Simulation and Research of Non-effectively Grounding Network of Single-phase Ground-fault

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Abstract. When the non-effectively grounding network of single-phase ground fault happens, the voltage, the current, the zero-sequence voltage and the zero-sequence current have a special change and this problem has been the focus of research attention. Subsequently, it has important effect about the analysis of power system fault characteristics and choice of protection scheme to modeling system of single-phase fault for little grounding current network and to use the zero sequence current amplitude and phase of identifying the fault line and fault phase based on MATLAB software platform in this paper.

Keywords: Non-effectively; grounding; network; single-phase-to-ground fault; MATLAB; zero-sequence current.

1. Introduction
In the little current system which its neutral is not non-effectively grounding, the voltage of fault phase will rise, not to select the fault circuit quickly and removal of a threat to the safe and stable operation of power grid equipment with the single-phase fault occurs. At the same time, with the change of power grid structure complexity and distributed power supply connected to the distribution network, the rapid development of technology and digital distribution network automation system, all these have put forward higher standards and strict requirements to the small current system, and it has always been the focus of researchers.

2. The Methods of Simulation to Non-effectively Grounding Network

2.1. The Simulation Model and Theoretical Analysis of Isolated Neutral System
Use MATLAB/Simulink software to build a simulation model of isolated neutral system, as FIG.1, “Three-phase source” used for the power source, the three phase source is 37KV, the frequency is 50Hz, the interior is Y connecting[1]. The transmission is L1 to L4, all of them use the “PI Section Line”. The line’s length is 1Km, 200Km, 120Km, 165Km. The other parameter:
Positive sequence resistance is $0.01273\, \Omega/\text{km}$, the positive inductance reactance is $0.9337 \times 10^{-3}\, \text{H/\text{km}}$, the positive capacitive impedance is $12.74 \times 10^{-6}\, \text{F/\text{km}}$, the backward resistance is $0.3846\, \Omega/\text{km}$, the backward inductance reactance is $4.1264 \times 10^{-3}\, \text{H/\text{km}}$, the backward capacitive impedance is $7.751 \times 10^{-6}\, \text{F/\text{km}}$.
The Lord1, Lord2, Lord3, Lord4 all use the “Three-phase Series RLC Lord”, the active lord is 3MW, 0.5MW, 6MW, 2MW, The other lord parameter: the line-to-line voltage is 37kV, the frequency is 50Hz.
We select the coiling out 1Km of first line which is C phase grounded (grounding resistance can be ignored) \cite{2,3}.

According to the setting parameter above and calculation, when it is C phase metallic grounded, the beginning zero sequence current’s effective value of each line

\[
3I_{04} = 3U_{0} \omega C_{04} = 3 \times (37 / \sqrt{3}) \times 10^{3} \times 314 \times 7.751 \times 10^{-9} \times 165 A = 25.74 A
\]

**Figure 1.** The simulating model of 3 5KV isolated neutral system

The same can be

\[
3I_{03} = 18.72 A \quad 3I_{01} = 3I_{03} + 3I_{04} = 44.46 A
\]

The ground point current is

\[
I_{D} = 75.80 A
\]

2.2. **The Simulation and Theoretical Analysis of Neutral Arc-suppression Coil System**

On the basis of Fig.1, add an inductance coil to neutral power source, the other parameter doesn’t change, showing as in Fig.2 \cite{4}.

**Figure 2.** The simulating model of neutral arc-suppression system
If we want to make the ground current to be similar to zero (compensation), it should be met

\[ C_Z = 3.767 \times 10^{-6} F \]

In the formula, \( L \) is the induction of blow-out coil; \( C_Z \) is system’s three-phase capacity grounding. If it is going to be compensation, it should be

\[ L = 0.8975 H \]

It is possible to have the problem of acceptor resonance over-voltage in. Compensation and under-compensation, in practical application [5]. It used to be over-compensation and its degree is nearly 10 percent, and the blow-out coil’s inductance is

\[ L = 0.8159 H \]

3. The Analysis of Simulation Result

The simulation time is set to be 0.5s, select Odel5s algorithm, use Power grid to set the sampling time is \( 1 \times 10^{-6} s \), it is going to be C-phase grounding when the system runs 0.1 s (grounding resistance can ignore).

