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Directional relays without voltage sensors for distribution networks with distributed generation: Use of symmetrical components

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ABSTRACT

This paper presents two local algorithms using only currents measurements that could be used as a back-up protection (after the loss of the voltage sensors) in directional relays for distribution networks with distributed generation (DG), or as additional directional relay dispatched along the feeders. These algorithms are based on the symmetrical components (0-zero, 1-positive and 2-negative sequences) of the 3-phases currents. Due to the power flows generated by the DG the positive sequence current argument is unforeseeable, thus it is not possible to use only the positive sequence. Then, we first propose in this paper an algorithm using the I_2/I_0 ratio to locate a phase-to-ground fault upstream or downstream the detector. The second algorithm measures the zero and positive sequence components of the fifth harmonic of the current and calculates the I_{0_5}/I_{1_5} ratio. The performances of these algorithms are analysed for several DG power, fault resistance, capacitive current and neutral grounding (resistive and compensative grounding). The fluctuations of the phasors measurements is also taken into account in the range ±5% for the modulus and ±5° for the argument. The present paper shows that these algorithms can be reliable in the major part of the studied cases.

1. Introduction

In power systems, the medium voltage distribution network makes the link between the transmission one and the loads (industrial loads or low voltage transformers that feed domestic loads). The MV networks are standardized for a voltage range between 1 and 50 kV by the IEC and often represent the main part of the electrical network. In France [1] the total length of the MV network is about 600,000 km that must be compared with LV network (600,000 km) and the transmission network (100,000 km) lengths.

The MV networks are mainly operated with a radial topology where the HV/MV primary substation feeds a busbar from which radial feeders are connected. The total length of one feeder can be up to several tenths of kilometres with many ramifications. Normally closed and normally opened switches are dispatched along the network to allow its reconfiguration.

Primary substations generally have from one to four power transformers, two being the most typical value. It allows a better reliability if one of these transformers fails.

The protection of such widespread MV networks is an important challenge for the utilities. MV networks are much more hit by faults than the transmission ones, the main faults being the phase-to-ground ones. The detection of a ground fault highly depends on the power transformer neutral grounding. The three main neutral groundings are (i) low impedance, (ii) resonant and (iii) isolated. In the present paper we will consider the two first, a resistive grounding (low impedance) and a compensated grounding (resonant).

Protection means faults detection, location and – eventually – reconfiguration. Up to 1980s, detection was made by electromechanical and static relays. The main protective function was the over-current ones (51 and 51 N) located at the head of each feeder, and several sectionalisers dispatched along the feeder. Since the beginning of the 90s, the digital relays allow the implementation of numerous protective functions in a single device and improve the fault detection through the digital processing of the measured signals (voltages and/or currents). Thus, it has become easier to detect faults such as transient faults, high impedance faults [2], or to discriminate between events such transformer internal fault and inrush current [3]. Moreover these relays can communicate between each over and with a control centre. Thus, the cross-correlations between the different protections help to increase the system reliability.

Regarding to the location function, we can either deal with a full location (which distance from the busbar and which section?)

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