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Single phase fault location in electrical distribution feeder using hybrid method

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ABSTRACT

Restoration of electrical energy after each distribution feeder's outage can improve the reliability indices and its efficiency. Accurate fault locating can cause the Power distribution (PD) systems to restore rapidly. PD networks include many branches, laterals, sub-laterals and load taps. Thus, accurate fault locating is very complicated and important. In the present paper, a new combined method is proposed for locating the single-phase fault to earth in PD networks. An impedance-based fault-location algorithm is also used to find the possible fault locations. Then, the new method is proposed for determining the faulty section using voltage sag matching algorithm. In this method, after single-phase fault to ground, the possible locations of fault are determined by using the impedance-based fault-location algorithm. The same fault is simulated in possible locations, separately. The voltage, then, at the beginning of feeder is saved and amplitude and angle of the voltage differences are determined and online databank is generated. This databank is compared with the obtained and recorded amplitude and angle of the voltage differences for actual fault. The real location of fault is specified by the matching value of each possible fault location.

1. Introduction

Power systems are composed of four sections: generation, transmission, sub-transmission and distribution. The reliability indices variation of Power Distribution (PD) and the consequences of service interruption depend on the number of interrupted customers, customer load type and size, occurrence time, frequency of outages, and the outage duration period [1]. Due to the serious fallout of system outages on customers and utilities, restoration of power supply to the healthy out-of-service loads in the least time is of profound importance. After occurring faults and interrupting PD feeder, locating fault should be applied to restore the maximum re-energized loads in minimum outage time duration for minimizing the energy rather supplying and satisfying the consumers [1–3]. Due to widespread geographical area covered by PD systems, determining the fault location in distribution networks feeders has several problems in terms of time, costs, and equipment [4]. Three types of methods are given for locating the faults in PD such as impedance method, traveling waves and intelligent methods. But, these methods still encounter some problems. Traveling wave-based method may face problems such as high sampling frequency, complex structure and requirement for the databank [5]. The intelligent methods might be problematic due to the complex structure as well as the requirement for a large and precise databank [6,7]. Finally, the most recent important issue presents the impedance-based fault locating method [8–15].

In Refs. [11,12], fault locating equations of impedance-based methods are generalized for different types of two- and three-phase faults either resistive or solidly. Results of variations in fault initial phase, fault resistance phase and load variations are presented. The results revealed that fault locating accounts for less than 10% error for most of simulated conditions except those associated with short circuits with resistance higher than 100 Ω. In this method, short-line model is considered to obtain accurate results; line parameters should be also accurate; inductor and capacitor should be taken into account in the line model. Also, for section detection, the neural network method is used. It can be specified that this method needs an offline databank while PD networks are changed continuously. Consequently, the accuracy of this method relies on this databank.

In Ref. [13] a new equation for fault location in distribution network is introduced. In this method, π line model (medium line model) is considered for each section and a modified impedance-based method is presented improving the precision. The

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Nomenclature

PD	Power distribution
IBFLM	Impedance based fault location method
DLM	distributed - parameter line model
SLM	short line model.
πM	π model
SL	static load
CL	constant load
FI	fault indicator
CP	current pattern
Nn	neural network
Pd	Protective devices
V	voltage magnitude
FBS	forward backward sweep
$X_{\Delta V}$	calculated fault distance from the obtained equation of the magnitude of voltage difference
i	a section of equation which is employed
x	distance
δ	the matching index
Δv_i	The magnitude difference of voltage
$\Delta\theta_i$	The phase angle variation of voltage
θ	phase variation
x_{actual}	the real fault distance
$x_{calculated}$	the calculated fault distance
l_t	total length of feeder
X_s	calculated fault distance from the proposed improved IBFLM
$X\Delta\theta$	calculated fault distance from the obtained equation of the phase variation of voltage
$\Delta\theta$	is the obtained distance derived from phase angle variation equation

