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Algorithm Development for Determination of Fault Location of Transmission Lines in a Branched Electrical Distribution Networks

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ALGORITHMDEVELOPMENTFORDETERMINATIONOFFAULTLOCATIONOFTRANSMISSIONLINESINABRANCHEDELECTRICALDISTRIBUTIONNETWORKS

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Algorithm Development for Determination of Fault Location of Transmission Lines in a Branched Electrical Distribution Networks

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Abstract- **The article proposes an algorithm for determining phase-to-phase fault of branched electrical networks power lines with 6-10 kV voltage. A feature of the algorithm is the application of the calculation theory of the emergency modes, taking into account the impact of network load and transient resistance in phase-to-phase faults.**

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I. Introduction

High rates of power grids development while reducing the specific numbers of operating personnel require the accelerated introduction of automation, including the fault location devices (FLD) on transmission lines (TL).

A variety of types and nature of faults and conditions of the power grid does not allow to obtain any universal algorithm for FLD.

According to this, a review of existing techniques for phase-to-phase faults and short circuits on the ground is reduced to the determination of section of the phase circuit by the use of sensors (indicators) of current, established, usually in areas of lines branching. The circuit rectification is conducted through the line bypassing by operation mobile team. Implementation of the methodology requires a serious financial investment (the cost of the project is proportional to the number of indicators of current), the organization of information transmission over a wireless communication channel [1-3]. Consequently, such indicators can be only "defining" points for the bypass route of the line.

Review of existing methods of FLD for more complex types of ground circuit (e.g. double ground circuit) does not give a clear idea of the accuracy of the distance calculations. As a rule, existing devices of the FLD determine only the fact of appearance of a double ground circuit, without specifying the characteristics of the fault (on the same or on different lines) and not indicating distances to points of damage. Thus, depending on the nature of a double ground circuit, the damage is defined as ground circuit determination or interphase short circuit [4-7]. There are FLD techniques and algorithms for a double ground circuit in electrical medium voltage networks with isolated neutral that are presented in works [8-12], novelty of these lies in the special scheme of resistance control devices connection at which the calculated emergency mode resistance is proportional to the distances to the locations of ground circuits.

FLD phase-to-phase faults are realized as one-way or two-way measurement fault quantities (FQ). Usually, by the calculation of short circuit loop resistance using symmetrical components of voltage and current of the line [2, 13-15]. This method is successfully applied in high voltage transmission lines that do not have branches. However, in the branched medium voltage networks accuracy of the method decreases due to the effect of load mode on branches of the network and the value of the transition resistance at the fault site.

The use of FLD devices based on the wave method requires special fault detection system configuration, and special high frequency joining devices line processing [16-18].

II. Algorithm Proposed For Solving The Problem

Modern methods of FLD on FQ imply assumptions that distort the results of calculation of the distance to the fault site. Such assumptions include the elimination of the influence of the load current or transition resistance in the place of short circuit [19]. Improving methods of FLD in FQ will reduce the error.

The algorithm is designed for determining distance to phase-to-phase short circuit (SC) of a complex configuration network with regard to the influence of the network load resistance and the transition resistance in the place of short circuit, indicating the damaged portion of the network.

To identify compensation algorithms, the network load and the resistance of the transition FQ has to be calculated on example of tri-end electric network with voltage of 10 kV (Fig. 1) and its equivalent circuit forward (reverse) sequence (Fig. 2) when two-phase short-circuit on the OL2 site (point K2).

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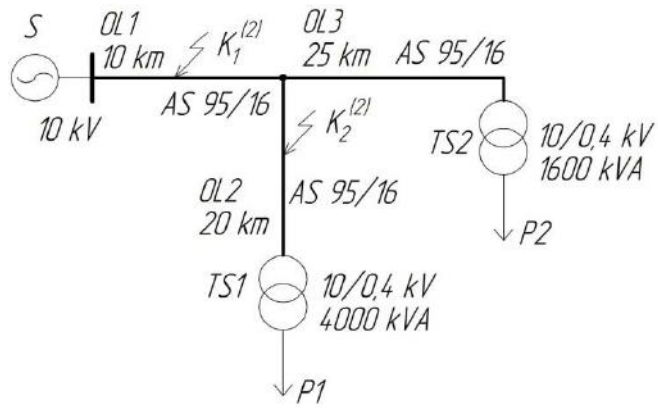

