A Fault Location and Protection Scheme for Distribution Systems in presence of DG Using MLP Neural Networks

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***Abstract*--Traditional electric distribution systems are radial in nature. These networks are protected by very simple protection devices such as over-current relays, fuses, and re-closers. Recent trends in distributed generation (DG) and its useful advantages perfectly can be achieved while the relevant concerns are deliberately taken into account. For example, penetration of DG disturbs the radial nature of conventional distribution networks. Therefore, protection coordination will be changed in some cases, and in some other cases it will be lost. The penetration of DG into distribution networks reinforces the necessity of designing new protection systems for these networks. One of the main capabilities that can improve the efficiency of new protection relays in distribution systems is exact fault locating. In this paper, a novel fault location and protection scheme has been presented to provide the distribution networks with DG. The suggested approach is able to determine the accurate type and location of faults using MLP neural networks. As case study, the proposed scheme has been assessed using a MATLAB based developed software and DIgSILENT Power Factory 13.2 on a sample distribution network.**

***Index Terms*-- Fault Location, Distributed Generation, Distribution System, Protection**

I. Introduction

ONE of the important threats for distribution network equipments which has been existed incessantly is occurrence of short circuit fault. Fighting to this danger and protect the system against this phenomena has been a major subject for power engineers for many years. Protection devices and algorithms in power system are the results of challenges to solve this problem and have been developed throughout the time. Recently, using of digital relays in power system protection causes capabilities of protection algorithms and schemes to be increasingly developed [1],[2]. Fault locating in power systems has been a major subject for power and protection engineers in recent years. In distribution systems, due to large variations of fault impedance, fault location problem has more importance and is more difficult to solve than transmission and generation systems. Furthermore, because of the low cost and significance of distribution network's equipments, it is not economically admissible in this case to design advanced protection schemes for these networks. On the other hand, the reliability of these networks can be greatly increased if the exact location of fault is determined using modified protection systems [3].

Presence of distribution generation and applying renewable energies in distribution networks has been one of the other noticeable subjects for electrical engineers in recent years. DGs are small generation units with lower operational capacity in comparison with large power plants, which use clean and environmentally compatible energy resources to produce electricity. Due to small generation capacity, it is not economical to transfer their energy productions through the power transmission lines. So, DGs are generally connected to distribution systems [4], [5].

Presence of DGs in distribution systems has changed their simple and conventional radial configuration and results in more complexity of their operation, control and protection. Consequently, determining the accurate location of probable faults will be more important in distribution systems including DG [6], [7].

Due to low fault impedance, it is not so intricate to find the fault location in HV transmission lines and is simply done by distance relays. On the contrary, we encounter various and relatively large impedances for faults in distribution systems which are extended in residential, urban and rural regions. With high amount of impedance and its extensive variations in distribution system, classic methods will not be appropriate to specify the fault location [8], [9].

Optimization algorithms and artificial intelligence such as neural network, genetic algorithm, game theory, fuzzy logic, ant colony and simulated annealing have been widely used to solve optimization problems in engineering, so that simplicity and high speed in finding the solution are the results of employing these algorithms. Artificial neural network is one of the powerful methods to solve engineering problems such as classification and function approximation. High capability of neural networks as well as their simplicity results in increasing their usage for solving such problems [10].

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In this paper, a novel fault location and protection scheme has been presented to provide the distribution networks with DGs. The suggested approach is able to determine the accurate type and location of faults considering fault impedance using artificial neural networks.

II. Protection Scheme

The general idea of the proposed protection scheme is based on dividing the distribution system into several zones. Zoning is done through considering locations and generation capacities of DGs along with network loads. For applying the zoning procedure in the distribution system, it is considering one zone for each DG, starting from the beginning of feeder, and each zone extends to the end of feeder as long as the DG within that zone is capable of supplying average load of that zone. When average load of substations located in the zone exceeds generation capacity of zone's DG, zone border finishes. In the case that there exists a second DG located within the supplying limit of first zone's DG, and as long as zone's average load does not exceed generation capacity of first DG, while moving towards end of feeder, the second DG is regarded within the same zone and zone border extends as far as the zone's average load does not exceed summation of two DG's capacity. Therefore, in each zone there is no DG, or if there is any, balance of generation and consumption in the average load regime in that zone is possible regardless of main network, and only using the power generated by DGs that are located in that zone.

