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Analysis of Choice on the Time of Paralleling the Resistance with Arc-suppression Coil

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Abstract: When a single-phase grounding fault occurs in small current grounding system, if the grounding fault is instantaneous, the shunt resistance would not be put into the system and the arc suppression coil can solve the fault by itself; if the grounding fault is permanent, the shunt resistance can be put into the system after a period of time and the shunt resistance can play a important role in line selection and elimination the arc voltage of the neutral point, It relate to the accuracy of line selection that when the shunt resistance are put into the system. This paper mainly focuses on analyzing the choice of time.

Key words: Small current grounding system, single-phase grounding fault, arc suppression coil, neutral point, shunt resistance

INTRODUCTION

When single-phase ground fault occurs in the small current grounding system, the fault current component is so small that the line selection is very difficult. There are many kinds of small current grounding fault line selection methods, but the accuracy of line selection is relatively low (Liu, 2002). Someone put forward using the arc suppression coil with parallel resistance in small current grounding fault line selection methods. Compared with other line selection methods, its main advantage is: when single-phase ground fault occurs, neutral point parallel connection resistor grounding method is able to provide enough power components for line selection and can effectively inhibit recovery voltage of fault phase, to avoid arc renewed (Zhou *et al*., 2003). Giving up parallel connection resistor after selecting the fault line, power grid continues to run under the neutral through Petersen coil grounding mode, to ensure the safe operation of the system.

THEORETICAL ANALYSIS AND FORMULA DEDUCATION

The time of neutral point connecting parallel resistance should abide by the following principles: when the grounding system are in a stable state and absent of transient current, parallel grounding resistance are connected with neutral point. Therefore, it is necessary to analyze the transient transition process of the single phase grounding fault in system.

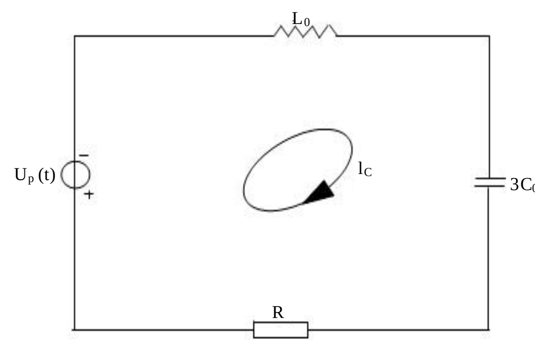

Fig. 1: Equivalent circuit of the transient zero sequence when the single-phase grounding fault occurs in grounding system of neutral point via arc suppression coil

As shown in Fig. 1, it is the equivalent circuits of the transient zero sequence when the single-phase grounding fault occurs in grounding system of neutral point via arc suppression coil. u_p (t) in graph is the equivalent voltage of A phase power; $3C_0$ is the equivalent capacitance to earth of line in the transient zero sequence circuit; L_0 is the inductance of line in the transient zero sequence circuit; R is the equivalent transition resistance in the transient zero sequence circuit.

Depend on Fig. 1, write the following differential equation:

$$Ri_C + L_0\frac{di_C}{dt} + \frac{1}{3C_0}\int_0^t i_C dt = u_p(t)i_c \quad (1)$$

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In the equation:

$$u_p(t) = U_{\varphi m}\sin(\omega t + \varphi)$$

$U_{\varphi m}$-the phase voltage amplitude when System run normally.

φ-the initial phase angle of voltage of the fault phase?

Making the Laplace transform for Eq. 1 with the initial conditions in which when t = 0, i_c = 0 and u_0 = 0, we can get:

$$RI_C(s) + sL_0 I_C(s) + \frac{1}{s3C_0} I_C(s) = U_p(s) \tag{2}$$

In the last equation:

$$U_p(s) = L\left[u_p(t)\right] = U_{\varphi m}(\cos\varphi \frac{\omega}{s^2+\omega^2} + \sin\varphi \frac{s}{s^2+\omega^2})$$

Equation 2 can be changed as follows:

$$I_C(s) = \frac{U(s)}{R + sL_0 + \frac{1}{s3C_0}} \tag{3}$$

When:

$$R < 2\sqrt{\frac{L_0}{3C_0}}$$

the transient process of capacitive current in the system have characteristics of periodic oscillation and attenuation.