Fig. 1: Sample one-line electrical network with voltage of 10 kV: S– Feed the power grid with a voltage of 10 kV, TS1, TS2 of the transformer substation with the voltage of 0.4 kV LV, OL1–OL3 – sections of the considered line; P1, P2 – load consumers

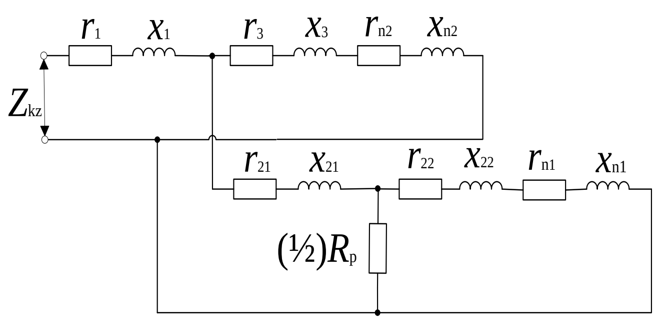

Fig. 2: An equivalent circuit of the direct (reverse) of the sequence design scheme of 10 kV network in emergency mode (smalllettering)

According to the equivalent circuit of the network in emergency mode (Fig. 2) full resistance Z_{kz} will be defined as:

$$Z_{kz} = Z_1 + \frac{(Z_3 + Z_{n2}) \cdot \left(Z_{21} + \frac{\frac{R_p}{2} \cdot (Z_2 - Z_{21} + Z_{n1})}{\frac{R_p}{2} + Z_2 - Z_{21} + Z_{n1}} \right)}{Z_3 + Z_{n2} + Z_{21} + \frac{\frac{R_p}{2} \cdot (Z_2 - Z_{21} + Z_{n1})}{\frac{R_p}{2} + Z_2 - Z_{21} + Z_{n1}}}, \quad (1)$$

where Zkz – impedance of the emergency mode defined by the phase-to-phase voltage with respect to the difference of currents of two phases (the classic circuit for measuring on resistance responsive to phase-to-phase damage [20-21]); Z_1, Z_2, Z_3 – impedance sections of transmission line; Z_{n1}, Z_{n2} – impedance of load of the consumers (including the resistance of the transformers TA); R_p is the contact resistance at the injury site.

In the expression (1) unknown quantity is the resistance Z_{21}, the inductive resistance of which is by way of transformation will be determined by a polynomial of 3rd degree:

$$C_0 + C_1 x_{21} + C_2 x_{21}^2 + C_3 x_{21}^3 = 0 . \quad (2)$$

Desired resistance x21 is obtained by discarding the imaginary roots of the equation, it will be proportional to the distance to fault on the section OL2:

$$L_к = x_{21} / x_{res} , \quad (3)$$

where Xres– resistivity direct sequence transmission lines.

Verification of the proposed FLD algorithm was conducted in the MatLab Simulink software package, in which the simulated circuit, shown in Fig. 1. has the parameters of the transmission line OL1-OL3: Gud = 0.33 Ω/km HUD = 0.37 Ohm/km; load: SP1 = 4000 kVA, SP2 = 1600 kVA, cosφ = 0,6. Point two-phase short-circuit (K2) on the line OL2 is set at a distance of 10 km from the start of the additional tap (20 km), the contact resistance Rp was equal to 20 Ohms.

Current and voltage oscillograms analysis in emergency mode showed the following results: the short-circuit current was 0.9 kA, the voltage across the tyre supply substation is 9.2 kV.

Distance to the fault by the formula (1-3) was identified as 10.8 km after the tap off, which is a 4% error of the FLD calculations.

Network damaged section identification is carried out by criterion of decrease in active power load as a result of changes in the parameters of network mode. So, in the event of short-circuit on the OL2 phase active power of the loads P1 into the joining was reduced to 1648 kW, and the load P2 to 1,077 kWh. Thus, the most profound reduction of active power on the load P1 indicates the damaged area OL2. Commited changes of output can be produced with the help of the analysis of electric energy digital meters indicators.

An additional criterion that allows to identify the damaged tap is the negative sequence voltage monitoring. The damaged consumer phase voltage negative sequence will be higher compared to consumers in the undamaged sections of the network [12].

Let's compare the results of FLD calculations with other techniques used in practice by the formula (1-3). So, the built-in function of the FLD waveform analysis in the Fast View program [22] indicates the 16.8 km (the error is 16%) distance to the fault site. In addition, this technique does not give information about the site location of the point KZ.

