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Full Length Article

Method of fault location for double line-to-earth faults in distribution networks

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ABSTRACT

Single line-to-earth fault may become double line-to-earth faults. In this case, the procedure for determining the fault location takes a long time, as a team of experts conducts bypassing the entire network. A method for fault location of double line-to-earth faults on different power lines of medium-voltage distribution network is proposed in the article. The method is implemented by determining the impedance of the line-to-earth fault circuit which is proportional to the distances to each of the places of faults. The results of theoretical calculations coincide with results of simulation performed in MatLab Simulink software environment.

1. Introduction

The most widespread faults in the distribution networks 6–35 kV are single line-to-earth faults (SLEF), which account for approx. 60–80% of total number of faults [1].

Continuous operation of a network with isolated neutral under SLEF condition may eventually cause occurrence of a line-to-earth fault at another point of the network [2]. The second line-to-earth fault usually occurs on the network segment where the insulation is most degraded. Fault location (FL) in case of line-to-earth faults is an extremely complicated task nowadays, and usually is performed by operational mobile teams by tracing the route of a power line (PL).

Fault location in case of double line-to-earth faults (DLEF) at the same line is implemented by usage of impedance measuring elements (IME) which measure the impedance of phase circuits. The values of inductive reactance of these circuits are proportional to the distances to the near and to the far places of faults [3,4].

The paper [5] present the methods of SLEF location in networks with compensated neutral by making artificial low-resistance fault at line termination. In Russia most networks have isolated neutral, so this paper is relevant for medium-voltage distribution networks.

In case of DLEF occurring on different lines, localization of faults basing on the values of the inductive reactance of phase circuits becomes impossible. Therefore, it is desirable to configure a connection scheme for IME in such a way that the impedances of the fault circuits are proportional to the distances to the places of faults. For the configured connection scheme of IME, it is necessary to calculate the parameters of the fault condition in order to determine the dependencies on the distances to the places of faults.

2. Description of the method

Calculations of fault condition parameters in the event of a double line-to-earth fault on different outgoing power lines were performed under the following assumptions:

1) load connected to the PL has high impedance, therefore, its effect on the fault current is excluded;
2) impedance values of the positive sequence and negative sequence of the supply system and of the power line are assumed as being equal to each other ($\underline{Z}_1 = \underline{Z}_2$);
3) capacitive impedance of the PL is neglected;
4) transition impedances at the points of line-to-earth faults are assumed to be zero;
5) power lines contain no branches;
6) 10 kV distribution network has one power source.

Calculation of current and voltage values in case of DLEF is performed using the diagrams shown in Figs. 1 and 2, which present the single-line diagram of the network (Fig. 1) and its simplified three-phase equivalent circuit under fault condition (Fig. 2), where

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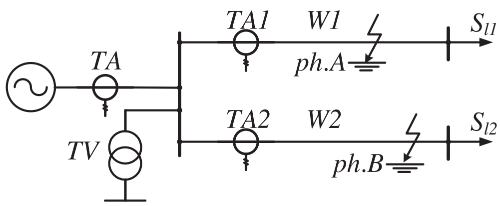

Fig. 1. Diagram of 10 kV network in case of a double line-to-earth fault.

$\underline{E}_{ph1}$, $\underline{E}_{ph2}$, $\underline{E}_{ph3}$ mean voltage of the supply system; $\underline{Z}_s$ means equivalent impedances of the system; *TV* means measuring voltage transformer; *TA1-TA6* mean measuring current transformers of outgoing lines; $\underline{Z}'_{1w1}$, $\underline{Z}'_{2w1}$, $\underline{Z}'_{0w1}$ mean impedances of positive sequence, negative sequence, and zero sequence to the place of fault on the first outgoing line; $\underline{Z}'_{1w2}$, $\underline{Z}'_{2w2}$, $\underline{Z}'_{0w2}$ mean impedances of positive sequence, negative sequence, and zero sequence to the place of fault on the second outgoing line; $\underline{Z}_{w1}$, $\underline{Z}_{w2}$ mean impedances of the respective phases of outgoing lines; $\underline{Z}_l$ means impedance of the load connected to PL; R_{p1}, R_{p2} mean transition resistances at the places of faults; R_g means earth resistance; *IME1*, *IME2* mean impedance measuring elements on the outgoing lines.

The individual sequences of the equivalent circuit shown in [6,7].

General formula for calculating double line-to-earth fault current is:

$$\underline{I}_{def} = 3\frac{\underline{E}_{ph1}-\underline{E}_{ph2}}{6\underline{Z}_{1s}+\underline{Z}_{0w1}\cdot(L_{1k}+L_{2k})\cdot(n+2)+3R_{p1}+3R_{p2}+3R_g} = 3\underline{I}_0 \quad (1)$$

where $n = \underline{Z}_{0w1}/\underline{Z}_{1w1}$ means the ratio of specific impedances of zero sequence and positive sequence of the PL.

