LOCATING FAULTS IN KUWAIT DISTRIBUTION NETWORKS

Wael Al-Hasawi
College of Technological Studies, Kuwait
wael_al_hasawi@hotmail.com

Mahmoud Gilany
College of Technological Studies, Kuwait
mahmoudgilany@ieee.org

ABSTRACT

This paper presents proposed solutions for three problems encountered in power distribution networks. Three novel circuits are proposed for directly identifying the location of open-circuit or short-circuit faults encountered in the network. The validity of the proposed circuits is examined in a real part of Kuwait power distribution network. The proposed circuits provide fault detection capabilities normally achieved by the advanced and expensive Distribution Automation System (DAS) with minimal cost.

INTRODUCTION

Electric power systems are designed to ensure a reliable supply of energy with highest possible continuity. Fast determination of fault location is recommended for further fast repairing of the fault to restore the power. Locating a fault in distribution networks represents a sophisticated problem since different locations of a fault can produce the same fault symptoms [1]. Fault location techniques in distribution system depend on the type of feeding (radial or ring) and the type of fault (short circuit or open circuit).

Regarding short circuit faults, and for feeders fed from one end, there are several fault location techniques in the literature [2, 3]. Current and voltage signals at the relaying points are used in such techniques to estimate the distance to the fault. This approach is not practical for two reasons. First, the voltage signals are not commonly used with distribution systems. Second, the error in the impedance estimated by the distance relays in such applications is usually large since the sequential feeders types and/or sizes are not identical. The fault location techniques used with systems fed from two ends, or ring systems, are more complicated. Global Position Satellite (GPS) with synchronized data is one of these techniques [4, 5].

There are also some Non Protective Devices used to detect the open conductor case like Kearny Manufacturing Company's Open Conductor Detection system (OCD). It uses the loss of voltage to detect downed conductor case. The system is only suitable for radial feeders. It depends on measuring voltage at the end of the feeder. If the voltage is lost then it sends a signal to the first upstream breaking devices to open the circuit if it has a voltage value [7].

For open circuit fault detection, there are different techniques [6]. Most of these techniques are designed for overhead distribution networks. A prototype Ratio Ground Relay for the detection of broken conductor is developed in Pennsylvania Power and Light in USA. This relay depends on ratio setting between the zero sequence current components and the positive sequence current component.

Considering the extensive size of distribution networks, locating network faults can be effectively achieved through implementing systems utilizing the available high-speed computer and communication technology. The Institute of Electrical and Electronic Engineers (IEEE) has defined a Distribution Automation System (DAS) as a system that enables an electric utility to remotely monitor, coordinate and operate distribution components in a real-time mode from remote locations [8]. The DAS is based on an integrated technology, which involves collecting data and analyzing information to make control decisions. The decision making feature of the distribution automation distinguishes it from the normal Supervisory Control and Data Acquisition (SCADA) system [9]. However, such systems may not be accepted because of its high expenses.

In distribution systems where the distances between substations are short, differential protection is usually the preferred protection scheme for the main feeders in the 132/11 kV network as well as for the feeders supplying the 11/0.415 kV distribution transformers. Overcurrent and earth fault protection schemes are only used with the main feeders tapped from the main station. Kuwait distribution network is a typical example [10].

Typically, there are four possible types of faults in a distribution system:

1. Short-circuit fault, which is successfully detected and isolated by the feeder differential protection system. The affected section is not directly identified.
2. An open-circuit fault which is not detected by any protection system.
3. A short-circuit fault which is not detected by any differential relay but isolated by the overcurrent protection of loop. The affected section is also not identified.
4. A short-circuit fault which is neither detected by the feeder differential relay nor the loop overcurrent relays but isolated by the station standby earth fault relay at the high voltage-side. This fault results in a complete shut down of the station. A novel circuit for avoiding this type is presented in Ref [10].

In many existing distribution systems, faults are dealt with by manual intervention and rectified in a time consuming way such as sending a team of people to a predicted faulted area to investigate what has happened. It takes long time to solve the problem and a lot of costs involved in this process.

In this paper, a novel technique for detecting and locating all above-mentioned fault types is introduced and validated. The technique is based on using specialized circuits to handle each type of the four common fault types. The proposed technique is meant for any distribution system protected by differential protection. Kuwait power distribution network is taken as a real example. The proposed circuits facilitate the automation of the network with very little added costs.

