Sequence component direction element based on power frequency variation

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Abstract. Unlike the relatively stable network structure of the transmission and distribution network, under the new distribution network, resulting in errors in the impedance tuning of the fault directional element, misjudgment of the fault directional element, and a decrease in sensitivity. For this reason, this paper proposes a sequence component adaptive fault directional element based on power frequency variation. The sequence impedance amplitude is calculated through the measured values of the voltage sequence component and the current sequence component of the relay location. Then the phase angle of the setting impedance is determined according to various sequence components in the system. It improves the problem that the setting impedance of power frequency distance directional element is greatly affected by the amplitude and phase angle fluctuation of distribution system impedance and line impedance. The reliability and stability of the sequence component adaptive fault directional element based on the power fresquency variation are verified by Matlab simulation.

1 Introduction

With the access of a large number of distributed generators to the distribution network and the diversity of grid connection locations, the distribution of power flow and fault current in the distribution network changes, which has a negative impact on the original relay protection system, resulting in selectivity loss and reliability decline. Therefore, traditional distribution network protection strategies may no longer be satisfied with the new distribution network protection system.

To solve this problem, this paper proposes a new idea that takes the comparison between the magnitude of the compensation sequence voltage variation and that of the fault sequence component as the direction criterion. Through the modification of the original criterion, the applicability of the directional element is also strengthened. Meanwhile, the directional element also performs setting protection for different types of fault components extracted from different types of faults, which can not only adaptively and quickly determine the fault direction, but also show fine reliability under the influence of the fault current polymorphism after the distributed generation grid connection.

2 Characteristic analysis of power frequency fault component distence protection element

The traditional power frequency fault component distance relay judges the forward and reverse of the fault by comparing the magnitude relationship between the compensation voltage variation $|\Delta U'|$ and U_{set} . The operation equation is as follows.

$$|\Delta U'| \ge U_{set} \tag{1}$$

The expression of compensation voltage variation is as follows:

$$\Delta U' = \Delta U_m - \Delta I_m \cdot Z_{set} \tag{2}$$

The expression of the fault voltage component at the forward measuring point:

$$\Delta U_m = -\Delta I_m \cdot Z_{sm} \tag{3}$$

The expression of the fault voltage component at the reverse measuring point:

$$\Delta U_m = \Delta I_m \cdot Z'_{sn} \tag{4}$$

The expression of fault voltage at point of short k in the case of forward fault is as follows:

$$-U_k = -\Delta I_m (Z_{sm} + Z_k) \tag{5}$$

The expression of fault voltage at point of short k in the case of reverse fault is as follows:

$$-U_k = \Delta I_m (Z'_{sn} + Z_k) \tag{6}$$

As can be seen, the forward criterion of the traditional power frequency fault component distance protection element is:

$$\left|Z_{sm} + Z_{set}\right| \ge \left|Z_{sm} + Z_{k}\right| \tag{7}$$

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Accordingly, the reverse criterion is as follows:

$$\left|Z'_{sn} - Z_{set}\right| \ge \left|Z'_{sn} - Z_{k}\right| \tag{8}$$

According to the above equations, the measured impedance Z_k in the direction criterion 7 and 8 of the traditional power frequency fault component directional element is difficult to be accurately measured. Therefore, since the traditional power frequency fault component directional element has certain defects in performance, it needs to be further enhanced.

3 Sequence voltage distribution in distribution network

In this paper, the modulus ratio of the sequence voltage fault component to the sequence current component at the measuring point is used as the modulus value of the R

sequence impedance, and β is its phase angle. That is, equation 2 is modified as:

$$\Delta U_{\alpha}' = \Delta U_{m\alpha} - \Delta I_{m\alpha} \cdot Z_{set\alpha}$$
(9)

$$Z_{\text{set}} = \left| \frac{\Delta U_{m\alpha}}{\Delta I_{m\alpha}} \right| e^{\beta j} \tag{10}$$

Where, $\Delta I_{m\alpha}$ is the sequence current component at the measuring point and $Z_{set\alpha}$ is the setting sequence impedance.

