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New ground fault detection criteria for MV distribution network protection

abstract of the doctoral dissertation written under the scientific supervision of

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Conventional ground fault protection based on protection quantities such as magnitudes of zero sequence voltage, current, zero sequence active end reactive power, admittance (susceptance, conductance) use only the fundamental components of the relaying signals. As such, they do not ensure sufficiently high sensitivity and selectivity during resistive and intermittent ground faults in MV distribution grids. Therefore, other methods of detecting ground faults, especially high-resistive and intermittent ones, are sought. These methods often use high-frequency components of relaying signals or other characteristic features of ground fault phenomena. The basic assumption in these methods is the possibility of using higher harmonics appearing in zero sequence voltage and currents measured in protected lines. To analyze the power of short-circuit signals in selected frequency bands, the Hilbert transform is also proposed.

Another criterion for ground fault detection in MV networks can be the randomness of ground fault phenomena or the asymmetry of the relaying signals. In other methods, detection is focused on recognizing characteristic patterns in relaying signals that are detected using a wavelet transform.

One should also mention the whole group of methods included in the so-called trend of artificial intelligence or also called soft methods. Extraction of patterns or relations between useful patterns unique for phenomenon in faulted lines is attempted to be carried out using artificial neural networks or fuzzy set techniques. One can also find proposals for hybrid solutions that by adaptation detects low- and high-impedance faults.

Another problem related to faults in distribution networks is the effective location of short circuits. Due to the complexity of distribution networks with relatively poor measurement, this task is a much more serious challenge compared to the problem of localization in transmission networks. It is necessary to distinguish the problem of a fault location in the network from the problem of faulted line detection. The content of the dissertation is related to the latter issue.

The submitted dissertation is devoted to the ground fault detection methods in non-effectively earthed MV grids. The research goal was to improve the detection sensitivity for relatively low-impedance ground faults, but yielding small values of zero sequence voltage and current measured in protected feeder. The second goal of the investigations was to develop an effective algorithm capable of detecting intermittent ground faults with relatively long gaps between re-ignitions of the arc.

Chapter 2 presents the purpose of the work and the main simplifying assumptions as well as the narrowing of modeling of MV networks and ground fault phenomena to a specific, limited set of cases. Three MV networks with five linear fields were modeled:

- 20 kV network with an insulated neutral point with a total capacitive ground fault current of approximately 79.5 A;
- The network with a total ground fault current of approximately 79.5 A with a neutral point earthed by a resistor 105 Ω;
- the network with a total capacitive ground fault current of approximately 79.5 A with a neutral point earthed by the Petersen coil, with Automatic Forcing of Active Component of 20.6 A.

In addition, the problem of short-circuited line detection in the MV distribution network has been included, as well as a review of the collected literature.

Chapter 3 is devoted to the neutral point grounding methods in most commonly utilized in Poland MV distribution networks. In this chapter, the networks with resistive grounded and reactance grounded neutral points have been characterized as well as insulated networks, and the characteristic values for particular neutral grounding methods are presented. Attention has also been paid to the fault conditions and their influence on the characteristics values of networks with ineffectively grounded neutral point

In chapter 4 the basic information about protection automation against ground faults in MV networks was collected. The criteria for detecting ground faults and their characteristic parameters determining their detection efficiency in networks with ineffectively grounded neutral point of medium voltage networks have been compared.

Chapter 5 contains a detailed description of the MV network model developed in the EMTP program, which was used to generate waveforms of signals supplying new ground-fault protection algorithms. Data obtained from modeling of the described network were used to optimize the filters of these signals and to test the protection functions presented in the further part of the work.

In this chapter were also given four models of different waveforms (scenarios) of phenomena at the fault location. The models proposed are not exact replicas of the models proposed in the literature, because some generalizations have been introduced that allow for the inclusion of the so-called "strange" short-arc fault behaviors, resulting from unidentified causes or caused by changing environmental conditions. This approach was dictated, among others worries about "rigid" as a result of optimization, the choice of parameters of the proposed protection criteria to possible "rigid" short-circuit models.

Chapter 6 presents the core idea of the proposed multi-frequency admittance criterion and its gradual simplifications leading to power criteria. On the path of subsequent, individual optimizations of relevant formula coefficients and the criteria and their tests obtained in this way, a preliminary verification of their effectiveness was carried out, which can be found in next chapter of the dissertation.

Chapter 7 presents the results of research on the effectiveness of non-linear programming in optimizing selected new criteria for earth fault detection in distribution lines of MV networks.

The proposed optimization method was used to design filters for protection signals used in earth fault protection of MV networks.

All the conclusions were included in Chapter 8. The results of the conducted research were to prove the thesis that: **it is possible to extend the frequency spectrum of currently used criteria for earth fault detection in MV networks**. It should be understood that it is possible and necessary to use the information provided by transient states provoked (generated) by the non-linear or non-stationary nature of physical phenomena occurring at the fault location.

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