LOCATING A FAULT

The objective of the proposed circuits is to quickly identify the faulty section remotely from a new control panel in the main 132/11 kV station in a way similar to DAS, but with minimal cost. The key to the design of the proposed circuits is to make use of the spare wires within the pilot cables associated with the differential relays in order to transmit certain information related to the affected section to the new control panel located in the main 132/11 kV station. Usually, the pilot wire consists of about 16 pairs of wires. In many cases, only one or two pairs are used while the others are spare. The transmitted information helps directly identifying the faulty section. The fault is then isolated and the power is restored. The details of the proposed circuits are given below in the subsequent sections.

Locating a short-circuit fault isolated by a feeder differential protection

In this case, there is a short circuit fault which is detected and isolated by the differential protection. The faulty section in this case will be opened from both sides after clearing the fault. For example, for the fault that occurred in the section between substations H75 and H53 as shown in Fig. 1, the differential relay associated with this section detects this fault and isolates the affected feeder. The two circuit breakers: CB1 and CB2 will be opened after clearing the fault. The customers will not be affected by opening the faulty feeder since the system is fed from more than one point. However, the normal current distribution between the three main feeders (F1, F2 and F3 in Fig. 1) is disrupted. The maintenance team usually depends on this sole variable – current distribution - to predict the location of the opened feeder. In many cases, this variation in the current distribution doesn't give a clear indication about the fault location, and hence, the maintenance team has to search for it from one substation to another.

The circuit breakers are usually accompanied by an "auxiliary normally-opened" and "auxiliary normally-closed" contacts. In the proposed circuit intended for this type of fault, the status of the "normally-open auxiliary contact" is transmitted to a control panel at the main station through the spare wires of the pilot cables.
For example, the status of the auxiliary contact of CB1 (see Fig. 1) is transmitted to main station M using the spare wires of two pilot cables: a spare pair from the pilot cable between substations "H75 and H33" and then a spare pair from the pilot cable between "H33 and, M". The only operation to implement this design is to join these two spare pairs to an indication lamp in the control panel located in the main station, M.

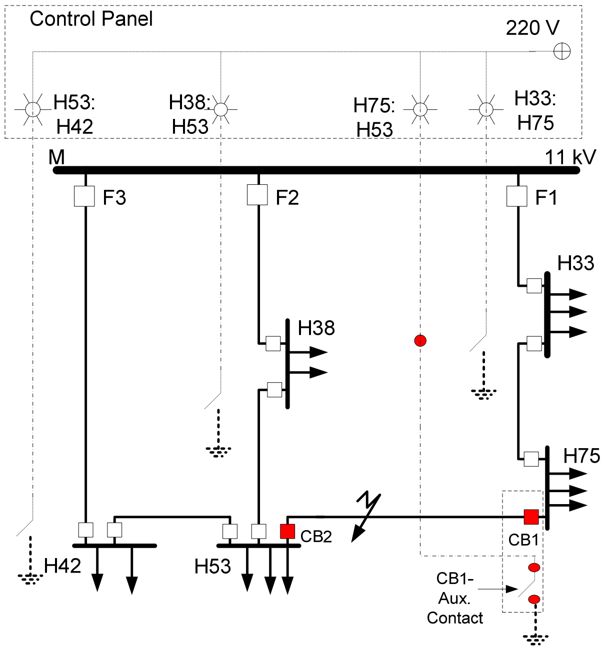

Fig. 1: Identifying a detected short circuit fault

Once a fault is cleared, the status of the auxiliary contact of CB1 will be changed from "open" to "close". Consequently, the electric circuit of the indication lamp "H53:H75" located in the control panel will be closed and hence, the lamp will instantaneously illuminate. Other detected short circuit faults are identified in a similar way. The main feature of this technique is that it instantaneously identifies the faulty section – like DAS - but with almost neglected cost added to the existing hardware thus saving a lot of time and effort.

Locating an undetected open-circuit fault

From the point of view of distribution utility, open conductor (downed conductors) is considered as a public hazard. It is not a system operation problem since the system could continue without fixing such a fault. The problem of open conductors is so dangerous that the IEEE Power engineering society issued a public affaires document to educate the public about the downed conductor problem [11].

An undetected open circuit fault may happen as a result of a cut in the power cable. In this case, the power cable (and may be the pilot cable as well) is opened but the circuit breakers of the faulty section - at both sides - are still closed.

The only available indication showing that there is a problem is the disturbance in current distribution between the three main branches of that loop. Again, it is not always easy to identify the affected section based on these current readings. The maintenance crew has to go through the stations one by one to check the status of the breakers.

