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PAPER ABSTRACTS

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A New Method for Fault Section Estimation in Distribution Network

R. Dashti, and J. Sadeh, *Member, IEEE*

***Abstract*-- Determination of fault section is a necessary step for locating the fault in the distribution power system. In this paper a new practical based method is presented for fault section estimation in distribution system. In the proposed method, at first different zones is defined using impedance classifier. Then, the suitable locations for installing the cutout fuses are determined using expert of designer. After that, special settings for cutout fuse links are determined in such a way that they operate coordinately. Finally, current waveforms are used to distinguish which cutout fuse operated or in which section fault occurred.**

***Index Terms*-- Distribution network, Fault section estimation, Cutout fuse.**

I. Introduction

In power systems, transmission and distribution lines are vital links that achieve the continuity of service from the generating plants to the end users. Protection systems for transmission and distribution lines are one of the most important parts in power systems. The security and reliability and service continuity of power distribution system are very important, but they are violating when faults occurred. Fast clearing and isolating of different fault types are critical in maintaining a reliable power system operation and improve service continuity indices such as the system average interruption frequency index (SAIFI) and system average interruption duration index (SAIDI). Consequently, having fault locator can reduce the bad effects of fault on SAIFI and SAIDI indices through three ways: first, fault location helps to speed up the restoration process [1-2]; second, by locating the faulted node it is possible to perform sectionalizer switching operations to reduce the affected area; and finally, by locating nonpermanent faults it is possible to perform scheduled preventive maintenance tasks to avoid future faults [1,3].

Based on a presented report, about 80% of interruptions are caused by faults in distribution networks [4]. Most of the researches presented so far in the field of fault location are focused on the fault location on the transmission lines; however, these algorithms are not suitable for locating the fault on the distribution networks. Since distribution systems are usually unbalanced nature such that mixed single phase and three phase laterals, non-homogeneous feeders, non-homogeneous phase conductor and unbalanced loading. These features can create some problems in fault location algorithm and also in fault section estimation, from which the multiple-estimation problem is the most important.

Distribution fault location methods are divided into three main categories: 1) Impedance- based methods, in which the main frequency components of voltage and current that are measured at substation are used [5-8,9]. The drawback of these methods is the multiple-estimation problem. 2) Traveling wave-based methods, in these methods high frequency components of voltage and/or current which are measured at substation are applied [10-11]. The disadvantage of these methods is the need for high sampling frequency. 3) Intelligent methods, in which special indices and learning based algorithm are utilized [1-12] for distribution fault location but these factors and indices are not unique and in different conditions may be multiple sections are estimated or have wrong fault location.

In this paper a new practical method is presented for fault section estimation in distribution network. Proposed method is divided into some main parts; zones classifying, special setting of cutout fuse links, time comparing and detecting the operated cutout fuse. In this paper, at first different zones is defined using impedance classifying. Then cutout fuses are installed in suggested positions of MV feeder and fuse links of installed cutout fuses are set specially using expert of designer. Then for real faults first faulted zone is detected and operated cutout fuse is detected with comparing operated time, which is calculated using current waveform. Based on this information, one can estimate the section of fault.

II. Proposed Method

This paper deals with fault section estimation with only special configuration of cutout fuses and their settings of fuse links. To present this method, let us make the following assumptions:

1. Fault-induced disturbance current waveform measured at the substation are available and
2. Time-current characteristic of fuse links which are used as the protective devices are assumed to be definite time.

In the proposed method, at first distribution network is divided into some different zones using impedance classifier and cutouts are installed and coordinated with the other protective devices. Impedance information of each zones and

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time setting of each cutout is saved in a data bank. Then occurred fault is distinguished with three phase voltage and current wave forms. They are measured at the substation, which are the inputs to the algorithm. Based on the gathered data, the following quantities are calculated:

1. Magnitude of fault current which flows through the over current relay in substation (I_s).
2. Magnitude of voltage (V_s).
3. Impedance of fault (V_s/I_s) which seen at the sending end of the feeder.
4. Duration of faulted current passes through the over current relay.

