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Influence of Arc-earthing Over-voltage When Paralleling The Arc-extinguishing Coil with a Resistance to Earth

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Abstract: When the single-phase ground fault occurs in the small current grounding system and grounding current extinguishes after zero out, high voltage will be produced as the recovery voltage more than dielectric insulation strength recovery. After the arc suppression coil is connected to neural point, on the one hand, the single phase grounding capacitive current can be compensated by arc suppression coil inductance current, grounding residual current was decreased; on the other hand, the speed of recovery voltage can be reduced a lot and it is helpful to extinction of fault arc. This study makes certain analysis on the influence of the arc over-voltage when the neutral point is connected to the resistor.

Key words: Small current grounding system, single phase ground fault, arc suppression coil, connected resistance, arc over-voltage

INTRODUCTION

Among the Low voltage distribution network system of China, the neutral of system is generally indirectly grounded. When the Single-phase ground fault occurs, the current flowing through the ground points is small and the arc of fault point can self extinguish. As a result, this system is named as small current neutral grounding system (Yao and Cao, 2000). It contains Non-ground neutral system, arc-suppression-coil-ground neutral systemand resistance-ground neutral system. When the single-phase ground fault occurs in small current neutral grounding system, the current is small and the phase to phase voltage is still symmetrical.

So the system is allowed to run for 1-2: Hours without tripping under the general condition. This is the significant advantage of small current neutral grounding system (Ma and Zhang, 2003).

But line selection and small current mode especially the resonance grounding have contradictory requirements on grounding current. Small current mode demands more small current to extinguish arc. Line selection needs bigger current to project fault characteristic and to select line accurately (Qi and Yang, 2002). In small current neutral grounding system, on one hand the fault signal using for selecting line is weak and it is hard for collection. On the other hand, the distribution between zero-sequen ce current of fault line and the fault current of normal line distribution are close to accordance and it makes fault signature not obvious. The selecting equipment is hard to select line for reasons mentioned above.

At present, there is no method to select the fault line completely (Li, 2000). So fault line selection based on small current has been a focus in electrical field. In recent years, selecting line has set off an upsurge to study.

Under this background, some scholars proposed a parallel resistor small current grounding fault line selection method, comparing to the other line selection, its advantage is mainly manifested in: the resistance grounded neutral parallel can effectively suppress resonance over-voltage when the power grid is running normal. The neutral point parallel resistance grounding method for line selection can provide active component and can effectively inhibit the failure recovery voltage to avoid reignition when single-phase ground fault occurs in power grid (Ceng *et al*., 2000). After the fault line has been selected, the parallel resistance can be removed and the grounding arc suppression coil can still compensate the capacitive current for electric grid.

ARC GROUNDING OVERVOLTAGE

Neutral grounding modes In China include the directly to ground of the neutral point, the by the arc suppression coil grounding and the neutral point f the neutral point does not be grounded

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(the neutral point insulation) three kinds. Overvoltage caused by Single-phase arc grounding mainly occurred in the ungrounded power grid. With the increasing of the line length and the operating voltage, single-phase ground-ing current is becoming bigger and the arc grounding fault cannot be self-extinguish. Meanwhile, stable arc can not be produced as the grounding current is not large. As a result, an unstable situation that arc extinction altering with arc reignition will appear. This arc process with intermittence leads to rapidly change of power grid and strong oscillations of electromagnetic energy (Li, 1993). Non-fault phase produce a overvoltage of transient process and this voltage is called Arc grounding overvoltage.

SUPPRESSION ON ARC GROUNDING OVER VOLTAGE WHEN NEUTRAL GROUNDED THOUGHA RESISTANCE

When single-phase ground fault occurs in small current grounding system and the grounding current extinguishes by crossing zero, recovery voltage is bigger than the recovery value of insulation, repeat breakdown can be produced and it causes overvoltage (Li, 2006). After the arc suppression coil has been connected, on one hand, single phase grounding capacitive current can be compensated by inductive current coming from arc suppression coil to reduce residual grounding current. On the other hand, the decrease of speed of recovery voltage will be helpful to extinguish the arc (Liu, 2002). The next part will do some analysis on the influence of arc grounding overvoltage when the neutral point connected to the resistor.