The figure below shows the system diagram of the simple power system and the positive sequence and negative sequence equivalent circuits .





(b) Fault additional positive sequence network



(c) Fault additional negative sequence network

Fig. 1 Simple power system and sequence equivalent circuits of positive and negative sequence

4 Criterion analysis of directional element based on power frequency sequence component variation

When the locations and the types of the short-circuit faults are different, the voltage distribution diagrams of the sequence voltage fault component ΔU_{ma} , the compensation sequence voltage variation $\Delta U'_a$, and the short-circuit point sequence voltage $\Delta U_{F\alpha}$ ($\alpha=0,1,2$) are as follows:



(a) Positive sequence voltage distribution diagram



(b) Negative sequence voltage distribution diagram



(c) Zero sequence voltage distribution diagram

Fig. 2 The distributed diagram of fault sequence voltage component

According to Fig.2, equations 7 and 8 are modified as follows based on the directional element of power frequency sequence component variation:

(1) In case of forward fault

$$\left|\Delta U_{\alpha}'\right| > \left|\Delta U_{m\alpha}\right| \tag{11}$$

(2) In case of reverse fault

$$\left|\Delta U_{\alpha}'\right| < \left|\Delta U_{m\alpha}\right| \tag{12}$$

After the criterion is modified, the directional element only needs to judge the magnitude relationship between $\Delta U'_{\alpha}$ and $\Delta U_{m\alpha}$ to determine the direction of the fault.

It can be seen from Fig. 2 that when a forward fault occurs:

$$\Delta U_{m\alpha} = -\Delta I_{m\alpha} \cdot Z_{sm} \tag{13}$$

$$Z_{set\alpha} = \frac{\Delta U_{m\alpha}}{\Delta I_{m\alpha}} e^{(\beta_1)j} = |Z_{sm\alpha}| e^{(\beta_1)j} \qquad (14)$$

$$\Delta U_{\alpha} = \Delta U_{n\alpha} - \Delta U_{n\alpha} \cdot |Z_{sn\alpha}| e^{(\beta)j} = -\Delta U_{n\alpha} \left(Z_{sn\alpha} + |Z_{sn\alpha}| e^{(\beta)j} \right) (15)$$

According to equations 13 to 15 and equation 11, the forward correction criterion of the directional element can be:

$$\frac{\left|Z_{sm} + \left|Z_{s}\right|e^{\left(\beta_{1}\right)j}\right|}{\left|Z_{sm}\right|} > 1$$
(16)

5 Simulation analysis

Matlab software is used to simulate and verify the performance of the fault element. The simulation model of the system is shown in Fig. 3. The simulation results indicate that the experimental data is consistent with the theoretical analysis.



Fig. 3 Topology diagram of distribution networks with DG

a. As shown in Fig.4, the negative sequence power frequency variation element is firstly verified. From 0.03s to 0.045s, the single-phase grounding short circuit, two-phase grounding short circuit and two-phase interphase short circuit occur respectively at K2. The difference between $|\Delta U'_{\alpha}|$ and $|\Delta U_{m\alpha}|$ at measuring point A3 is shown in Fig. 4 as follows.

b. From 0.03s to 0.045s, single-phase grounding short circuit, two-phase grounding short circuit and two-phase interphase short circuit occur respectively at K2. The difference between $|\Delta U'_{\alpha}|$ and $|\Delta U_{m\alpha}|$ at measuring point A2 is shown in Fig. 5 as follows. Within 0.03s to 0.045s, a three-phase short circuit occurs at K2, and the difference between $|\Delta U'_{\alpha}|$ and $|\Delta U_{m\alpha}|$ at A2 is shown in Fig. 5 below.



Fig. 4 Characteristics of measuring point of A3 when K2 experiences a forward fault



Fig. 5 Characteristics of measuring point of A2 when K2 experiences a forward fault

6 Conclusion

In this paper, based on the traditional power frequency variation fault component distance protection element, certain improvements have been made to make it suitable for a new type of distribution network with a large number of distributed generators connected to the grid, and it has shown excellent characteristics in the simulation verification.

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