Monitor Placement for Fault Location in Radial Distributed Network Based on Current Sensitivity and System Topology

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A R T I C L E   I N F O

A B S T R A C T

This paper presents a method for monitor placement for fault localization in radial distribution systems. The proposed method is based on the fault current sensitivity of system buses and topology. By considering bus fault current sensitivity and system topology, a systematic procedure is developed and tested with IEEE 33 bus radial distribution network. The results shows that only 4 monitors are required for finding the faulty feeder in the system instead of placing monitors at each bus. This method can be further extended for exact location of fault in the distribution systems.

INTRODUCTION

Electric power distribution systems are complex and approximately 80% of overall faults in power distribution system come from a wide range of phenomena including equipment failure, severe weather and human factors (Marusic, A., 2006) In the case of a failure, the faulty element should be disconnected from the healthy part of the system and service must be restored in a fast and accurate manner. Therefore, identifying the fault location is one of the essential tasks in fault diagnosis and power restoration planning. It has attracted prevalent consideration among electrical engineers and researchers. So far many fault location methods has been reported in the literature and it can be broadly classified in to impedance (Mora-Fl`orez, J., 2008), high frequency travelling wave (Thomas, D.W.P., 2003), artificial intelligence based methods (Ziolkowski, V., 2007).In impedance based methods, the location of fault is obtained by calculating the impedance from measurement of voltage and current at the monitored substation. However, this method is unreliable because the electrical distance from the measuring point may be identical in a multi feeder network (Thomas, D.W.P., 2003). In 2003 suggest the use of fault sensor devices which detect and distinguish abnormal current and voltage events at the overhead power lines as solutions for multiple estimation of fault location.

In case of travelling based methods, the incoming voltage or current surges are detected at both ends of the line and the time of arrival of the surge is used to locate the fault (Bo, Z.Q., 1999). However this method is difficult to adopt in distribution feeders because of short feeder lengths and several discontinuous points (Thomas, D.W.P., 2003). Recently, artificial intelligence application such as neural networks (Gastaldello, D.S., 2012) and fuzzy logic as powerful tools in the fault location has received much interest. Sadeh (1999) proposed a new and accurate fault location algorithm using ANFIS in a combination between transmission line and under-ground cable. Fundamental frequency of three-phase current and neutral current was taken as input while fault location is considered in term of kilometre distance as an output for the system. However, considering the structure and training algorithm of the ANFIS, the speed of this method is not suitable for fast and accurate fault location. Moreover, accuracy of intelligent based methods depends on input data from the monitoring devices and size of the training data.

From the above discussion the fault location method and their accuracy general depends on the available instrumentation used for monitoring the system. Although distribution systems are less closely monitored, it is important to have more instrumentation and monitoring system for accurate fault location. However, too many measurements may not be economically possible. Also too few measurements may lead to multiple possible fault locations depending on the meter locations (Yuan Liao, 2009). Currently there are very few research works related to meter placement for fault location in distribution systems (Yuan Liao, 2009).Thus, for the intention of better fault location in distribution system, meter placement must be designed to accurately fault

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locations considering fault characteristics. This paper deals with finding an appropriate location to install monitors for fault location purpose in distribution network.

Proposed Monitor Placement Method:

In order to determine the monitor positions for fault location in radial distribution networks it is impotent to consider fault current levels in different points and the topology of the system. The following subsections highlight the importance of these two factors.

A. Topology consideration:

Based on Kirchhoff's Current Law, in a radial distribution system, the fault current always flows from the source to fault location. Considering tree structure, if a monitor is placed at a bus with many descendants in the tree, the monitor can cover more extensive areas than a monitor place bus with few descendants. Furthermore, if the outflow currents are monitored from a monitoring bus with many decedents, it can more accurately verify whether the fault location is coming from upstream or downstream. Therefore, components with many descendants must receive more attention in monitor placement for fault location purpose (Won, D.J. and S.I. Moon, 2008).