After network zoning and determining zones' boundaries, some circuit breakers which are capable of operating repeatedly and quickly and are also able to receive remote signals, are placed between each two zones of the system. These CBs must also be equipped with check-synchronization relays. To implement the protection scheme, it is required to place a computer-based relay with high processing power and large storage capacity in supplying substation (sub-transmission substation) of the distribution network. The computer-based relay installed in sub-transmission substation holds the main responsibility of system protection and operates through steady monitoring of the currents flowing through some specific points of network. The specific points of network that their currents must be measured and monitored continuously are:

- All currents flowing through all DGs and the main source;
- Currents flowing through isolating CBs of zones;

To perform Load shedding, load break switches with shunt trip mechanism that permits remote tripping shall be provided to have facility to connect to the main relay.

Fig. 1 shows the outline of the suggested scheme [2].

III. Fault Location Scheme

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, 4 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.

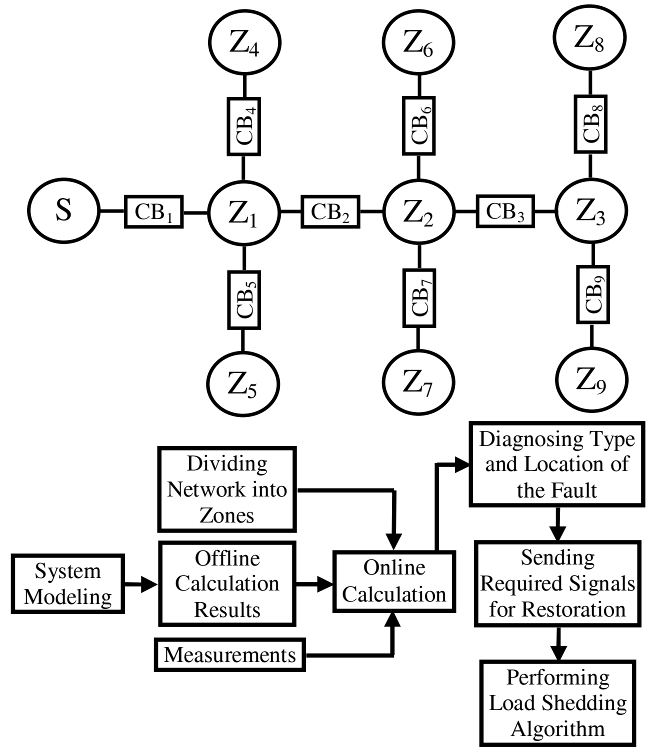

Fig. 1. Outline of the proposed protection scheme

The proposed method in this study consists of two parts which are recognizing fault type and determining fault location. These two parts are described in the following sections.

A. *Recognizing the fault type*

In order to determine the fault type, only the 3 phase current of the main source is used. At this point, there is no need to ANN and it can be determined with normalizing 3 phase output current of the feeding substation. To normalize the mentioned currents, the following equation is used:

$$I_{normal} = \frac{I}{I_{\max}} \tag{1}$$

Where:

I: phase current

I_{max}: maximum phase current

Fault type can be determined using (1) and table I.

B. *Determining fault location*

After recognizing the fault type, its location should be determined. In this paper, MLP neural network is used for specifying exact location of the fault. The outline of the proposed method is shown in Fig. 2.

After recognizing fault type by its corresponded unit, the trained neural network of this kind of fault is activated and receives the input data which has been prepared by the input data preparation program. The output of the neural network will be the fault distance from all DGs and the main source.

