International Journal of Frontiers in Engineering Technology
ISSN 2706-655X Vol.4, Issue 6: 15-21, DOI: 10.25236/IJFET.2022.040603

Method of the Earth Fault Location in Power Distribution Network Besed on Mearing Earth Conductor Current

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Abstract: *The copper foil shielding layer and armoring layer of the three-core cable and the grounding electrode of the distribution network constitute the grounding network of the distribution network. When a grounding fault occurs in the power grid, a regular ground current distribution is formed in the grounding network. .This paper analyzes the distribution law of the ground wire current in the arc suppression coil and resistance grounded distribution network: for the distribution network with the neutral point through the arc suppression coil and resistance grounded, the active component of the ground wire current of all cable segments without ground faults is Pass-through, that is, the active components of the ground current at the head and end of the cable are equal in magnitude and in the same direction; the sum of the active components of the ground current at the head and end of the ground fault cable segment is equal to the active component of the fault current at the ground fault point. According to this distribution law, this paper proposes a ground fault location method in which the neutral point is grounded by the arc suppression coil and resistance grounded grid, and its effectiveness is verified by simulation.*

Keywords: *Distribution Network, Ground Fault, Ground Current, Arc Suppression Coil Grounding System, Ground Fault Location*

1. Introduction

Ground fault protection is one of the most important protections in distribution network relay protection. Regardless of whether the neutral point is effectively grounded or non-effectively grounded, at present, the protection of single-phase-to-ground faults is based on the distribution (amplitude and phase) of the zero-sequence current in the three-phase conductors of the power grid. Commonly used principles are: zero-sequence current amplitude method, zero-sequence current direction line selection, zero-sequence active current direction line selection [1], Zero-sequence current group ratio amplitude and phase comparison method, zero-sequence admittance method and improved line selection [2], Zero-sequence characteristic perturbation method [3], fifth harmonic method [4], etc. The vertical distribution network (from the load to the substation bus) has many stages, many branch lines, and the network structure is complex. The above ground fault line selection and ground fault protection are far from meeting the requirements for improving the reliability of power supply and reducing the fault cycle. trace range requirements, People hope to isolate the ground fault more effectively and reduce the scope of disconnection of the power supply due to the ground fault[5,6,7].

Due to people′ s pursuit of a beautiful urban environment and the demand for higher power supply reliability, at the same time, due to the improvement of power cable production technology and the reduction of cable application costs, 10kV urban distribution networks are increasingly transformed into three-core cables. Power supply. For the cable distribution network, this zero-sequence current is present in the conductors of the distribution network, the zero-sequence impedance to the ground of the power grid and the ground wire network (the shielding layer, armoring layer of the cable and various substations, switching stations, distribution A loop is formed in the ground electrode of the station, ring site, etc.).This zero-sequence current flowing through the three-phase conductor will all flow through the ground wire network, and there is only zero-sequence current in the ground wire network. The copper foil shielding layer and armored layer of the three-core cable and the grounding electrode of the distribution network constitute the grounding network of the distribution network. When a grounding fault occurs in the power grid, the distribution of the ground current is formed in the grounding network, and this the distribution is regular. In this paper, starting from the analysis of the ground current distribution of the cable network, according to the distribution law of the ground current in the ground network, a ground fault location method for the neutral point arc suppression coil and resistance grounded distribution network is proposed, and the design and Implemented a ground fault location system.