Under such conditions, and since none of the indication lamps shown in the previous circuit (Fig. 1) is illuminated and at the same time there is disturbance in currents through the three main feeders then this case is identified as undetected open-circuit fault.
In the second proposed circuit, the three main circuit breakers (F1, F2, F3 in Fig 2) are required to be opened for a few seconds to help identifying the faulty section. Each bus bar in the closed loop covered by the second proposed circuit is connected to an indication lamp located in the control panel at the main station through another spare wire of the pilot cables as shown in Fig. 2. Junctions are made in the pilot wires to facilitate the transition of the bus bar's status from the far stations.

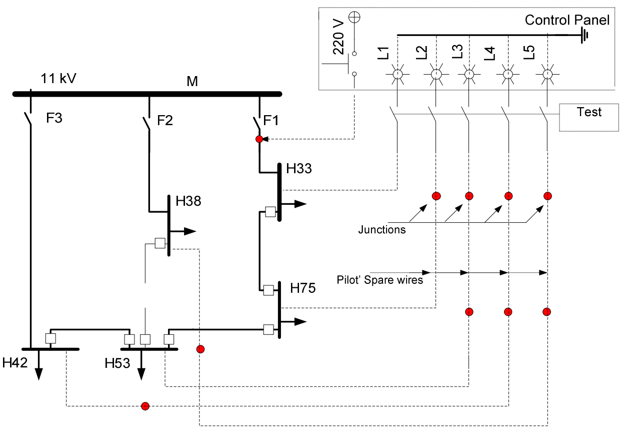

Fig. 2: Identifying a permanent open circuit fault

Under normal conditions, the circuits of the indication lamps are set opened. To locate an open circuit fault, a 240 V signal is injected from the first outgoing feeder, F1 after disconnecting the main 11 kV supply. The lamps L1 to L5 in Fig. 2 correspond to stations H33, H75, H53, H42 and H38 respectively. When the 240V signal is injected, only the lamps corresponding to the stations located before the opened-section will illuminate while the lamps connected to the station located after the opened-section will be dark. Consequently, the affected section is easily identified.

For example, if an undetected open circuit fault is assumed on the section between stations H38 and H53, then all lamps will be illuminated except L5. This indicates that the fault is located in the section proceeding substation H38. As another example, if the open circuit fault is located in the feeder between substations H53 and H75 then only the lamps up to L2 will be illuminated while the others will be dark. Disconnecting the 11 kV supply during the 240V injection takes only a few seconds. However, with this simple technique, it is easy to identify directly the open-section, after which the power can be resumed.

Locating a short circuit fault isolated by the loop overcurrent protection

The third scenario of faults in a closed loop is to have a permanent short circuit fault which is not detected by the differential protection but it is cleared by the overcurrent protection at the main feeders: F1, F2 and F3. This may happen in case of high impedance faults. In this case, there is a clear indication of a fault (the opening of the three breakers) but there is no information about the fault location. This is one of the most difficult faults since the maintenance team has to go through the network's feeders one by one until they discover the fault location. Under such conditions, even after opening the main breakers, the short circuit is still there and needs to be fixed before resuming the power.

The proposed circuit is illustrated schematically in Fig. 3. The objective of the circuit is to quickly identify the faulty section. In this case, the three main circuit breakers in the station are already opened by the overcurrent protective relays. The spare wires in the pilot cables are used in this proposed circuit to control the ON/Off operation of the motorized circuit breakers at certain places.