TABLE I
NORMALIZED CURRENT VECTOR OF THE MAIN SOURCE FOR DIFFERENT FAULT TYPES

Fault Type		I_a	I_b	I_c
1-phase	Ag	1	0	0
	Bg	0	1	0
	Cg	0	0	1
2-phase	AB	1	-1	0
	AC	1	0	-1
	BC	0	1	-1
2-phase to ground	ABg	1	1	0
	ACg	1	0	1
	BCg	0	1	1
3-phase	ABC	1	1	1

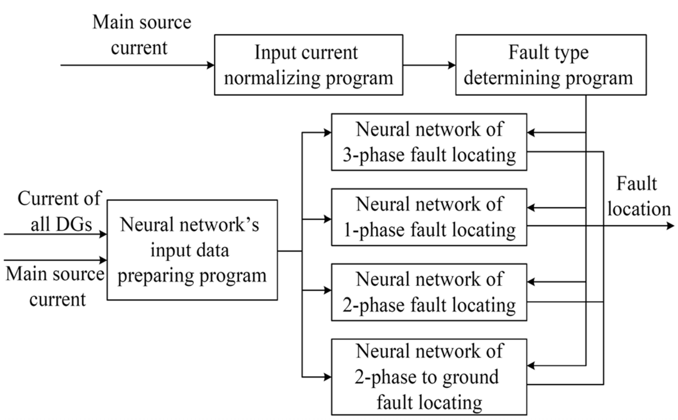

Fig. 2. The outline of the proposed fault location scheme

As mentioned previously, the major problem of fault locating in distribution networks is fault impedance. For the purpose of minimizing the effect of fault impedance to the output of neural network, appropriate characteristics have to be defined for neural network. Proportional relationship between injected fault current of DGs and feeding substations to each other is taken as the input of neural network in this study.

Injected fault current of each DG can be calculated using (2).

$$I_f = \frac{V}{Z_{th}} \quad (2)$$

Where V is power supply terminal voltage and Z_{th} is the equivalent Thevnin impedance of the network. For instance, in the network depicted in Fig. 3, in the case of zero-resistance short circuit in A, equivalent impedance of DG and network is:

$$Z_{DG} = Z_{34} + Z_{3a} \quad (3)$$

$$Z_S = Z_{12} + Z_{2a} \quad (4)$$

Where:

Z_{12}: impedance of transmission line between bus 1 and bus 2;

Z_{34}: impedance of transmission line between bus 3 and bus 4;

Z_{3a}: impedance of the part of the transmission line between bus 3 and point A (fault point);

Z_{2a}: impedance of the part of the transmission line between bus 2 and point A (fault point);

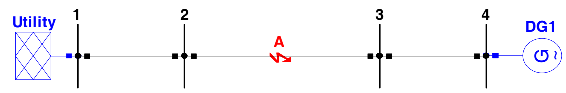

Fig. 3. A simple distribution network with one DG

In this network the proportion of short circuit current of the network to short circuit current of the DG is

$$\frac{I_S}{I_{DG}} = \frac{Z_{34} + Z_{3a}}{Z_{12} + Z_{2a}} \quad (5)$$

Assuming nonzero-impedance short circuit at point A**,** the mentioned relation is:

$$\frac{I_S}{I_{DG}} \approx \frac{Z_{34} + Z_{3a} + Z_f}{Z_{12} + Z_{2a} + Z_f} \quad (6)$$

Which is approximately the same as (5). So, using this proportion, i.e. the relation of injected fault current of various resources as the input of the NN, the impact of the fault impedance will decrease to its lowest amount [3]. It can be observed that this method is applicable on distribution networks which include DG. This means the proposed method is only worthwhile for using in those networks and cannot be applied for fault location in conventional distribution systems.