2. Ground Wire Current Distribution in Neutral Point Arc Suppression Coil and Resistance Grounded Distribution Network

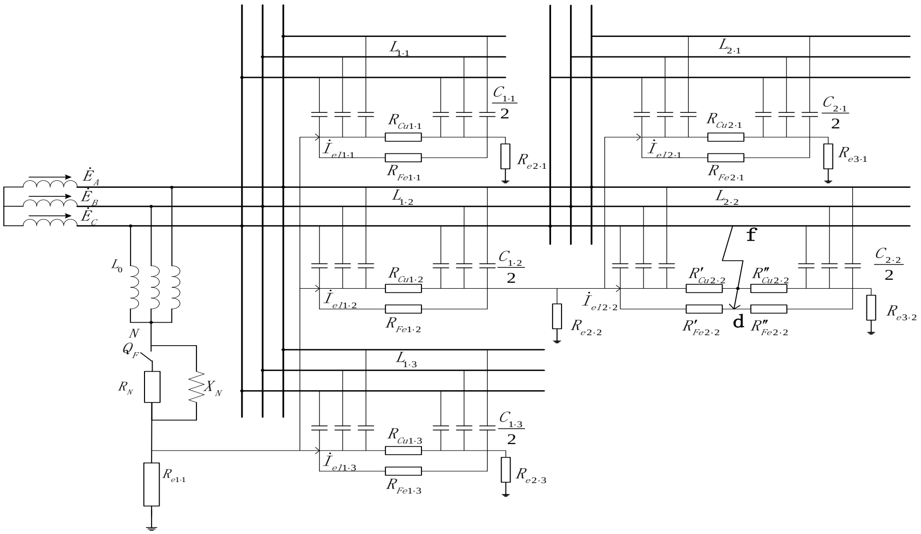

Figure 1: Three-phase simulation model of ground fault in three-core cable distribution network

Figure 1 is a simple cable distribution network. The cable adopts a π-type model. Because the resistance and reactance of the cable core and the reactance of the copper foil shielding layer are not only much smaller than the capacitive reactance of the distributed capacitance to the grid and the grounding impedance of the neutral point, but also Much smaller than the resistance of the copper foil shield, they are ignored in the figure to simplify the analysis. For a relatively complex distribution network, considering the ground wire and the ground electrode, there may be at least dozens of “nodes” and a complex circuit with hundreds to thousands of “mesh”, it is difficult to directly analyze it. Of. According to the symmetrical component theory and the circuit substitution theorem, the three-phase circuit in Fig. 1 can be simplified as the zero-sequence equivalent circuit in Fig. 2 for analysis [8].

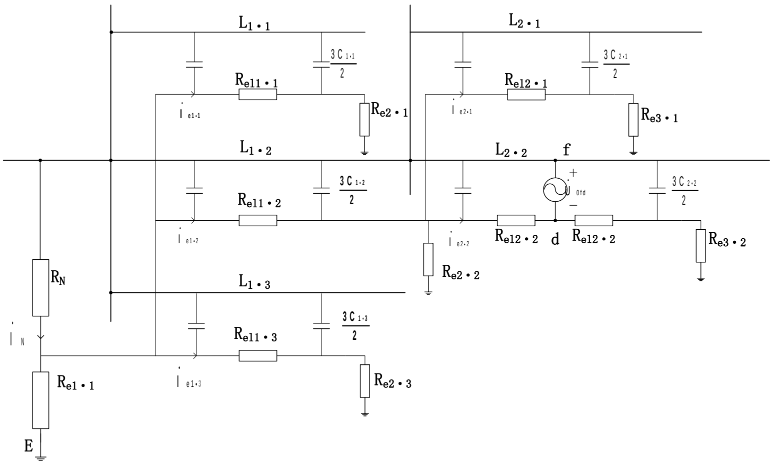

Figure 2: Zero-sequence equivalent circuit of ground fault in three-core cable distribution network

In the figure: $i=1\sim n$ the serial number from the grounding pole of the main substation to the grounding pole of the user side; $j=1\sim m$ is the serial number of the ground wire connected to the “i” th grounding electrode resistance, m is the total number of ground wires connected to the “i” th grounding resistance; $\dot{I}_{eli.j}$ is the current of the jth ground wire connected to the ith ground pole;

$R_{Cui.j}$、$R_{Fei.j} and C_{i.j}$ are the copper foil shielding layer (three-phase), armor layer resistance and distributed capacitance of each phase of the jth cable between the i-th and i+1; $R_{ei.j}$ is the ith ground electrode resistance; RN is the neutral grounding resistance; $\dot{E}_a$、$\dot{E}_b and \dot{E}_c$ are the three-phase power supply potentials, respectively。$R_{eli.j} = R_{Cui.j} // R_{Fei.j}$ is the resistance of the jth ground wire between the ith and i+1.

