PSCAD simulation study on the distribution network voltage transformer failure

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Abstract: In the distribution network, the single phase grounding fault of potential transformer (PT) caused by burning phenomena occur. PT transient characteristics of the primary side current, On the basis of single-phase grounding fault and the equivalent model simulate PT transient characteristics of the primary side current. The main causes of PT failure are deduced for distribution network single-phase ground capacitor current value caused by a larger. The simulation of a group of 6kV PT by using power system simulation software PSCAD/EMTDC, and the comparison of the three solutions: the PT of one side through the non-linear resistor (harmonic elimination device), Open triangle parallel resistance and the system neutral grounding via arc suppression coil. Finally obtains that the neutral point through the arc suppression coil grounding is the most the right way to solve this problem in the distribution network.

Introduction

The 6/10kv distribution network is one of neutral point ungrounded system, bus mounted electromagnetic voltage transformer are Y0/Y0 open delta connection. When the system single-phase grounding, will cause Blown fuse o the high side bus PT, or even burned phenomenon PT. Because most of the PT failure after a single-phase ground fault disappears, field technicians habitually think happened PT ferromagnetic resonance. In this paper, the equivalent model grid single-phase ground fault disappears before and after analysis of the transient characteristics of PT primary current, pointing out the main factors which leading to the distribution network failure of PT. The single phase to ground fault simulation model has been improved, with PSCAD/EMTDC in three to single-phase custom V-I characteristic curve of volume three UMEC (Unified Magnetic Equivalent Circuit) module and the three single-phase transformers module, respectively, simulation 6kV bus PT actual operation of the transformer and the ground, the actual operation situation makes the model can to reflect more accurately the power grid. At the same time, further simulation comparison of PT primary side through nonlinear resistance grounding, open delta and resistance and the neutral grounding via arc suppression coil three solutions, choose the most suitable for the actual situation of distribution network in solving measures.

The analysis of the bus PT failure reason

The 6/10kv distribution network is neutral point ungrounded system, so the high voltage side of the neutral point grounding busbar PT becomes the only place the entire 6kV grid. System of single-phase ground fault process can be divided into single-phase ground stabilization and ground fault disappears in two stages. Firstly, the first phase, to facilitate analysis, assuming that the single-phase grounding fault phase occures metallic grounding. Non-fault B, C phase voltage rises to the line voltage, the ground capacitance C0 will be charged and at the same time the electric charge of this portion of the capacitive current generated by the power supply and the ground form a loop. Because magnetizing impedance PT is large, the current value flowing high-voltage side winding at that time is very small, PT at this stage is generally not high pressure side fuse failure.

When the second phase of the single-phase ground fault disappears, Non-fault phase recovery phase from line voltage to normal voltage level. However, due to the elimination of the fault, cutting off the passage of charge to earth ground, at this relatively non-fault stored charge capacitance constitute only released to the earth through the primary side of the neutral point PT(as shown in Figure 1 from one phase analysis).Therefore, the current single-phase ground fault disappears after PT primary side should consist of two parts: system power production into non-mandatory components and charge decay through PT neutral point discharge formation decay component.

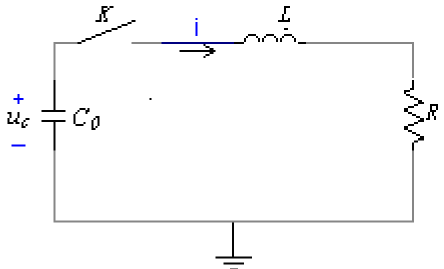

Figure 1 charge discharge circuit after single-phase grounding fault disappears

The single-phase grounding fault elimination of closing the switch can be arranged from the figure 1:

$$LC_0\frac{d^2u_c}{dt^2}+RC_0\frac{du_c}{dt}+u_c=0 \tag{1}$$

$$i=-C_0\frac{du_c}{dt} \tag{2}$$

$$u_c(0_+)=u_c(0_-)=U_k \tag{3}$$

$$i_c(0_+)=i_c(0_-)=0 \tag{4}$$

U_k is the capacitor voltage When single-phase ground fault elimination. Because $R<2\sqrt{L/C_0}$,

Solution of equation (1) is $u_c=\frac{U_k\omega_0}{\omega}e^{-\delta t}\sin(\omega t+\arctan\frac{\omega}{\delta})$

In the formula:

$$\delta=R/2L$$

$$\omega_0=\sqrt{1/LC}$$

$$\omega = \sqrt{\omega_0^{\ 2} - \delta^2}$$

According to equation (2) $i = \frac{U_k}{\omega L} e^{-\delta t} \sin(\omega t)$

