Phase Asymmetry: a new Parameter for Detecting Low Current Faults in High Impedance Grounded Networks

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1. Introduction

The main advantage of using high impedance grounded systems in distribution networks, such as compensated, isolated or high impedance, lies in the limitation of fault current when a fault has just happened. However, the difficulty in these faults detection and selection undoubtedly implies a specific and differential conception of the used line protection [1].

Due to the low value of the fault current, single phase earth faults with a high resistive value may last for a long time without disturbing the steady operation of the distribution network. As a consequence, the power supply will be interrupted in very few cases, in spite of the existing fault.

Considering the above mentioned reasons, the detection of high resistive single-phase earth faults is certainly difficult. In fact, as it is recognised in the conclusions of the Working Group D15 of the IEEE Power Engineering Society [2], "no matter what method is used, not all high impedance faults (HIF) are detectable" and "practically, it is impossible to detect all HIFs and at the same time achieve a high degree of security against false outputs".

Nevertheless, detecting and repairing the origin of these kinds of faults makes the difference, mainly because of two facts:

- A resistive fault that lasted for too long might evolve to a more serious short-circuit.
- Usually, these resistive faults are caused by a downed conductor or by the contact with a fallen tree or branch. In these cases, there is a very clear situation of electrical risk.

In this paper, a new parameter is described: the phase asymmetry. This parameter can be used to detect permanent single-phase earth faults in distribution systems with high impedance grounded systems. In addition to this parameter, the results derived from the application of the phase asymmetry to the detection and selection of low current faults in compensated and isolated grounded systems are presented. This study has been developed by the use of the software Resfal [3], which is based on Matlab/Simulink.

Keywords: Fault detection, Distribution networks, High impedance grounding, Single phase earth faults.

2. Low Current Faults Detection

In order to detect low current faults (LCF), several methods based on the use of different techniques and watching diverse parameters have been proposed. Hence, in some cases, the phase of residual currents or the phase of their variations is watched (DESIR methodology) [1,4]. Some other occasions, the combined use of two algorithms is proposed, one of them based on changes in neutral voltage, while the other one analyses differences in zero-sequence currents [5].

There are also another group of methodologies that detect LCF in compensated networks (identifying the faulted feeder and phase), by means of using the calculation of per-phase resistance-to-ground of feeders, the relative variation of the line asymmetries or the partial residual neutral voltages. These magnitudes have to be obtained from the steady-state data. That is why it is completely necessary a periodic characterisation of the distribution network, specially its line-to-ground admittances and the line asymmetries of each feeder. This characterization is achieved by measuring several variables in two different situations, both non-faulted situations. While some authors propose the injection of 50/60 Hz currents [6,7] to attain those differences, other possibilities are based on the modification of the compensation coil tuning [8], or even on the superimposition of voltage signals [9] with a frequency above the rated frequency of 50/60 Hz.

The new parameter presented in this paper can be directly used with any of these last mentioned methodologies. This way, it offers an extra source of information, which can be extremely valuable in order to improve the efficiency and reliability of the such faults complex detection process.

3. LCF detection by the use of phase asymmetries

The phase asymmetry is a new decision parameter, defined similarly to line asymmetry, which provides an approximate idea about the differences in lines and loads that are supplied by each phase of the incoming feeders.

Contrary to what applies to a feeder's line asymmetry, the phase asymmetry is just a theoretical concept that has no correspondence with a specific, physical characteristic of the system. Consequently, whereas the line asymmetry provides clear and precise information about the existing load balance in a certain circuit (including distribution lines), the phase asymmetry results from the application of the same concept to those loads that are feed by different circuits, although they belong to the same phase. It is obvious that this value will not offer any information in itself, apart from verifying the differences of some circuits, which do not have to be either comparable or symmetric.

On the contrary, the research accomplished has shown that, by the analysis of the deviation in phase asymmetries trough time, it is possible to establish a mechanism to detect significant changes in a phase of the electrical system, while the other phases have not been affected.

This last fact has proved to be very useful. Combining it with the variation of line asymmetries, it is possible to detect single-phase earth faults, as well as differentiate them from any topology changes or other normal situations in the everyday network operation.

In this paper, the results derived from the use of phase asymmetries will be shown, in order to detect and select LCF by the use of superimposed voltage signals. Nevertheless, this parameter can also be used in those methods based on current injections.

The use of this parameter has been verified in isolated and compensated grounding systems. At the same time, a vast number of faults with different characteristics have been chosen, varying the value of its fault resistance and/or its location. Thus, fault resistances from few ohms to more than 15 kΩ have been used. Moreover, different faults located in different points of the modelled distribution system have been analysed: in every phase and feeder, near and far from substation, and in ramified areas with different number of loads between the fault point and the substation.

The results obtained in these simulations have validated this new parameter, allowing its use to detect and select LCF in high impedance grounded networks. Not only have all the simulating faults been correctly detected in isolated grounding systems, but also in resonant grounding systems. Besides, in every single case the faulted circuit and phase have been correctly identified. In the same way, its reliability has also been checked without any false detection in all kind of topology changes.

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