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Research on Arc-grounding Overvoltage in the 10kV Distribution System

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Abstract

The using rate of cable which causes the capacitance current raise up out of limits in the urban distribution system is growing up very fast during the past years. It threatens the security of power-supply. In this paper, the author made lots of works analyze many methods of grounding through the natural point. The author also made the simulation models with EMTP/ATP program in theory and combine the fault of single-phase grounding in practice.

Keywords- capacitance current; arc-grounding overvoltage; arc-suppression coil; EMTP/ATP program

1. Introduction

When the fault of single-phase grounding happens in un-grounding system, the current Ig flow through the grounding point is the sum of all un-fault phases' capacitance current. If the current is small, it will cause a transient process of extinguish when the current flow through the null point. The grounding arc will be pulled long by the effect of electrodynamic force and hot air convection. The arc will be burned again if the arc insulation recover speed is low than the fault phase voltages recover speed. It will extinguish completely and the fault will be eliminated if the insulation recover intension is strong enough to support the recover voltage. This kind of current can self-extinguish in seconds to scores of seconds later. As the system capacitance and current amplify, Ig amplifies too. When Ig amplifies to an definite value of number, the ground arc can not self-extinguish, then the perpetual fault happens. What's more, if the system capacitance current is large enough, it will be a big problem in the actual motion even use then ground fault neutralizer to compensate the capacitance current.

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There is a single-phase earth fault equivalent-circuit diagram on Figure 1.

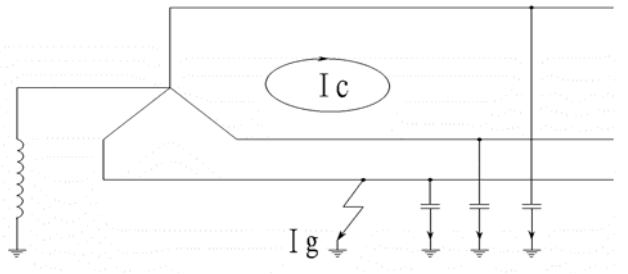

Figure1 Single-phase earth fault equivalent-circuit diagram

Now the 10kV transmission systems use more cables and insulated wires than before. In these systems if the cable or the insulated wire is being damaged, it will cause the intermittency electric arc, and the amplitude of the power frequency overvoltage and the high frequency extinguish arc overvoltage increases to 6-8 times of the phase voltage. This voltage keep a high amplitude and continues long and it will do harm to the equipments even if the system have the overvoltage protective devices. As the reasons above, the systemic research on the arc-grounding overvoltage is important.

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2. Contrast of several neutral grounding practice of minium voltage of distribution network

In un-grounding system, the arc light will be not self-extinguishment when the fault of single-phase grounding happens and capacitance and current of power line is oversize. Stabilizing un-grounding overvoltage is generally 3 to 5 times the phase voltage or even higher. Due to the un-grounding system allows single-phase to run 2h, arc voltage will be run electrical devices in the system long time, it can result short circuit between phases.

In order to prevent arc over-voltage using of two measures: One is changing un-grounding to direct grounding. In single-phase ground, can produce large short-circuit current, although the arc stable burning, but we can cut off the short circuit current with the relay trip, to prevent over-voltage; On the other hand changing un-grounding to arc line grounding which can not only reduce the residual flow, promote rapid self-extinguishing arc, but also prevented renewed and prevent arc over voltage.

Table 1. Comparison on the safety of different up-grounding methods

Grounding methods	Low resistance grounding	Ungrounding	Arc-suppression coil grounding
Single-phase grounding fault current	300～600A	<10A	<10A
Touch voltage and step voltage	Attainability300V	Less than5V	Less than5V
Contact fault danger probability	Large	Largel	Large
Non-contact fault danger probability	Large	Small	Small
Ground-coupled interference	Large	Small	Small

Table 2. Supply characteristic of different up-grounding methods

Grounding methods	Low resistance grounding	Ungrounding	Arc-suppression coil grounding
Permanent fault	Trip	Allow running with fault	Allow running with fault
Transient fault	Poor（Trip）	Good	Good
Alignment	Good	General	Poor
Protection	Good	General	Poor
Supply continuity	Poor	Good	Good

3. Simulation

In this paper, devices and circuits attached a 66kV substation 10kV side bus bar in Jilin province as the simulation model. The system wiring diagram is shown in figure 2. Figure 3 build simulation model based on the figure 2, and Line with distributed parameters module is 10 cable outlet in total. The 66kV high voltage line is instead of a 66kV 3-phase power; the system transformer is applied model[3] in the EMTP model library. The connection wiring is one-triangular of stars; using the grounding transformer to introduce the artificial neutral point; the length of 10 cable line is total of 22.245km.