From equation (4) shows the amplitude of current I high side PT is mainly concerned with. When ground capacitance value of the system is larger, the smaller the free oscillation frequency, the greater its corresponding current amplitude, while the low-frequency oscillations under the current role of PT's core will quickly saturate the excitation current increases rapidly, then the high-pressure side of the blown fuse can cause severe winding insulation will endanger the PT. Similarly when the capacitance value C0 is very small, although it will also lead to an oscillating current, but this time it is much higher, free-running currents have much smaller, but Peterson resonance condition C0 is small, the system may occur in accordance with the fundamental frequency , crossover and high frequency resonance. However, combined with the actual situation of coal production - ground and underground cables are powered by multiple mines capacitive current test, the value of up 90A, also the smallest 35A, away from the resonance parameters Peterson conditions, it is considered low-saturated over-current is the main factor causing mine PT grid failure.

Voltage value	Current value	Voltage value	Current value
0.557	0.600	1.501	3.067
0.866	0.867	1.631	4.387
1.000	1.000	1.732	6.000
1.097	1.207	1.847	8.667
1.212	1.540	1.905	10.20

Table 1 PT V-I characteristic parameters

Note: The values in Table 1 are the unit value, the voltage reference value is $6000/\sqrt{3}V$, the current reference value is 1.5mA.

Build simulation models and simulation calculations

Actually the transient after single-phase ground fault eliminated is very complex, and is generate din the three-phase circuit, and if it is converted into a single-phase circuit to analysis, it will actually produce some differences. Therefore, this paper using common international power system analysis software PSCAD/EMTDC, it carried out a detailed simulation analysis of the whole process of single-phase ground fault and measures to eliminate faulty PT.

Establish bus PT model

As noted above in the role of the low-frequency oscillating current, the inductance of PT has a sharp decline, so the field characteristic of PT have a direct impact on its failure occurred. In the previous simulation analysis, we usually use nonlinear inductance in series with a resistor to simulate the high-voltage side coils of PT, but ignores the iron loss and leakage reactance PT itself, making the simulation error is large. We can use three custom V-I characteristic single-phase three-volume UMEC (Unified Magnetic Equivalent Circuit) module in PSCAD to simulate actual running 6kv bus PT (Fig. 2) In this article, rxis the harmonic resistance values in the high-pressure side of neutral point [4].In the process Simulation, we measured zero sequence voltage at the opening of the triangle (N, L) from the model, it will be more efficient, more accurate to simulate the operating characteristics of the bus PT. The V-I characteristic parameters of UMEC Module are the measured data of JDZJ-6-type voltage transformer. (Table1).

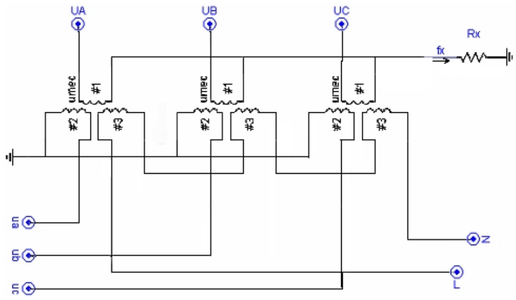

Figure 2 bus PT simulation model

Establish grounding transformer model

The distribution network of 6/10 kV is small current neutral grounding system, the reason of which is that the side of 6/10Kv is delta connection, as a result, there is no neutral point connected by Petersen coil, therefore, an artificial neutral point made of special grounding transformer should be applied to connect Petersen coil. The connection mode of grounding transformer is Zn,yn11, y side load of grounding transformer is not considered in this paper, three single-phase transformers is packed to form a grounding transformer of 400KVA in PSCAD.（As shown in Figure 3）

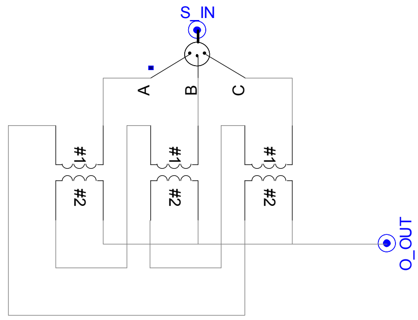

Figure 3 grounding transformer model

Simulation

Taking a 6 /10kv distribution network ungrounded power grid model, PT high voltage side of the neutral point directly to ground, assuming that the system under normal operating conditions, 0.2SA phase single-phase ground fault occurs, the transition resistance of 50Ω, after the failure to eliminate persistent 0.2S, this process of zero-sequence voltage and high-voltage side of the excitation current PT simulation analysis.