Let:

$$\omega_0 = \sqrt{\frac{1}{3L_0C_0}}, \delta = \frac{R}{2L_0}$$

And:

$$w_f = \sqrt{\omega_0^2 - \delta^2} = \sqrt{\frac{1}{L_0 3C_0} - \left(\frac{R}{2L_0}\right)^2}$$

inserti-ng these into Eq. 3,we can get:

$$I_C(s) = \frac{1}{L_0}\frac{sU(s)}{(s+\delta)^2 + w_f^2} \tag{4}$$

Making Laplace transform for formula (4),we can get:

$$i_C = I_{Cm}[(\frac{\omega_f}{\omega}\sin\varphi\sin\omega_f t - \cos\varphi\cos\omega_f t)e^{-\delta t} + \cos(\omega t + \varphi)] \tag{5}$$

In the equation:

$I_{Cm} = U_{\varphi m}3\omega C_0$ the amplitude of steady-state capacitive current

w_f-the angular frequency of transient free oscillation component

$$\delta = \frac{1}{T_C} = \frac{R}{2L_0}$$

the attenuation coefficient of free oscillation component, in which T_c is the time constant of loop.

The front part of Eq. 5 is the transient free oscillation component of zero sequence capacitive current in the system:

$$i_C'' = \left(\frac{\omega_f}{\omega}\sin\varphi\sin\omega_f t - \cos\varphi\cos\omega_f t\right)e^{-\delta t} \tag{6}$$

The later part of Eq. 5 is the steady-state power frequency component of zero sequence capacitive current in the system:

$$i_C' = I_{Cm}\cos(\omega t + \varphi) \tag{7}$$

It can be seen that the capacitive component i_c of zero sequence current in the system is made up by the transient free oscillation component and steady-state power frequency component and i_C'' determines the transient process of attenuation of i_c.

Studies show that when a single-phase grounding fault occurs in small current grounding system, the voltage of fault phase is close to the maximum moment; the transient capacitive current in system is the maximum. So plugging $\varphi = \pi/2$ in the Eq. 6, we can get the capacitive current $i_{C.max}''$ of transient zero sequence of maximum amplitude of i_C'' :

$$i_{C.max}'' = I_{Cm}\frac{\omega_f}{\omega}e^{-\frac{T_f}{4T_C}} \tag{8}$$

When t = T_f/4 (when $T_f = 2\pi/\omega_f$, it is free oscillation cycle), the transient capacitance current also can appear maximum:

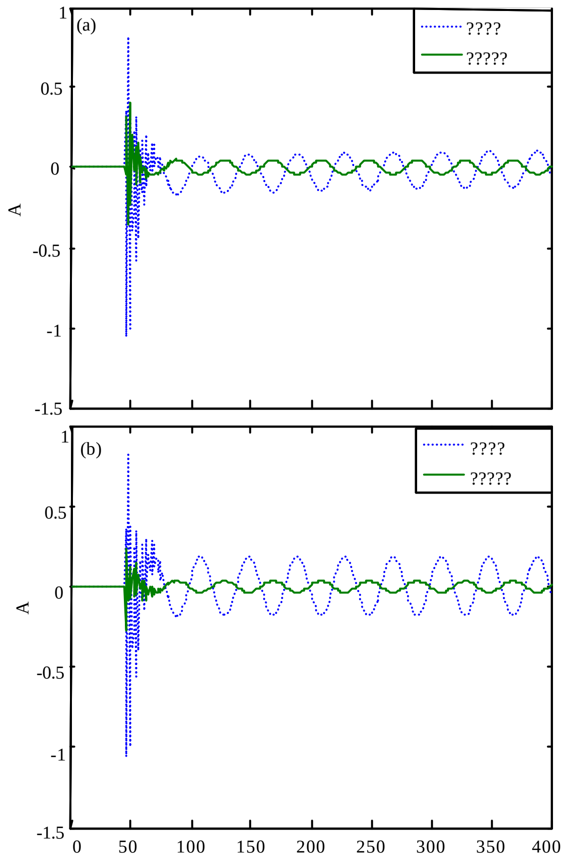

Fig. 2(a-b): Transient zero sequence current of single-phase grounded fault of metallicity, (a) Isolated neutral system and (b) Neutral grounded system though arc suppression coil