3.1. The Simulation Result and Theoretical Analysis of Insulated System

It is going to be C-phase grounding when the system runs 0.1 s, and the voltage of C-phase is zero, the phase voltage between A and C, B and C rise \( \sqrt{3} \) times. It still remain symmetry, so it doesn’t influence the lord. The change of each electric parameter is as Fig.3.

![Figure 3. The oscillogram of zero sequence voltage \( 3U_0 \), zero sequence current \( 3I_0 \), fault point current \( I_D \)](image)

According to Fig.3, each line’s beginning zero-sequence current’s and fault point grounding current’s effective value are

\[ 3I_{04} = 25.63A, \ 3I_{03} = 18.65A, \ 3I_{01} = 44.38A, \ I_D = 75.56A \]

They are nearly equal to the theoretical values.

From Fig.3 we can see that the zero sequence voltage of normal line lagging 90°to zero sequence current in the condition of isolated neutral system. The zero sequence current on the fault line is equal to the sum of the whole system’s normal component grounding capacity current and it is lagging 90°to zero sequence voltage. It can be concluded that the zero sequence current on fault line and normal line is opposite, it is similar to the theoretical analysis, as Fig.4[6].
3.2. The Simulation Result and Theoretical Analysis of Neutral Arc-suppression Coil System

The circuit diagram of grounding system through the arc suppression coil is shown as figure 5 and simulation results of the system is shown as figure 6. According to these Figures, we can see that the ground current effective value of the fault point is 9.3 A when the single-phase earth fault transient ends and that is far less then the ground current of the isolated neutral system. Thus the compensation effect is very obvious.

Figure 4. Single-phase ground and zero sequence equivalent network

Figure 5. Single-phase grounding zero sequence current equivalent network of Neutral arc-suppression coil system

Figure 6. The oscillogram of zero sequence voltage $U_0$, zero sequence current $I_0$, arc-suppression coil current $I_L$, fault point grounding current $I_D$ in neutral arc-suppression coil system

According to Fig6, the zero-sequence current in the normal line is still the capacity current, it flows from bus-bar to lines, and its phase lagging 90° to the zero sequence voltage. In this regard, it is same as isolated neutral system[7].
But in this condition, the zero sequence current is much higher than capacity current, the direction is also from bus-bar to lines. So it can not judge the fault line based on the direction of zero sequence current.

4. Conclusion
According to above, the change of voltage, current, zero sequence voltage and zero sequence current on fault lines and normal lines can be reflected fast and accurately by using MATLAB to model and simulate on the single-phase fault of neutral indirect ground. At the same time, the protecting project can be proposed on the discrepancy, such as:

4.1. Zero Sequence Voltage Protection
When single-phase grounding fault happens in non-effectively grounding current system, there will be a prodigious zero sequence voltage on the same voltage degree, according to this attribute, it will set monitoring device on normal bus-bar\[8\].

4.2. Zero Sequence Current Protection
According to Fig 3 and Fig 6, we can see that the zero sequence current on normal and fault lines vary widely when there is a fault on one line, and the zero sequence current on the normal line is only its own capacitive current, is smaller than it on fault lines, the zero sequence current is exactly based on this discrepancy to ensure acting selectivity, protecting device’s acting setting value is

\[ I_{set} = K_{rel} 3U_{φ} φC_0 \]

\[ C_0 \]—grounding capacity on each line

4.3. Zero Sequence Directional Protection
The zero sequence current on normal and fault lines in the isolated neutral system is opposite, the zero power’s direction is also opposite, and zero sequence directional protection is based on this attribute to accomplish the selecting protection on lines.

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