Equivalent model of the system is shown in the Figure 4，Which 110kV power through a Yd, 11 connected to the wiring of the main transformer 6kV bus, each cable outlet bus with centralized parameter indicates，By setting the ground capacitance value of each outlet, and then change the current system capacitance to ground zero sequence reactance, through the test of capacitive current, the measured mine 6kv power single-phase ground is about 60 A, the system ground capacitance value of about 17μF.In the figure, G_T ground transformers, bus PT open delta switch in parallel by the resistance of the resistor 2Ω.

In simulation solutions, this paper respectively: ①PT the primary harmonic elimination by grounding; ②PT open delta paralleled resistance; ③ neutral point arc suppression coil grounded three solutions were simulated and compared, to find a solution mine grid the best way for this problem.

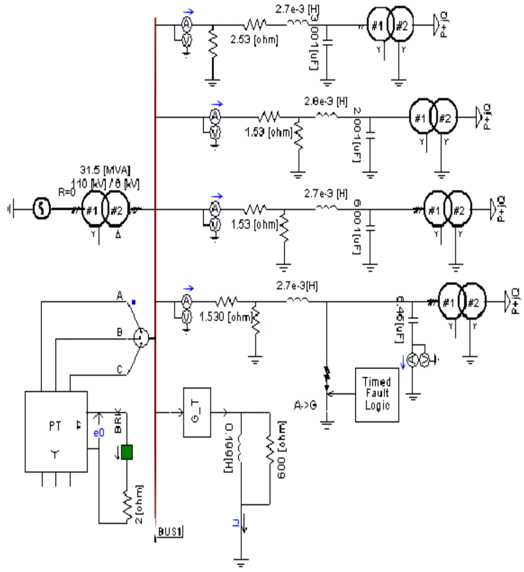

Figure 4 distribution system simulation

The simulation results and analysis

Analysis of simulation results

When the bus arc suppression coil is not put into operation, After 0.4 seconds ,single phase- to -earth fault vanishes and the excitation current waveform of the faulted phase PT、fault phase voltage waveform and zero-sequence voltage waveform at that moment are showed In Figure5, It can be seen that when the fault disappears the faulty phase voltage waveform is superposed by supply voltage components and zero-sequence voltage component [3.11]，and the zero-sequence voltage frequency is about 2.2Hz , Under the action of this voltage , PT core reaches capacity quickly and high side excitation current's Maximum peak reaches to 1A , phase voltage level is high and fall time is long.

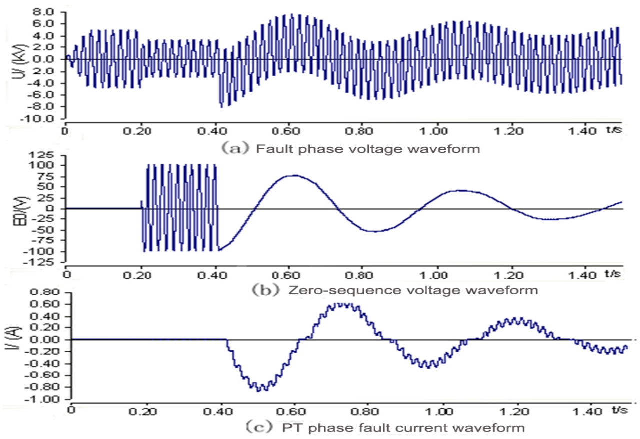

Figure 5 single-phase ground fault simulation waveforms

Analysis and comparison of the effect of three kinds of solutions

PT high side series nonlinear resistance (Resonance eliminator)

Neutral series nonlinear resistance equivalent to increase of the resistance of the resistor in Figure1, When the single-phase grounding fault disappear, The low-frequency saturation current component flows into the earth through resistor , resistor undertakes the bulk of the voltage drop, Greatly limits the low-frequency Saturated over current. When the discharge circuit in figure1 is in over damped state, Low frequency oscillation process turn into a non oscillatory discharge process[3-9]. Figure6 show the fault phase voltage of bus、the high-pressure side of the excitation current waveform of PT after PT primary side of the neutral point connects nonlinear resistor，it can be seen that the PT Saturated over current and overvoltage are suppressed well, but recovery time of phase voltage is too long.