Above mentioned quantities are compared with data bank which are stored prior. After that, using the measured impedance faulted zone is detected and by analyzing the duration of fault, the operated cutout fuse is determined. Based on this information, the section of fault can be determined.

Different parts of the proposed method are explained in the following subsections.

A. *Impedance classifier*

At first distribution network is separated into different number of zones by impedance classifier. Consequently, each zone is detected using the calculated impedance with compare to the recorded impedances in the data bank. In Fig. 1, a distribution network is shown which consists of three separated zones, named Z1, Z2 and Z3. Table I presents the range of impedances in each zone.

TABLE I
THE RANGE OF IMPEDANCE FOR DIFFERENT ZONES

	Zones	Impedance range of zones
1	Z1	$0\text{-}a^{\Omega}$
2	Z2	$a^{\Omega}\text{-}b^{\Omega}$
3	Z3	$b^{\Omega}\text{-}c^{\Omega}$

B. *Select number of cutout fuses and their positions*

In the proposed method degree matrix is constructed using the information of topology of distribution system. Each component of degree matrix, named D(i), is the number of lines which is connected to *i*th bus. For example, in Fig. 1, the number of lines which is connected to the node A is four.

According to the degree matrix, the number of cutouts is identified. If the degree of the *i*th node is N, that means that N-1 laterals are connected to this node. For this situation, in order to have a complete protection it is necessary to have N-2 cutout fuses in the downstream laterals. Also in large networks, another cutout fuse is installed behind the bus *i* with the aim of backup operation. In order to distinguish the section of fault, special settings are needed for these cutout fuse links. These fuse links should be set different.

C. *Fault section estimation with respect to protective coordination*

Suppose that fault is occurred at point F (in front of C3) as shown in Fig. 1. For this fault the cutout fuse C3 operates, interrupts the fault current and clears the fault. Current waveform in phase A is shown in Fig. 2 which is measured in substation at bus M (in Fig. 1).

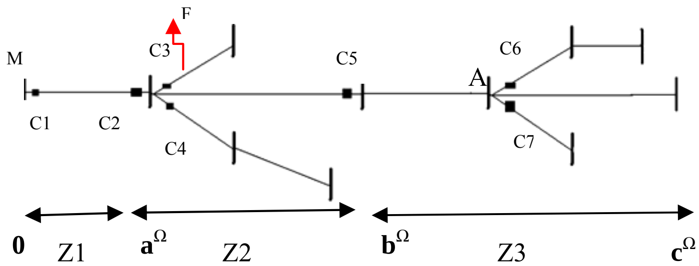


Fig.1. Distribution network with cutout configuration

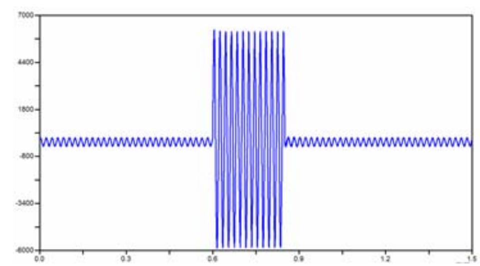


Fig.2. Fault current waveform for fault at point F

In order to distinguish the section of fault, in this paper, a special setting for the cutout fuse links is suggested, which are explained in the following. In zone 2 (Z2) of Fig. 1, operating time of cutout C3 is set on the minimum available time. Then operating time of cutout C4 is selected to be the operating time of cutout C3 plus CTI (CTI=400ms). Also in order to have backup these fuses the operating time of cutout C2 is selected to be the operating time C4 plus CTI. The same procedure is done for the other zones. In zone 3 (Z3), operating time of cutout C7 is set on the minimum available time. Then operating time of cutout C6 is set to the operating time of cutout C7 plus CTI and the operating time of cutout C5 is selected to be the operating time C6 plus CTI. Also in zone 1, the operating time of cutout C1 is the maximum of the operating time C2 and C5 plus CTI.

D. *Locate fault position*

Upon the section of fault is determined, it can be applied one of the presented methods in the literature for fault location. In this paper impedance-based method [1] is suggested.

In Fig. 3, the flowchart of the proposed algorithm is shown.

