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DIAGNOSTICS OF THE POINT OF EARTH FAULT BY MEANS OF AN INJECTED TEST SIGNAL

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Abstract − The contribution deals with the basic description of a method for the diagnostics of the point of earth fault in the distribution network of 22 kV high-voltage long-distance lines. The method is based on the principle of impedance and uses the superposition of a suitably injected test signal on the line voltage. The method proposed is considered for localising the point of earth fault in the radial high-voltage long-distance lines that are operated with an ineffectively earthed neutral by the arc-suppression coil. The result of the method is not any absolute expression of the distance between the affected point and the initial point, but it is the determination of such section of the line, in which the earth fault could occur.

Keywords: diagnostic, earth faults, test signal

1. INTRODUCTION

The timely identification of the origin as well as at least the approximate location of the point of earth fault is a necessary precondition for securing, if possible, continuous electrical energy delivery.

The method proposed is considered for localising the point of earth fault in the radial high-voltage long-distance lines that are operated with an ineffectively earthed neutral by means of the arc-suppression coil. Thus, the result of the method is not any absolute expression of the distance between the affected point and the initial point, but it is the determination of such section of the line, in which an earth fault could occur.

2. DESCRIPTION OF THE PROPOSED METHOD OF THE DIAGNOSTICS OF THE EARTH FAULT POINT

The principle of the diagnostics of the earth fault point rests on the impedance method. For localising the point of earth fault, dependences of parameters of the lines on the distance of the point affected are used; these parameters being given especially by their design. However, the current state of line loads must be taken into account in the course of the subsequent calculation.

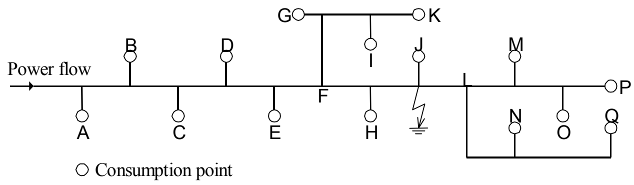

Fig.1. Example of a radial network of the distributin system

In Fig.1 an example of radial network of the distribution system of high voltage affected by earth fault is presented. The line is divided into separate sections formed by boundaries of connection points of loads, branches and switching points. These sections are alphabetically designated.

The method presented above is based on an assumption that for each point in the network, impedance patterns of the zero impedances Z_0 of particular phases of the earthed outgoing line are different. By comparing the actual measured state with calculated values for individual points of the network we shall arrive at a section with the highest probability of earth fault occurrence. Suitable inserting the source of diagnostic voltage in the circuit ensures meeting the assumption of method application. In the circuit, this source is there in the node of supply voltages of the three-phase electric power distribution of the 22 kV grid. The source of the diagnostic frequency f_x is single-phase. By the mode of its inserting in the circuit, a superposed component of our diagnostic frequency will occur on all three phases of the rotary system of the system voltage. This superposed component has, substantially, the same amplitude and the same phase difference in all the phases of the system. In Fig. 2, the principle of inserting the source of a test impulse in the circuit of the 22 kV power distribution system is illustrated. By connecting to the secondary power winding of the arc-suppression coil, a power low-frequency source of the frequency f_x is inserted into the circuit by means of the switch S2. The connection of the source to the secondary winding is made by a filter, through which the known frequency f_x is injected into the system with an earth fault at minimum losses, and simultaneously it prevents the source from penetrating the system

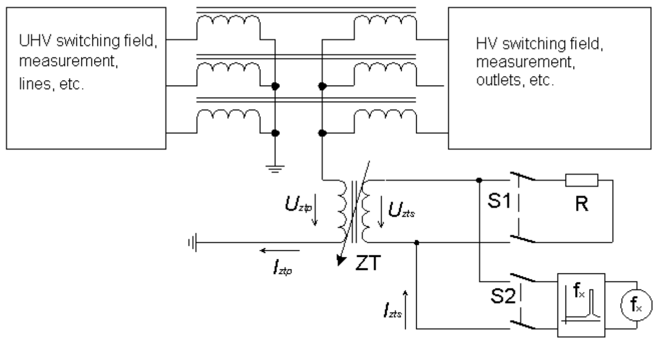

Fig. 2. The principle of inserting the source of a test impulse in the circuit 22kV power distribution system

frequency of 50 Hz. The choice of frequency is given by the basic demand to include the frequency neither in the current spectra of loads nor in the voltage spectra of sources at all. Interharmonic frequencies from the area of the frequency band from 150 Hz to 300 Hz can be taken into account. The choice of power of the diagnostic signal source is expected at the level of 10 kVA. In the no-load state, the expected voltage induced to the neutral point of the source through the arc-suppression coil is lesser than 1 kV. The purpose of this magnitude of diagnostic voltage is to "push" the diagnostic current of the magnitude of minimally 1% of the value of the current of system frequency on the line input through the point of the fault. This percentage limit is given by the accuracy of reading the values of U_{fx}, I_{fx}, φ_{fx} when processing measured values, i.e. values determining the proper accuracy of the calculation of the distance of the point of fault.

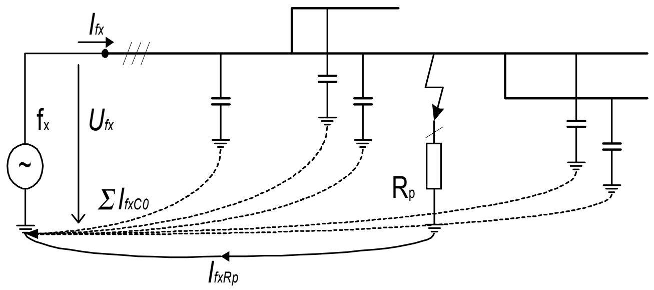

Fig.3. The distribution of the current of diagnostic frequency

In Fig. 3 the distribution of the current of diagnostic frequency in the line affected by an earth fault is illustrated in a simplified way.