Voltages of the faulty phases at the places of IME installation (at the substation busbars) are determined by the following expressions

$$\underline{U}_{ph1} = \underline{I}_{def}\cdot\left(\frac{1}{3}\underline{Z}_{0w1}+\frac{2}{3}\underline{Z}_{1w1}+R_{p1}+R_g\right) \quad (2)$$

$$\underline{U}_{ph2} = \underline{I}_{def}\cdot\left(\frac{1}{3}\underline{Z}_{0w2}+\frac{2}{3}\underline{Z}_{1w2}+R_{p2}\right) \quad (3)$$

In order to determine the distances to places of faults, IME must be configured for sensing the line-to-earth voltage and zero sequence current [8–13]. In this case the calculated impedance Z_{ph} at IME will be proportional to the distances to fault locations:

$$\underline{Z}_{ph1} = \frac{\underline{U}_{ph1}}{3\underline{I}_0} = \frac{3\underline{I}_0\cdot\left(\frac{1}{3}\underline{Z}_{0w1}+\frac{2}{3}\underline{Z}_{1w1}+R_{p1}+R_g\right)}{3\underline{I}_0} = \frac{1}{3}\underline{Z}_{0w1}+\frac{2}{3}\underline{Z}_{1w1}+R_{p1}+R_g \quad (4)$$

$$\underline{Z}_{ph2} = \frac{\underline{U}_{ph2}}{3\underline{I}_0} = \frac{3\underline{I}_0\cdot\left(\frac{1}{3}\underline{Z}_{0w2}+\frac{2}{3}\underline{Z}_{1w2}+R_{p2}\right)}{3\underline{I}_0} = \frac{1}{3}\underline{Z}_{0w2}+\frac{2}{3}\underline{Z}_{1w2}+R_{p2} \quad (5)$$

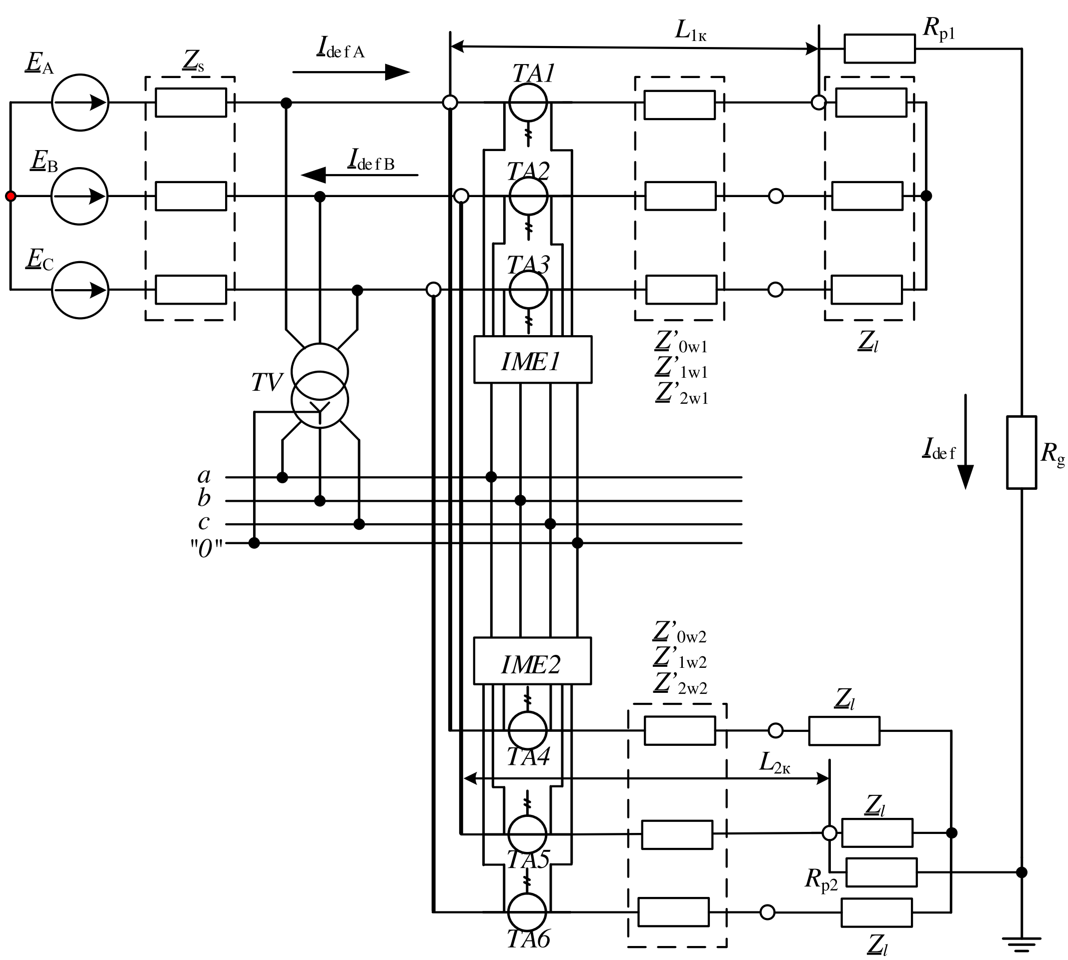

Fig. 2. Equivalent circuit of the network in case of a double line-to-earth fault, phase *A* fault at the distance $L_{1к}$ and phase *B* fault at the distance $L_{2к}$.

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