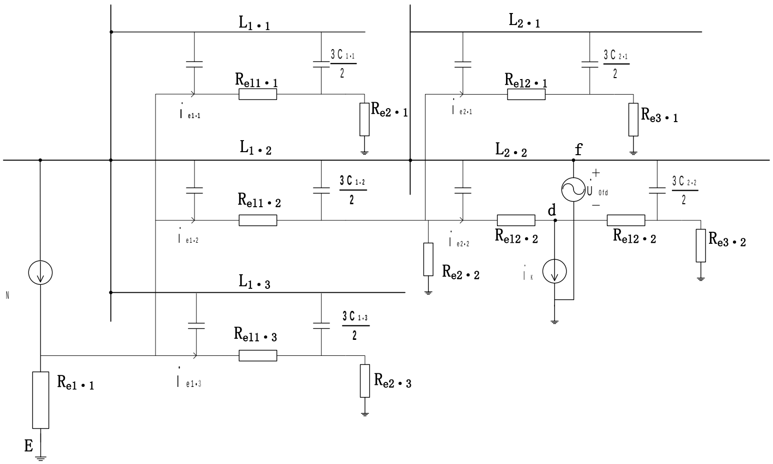

Figure 3: Zero-sequence equivalent circuit of ground fault in three-core cable distribution network

According to the superposition principle of linear circuits, Figure 2 can be decomposed into three circuits [8], and the ground current, $\dot{I}_{Ueli.j}$、$\dot{I}_{Neli.j} and \dot{I}_{keli.j}$, can be independently analyzed and calculated in the three circuits. Then, adding up the three analysis results ($\dot{I}_{eli.j} = \dot{I}_{Ueli.j} + \dot{I}_{Neli.j} + \dot{I}_{keli.j}$) can accurately obtain the ground wire current distribution during the single-phase grounding fault in the three-phase distribution network as shown in Figure 1.

In the formula: $\dot{I}_{eli.j}$、$\dot{I}_{Ueli.j}$、$\dot{I}_{Neli.j} and \dot{I}_{keli.j}$ respectively: The ground wire current of the jth branch ground wire of the ith ground electrode, the ground wire current under the action of the zero sequence voltage $\dot{U}_0$ alone, Ground wire current under the action of neutral point current alone $\dot{I}_N$ and ground wire current under the action of fault current alone $\dot{I}_k$ .Considering that the active component of the ground wire current is used here, and the reactive component current (to the ground capacitance current and the arc suppression coil current) is not involved, Therefore, only the active component distribution of the ground current is analyzed here, That is, the distribution of the active component part $\dot{I}_{Neli.j}$ and the active component part of $\dot{I}_{keli.j}$ .The ground current is equal to the sum of these two parts, namely $\dot{I}_{eli.j} = \dot{I}_{Neli.j} + \dot{I}_{keli.j}$.