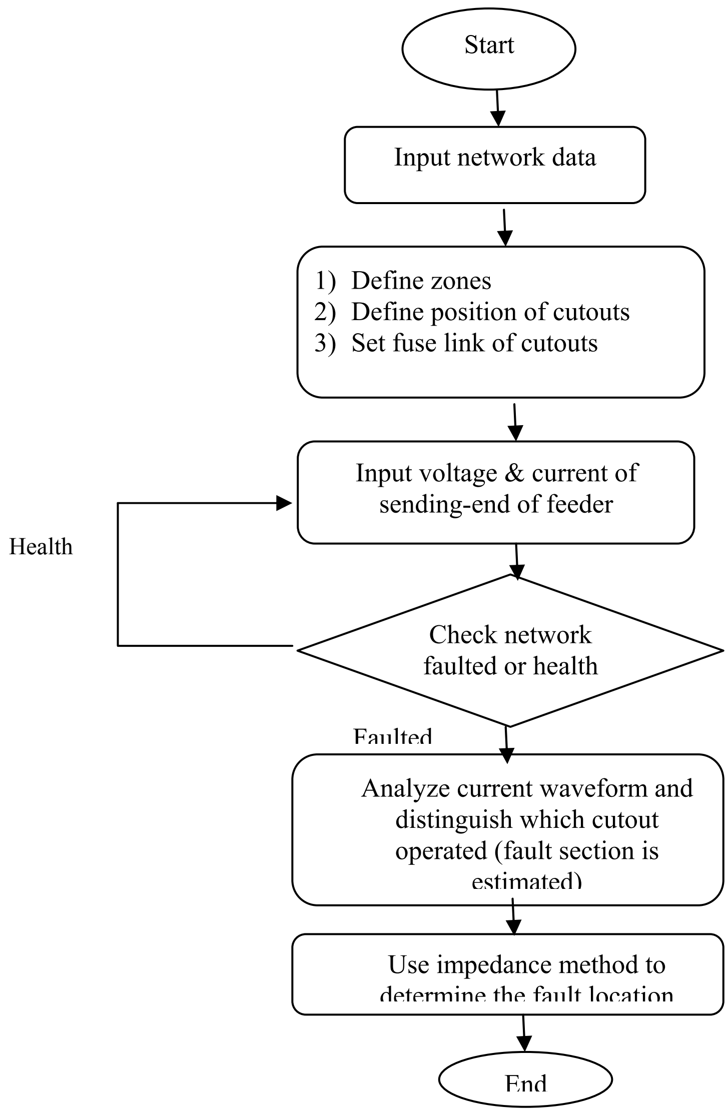


Fig.3. Flowchart of the proposed algorithm

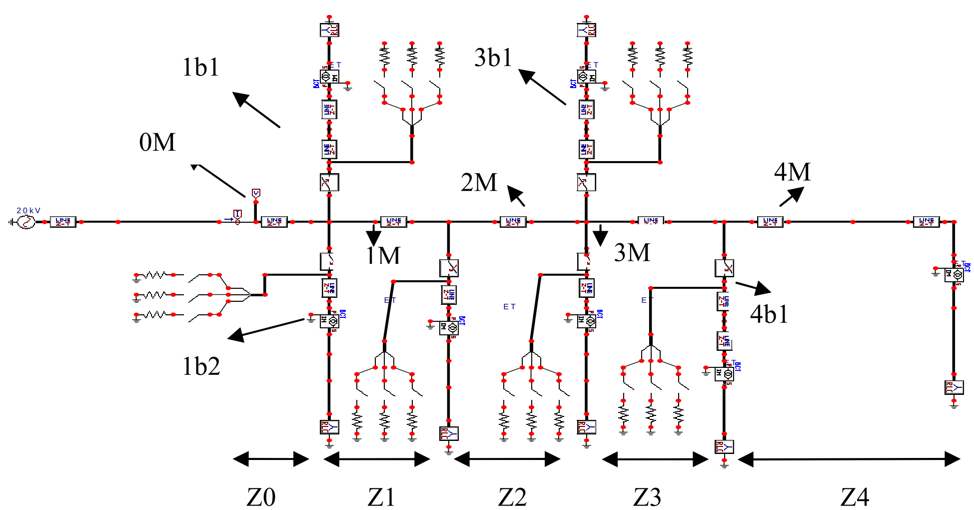
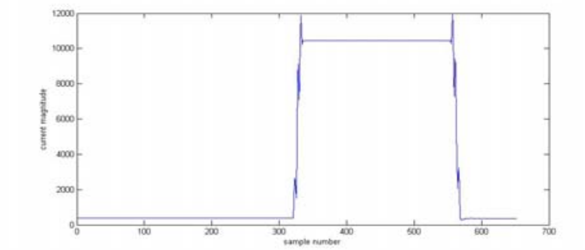
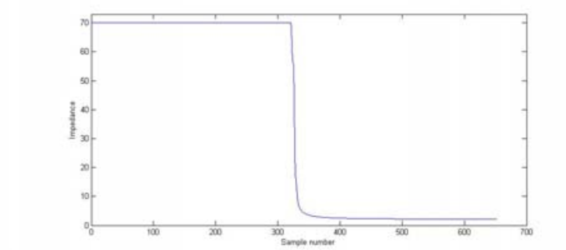
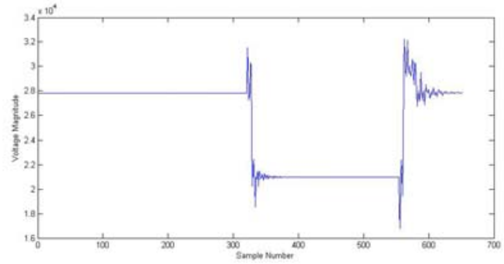


