Risk Analysis for Adaptive Centralized Protection Scheme for Electric Distribution Systems in Presence of Distributed Generation

M.-R. Haghifam
Tarbiat Modares University
haghifam@modares.ac.ir

S.A. Javadian
Islamic Azad University
am.javadian@seiau.ir

M.E. Honarmand
Gillan Electric Distribution Company
m_e_honar@yahoo.com

ABSTRACT

Electric distribution networks have a simple protection system including fuses, re-closers, and over-current relays. One of the negative effects of DG installation in distribution network is miscoordination of protection devices and conflict between DG operation as islanding mode and protection purposes. This paper for overcoming to this difficulty proposes an efficient algorithm based on dividing a distribution network into several zones, each zone, capable of operating in island operation. In the proposed method, risk analysis is used to optimize the protection zones by optimal placement of protective devices. The proposed scheme has been implemented on a real distribution network.

1- INTRODUCTION

Radial distribution feeders are the most conventional configurations of distribution systems. In such networks, primary distribution feeders are extended from sub-transmission substations towards lateral feeders. The main advantages of radial configuration are its simplicity in planning and operation and its low cost in installation.

in recent years, some issues like environmental and geographical restrictions of generation units, increasing trend of load growth in distribution systems and the necessity for constructing new power plants as its consequence, tendency toward applying clean energies and independency from fossil fuels strategy, have caused distributed generation to draw attention to a great extent. Presence of DGs in distribution networks, like many other technologies, has some disadvantages [1]-[9]. Among advantages of DGs one can mention improvement in power quality and reliability and reduction of loss, meanwhile using DGs leads to complexity in operation, control and protection of distribution systems [1], [2]. Operation of DG in islanding mode can caused a significant effect in reliability of distribution network.

Injection of DGs currents to a distribution network results in losing radial configuration and consequently losing the Existing coordination among protection devices [2]-[7]. The extent at which protection coordination is affected depends on the size, type and location of DG, in some cases coordination is lost completely and in other cases the coordination range diminishes [4], [5].

Problems that arise due to the application of DGs are: false tripping in feeders, false tripping in generation units, protection blinding, increasing and decreasing short circuit levels, undesirable network islanding and preventing automatic and asynchronous re-closing [5]. Appearance of these problems depends on the characteristics of the network and DGs. In most cases network protection scheme must be thoroughly changed in order to avoid the above problems. Such changes may be complicated, since it is needed to model whole distribution system including distribution network in addition to DG. Consequently, obtaining the best protection scheme is still difficult [5]. Also by conflict between DG operation in islanding mode and protection of DGs and distribution network, reliability enhancement by DGs cannot be achieved. The effect of DG on re-closing operation was studied in [8]. It showed that the presence of DG causes inefficiency in re-closing operation of distribution networks and also transient faults may not be cleared. It is also shown that island operation leads to losing network synchronism and when re-closing operation is carried out in an asynchronous network, heavy damage is imposed on the distribution system devices.

In this paper a new approach for the protection of distribution networks in the presence of DGs is presented. The algorithm is based on dividing an existing distribution network into several zones, each capable of operating in island operation. In the suggested method, risk analysis is used to optimize the protection zones by optimal placement of protective devices and MLP neural networks are used for determination of faults. The proposed scheme has been implemented on a real distribution network and a MATLAB based developed software has been used to implement the proposed algorithm on the real network data.

2- General View of the Proposed Scheme

The main purpose of a protection scheme is to diagnose the faulty part and isolate it from the rest of the system. In traditional distribution systems, when a fault occurs in a specific part, whole downstream network is disconnected from the rest of the system or supplied through network tie lines. Assuming it is impossible to supply through other parts of network and a DG exists in the downstream network of the faulty part, according to conventional protection logic, it will not be possible to utilize the DG any more. This will result in not being able to utilize the DG sources optimally, and the amount of Energy Not Supplied (ENS) in network increases so system reliability decreases. In the proposed scheme, the general approach is to utilize the DGs to the fullest in island operation when fault occurs.

In the suggested scheme, the distribution system is divided into several zones in such a way that in each zone there is no DG, or if there is any, balance of generation and consumption in that zone can be maintained using only the power generated by DGs that exist in that zone, regardless of the total generation network. In other words, distribution system is divided into two categories that have the following characteristics:

- First category includes zones that have no DG and their loads are fully supplied through the entire network and other zones of the distribution network.
- Second category includes zones that have DG. At least one generating unit in each zone must be equipped with frequency control system in order to be capable of controlling the zone frequency in the case that the zone is in island operation state.

As it can be seen in Fig. 1, a number of circuit breakers are placed in the network to interconnect the zones. These breakers have fast and consecutive open and close capability as well as receive remote open and close command. Besides, these breakers must be equipped with check-synchronization function to be able to maintain zones synchronization when it is needed to connect two islanded zones.