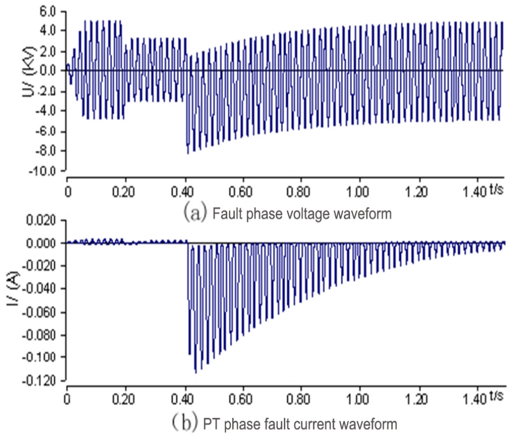

Figure 6 PT primary side of the neutral point connects nonlinear resistor

At the same time there are some drawbacks to cascade non-linear resistor: Firstly , if the quality of nonlinear resistor is poor, Although it is possible to suppress saturation overcurrent better by larger Resistance, but it also let PT open delta zero-sequence voltage value become too small, Thus affecting the operation of selecting device, the situation happened in Jincheng Mining to install line selection device; Secondly, when single-phase ground fault is eliminated the current flows through the non-linear resistor is great, resistance heat capacity is also an important issue.

PT secondary-side shunt resistor

PT secondary-side shunt resistor, equivalent the high-voltage winding PT parallel resistance, the main purpose is to suppress the occurrence of resonance. Such existing devices are mostly based on detect the different frequency components in the zero-sequence voltage, to determine whether the system occurs a single-phase ground fault or resonance failure, if the judgment is resonant fault we should control the resistance input, such a judgment process will make resistance into a certain delay [5], As shown in figure 7, assuming when the ground fault is eliminated after 0.1s, parallel a 2Ω resistor in the opening triangle the fault phase voltage and PT high-voltage side of the excitation current waveform.

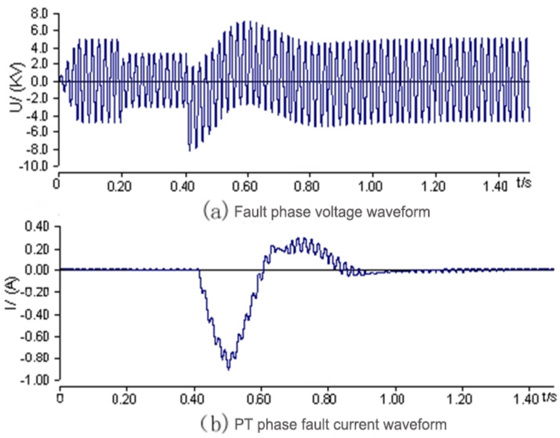

Figure 7 the way of PT secondary-side shunt resistor

It can be seen from Figure 7 that even after input the resistor, there also be about a half cycle (0.1s) low-frequency overcurrent. At the same time, a current Presence (I peak current for 27A and for 0.5 seconds) at the open delta current open delta.

The system neutral grounding via arc suppression coil

Petersen coil capacity is large, and the impedance is much smaller than the PT field excitation impedance of the inductor, It is equivalent to the high voltage side coil PT is temporarily shorted after Single-phase ground fault is eliminated. Low-saturation current constitute loop by Petersen coil and earth. So as not to cause a PT due to excessive current caused by high voltage side fuse or itself burnt phenomenon. Also Petersen coil can also be compensated single-phase ground capacitive current time. Figure 8 the arc suppression coil is in the state of overcompensation. Figure 8 Petersen coil in overcompensation state, off Degree of 6.28%, the inductance value 0.199H, parallel resistance is 600Ω, fault phase voltage and high-voltage side excitation current waveform after the failure to eliminate.

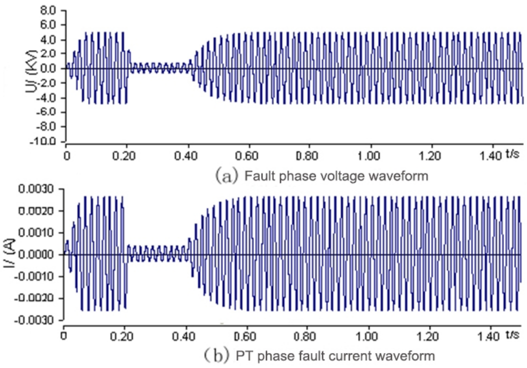

Figure 8 the system neutral grounding via arc suppression coil method

Conclusion

We made a detailed simulation analysis on the PT failure which is caused by failure elimination of6 /10kv distribution network single-phase ground fault and solving measures by PSCAD / EMTDC, simulation results can be drawn from 6 / 10kv distribution grid PT failures caused by a single-phase ground mainly by the failure to eliminate low frequency after overcurrent caused. Using secondary-side shunt resistor method can not be resolved by the elimination of single-phase ground fault overcurrent caused PT saturation problems, priority should be using the system neutral point arc suppression coil grounding.

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