Fig. 4. Simulated distribution network





(a) (b)



(c)

Fig. 5.Curent magnitude(a), Impedance(b) and voltage(c) for fault in branch 2 of zone1

III. Simulation Results

In order to evaluate the feasibility and accuracy of the proposed method, the distribution system shown in Fig. 1 is simulated using ATP/EMTP software. The simulated system is shown in Fig. 4. This system can be separated to five zones, which are shown with Z0, Z1, Z2, Z3 and Z4. In Table II different impedance ranges of each zone is indicated for detecting fault zone. Based on the presented method for setting of the cutout fuse links, these protection devices are set as shown in Table III.

TABLE II
DIFFERENT RANGES OF IMPEDANCE FOR EACH ZONE

	Zones	Impedance range of each zone
0	Z0	0-1.412
1	Z1	1.412-2.86
2	Z2	2.86-4.32
3	Z3	4.32-5.82
4	Z4	5.82-10

Suppose that a three-phase fault is occurred in branch 2 of zone 1. With current waveform which is shown in Fig.5-a, duration of cutout operation is 0.5 second. With attention to fault impedance in Fig.5-b, faulted zone is distinguished as zone1. Then fault may be occurred at 1M, 1b1 or 1b2. With attention to calculated time of cutout operation (0.5 sec) from current waveform, it can be concluded that cutout of branch 2 is operated. Then faulted section is identified as branch 2 of zone1. Three-phase fault is simulated at different distances in the different zones and in all cases, the correct solutions are achieved. Also, fault at 1 to 5 percent of length of the beginning of the laterals is placed and correct faulty section is resulted.

TABLE III
TIME SETTING OF CUTOUT FUSE LINKS

Branch Cutout number	Time setting (second)
1b1	0.1
1b2	0.5
2b1	0.1
3b1	0.1
3b2	0.5
4b1	0.1

IV. Conclusion

This paper presents a practical approach to estimate faulty section and eliminate the multiple estimation problems of the impedance-based fault location methods. The method is based on the apparent impedance calculation and fundamental quantities which are measured at the substation. Furthermore, the method considers the specific characteristics of distribution systems, being capable of locating faults in systems with intermediate loads and laterals/sub laterals. In the proposed method, faulted zone is found with calculation impedance and section is estimated with special setting of cutout fuse links and calculation of the duration of faulted current. This method is also applicable for large distribution systems. According to the test results, the proposed approach has very high performance, in the case of the analyzed circumstances of simulated faults. Finally, this approach also contributes to improve the power continuity indices in distribution systems by the opportune zone fault location.

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VI. BIOGRAPHIES

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