Furthermore, it is important to be mentioned that by increasing the number of DGs connected to distribution system, the accuracy of fault locating of neural network will be improved due to growth of number of its inputs. For example, in the case of one DG in the network only one input can be used for training the neural network while in the case of n DG resources connected to the network, the number of inputs of neural network is:

$$N = \binom{n}{2} \quad (7)$$

Where n is the number of suppliers of fault current (one the network and n-1 DG resources). The number of outputs of neural network is n which is equal to the number of fault current suppliers and each output uniquely determines the distance of the fault from its power supply. So, the structure of neural network used in this paper is shown in Fig. 4.

Only one hidden layer is used for the purpose of constructing the neural network, while the neurons number is related to the modifying conditions and cannot be specified precisely. It has to be mentioned here that in a particular problem, the number of neurons in the hidden layer can be determined with try-and-error method. The number of output layer neurons is equal to the number of outputs. Linear type and hyperbolic tangent type transfer function is considered for output and hidden layer neurons, respectively, and Levenberg-Marquardt algorithm for neural network training method.

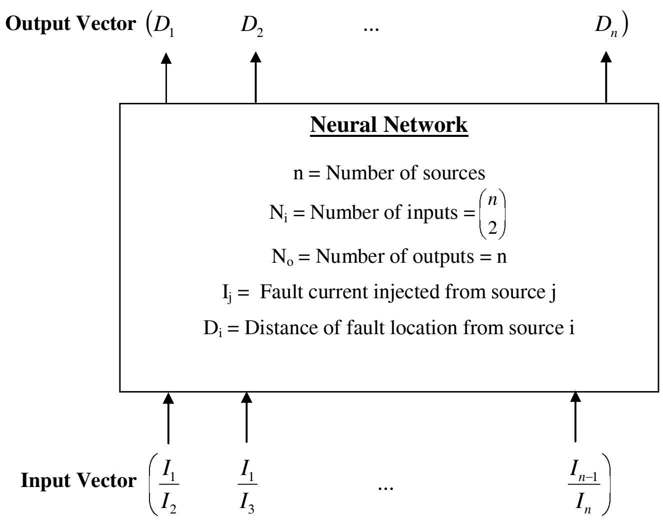

Fig. 4. The structure of neural network

IV. Fault Isolation and Network Restoration

In the proposed scheme, the aim is to separate faulty zone from the rest of network using opening of its isolating circuit breakers along with supplying network zones as far as it can be done. To achieve this purpose, disconnection signal is sent to all circuit breakers placed in faulty zone and downstream zones after diagnosis of location and type of the occurred fault. Also, to cut off supply of faulty zone in the case that there are DGs inside that zone, relay sends disconnection command to all DGs inside that zone. In this condition, faulty zone faces power cut thoroughly, its electrical connection with other parts of network is cut off, and upstream zones continue their synchronous operation with the global network. It is obvious that upstream zones are supplied through main source and their own DGs. Downstream zones, are supplied through island operation of their DGs, if they have any, otherwise their supply is disconnected [1].

Re-closing operation is carried out using zones isolating switches, through main relay control. The operation procedure is that after isolation of the faulty section, re-closing is performed through connecting zone breaker to its upstream network at the command of main relay. After each re-closing operation, the relay investigates network status and if the fault still exists, relay issues disconnection command. In the case that fault is temporary and is removed during re-closing operation, relay issues restoration commands.

For example, in Fig. 1, if a temporary fault occurs in Z_2, relay first sends disconnecting signal to CB_2, CB_3, CB_6, CB_7, CB_8, CB_9 and all DGs located in Z_2 and then sends re-closing signal to CB_2 to diagnose temporary fault. In the end, after clearance of fault, relay sends closing signal along with synchronization to CB_3, CB_6, CB_7, CB_8, CB_9 and all DGs located in Z_2 to restore the network completely [2].

V. Load Shedding

When network load is higher than average load and a fault occurs in system, some of network zones may go into island operation after network restoration procedure. So, it is required to perform load shedding operation in these zones.