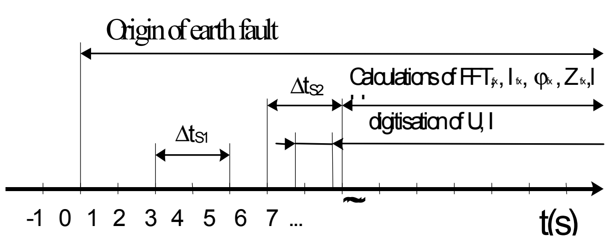

Fig. 4. An example of a time line for the process of diagnostics of the point of earth fault

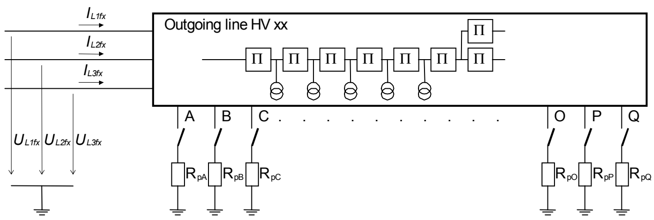

Fig. 5. There is a simplified model of the outgoing line for the calculation of a section with the point of earth fault

In Fig. 4 an example of a time line for the process of diagnostics of the point of earth fault is presented. The activity of the source begins after identifying the earth fault origin by adequate protections on individual outgoing lines from the substation with a time delay being necessary for the stabilisation of transient processes accompanying the earth fault occurrence. The interval Δt_{S1} is reserved for connecting the power resistor R to the circuit – necessary for the activity of common protections of identification of its origin, Δt_{S2} is the interval of connecting the diagnostic source to the circuit of the network; for more details see Fig. 2.

In Fig. 5, there is a simplified model of the outgoing line for the calculation of a section with the point of earth fault. Between particular consumption points and branches, the line is divided into short sections that are replaced by the line model – element Π (see Fig. 6).

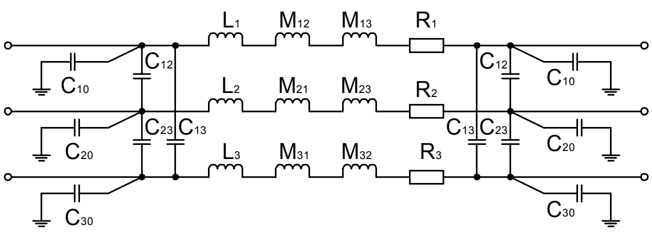

Fig.6.

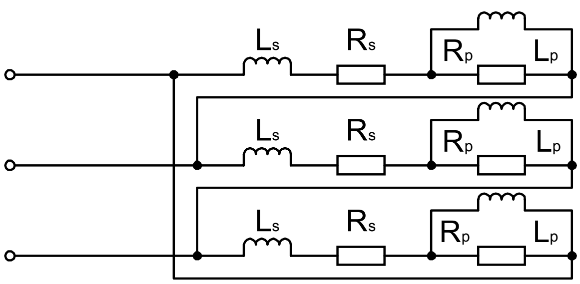

Fig.7.

Circuit parameters of the element Π are determined by calculations from construction dimensions of the line in the section concerned. In the line, the delta connection of specific loads is used; their inner diagram formed by element Γ is illustrated in Fig. 7. Values for the substitution diagram will be calculated from the nominal installed capacity in individual demands by employing the comparative method from the current load of the line at the moment of measurement. At the calculation, the state of symmetric load is considered. Values of the transient resistance of earth fault, designated as R_{pxx} in the diagram, will be determined on the basis of the value of resistance of the active component of impedance of the fault loop, from which the resistance of the line to the point of earth fault is to be deducted.

The calculation itself is performed in the iteration cycle; into the circuit, e.g. according to Fig. 5, into the places of branch points the expected value of the transient resistance R_{pxx} is incorporated. Values that are searched for in the calculation are zero impedances of the outgoing line Z_0 of particular phases of the outgoing line for individual earth fault combinations on the outgoing line. The result of zero impedances for the section of the line with the presupposed earth fault will have the magnitude of zero impedances closest to the state measured at the earth fault in the specific network.

Factors affecting the accuracy of the calculation are as follows:

- the ability to measure exactly the variables U and I at triggering the diagnostic process. It will be primarily the case of the phase and the frequency adherences of converters of voltage and current. The calculation itself of values of U_{fx}, I_{fx}, φ_{fx} is supposed by using the algorithm of Discrete Fourier Transformation.
- The ability to copy close to impedance conditions in the line. It is the case of knowledge of line construction and network configuration.

3. CONCLUSIONS

At present, no similar method that would, in the course of service of the network of high-voltage overhead distribution, enable earth fault localisation without any necessity of making any test switching operation with the lines, is employed in operation.

The proposed method has been tested in two cases in co-operation with distribution companies. At limited means of the output of the diagnostic source, the earth fault location has been successfully determined by using the proposed method at the accuracy of about 20% of the total length of the line operated, which can be considered to be encouraging for the next development and verification of the method. The proper process of calculations concerning the specific network was conducted on the personal computer with using the ATH-EMTP program. If it was possible to minimise errors in measurements of voltage and current from the point of view of both amplitude and phase, and to increase the injection performance of the test signal to the expected magnitude, a lesser error in measurement could be considered.

Furthermore, if the whole calculating algorithm were converted into the automated form on the personal computer, any barriers to the introduction into practice would exist no longer. Before introducing into practice, verification would be advisable for various states of earth fault.

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