maximum fault for 34-node IEEE (Institute of Electrical and Electronics Engineer) network is reported as 1.58% which equals to 1551 m considering the total length of the network (98180 m). This method is presented only for determining the fault distance while in distribution network, section detection is very important. Another method is proposed in Ref. [14] which uses the distributed model of transmission line as well as voltage and current at the beginning of feeder. In this method, different fault location equations are presented based on the fault types which are a function of voltage and current at the beginning of the feeder. This method does not present any method for fault section estimation. An impedance-based fault location method presented in Ref. [15] uses the fault location utilizing voltage and current registered at the beginning of feeder. In this reference, three impedance indicators are introduced and fault distance is determined in various types of faults. Based on the results, it might be seen that the mentioned method is sensitive to fault resistance. Moreover, line capacitance is ignored in this method which causes the error to increase. In what follows, a new improved impedance-based fault location method is given which is used in accurate load model and distributed parameter line model [8]. Then a new fault section estimation method is suggested using the coordination among protection devices in distribution system [9]. In another research by these authors, a matching algorithm is proposed for faulty section detection using fast Fourier transform and impedance based method [10].

Impedance-based methods use the installed measurements at the beginning of feeder to determine the fault distance, while in practical system, current is only stored in a few cycles before and after fault in over-current relays and extra registers would also be needed to store the voltage. Thus, in Ref. [16] two methods are presented where current phasor and current amplitude are respectively used for determining the fault distance. The accuracy of this method reaches to 8%.

Since most impedance-based methods determine fault location using the iterative algorithms, a technique proposed in Ref. [17] estimates the location of fault in less iteration. It exploits impedances of positive, negative and zero components as well as recorded voltage and current information at the beginning of the feeder. It is applied for looped feeders.

In Ref. [18], the voltage and dip voltage of each node is determined using voltage and current data at the beginning of feeder and some other points of feeder during fault occurrence. This method assumes that fault can be occurred in each section and tries to find the fault current in that section. The dip voltage of each node is calculated from recorded voltage and current data. Then, they are compared. If the values match, fault has occurred and the fault distance is determined utilizing the recorded voltage and current. In Ref. [7] dip voltage phase and amplitude, at first, are calculated for the simulated fault in each node and then are stored in offline databank. Then, dip voltage amplitude and phase are derived based on the fault voltage data and compared to generated offline databank which leads to the extraction of possible locations. Then, based on the calculated dip voltage amplitude and phase for each possible fault location, the desired points in the plane are specified and the distance between perpendicular line and straight lines are determined. Then the location whose perpendicular line is less distant from fault point is selected as the main fault location. The same method is executed in Ref. [6] but the mentioned algorithm is divided into two different planes; dip voltage amplitude-fault distance and dip voltage phase-fault distance. The drawback of the methods given in Refs. [6,7] is needed for databank while it is known that the distribution networks are changed continuously. Moreover, the important papers in this title are reviewed and some important details and characteristics of them are shown in Table 1.

In this paper, a new combined method is proposed for determining the fault distance and faulty section in PD networks for single-phase to ground fault. In this article, initially, the possible locations of fault are determined using the improved impedance-based fault location method (IBFLM). In enhanced IBFLM, the distributed line model without any approximation is used for any part of PD network. Since IBFLM might be multi-response, consequently, the matching value is defined and supposed for determining the section of fault by using voltage sag data. Two new third-order algebraic equations are obtained for defining the amplitude and angle of voltage difference at the beginning of feeder relative to fault distance. When the fault is occurred, the possible locations are determined by the proposed improved IBFLM. Then, these voltage differences are determined from the recorded voltage at the beginning of feeder. Then, the same fault is simulated in the possible locations and online databank of magnitude difference and phase variations of voltage is generated. Now, the recorded voltage differences are compared with the simulation results and the matching one is the real location of fault. The modified IEEE 34 Node Test Feeder is selected for evaluating the proposed method. The simulation of test feeder and calculation of differences' values are done in Simulink/Matlab in different types of fault, different fault inception algorithm, different fault distances and different