The parameter is as follows:

Z1= (0.125+j0.095) Ω/km;

Z0= (0.97+j1.590) Ω/km;

positive-sequence recipiency is b0=98.156μs /km; zero-sequence recipiency is b0=98.156μs /km, the length of pole line is 9km，the parameter is Z1=(0.270+j0.351) Ω/km, Z0=(0.475+j1.757)Ω/km, b1=3.267μs/km,b0=1.100μs/km[4].

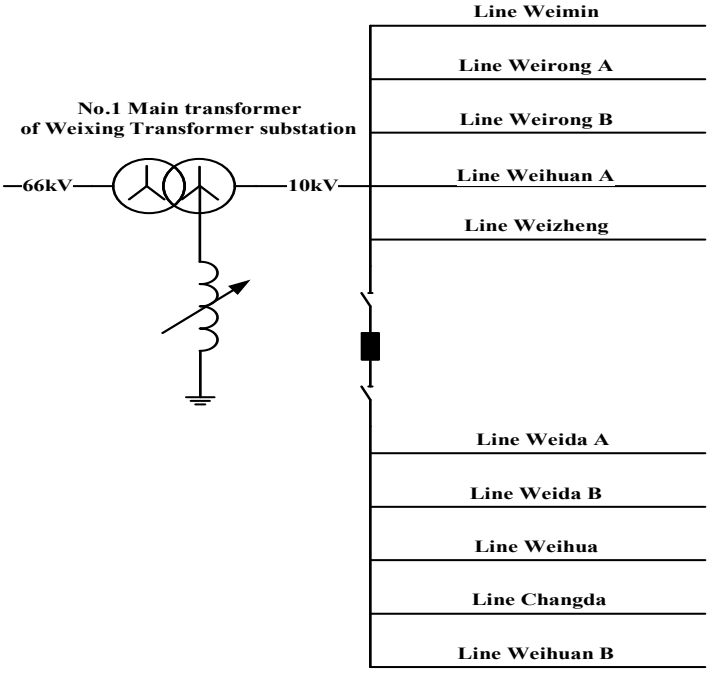


Figure 2 Substation system wiring diagram

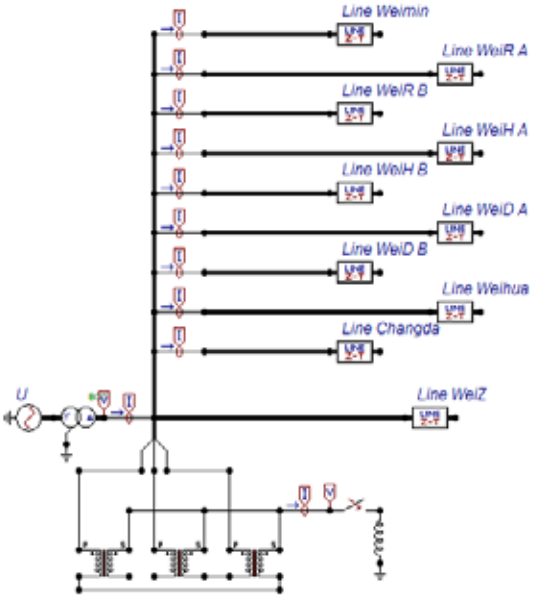
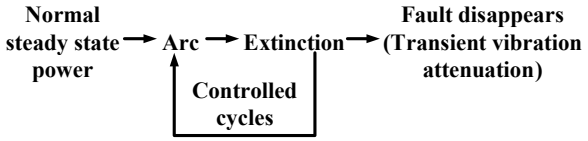


Figure 3. substation simulation wiring diagram

4. Results and analysis

The whole process of simulation for arc voltage grounding which using C relative to extinction-arc and combustion-arc state is as shown in follow.



The extinction-arc conditions conclude Petersen theory and Peters and Slepian theory [1]. When we numerical using rekindle time to put out high-frequency arc extinction theory and the frequency theory.