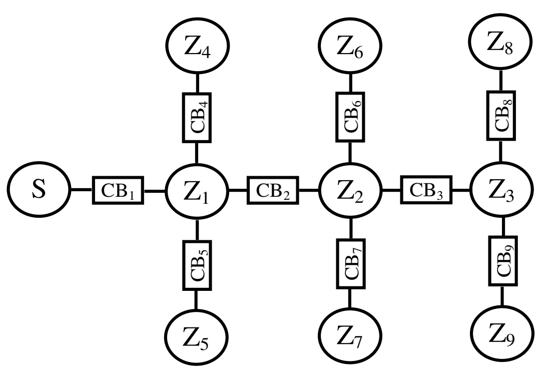

Fig.-1: Protective Zones in Distribution Network

To implement the proposed algorithm, a computer-based relay with capability of performing calculations and storing data must be installed in the sub-transmission substation. This relay is able to receive the required input data (provided through measuring some network parameters), to process them, and in the end, to diagnose location and type of fault in order to send proper commands to the protection devices. The General Flow diagram of proposed method is sown in Fig.2

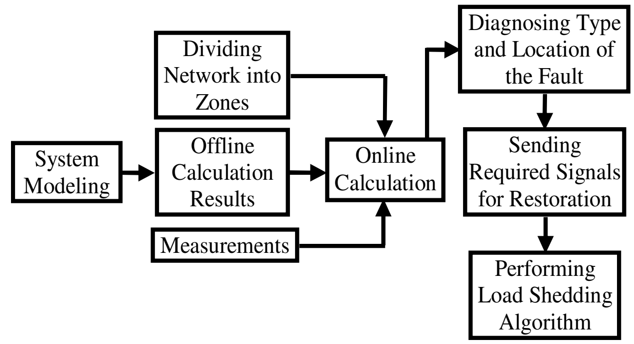

Fig.2. General view of the proposed protection scheme

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3- Required Offline and online Input Data in the algorithm

The input offline data needed for proposed relay is:

- Technical characteristics of all network
- Estimated hourly load curve for all loads
- Data regarding network zoning
- All operational data of the main relay for different faults

- To implement the proposed protection scheme, it is required to carry out the following measurements and continuously provide the main relay with its results.
- Synchronized three-phase current in phasor form flowing through all DGs and through the main source;
- Synchronized three-phase current in phasor form flowing through laterals, except those branches that have DG;
- Synchronized three-phase current phasors flowing through zone-forming breakers;
- A signal which is indicative of current direction flowing through the breakers that form zones;

4- Fault Location and type Scheme based a Neural Network

The most important part of a protection system is accurate determination of the type and location of occurred faults in its protection zone. In this paper, through offline calculation, a MLP neural networks are trained with the proper input data which is gathered by system modeling and performing short circuit calculations in different locations and with various fault impedances. Then, in case of a fault occurrence, through online calculation, the accurate type and location of the fault are determined by the main relay.

5- Network Zoning Approach

In order to optimize the protection scheme based on feeder sectioning, it should be determined number and locations of CBs. In this paper, risk analysis has been used for optimizing the number of CBs.

For calculation of protection system risk, the mathematical expectations for loss of load for each contingencies with consideration of load variationsshould be calculated as shown in (1):

$$R_i = \sum_{k=1}^{m} \sum_{j=1}^{n} P_j . L_{j,k} \qquad (1)$$

Where:

R_i: the total risk of protection system in situation i;

P_j: the probability of fault happening on the line number j of the network;

$L_{j,k}$: the total load that will face power cut by outage of line j and in time k;

To show the capabilities of proposed protection scheme, a real is considered as shown in Fig-3. The selected distribution network is a primary distribution feeder with 20 kV, 12335m in length and is supplied through a 63/20 kV sub-transmission substation. This feeder supplies 34, 20/0.4 kV distribution substations, including 3 ground and 31 aerial ones.

All the data of this sample network has been extracted from a real application database, and loads data for the substations on this feeder has been modeled using load research procedure.

To test the operation of the proposed protection scheme on the sample network, a 400 kVA diesel generator has been connected to Bus 12, a 300 kVA diesel generator has been connected to Bus 23, and a 120 kVA diesel generator has been connected to Bus 40 (all have 0.8 lag power factor).

For placement of CBs in this network, there are 42 locations that have the possibility of installing CB. These locations are on all distribution lines of the network. Because there are 3 DGs connected to the network, at last, 6 CBs can be installed. But, the protection system with less than3 CBs may have lower risk. So, the previously explained method for risk analysis should be done for all cases of protection system with 6 CBs, protection system with 5 CBs, protection system with 4 CBs, protection system with 3 CBs, protection system with 2 CBs, and protection system with only 1 CB.

These calculations have been done by considering the value of 0.01 for the probability of fault occurrence on all lines of the network and its output results are presented in table 3.

As it can be seen in table 3, the minimum risk value is for the network with 4 CBs when these CBs installed on lines connected buses 1 to 2, 7 to 8, 35 to 36, and 39 to 40. The network configuration in this situation as well as protection zones is shown in Fig.3.