2.1 Ground Current Distribution under the Action of Neutral Point Current (Active Component Part) Alone

In Figure 3, since the capacitive reactance of the distributed capacitance is much larger than the ground electrode resistance and the ground wire resistance, the distributed capacitance is regarded as an open circuit, and let: $\dot{I}_k = 3\dot{I}_0 = 0$ (open circuit), $\dot{U}_0 = 0$ (short circuit),The circuit and current path under the action of neutral point current $\dot{I}_N$ alone are formed, as shown in Figure 4-1.The neutral point current $\dot{I}_N$ starts from the neutral point grounding element, passes through the ground wire and the ground electrode resistance to the earth E, then returns to the ground fault point, and returns to the neutral point impedance Z_N through the three-phase wire of the fault line to form a loop. This current only flows through the line from the fault point to the neutral point impedance Z_N in the conductor, and other lines (such as non-fault lines) do not flow through this current. In the grounding grid, since the grounding electrode resistance of the 110kV substation is much lower than that of other switching stations and power distribution stations, it is mainly from the grounding electrode resistance $R_{e1.1}$ of the 110V substation to enter the earth E, The current entering the earth E through the grounding grid and other grounding electrodes is relatively small. Moreover, this current is traversed through the transformers at the beginning and end of the ground wire of any cable segment. Under the action of the neutral point current I_{Np} (active component part) alone, if we set the direction of the ground wire at the head and end of the cable flowing into the ground bus as the positive direction, and the calculation ΔI_{Npi} is equal to the ground wire current at the head end and the ground wire at the end of the i-th cable difference in current, all cable segments have ΔI_{Npi} equal zero.

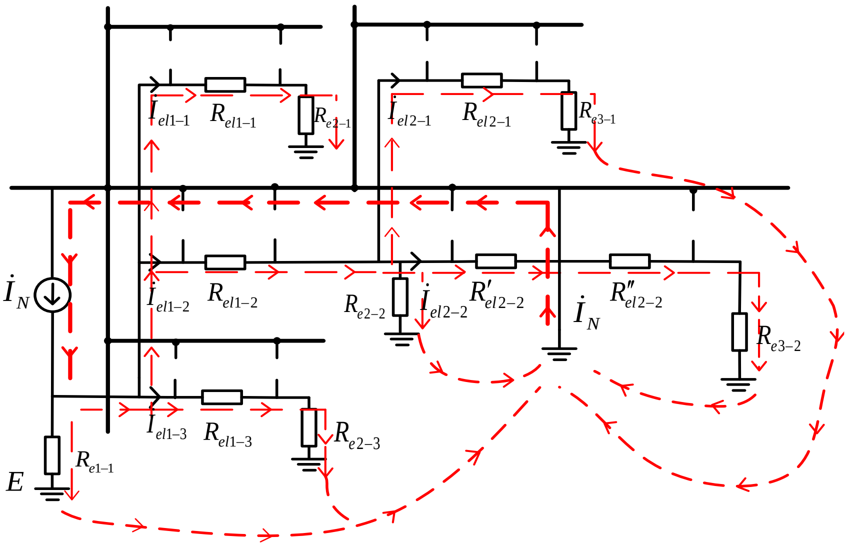

Figure 4: Current distribution under the action of neutral point current alone

2.2 Ground Current Distribution under the Single Action of Fault Current at Fault Point F

In Figure 4, also because the capacitive reactance of the distributed capacitance is much larger than the ground electrode resistance and the ground wire resistance, the distributed capacitance is regarded as an open circuit, and let: $\dot{I}_N = 0, \dot{U}_0 = 0$,The circuit and current path under the single action of the fault current at the fault point f are formed, as shown in Figure 3.The fault current $\dot{I}_k$ does not flow through the wire, but only through the ground wire and the ground electrode of the grounding grid. $\dot{I}_k$ Starting from the fault point, it is divided into two paths, one path $\dot{I}_k''$ goes to the right through the grounding electrode resistance $R_{e3.2}$ and goes to the ground to form a circuit to the fault point;The other way $\dot{I}_k$ flows to the grounding grid via $R'_{el2.2}$.Since the grounding resistance of the system grounding grid is much larger than that of the grounding grid, therefore, $\dot{I}'_k >> \dot{I}''_k$

And, $\dot{I}_k$ for all cable segments without ground faults, this current also passes through the ground current transformers at the beginning and end of the cable at the same time. Under the action of ground fault current $\dot{I}_k$ alone, if we set the direction in which the head and end of the ground wire of the cable flow into the ground bus as the positive direction,

If ΔI_{kpi} is equal to the sum of the active component of the ground wire current at the head end and the active component of the ground wire current at the end of the i-th cable, then all cable segments without ground faults also have ΔI_{kpi} equal to zero;For the cable section with ground fault, the fault current $\dot{I}_k$ flows from the ground fault point to the ground current transformers at the head and end of both sides. Therefore, for the cable section where the ground fault occurs, $\Delta I_{kpi} = I_{kp} . I_{kp}$ is the active component of ground fault current $\dot{I}_k$.