Whether the arc of fault point reignites or not, in addition to the arc current, it depends on whether the recovery speed of insulating strength of arc gap exceeds the rising speed of recovery voltage or not. In Fig. 1, point a, b mean the arc gap. Arc can extinguish when the current is crossing zero. Arc extinguishing is the equal of the disconnection of switch K (Chen *et al*., 2004). The Fig. has ignored the loss of arc suppression coil and the insulation resistance of grid.

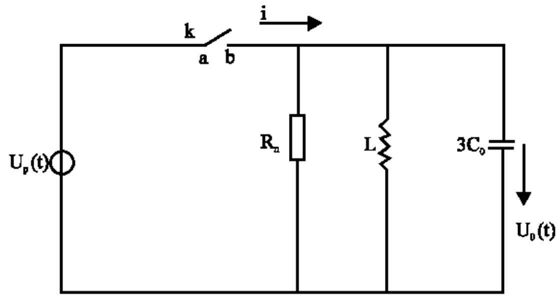

Fig. 1: Equivalent circuit of Single-phase arc grounding of Arc suppression coil grounding system

Voltage between point α and point b is the recovery voltage u_h (t) of fault phase (A phase), Electric potential of point b is the potential of neutral point u_0 (t) of compensated grid (Sun Fusheng, 2010). Assume that when the arc extinguish, the initial phase angle of A isφ, the maximum value of supply voltage is $U_{\phi m}$, then we have:

$$u_p(t) = U_{\varphi m} e^{j(wt+\phi)} \quad (1)$$

The change law of the voltage of point b is a oscillating and damping process. The voltage is:

$$u_L(t) = -U_{\varphi m} e^{-\delta t} e^{j(w_0 t+\phi)} \quad (2)$$

Recovery voltage is:

$$u_h(t) = U_{\varphi m}\left[e^{j(wt+\phi)} - e^{-\delta t} e^{j(wt+\phi)}\right] \quad (3)$$

Simplify the Eq. 2-3, we can get:

$$u_0(t) = -U_{\phi m} \cos(\omega_0 t + \varphi) \quad (4)$$

$$u_h(t) = U_{\phi m} \cos(\omega t + \varphi) - U_{\phi m} e^{-\delta t} \cos(\omega_0 t + \varphi) \quad (5)$$

In the equation: $U_{\phi m}$ Amplitude of power supply φ initial phase angle of power supply which is the fault phase δ attenuation coefficient of the power system $\delta = 1/6R_nC_0$

Setting the damping ratio: $d = 1/3\omega R_nC_0$

And then δ is given by: $\delta = \omega d/2$ We can get ω_0 according to the Eq. of off tuning degree $v = 1\text{-}1/3\omega^2 LC_0$ ω_0 can be expressed as:

$$\omega_0 = \omega\sqrt{1-v_0}$$

As the off tuning degree v is small, so it can be inferred that:

$$\begin{aligned}\omega_0 &= \omega\sqrt{1-v_0} \\ &= \omega\left(1 - \frac{1}{2}v + \frac{1}{2\times 4}v^2 - \frac{1\times 3}{2\times 4\times 6}v^3 + \ldots\right) \\ &= \omega\left(1 - \frac{1}{2}v\right)\end{aligned}$$

The Equation 4 can be changed as follows:

$$u_h(t) = U_{\phi m}\left[\cos(\omega t+\varphi) - e^{-d\omega t/2}\cos(\omega t - \frac{1}{2}v\omega t+\varphi)\right] \quad (6)$$

If the Arc suppression coil grounding system is full compensated, just as v = 0, the u_h (t) is:

$$u_h(t) = U_{\phi m}(1-e^{-d\omega t/2})\cos(\omega t+\varphi) \quad (7)$$

At this moment, due to the influence of parallel resistor of neutral point , the electric potential of neutral point is decreasing and the recovery voltage of fault phase is increasing until it reaches the initial phase voltage.