Table 1. Risk Analysis Results for Simulated Distribution Network

Situation	Minimum Risk Value	Optimum Location of CB(s)
Network with 6 CBs	16.13	B_1-B_2,B_5-B_6, B_8-B_{14}, B_{14}-B_{20}, B_{25}-B_{34}, B_{38}-B_{39}
Network with 5 CBs	15.96	B_1-B_2,B_7-B_8, B_{14}-B_{20}, B_{36}-B_{37}, B_{38}-B_{39}
Network with 4 CBs	15.24	B_1-B_2,B_7-B_8, B_{35}-B_{36}, B_{38}-B_{39}
Network with 3 CBs	16.68	B_1-B_2,B_7-B_8, B_{36}-B_{37}
Network with 2 CBs	18.91	B_1-B_2, B_{14}-B_{20}
Network with 1 CB	20.87	B_1-B_2

6- Conclusion

An algorithm for the protection of distribution networks in the presence of DG is proposed in this paper. The algorithm uses network zoning approach, in which each zone is an independent section, capable of island operation whenever needed. Also, an optimization method for placement of protective circuit breakers in distribution networks based on risk analysis has been presented in this paper. In the proposed method, the installation location of protective devices is calculated with the goal of minimizing the total risk of the system. The suggested method was implemented on a real distribution network and its results were presented.

7- References:

[1] Javadian Javadian, S.A.M., Haghifam, M.-R., " Protection of distributed network in presence of DG using distribution automation system caabilities , Proc. 2008 IEEE Power Engineering Society General Meeting, 20-24 July 2008, pp. 1-6.

[2] Brahma, S., and Girgis, A., "Development of Adaptive Protection Scheme for Distribution Systems with High Penetration of Distributed Generation," IEEE Trans. Power Delivery, VOL. 19, NO. 1, JANUARY 2004, pp. 56-63.

[3] Barker, P. P., and de Mello, R. W., "Determining the impact of distributed

generation on power systems: part1-radial distribution systems," IEEE Trans. Power Delivery, vol. 15, Apr. 2000, pp. 486–493.

[4] Dugan, R. C., and McDermott, T. E., "Operating conflicts for Distributed Generation interconnected with Utility Distribution Systems," IEEE Industry Applications Magazines, 19-25, Mar/Apr. 2002.

[5] Kauhaniemi, K., and Kumpulainen, L., "Impact of distributed generation on the protection of distribution networks," Proc. Developments in Power System Protection, Eighth IEE International Conference , 5-8 April 2004, Vol.1, pp. 315 - 318.

[6] Girgis, A., and Brahma, S., "Effect of Distributed Generation on Protective Device Coordination in Distribution System," Proc. Large Engineering Systems Conference, 11-13 July 2001, pp. 115 – 119.

[7] Doyle, M. T., "Reviewing the Impacts of Distributed Generation on Distribution System Protection," Proc. Power Engineering Society Summer Meeting, 2002 IEEE, Vol.1, pp.103-105.

[8] Kumpulainen, L. K., and Kauhaniemi, K. T., "Analysis of the impact of distributed generation on automatic reclosing," Proc. Power Systems Conference and Exposition, IEEE PES 10-13 Oct. 2004, Vol.1 pp. 603 - 608.

[9] Hadjsaid, N., Canard, J., and Dumas, F., "Dispersed generation impact on distribution networks," IEEE Comput. Appl. Power, vol. 12, pp. 22–28, Apr. 1999.

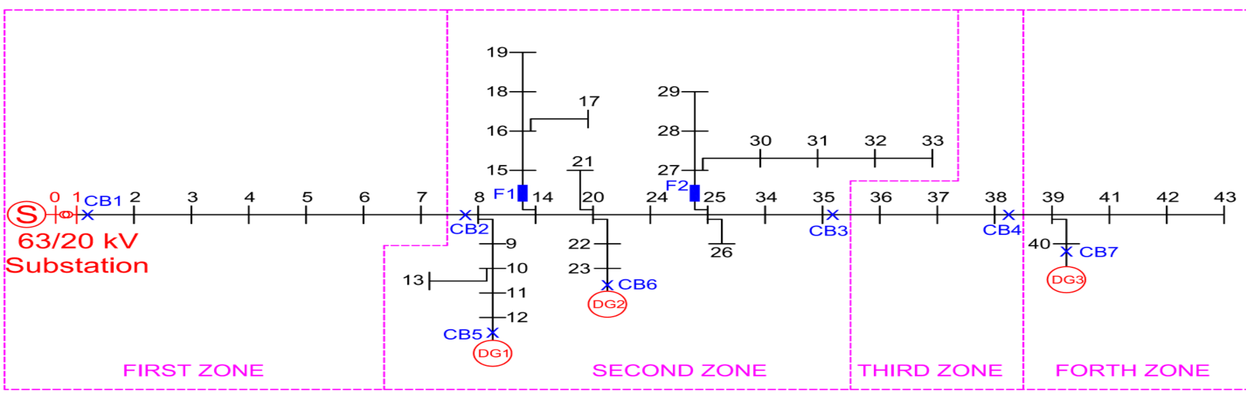

Fig.-3: Test Network