B.   Fault current level consideration:

The principle of determining the monitor placement must also consider total monitoring bus outflow current changes in its descendent branches, if a ground fault occurs, in the system. The buses with the most significant total outflow currents can be observed and utilized to decide the monitor positions for fault location in radial distribution system. In the proposed method, total bus outflow current changes in its descendent branches are considered as one of the guideline for the motor placement. The basic procedures to obtain the bus outflow currents from bus *i* due to fault at bus *k* can be obtained as follows Chang (2007). For a balanced three-phase ground fault at bus k, the short-circuit current can be calculated by

$$I_f^k = \frac{V_k}{Z_{kk} + Z_f^k} \tag{1}$$

where I_f^k is the fault current at bus *k* and V_k is the voltage before the fault at bus k. Commonly, each network bus voltage before the fault can be considered as 1.0 p.u. Z_{kk} is the Thevenin impedance at bus *k* and can be obtained from diagonal entries of the impedance matrix (Z_{bus}). Z_f^k is the is the fault impedance.
From (1), it is found that the voltage drop at each network bus *i* during the fault at bus *k* is

$$\Delta V_i^k = Z_{ik}(-I_f^k) \tag{2}$$

Where, Z_{ik} is the transfer impedance between bus *i* and bus *k* of Z_{bus} .
Thus, the bus voltage at any bus *i* during the fault become

$$V_i^k = 1 + Z_{ik}(-I_f^k) \tag{3}$$

Now, if the voltages during fault at busses i and j are known, the fault current I_{ij}^{fk} on the branch with impedance z_{ij} which is leaving bus *i* can be expressed as

$$I_{ij}^{fk} = \frac{V_i^k - V_j^k}{z_{ij}} \tag{4}$$

and the sum of currents flowing out of bus *i* due to the fault at bus *k* can be expressed as

$$I_i^{fk} = \sum_{\substack{j=1 \\ j \neq i}}^{N} \frac{V_i^k - V_j^k}{z_{ij}} \tag{5}$$

Finally sum of outflow currents of bus *i* due to the fault at any bus can be expressed as

$$I_i^f = \sum_{k=1}^{N} \sum_{\substack{j=1 \\ j \neq i}}^{N} \frac{V_i^k - V_j^k}{z_{ij}} \tag{6}$$

The bus with the maximum value of system fault current implies that the bus is the most sensitive to the fault. By following the above two guidelines the overall procedure of monitor placement for fault location in radial distribution systems can be described as a flowchart shown in Figure 1.
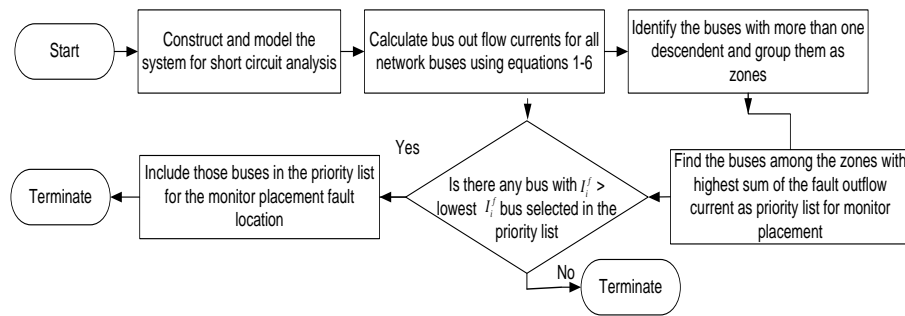
**Fig. 1:** Flowchart of monitor placement for fault location.

RESULT AND DISCUSSION

The proposed monitor placement method for fault location is tested on IEEE 33 bus test system. It is an 11 kV voltage balanced three-phase system consisting of 33 bus and 32 lines as shown in Figure 2. All the loads are fed from the substation located at Bus 1. The system has 32 loads with total 3.72 MW and 2.29 MVAr, real and reactive power loads, respectively (Prakash, K. And M. Sydulu, 2011). The simulation model is built in DIGSILENT software and balanced three phase fault at each bus is applied to obtain bus outflow current as explained in the previous section. Figure 3 shows the result of three phase fault analysis which indicates the total accumulated bus outflow current due to faults at every in the system. From Figure 3 it can be noted that the total outflow currents for Buses 1 to 6 is relatively high compare to the total outflow current recorded for other buses. Therefore these buses can be considered for the placement initially. However according to the procedure, zones are created from a bus which have many decedents as shown in Figure 2 and high propriety is given to the bus with highest outflow currents. In this case, considering the topology of the system, Buses 2, 3 and 6 are selected as priority buses for monitor placement fault location.