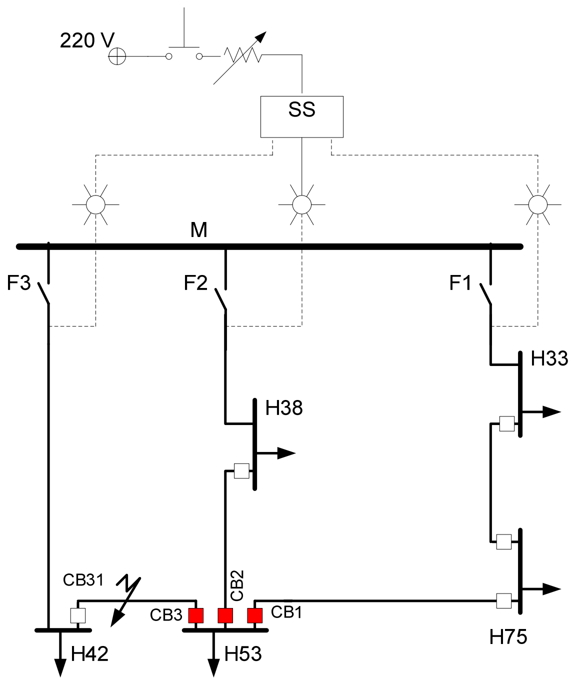

Fig. 3: Identifying a permanent short circuit fault

In the first step, the circuit breakers CB1, CB2 and CB3 shown in Fig. 3 are remotely opened. The system is now split into three radial branches. The fault is located in one of these three branches. Let's assume that the fault is located in the third branch, F3. Using a selector switch, a 240 V signal is gradually injected in each branch through a variable resistance to avoid the severe increase in the current. Only the lamp related to the affected branch will illuminate since it is the only lamp located in a closed circuit.
In the second step, the specific faulty section - within the affected branch - is identified by opening circuit breaker CB31 and gradually re-injects the 240V. If the lamp

illuminates then the fault is located in the first section (between M and H42). Otherwise, it must be in the second section (between H42 and H53).

After identifying and isolating the faulty section, all the circuit breakers can be remotely re-closed - except for the two breakers at the ends of the faulty section - and the power can be resumed. The exact fault location within the faulty section is determined (off-line) after resuming the power using any traditional Cable Tracer. The proposed circuit takes a few minutes to identify the faulty section compared to the traditional technique which takes several hours since it needs to disconnect all sections and test them one by one in a time-consuming operation.

In all previous circuits, the resistance of pilot cable's wires is typically 8 Ω/km. The maximum distance from the main station to any substation is around 1700 m. The rated current of the used lamps is less than 0.1 Amp. Thus, the voltage drop across the pilot wire is neglected.

CONCLUSIONS

This paper presents practical field experiences with power distribution networks. Kuwait distribution network is taken as a real example in the simulation studies. Novel circuits are presented for identifying the faulty section in case of three different fault types namely: short circuit faults isolated by the feeder differential protection, undetected open-circuit fault and short circuit faults isolated by the loop overcurrent protection. The proposed-circuits reduced technical and commercial losses, lower electric service restoration time, reduce equipment damage, and enhanced power quality and reliability. These circuits fulfil many tasks of DAS systems with very little added cost.

ACKNOWLEDGMENTS

The financial support from the General Authority for Applied Education and Training in Kuwait (Project No. TS-02-08) is highly appreciated.

REFERENCES

[1] A. I. Taalab, Hatem Darwish, 2001 "Comparative Study of Fault Location Methods for Radial Distribution Systems", *8th International Middle East Power System Conference,* Egypt. pp. 801-807.

[2] Adly Girgis, Christopher M. Fallon,1993 "A fault location technique for rural distribution feeders", *IEEE Transactions on Industry Applications,* Vol. 29, No. 6, pp. 1170-1175.

[3] Jun Zhu, david Lubkeman, 1997 "Automated Fault Location and Diagnosis on Electric power Distribution Feeders", *IEEE Trans. On Power Delivery*, Vol. 12, No. 2, pp. 801-809.

[4] Adly A. Girgis, David Hart, William Peterson, 1992, "A New Fault Location Technique for Two-and Three-Terminal Lines", *IEEE Trans. On Power Delivery*, Vol. 7, No. 1, pp. 98-107.

[5] R. E. Lee , M. T. Bishop, 1983, "Performance Testing of the Ratio Ground Relay on A Four Wire Distribution Feeder", *IEEE Trans. On PAS*, Vol. PAS-102, No.9.

[6] Carl L. Benner, and B. Don Russell, 1997, "Practical High –Impedance Fault Detection On Distribution Feeders", *IEEE Transaction on Industry Applications*, Vol.33, No. 3.

[7] L.A. Liar et al.,1979, "Innovative Relay Methods for Detecting High Impedance Fault Detection on Distribution Circuits", *Proc. of the American Power Conference*, Vol. 41.

[8] R.P. Gupta and R.K. Varma, 2005, "Distribution Automation: Present Status", *Academic Open Internet Journal*, Volume15.

[9] Musse M. Ahmed, 2006, "Electrical Distribution Automation System for Low Voltage (LV) System", *First International Power and Energy Conference*, Putrajaya, Malaysia

[10] M. Gilany, Wael Al_Hasawy, K- El-Nagaar, 2006, "Field Experience with Kuwait Distribution Networks", *15th International Conference on Power System Protection*, Bled, Solvenia, pp. 282-286.

[11] IEEE Power Engineering Society Public Affairs Document, (Green Book),1989, *"Downed Power Lines: Why They Can't Always Be Detected*".