The closest solution to the designed algorithm is a patent solution [23]. The calculation using the presented technique indicated distance to a fault 13.9 km from the beginning of the tap off, the error is about 20%.

Thus, the distribution networks of medium voltage FLD algorithm was determined, based on the control FQ, which differs from other methods of FLD that perform calculating the distance to fault when considering a tree topology network, as well as the transient resistance of the fault.

A series of model studies show the magnitude effect of the load power and the values of the transition resistance at the fault site on the accuracy of the FLD process in the proposed method according to calculations by the formulas (1-3). Calculation error results are illustrated in figure (Fig. 3), which shows that at the maximum power load of the consumers is 8 MVA and the transition resistance of 25 Ω, the FLD error does not exceed 9%, which is lower compared to other techniques used in practice.

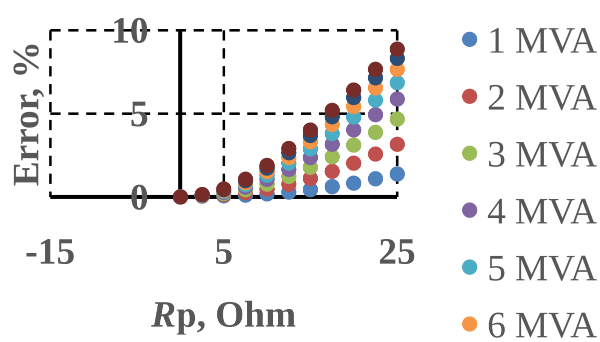

Fig. 3: Relative error depending on the transition resistance and load.

Calculation of the FQ on example of the same electric network with voltage of 10 kV (Fig. 1) in the two-phase short-circuit in the K1 at the site OL1 (distance to fault 5 km, the contact resistance is 20 Ohms). An equivalent circuit of the direct (reverse) sequence in emergency mode shown in Fig. 4.

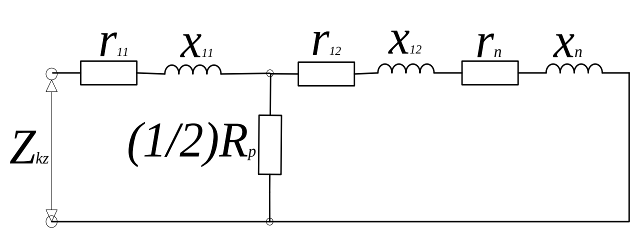

Fig. 4: An equivalent circuit of the direct (reverse) of the sequence design scheme of 10 kV network in emergency mode

In this case, the impedance Z_{kz} will be defined as:

$$Z_{\text{kz}} = Z_{11} + \frac{\frac{R_{\text{p}}}{2} \cdot \left(Z_1 - Z_{11} + Z_{\text{n}} \right)}{\frac{R_{\text{p}}}{2} + Z_1 - Z_{11} + Z_{\text{n}}}, \quad (4)$$

Where Z1=Z11+Z12 is the impedance of the main part of the transmission line, Zn is the impedance of consumers load (including the resistance of the transformers on TS) and lines defined by the formula:

$$Z_n = r_n + jx_n = \frac{(Z_2 + Z_{n1}) \cdot (Z_3 + Z_{n2})}{Z_2 + Z_{n1} + Z_3 + Z_{n2}}. \quad (5)$$

Then, the solution of the FLD problem is similar to the first example.

FLD calculation according to the formulas (1-5) showed the following results: distance to fault was 5.1 km, the relative error is 1.6 %.

Built-in FLD waveform analysis function of Fast View program, and the method of [23] indicates 5.5 km distance to the fault site (the error is 10.7%).

However, the comparing analysis of changes in the active power of the loads P1 and P2 shows a slight divergence between them, which is the criterion of damage on the main section of the line. The active power of the loads P1 amounted to 1684 kW, and load N2 – 929 kW.

The fault distance calculation according to the presented method in networks with a large number of taps (of any configuration) will be similar to the two examples above.

The fault location algorithm can be realized on the existing microprocessor elements (the terminal), or on a separate computing device.

III. Conclusion

The algorithm of determining the distance to a two-phase fault is developed, considering the influence of load current and the transition resistance in the place of circuit, the error of which on average 10% lower compared to the existing and applied in practice the methods of the FLD.

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