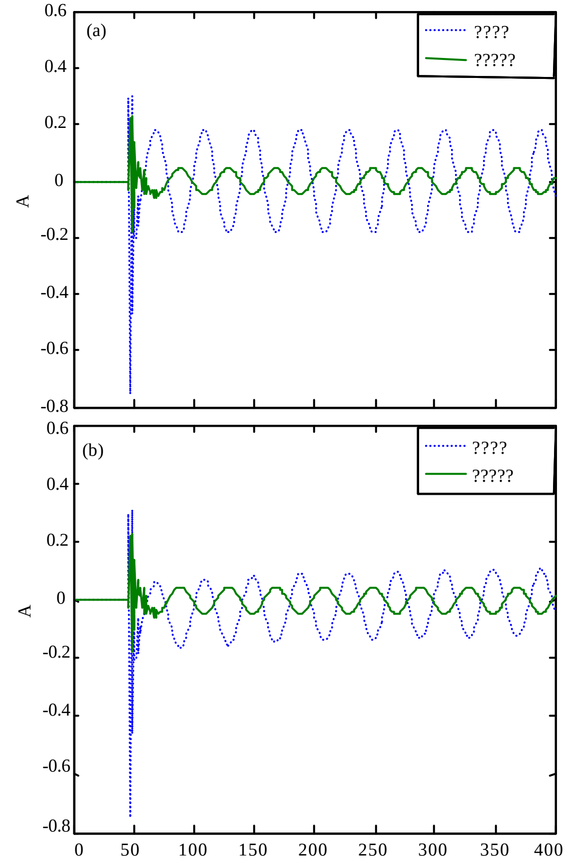

Fig. 3(a-b): Transient current of the zero sequence of the small current grounding fault with transition resistance, Isolated neutral and (b) Neutral grounded

$$i''_{C.max} = I_{Cm}\frac{\omega_f}{\omega} e^{-\frac{T_f}{4T_c}}$$

SIMULATION VALIDATION AND DATA THEORETICAL ROCESSING

The decay rate over time of transient free oscillation component i''_c of system depends on the attenuation coefficient δ.

What are shown in the Fig. 2 and 3 are, respectively the waveform of transient zero sequence current when single-phase grounding fault occurs in the small current grounding system.

By Fig. 2 and 3, you can see that, the zero sequence transient current of system can finish attenuation basically within 1~2 cycles after the single-phase grounding. Usually, because of the zero-sequence inductance value of line is very small, but when single-phase grounding fault occurs , the line often exist transition resistance, so the value of attenuation coefficient of the free oscillation component δ is compared commonly big. the attenuation time constant $T_C = 1/\delta = 2L_0/R$ of transient capacitance current of grounding loop is commonly: 0.1~5 m sec when single-phase grounding fault occurs. So the above conclusion is proved, namely the zero sequence transient current of system can finish attenuation basically within 1~2 cycle after single-phase grounding fault occurs in the system. The bigger is the value of the transition resistance, the faster is the attenuation of system zero sequence transient current of system. Therefore, it can be concluded that when the single-phase grounding fault occurs in system, parallel resistor should be connected with neutral point after the fault of two power frequency cycles. The fault line selection of system can basically not affected by transient process of the grounding fault and we can get the best result of line selection at that time.

CONCLUSION

This study analyze the fault line selection method of small current grounding of paralleling arc suppression coil with resistance through a lot of theoretical analysis, formula deduction and simulation validation, data processing and get the conclusion: when the single-phase grounding fault occurs in system, parallel resistor should be connected with neutral point after the fault of two power frequency cycles. The fault line selection of system can basically not affected by transient process of the grounding fault and we can get the best result of line selection at that time.

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