overheating, on the other hand TV may also be burning due to excessive current. When flow occurs, it will be short circuit in the broken corner of TV secondary delta connection, which will increase the flow of value.

To avoid the above situation, it is usually adopted to damping resistance instant access when the single-phase earth fault eliminate. In this paper, the simulation of damping resistance value is 0.1Ω, TV primary voltage and current waveforms is shown in Fig.13 and Fig.14.

From Fig.13, when the damping resistance instant access, it will produce a high amplitude impact current, which is only lasted half a cycle, so it is not enough to cause TV primary fuses blown and the suppression effect is very good.

From fig.14, when the damping resistance delayed for 1s access, resonance happens before resistance access. Under the long time action of over current, TV primary fuses blow extremely easily, so the investment time of this measure is not improper,which would be risky, and it needs further perfect in principle.

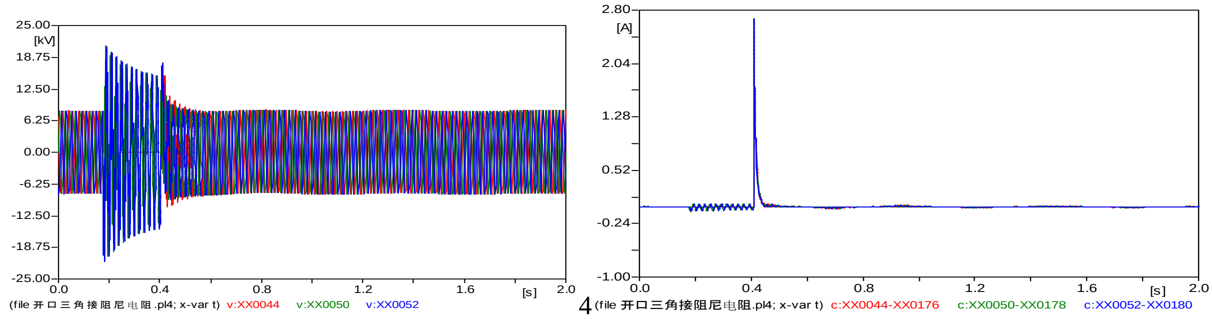


Fig.13 TV primary voltage and current waveforms when the damping resistance instant access

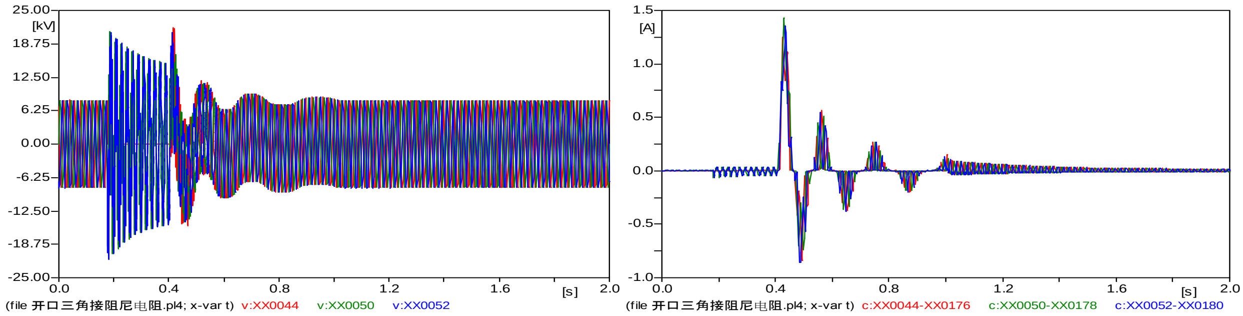


Fig.14 TV primary voltage and current waveforms when the damping resistance delayed access

CONCLUSION

Ferroresonance and LFO in the distribution network can lead to TV primary fuses blown, and cause great impact on the safe and stable operation of power system. Based on the mathematical model of ATP-EMTP, it is simulated the main influence factors and rules of TV primary fuses blown when the single-phase earth fault eliminated, which provide the basis of prevention and control measures for further research. Furthermore, to make a comprehensive comparative analysis of existing various prevention measures, it helps to improve and optimize itself, which has significant engineering value and practical significance.

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