We calculate the two extinction-arc, Assuming C-phase ground occur fault, when the C-phase supply voltage is peaks, grounding resistance take 5Ω. To the high frequency extinction–arc theory, as the first zero point after short-circuit current after crossing that is the high-frequency current over-zero, and the arc extinguished; the arc renewed in the first voltage of the peak after arc- extinction phase. We select 4 times to simulation calculated. Corresponds to the frequency extinction theory, short-circuit current in the half-frequency waves near the high frequency components have very little attenuation, this time over zero-frequency current that is zero, the arc extinguished; the arc renewed in the first voltage of the peak after extinction-arc phase. We choose 4 times to simulation calculated.

Suppose C phase voltage occurs fault when reaches its maximum instantaneous ground, T = 0.013334S, the time table of the recovery voltage peak and reached the peak of the take on the up-grounding via arc suppression simulation after the first arc grounding in different resonance degree v is as shown in Table 3.

Table 3. The recovery voltage peak and peak time of different resonance degree v

Resonance Degree v	Recovery voltage in High-frequency extinction theory		Recovery voltage of Frequency extinction theory	
	Peak time（S）	Peak（V）	Peak time（S）	Peak（V）
-0.1	0.021643	9103.2932	0.251865	14773.176
-0.05	0.021332	9776.031	0.432002	13119.248
0	0.011667	8587.0945	0.001667	8587.0945
0.05	0.521267	13515.76	0.381357	13362.779
0.1	0.341494	15193.374	0.201304	14959.116

From the table3 we can see that:

(1) The ground fault neutralizer can reduce the recovery voltage peak, slow down the rise speed;

(2) The restoration voltage of arc-suppression coil is minimum when it works in full compensation state, and corresponding peak time is maximum. With the resonance degree of the increase in absolute value, the recovery voltage is increases, and the corresponding peak time is decreased.

(3)From the simulation data of the absolute value of the same degree of resonance can be seen that recovery voltage of over- compensation state is lower than the under-compensation, owed to the state than the peak is low, the corresponding peak time is longer, and The smaller the absolute value of off Degree , the more obvious the difference.

If the arc-suppression coil can be efficiently, when power line occurs single-phase ground fault, the arc will be not renewed, and will not cause a high overvoltage. When the voltage of the fault-phase reaches its maximum in situation, renewed occurs. Considering the limit, we assume that arc still occur renewed after arc-suppression coil effective compensation, the power occur fault of single phase ground. The high-frequency extinguishment–burning arc is 4 times, the number is 2 times.

Figure 6 shown the fault phase recovery voltage waveform when the resonance degree v is 0, and high-frequency arc is 10% to -10%, we can see that the recovery rate of voltage increase is very slow when V=0, and when $v \neq 0$, the recovery voltage present beat nature.

The simulation results shown that up-grounding mode simulation in a very strict condition (not only because of the low rate of line to line leakage damping residual charge less, but also out in the event of high frequency arc, the strict accordance with the high-frequency The first zero arc arc out over the harsh conditions, income has been high over-voltage), occurs the coil does not appear as a result of the phenomenon of the overvoltage caused by the arc-suppression coil is not occurred; using frequency extinction-arc theory calculation and analysis, when the resonance degree is large, the difference is not large by arc-suppression coil grounding system and the up-grounding system.

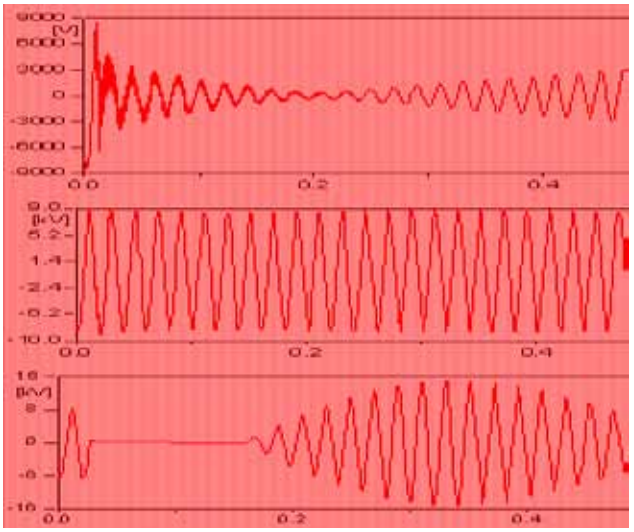


Figure 4. High-frequency restoration of extinction of the fault phase voltage waveform

（a）v=0，（b）v=－10%，（c）v=10%

Figure 5, Figure 6 are each phase voltage and the up-grounding voltage waveform for the resonance degree v =- 10%, respectively, 4 times high-frequency out arcing and 2 times frequency out arcing.