3. The Principle of Judging the Ground Fault Line by the Active Current Amplitude of the Ground Wire

According to the above analysis of the distribution characteristics of the active component of the ground wire current in the distribution network where the neutral point passes through the arc suppression coil and is resistance grounded, it can be seen that for all cable segments without ground faults, when I_N and I_k act independently, the ground wire The current is through-through, that is, the same current flows through the current transformers at the beginning and end of the cable ground wire, so both ΔI_{Npi} and ΔI_{kpi} are equal to zero.

Set a fault judgment quantity ΔI_{pi} , which is equal to the sum of the ground currents at the head and end of any cable segment, namely $\Delta I_{pi} = I_{spi} + I_{mpi} = \Delta I_{Npi} + \Delta I_{kpi}$, where: are the active components of the ground currents at the head and end of the cable, respectively. Considering the insulation conductance current of the cable (generally very small, close to zero), the measurement error of the current transformer and the calculation error of the monitoring device, etc., set a given value as the threshold value of the fault judgment quantity to prevent misoperation (false alarm).This given value can be considered in consideration of the sensitivity of the ground fault response. If the sensitivity of the ground fault is required to respond to the 1kΩ ground fault point resistance, the given value can be set to 5774V /1132Ω=5.1A, where 132Ω is the middle The resistance value of the neutral point arc suppression coil. You can take this given value equal to 5A.

It can also be seen from Figure 3 that if the ground fault does not occur on the cable, but on the busbar (in the switchgear, or on the busbar, etc.), then this fault current I_k affects the ground current at the head and end of all cable segments. Transformers are penetrating, therefore, the fault quantity ΔI_{pi} of all cable segments is less than the set value.

According to the above analysis, for the neutral point through the arc suppression coil and resistance grounded distribution network, the principle of judging the ground fault line by the active current amplitude of the ground wire is as follows: monitor the zero-sequence voltage of the distribution network, when the zero-sequence voltage exceeds a set value. value, it means that there is a single-phase-to-ground fault in the distribution network. Set a fault judgment quantity ΔI_{pi} , which is equal to the sum of the ground currents at the beginning and end of any cable segment, namely $\Delta I_{pi} = I_{spi} + I_{mpi} = \Delta I_{Npi} + \Delta I_{kpi}$ .If the fault judgment quantity ΔI_{pi} of any cable segment is less than a given value (that is, the setting value of the ground fault), there is no ground fault in this segment of the cable; if the fault judgment quantity ΔI_{pi} of the only segment of the cable is greater than this given value, then this segment of the cable has no ground fault. The cable must be the segment of the cable where the ground fault occurs. If the fault judgment value ΔI_{pi} of all cable segments is less than the given value, the end bus of the corresponding feeder cable with the largest active component of the ground wire current at the head end or end of the cable has a ground fault.