Next, other buses which are not included in the zones are scanned for higher outflow currents which are greater than the lowest outflow bus currents which is already been selected. In this case, as shown in Figure 3 below, Bus 1 has total outflow current equal to 28.1 p.u which is greater than outflow current 18 p.u recorded at Bus 3 monitor. Thus Bus 1 is selected as the 4th bus for monitor placement. Therefore, for IEEE 33 bus test system, 4 monitors at Buses 1,2,3 and 6 are required for fault location purposes
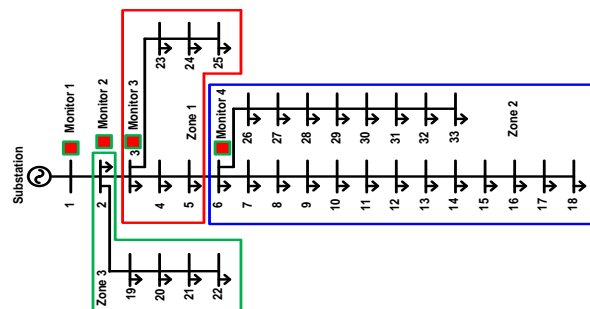
Fig. 2:   IEEE 33 bus system indicating the monitor locations for fault location.
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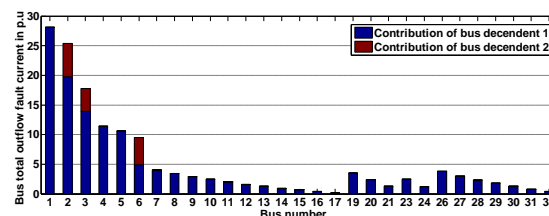
Fig. 3: The bus total outflow current in IEEE 33 bus system.

To demonstrate how these 4 monitors can be used for fault location, consider three phase faults at Buses, 4, 10 and 21. Table 1 shows the recorded fault current by the monitors at Bus 1, 2, 3 and 6 during the faults. From the table it is clear that current recorded at particular monitor is relatively high when the fault happens in the

respective zone of the monitor. For example when the fault happens at Bus 21, monitor at Buses 1 and 2 register vary high current at branch between Buses 1 and 2 as well as branch between Buses 2 and 19 compare to the recorded current at other monitor location. Therefore the fault location is expected to be between Bus 2 and 22.

Table 1: Monitored voltage and currents in IEEE 33 bus network.

	Monitor 1		Monitor 2			Monitor 3			Monitor 4		
	Bus 1	Line 01_02	Bus 2	Line 02_03	Line 02_19	Bus 3	Line 03_04	Line 03_23	Bus 6	Line 06_07	Line 06_26
Fault bus	Voltage p.u	Current p.u	Voltage p.u	Current p.u	Current p.u	Voltage p.u	Current p.u	Current p.u	Voltage p.u	Current p.u	Current p.u
B4	0.66	1.62	0.61	1.58	0.04	0.38	1.56	0.02	0.21	0.01	0.01
B10	0.91	0.55	0.89	0.49	0.05	0.82	0.43	0.04	0.60	0.40	0.02
B21	0.83	0.77	0.81	0.12	0.65	0.79	0.07	0.04	0.76	0.02	0.02

Conclusion:

This paper illustrates a method for monitor placement for fault location purpose in radial distribution system. It considers system topology and the fault current sensitivity levels at various system buses. The result shows that the method can be used to identify the faulty feeder in the system by using only few monitors. The simulation with IEEE 33 bus test system show that only 4 monitors at Buses 1, 2, 3, and 6 are required for fault location.

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