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Tree-related high impedance fault location using phase shift measurement of high frequency magnetic field

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ABSTRACT

Tree-related high impedance faults (THIFs) are one complex type of high impedance faults which occurs when power lines come in contact with live vegetation. These faults could not cause the overhead line to be removed by power line over-current protection during the first cycles. But if the fault current continue to flow through the vegetation, the THIF will eventually go to flashover. Furthermore, the physical changes created by a transient THIF current flowing through the vegetation are irreversible. So, if subsequently a THIF again occurs on the previous vegetation, the fault current goes directly to flashover and line tripping after a very brief delay. Consequently, the failure to early location of THIFs may results in blackout. Therefore, determining the exact distance of the THIFs efficiently contributes to increase reliability of power systems. Given that available high-impedance fault location techniques are not fully effective in the case of a THIF, the need for a more accurate method seems obvious. So in this paper, a novel single-terminal location method based on noncontact magnetic field strength measurement is proposed for THIFs. Suggested technique determines the exact distance of the THIF fault from the sensing point based on the total phase shift of the high frequency component of the magnetic field strength in the plane perpendicular to the conductor axis. Indeed, this study is a follow up to a previous study (Bahador et al., 2017).

1. Introduction

One of the most challenging problems in protection of power distribution networks is high impedance faults. These faults which comprise about 10 percent of the distribution faults have current magnitude close to the load current level or even lower and therefor are not detectable by conventional protection schemes [2–4]. The presence of these faults threatens both the public safety and reliability of the distribution system [5,6]. For these reasons, the knowledge of the HIF's location is of vital importance.

This research is just focused on the HIF current that passes through live vegetation. It occurs when power line come in contact with live trees. The reason for making this choice is that tree-power line contact is the major cause of power outages in the United States according to the Edison Electric Institute [7].

The main reason for getting into this study is that the problem of locating tree-related high impedance faults was of less consideration and no specific technique has been proposed to determine the exact distance of these faults [8–12]. In addition, the ability of the proposed algorithms to locate low-current high impedance faults such as tree-related HIF is low. Furthermore, most of the previous location methods for high impedance faults were based on current and voltage measurements [13]. Firstly, these techniques require the installation of a large number of voltage/current sensors for all three phases of distribution feeders which cost a lot and are not economically feasible. Secondly, tree-related HIFs do not have a significant effect on the network voltage in the early stages [1], and therefore, methods based on the voltage drop or voltage unbalance in different parts of the distribution system are not effective in the case of tree-related HIF. Furthermore, the locating approaches based on high-frequency voltage disturbances [14] are also not applicable for tree-related HIFs because these high-frequency voltage disturbances are caused by very fast step discontinuities or chopping in the fault current, this is while there is no discontinuities and chopping in the tree-related HIF current during first cycles [1].

Therefore, for all the reasons mentioned above, the aim of this paper is to study a new method for locating tree-related HIF. In proposed method, the magnetic field strength signal is considered as a signature of tree-related HIF. Fault location criteria in this method is the specific trend between phase of high frequency magnetic field components over one period. This criteria is presented under the assumption that the spatial variations of the high-frequency components of the magnetic

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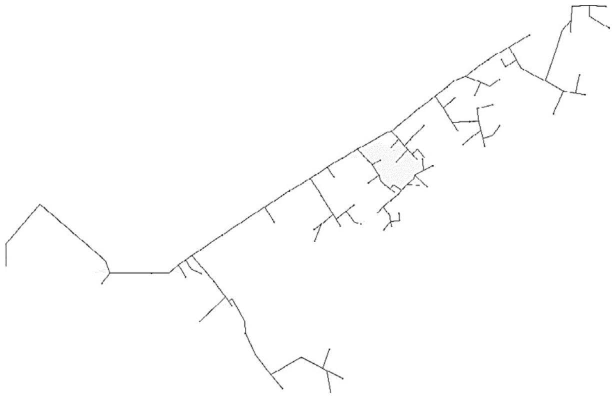

Fig. 1. Test distribution system.

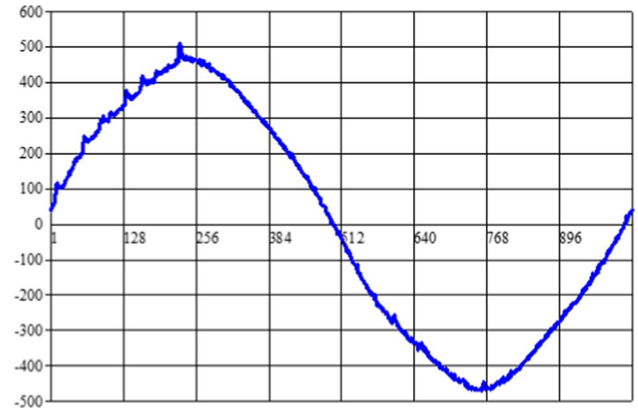

Fig. 3. Fault's current of tested Walnut Tree (mA).

field are appeared in phase shifts of the magnetic field vectors at the sensing point. This assumption is discussed in details in Section 4.

The rest of this paper is organized as follows: Section 2 summarizes the results obtained from the on-site measurements. Section 3 describes the main motivating factors for using magnetic field signature for tree-related high impedance fault location. The method of faulty feeder detection based on magnetic field strength measurement is discussed in Section 4. Section 5 presents the core algorithm for locating tree-related high impedance fault and this location technique is the novelty of current paper. The proposed method performance is evaluated for a typical power line in Section 6. A comparative assessment with existing methods are also summarized in Section 7. The final conclusions drawn in the last section.

2. Tree-related high impedance fault test

The test system was one of the 20 kV Hamedan distribution feeders with 63 buses and a length of 12 km (Fig. 1). This feeder was covered by massive Walnut trees growing to over 12 m tall which were much more likely to come into contact with 20 kV power lines. To collect data for tree-related high impedance fault, a 20 kV single core copper conductor XLPE insulated power cable was connected to the power line and providing connection to tree (Fig. 2). To measure the total leakage flowing to the intended connection, current probe of power analyzer with resolution of 0.1 mA (Model Prova 6830A + 6801) was closed around the cable. The fault's current waveform of Walnut was captured by using a power analyzer that provides a high sampling rate of 1024 samples/period. Stored data were downloaded using a laptop. The obtained result from THIF test of Walnut on MV power lies is documented in Fig. 3.

3. THIF location applying magnetic field strength sensor

The power systems measurement using magnetic field sensors has long been evaluated by several studies. This kind of measurement provides information about network's three phase currents without physical contact. These sensors have also wide frequency bandwidth from DC to hundreds of megahertz to detect magnetic field with resolution of micro gauss. They can separately measure the three components of the magnetic field in three dimension space as well. They have also the capability of being powered by solar panels. So using magnetic field strength sensor provides a low-cost location approach which is commercially feasible.

Fig. 2. Test configuration for HIF on live Walnut.