4. Simulation Verification

In order to verify the effectiveness of the ground fault location method proposed in this paper, the three-phase simulation model of the ground fault in the three-core cable distribution network in Fig.1 is selected for simulation. In the simulation, cables L1.1, L1.2 and L1.3 are respectively 400mm2, 2km, 2km and 3km long, and L2.1 and L2.2 are both 240mm2 and 2km long, corresponding to $C_{1.1} = C_{1.2} = 0.652\mu F$, $C_{1.3} = 0.978\mu F$, $C_{2.1} = C_{2.1} = 0.532\mu F$; $R_{Cu1.1} = R_{Cu1.2} = 1.075\Omega$, $R_{Cu1.3} = 1.612\Omega$, $R_{Cu2.1} = R_{Cu2.2} = 0.917\Omega$, $R_{Fe1.1} = R_{Fe1.2} = 0.414\Omega$, $R_{Fe1.3} = 0.621\Omega$, $R_{Fe2.1} = R_{Fe2.2} = 0.778\Omega$; $R_{e1.1} = 0.5\Omega$, $R_{e2.2} = 2\Omega$, $R_{e2.1} = R_{e2.3} = R_{e3.1} = R_{e3.2} = 4\Omega$; $R_N = 132\Omega$;The arc suppression coil is fully compensated. The simulation results are shown in Table 1.In the table, fL means that the ground fault occurs on the cable, and this simulation is on L2.2; fM means that the ground fault occurs on the busbar or switchgear, and this simulation is on the bus at the end of the L1.2 cable.

Table 1: Data table of simulation results

	cable segment	L1.1	L1.2	L1.3	L2.1	L2.2
		start/end	start/end	start/end	start/end	start/end
fL(0Ω) ground	I_{el} (A)	0.76/0.80	37.46/37.5	0.71/0.77	1.75/1.78	43.15/2.84
	ΔI (A)	-0.04	-0.04	-0.06	-0.03	40.31
fM(0Ω) ground	I_{el} (A)	0.70/0.74	38.14/38.17	0.65/0.71	1.89/1.85	1.89/1.85
	ΔI (A)	-0.04	-0.03	-0.06	0.04	0.04
fL(10Ω) ground	I_{el} (A)	0.75/0.79	37.21/37.21	0.71/0.77	1.77/1.74	42.87/2.83
	ΔI (A)	-0.04	0	-0.06	0.03	40.04
fM(10Ω) ground	I_{el} (A)	0.55/0.69	35.75/35.62	0.46/0.67	1.73/1.84	1.84/1.73
	ΔI (A)	-0.06	-0.13	-0.21	-0.11	0.11
fL(100Ω)ground	I_{el} (A)	0.43/0.45	21.23/21.26	0.40/0.44	1.01/0.99	24.47/1.61
	ΔI (A)	-0.02	-0.03	-0.04	0.02	22.86
fM(100Ω) ground	I_{el} (A)	0.39/0.42	21.61/21.64	0.37/0.40	1.07/1.05	1.07/1.05
	ΔI (A)	-0.03	-0.03	-0.03	0.02	0.02
fL(1000Ω) ground	I_{el} (A)	0.08/0.08	4.43/4.43	0.08/0.08	0.21/0.21	5.02/0.33
	ΔI (A)	0	0	0	0	4.69
fM(1000Ω)ground	I_{el} (A)	0.08/0.08	4.43/4.43	0.07/0.08	0.21/0.21	0.21/0.21
	ΔI (A)	0	0	-0.01	0	0

5. Conclusion

The distribution network has many vertical stages, many branch lines, short lines, and complex network structure. The ground fault line selection and ground fault protection are far from satisfying people′ s need to quickly isolate the ground fault of the distribution network, thereby improving the reliability of power supply and reducing the size of the ground fault. The requirements of fault tracking range, fault section location and fault location are beginning to receive attention. This paper opens up a new path for the location of the ground fault segment from the aspect of signal extraction, and uses the ground wire network of the cable power supply network to locate the fault segment cable. On the basis of analyzing the current distribution law of the ground wire in the neutral point through the arc suppression coil and resistance grounded grid, this paper proposes a ground fault location method for the neutral point through the arc suppression coil and resistance grounded grid. The simulation analysis proves that it is Effective. This locating method can also locate high-resistance ground faults well.

Acknowledgments

This work was financially supported by State Grid Jiangsu Electric Power Company Science and Technology Project (J2020047)

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