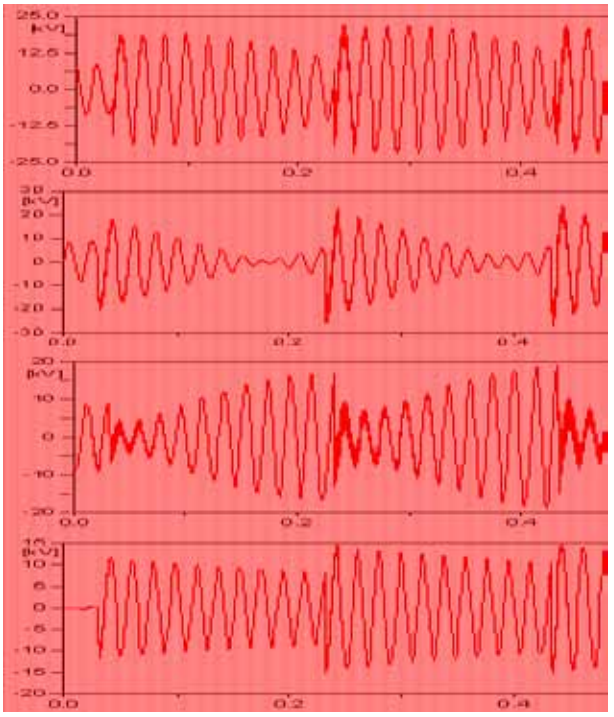


Figure 5. Frequency extinction voltage of each phase and the neutral point voltage waveform

(a) non-fault phase A-phase, (b) non-fault phase B, (c) fault phase C phase, (d) the neutral point voltage

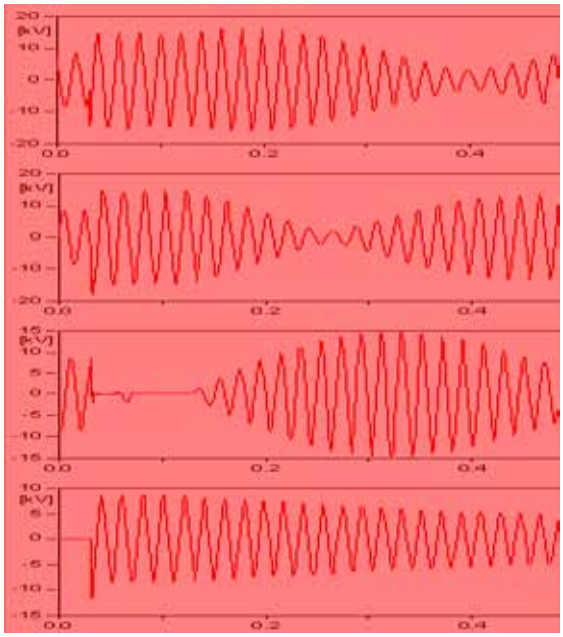


Figure 6. Frequency extinction of each phase voltage and neutral point voltage waveform

(a) non-fault phase A-phase, (b) non-fault phase B, (c) fault phase C phase, (d) the neutral point voltage pressure

5. Conclusion

Through analysis the overvoltage theory and detailed numerical simulation of up-grounded and arc-suppression coil grounding mode shows that the neutral grounding via arc suppression coil grounding can effectively inhibit the arc voltage, and concluding as follows:

(1) up-ground by arc-suppression coil grounding mode coil can reduce the arc voltage amplitude;

(2) the inductor and current of up-ground by arc-suppression coil grounding mode can effective compensate the capacitance and current of grounding, ground residual flow is less than 10A, grounding arc is easy to self-extinguishing; after arc extinguished it can recover the voltage amplitude and initial velocity, and avoid grounding arc renewed, even if ground arc occurs, the voltage amplitude is also greatly reduced;

(3) The arc grounding overvoltage in the up-ground by arc-suppression coil grounding mode is reduced from 2.01pu to 0.97pu.

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