As the two frequency of the Eq. 6 is different, when the power system is running at a state of overcompensation or undercompensation, where v>0 orv<0, the recovery voltage of fault phase will present a nature of beat-frequency and the regular frequency of beat-frequency is W-W∩ .

It also can be seen that as the connecting of grounding resistance R_n to the neutral point, damping ratio of the grid increase a little. The rising speed of recovery voltage belonging to fault phase is slow comparing with arc suppression coil grounding and neutral non-grounding. That is good for arc extinguishing. Adapt the Eq. 7 to the plural form and just take the real part, we can get:

$$u_h(t) = \mathrm{Re}\left[U_{\phi m}e^{j(\omega t+\varphi)}(1-e^{-(d+jv)\omega t/2})\right] \quad (8)$$

The part in brackets of the Eq. 7 multiplied by the corresponding conjugate and then takes its real part to extract a root u_{hb}:

$$u_{hb}(t) = U_{\phi m}\left[1+e^{-d\omega t} - 2e^{-d\omega t/2}\cos(v\omega t/2)\right]^{1/2} \quad (9)$$

Suppose that v/d = k, we can change Eq. 9 into:

$$\left(\frac{u_{hb}(t)}{U_{\phi m}}\right)^2 = 1+e^{-d\omega t} - 2e^{-d\omega t/2}\cos(v\omega t/2) \quad (10)$$

In terms of v/d = k and Eq. 10, we can make envelope of recovery voltage of fault phase by using Matlab. The envelope is shown in Fig. envelope with different K values when single-phase ground fault occured.

We can derive from fig. 2 that: In the small current grounding system, while the off tuning degree v of this system is a certain value, the damping ratio of grounding system is larger and the corresponding value of K is smaller, the smaller K leads to a slower rising speed of amplitude of u_{hb} (t) and it is benefit for extinguish of Residual voltage of grounding point.

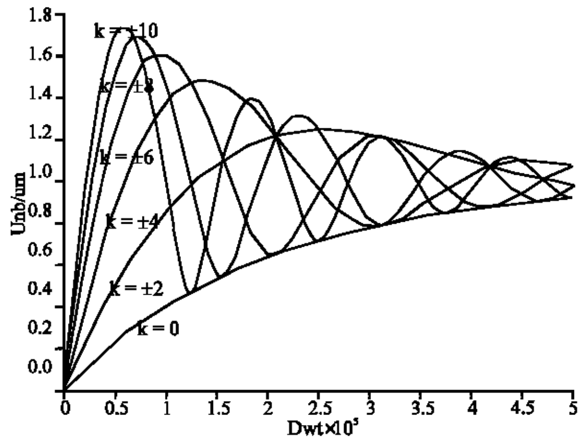

Fig. 2: Faulted phase recovery voltage

Researchers have shown that not all residual arc of grounding point will extinguish when the current cross zero at its first time. Sometimes the residual arc exits for a period of time. For the neutral grounded through arc suppression coil, as the smaller damping ratio and slower attenuation of neutral voltage, through a half cycle of beat vibration $\pi/(\omega-\omega_0)$ after arc extinguished, repeating breakdown will happen again when the amplitude of recovery voltage reach its maximum. The overvoltage produced accordingly.

CONCLUSION

It can be inferred from the above analysis that the effect of arc-suppression coil is not to reduce arc grounding overvoltage but to make it easy to extinguish arc and to prevent reignition. As the existing of arc-suppression coil, times of arc reignition has been reduced and the continuous time of overvoltage has been shortened. The chance of high multitude overvoltage has been lowed.

After the neutral point connected to paralleling grounding resistance, corresponding to decreasing value of K in Fig. (2), the increasing damping ratio d accelerates decay rate of neutral point potential and it reduces the rising speed and the amplitude of recovery voltage. All of these contribute to reduce the chance of repeating breakdown. Even the recovery voltage reaches its maximum and the breakdown has happened, the value of voltage would decrease a little.

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