In the protection scheme of this paper, it has been proposed that to determine the load difference in each zone, by summation of the currents flowing through zones isolating switches at the time exactly before occurrence of fault.

$$\Delta P = \sum P_{CBi} \tag{8}$$

$$\Delta Q = \sum Q_{CBi} \tag{9}$$

When for each zone ΔP and ΔQ are known from (8) and (9), it is possible to determine shortage or excess of load regarding generation capacity of each zone. Then, using estimated hourly loads curves of the zone, fault time, ΔP, ΔQ, and loads degree of importance, load shedding can be done to the extent at which the balance between generation and consumption in each zone is maintained. Of course this operation is needed to be done in the zones that face overload at time of fault occurrence. In the case that at time of fault occurrence loads within the island zone are lower than the total generation capacity of zone's DGs, relay issues no disconnection signal in order zone's frequency control system decreases generation of DGs to have nominal system frequency. It must be mentioned that when load shedding is needed to be performed as well as determining which loads have to be shed, relay sends disconnection command to load break switch of the relevant distribution substation.

VI. Case Study

The proposed algorithm in this paper has been implemented using MATLAB and a software application has been provided to implement designed protection scheme and to simulate operation of the main relay installed in sub-transmission substation. A 22-bus, 20 kV distribution network with a 3.5MVA diesel generator connected to buses 22 and a 4.5MVA diesel generator connected to buses 4, is considered as a test system for simulations. Single line diagram of this network is illustrated in Fig. 5. The technical data of the equipments are given in the Appendix.

Fig. 6 shows the single line diagram of the studied distribution feeder after performing zoning approach as well as required circuit breakers and their location for dividing the network into protection zones. The feeder will have 4 zones after performing zoning procedure; two zones include DG and have the capability of island operation. The zones are isolated from each other by CB_1, CB_2, CB_3 and CB_4.

In order to prepare the required data for training the neural network and perform offline calculation, all types of faults in the system in each 100 meter and with 0, 50, 100, 150 ohm fault impedance is simulated and the output current of all power supplies are exploited. These simulations have been done using DIgSILENT Power Factory 13.2. Training results of all neural networks are shown in Figures 7 to 10. Neural network structures for each fault type as well as their training error are tabulated in table II.

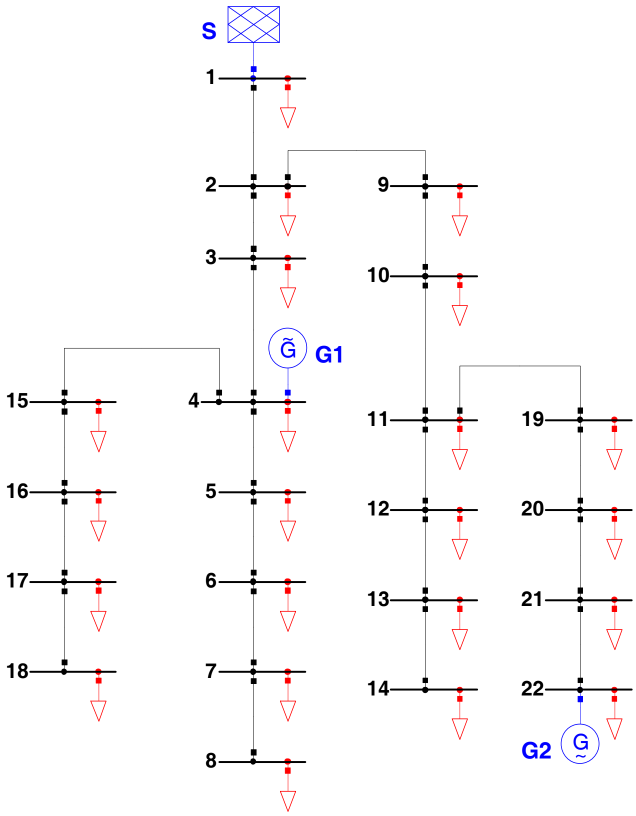

Fig. 5. Single line diagram of the studied distribution system

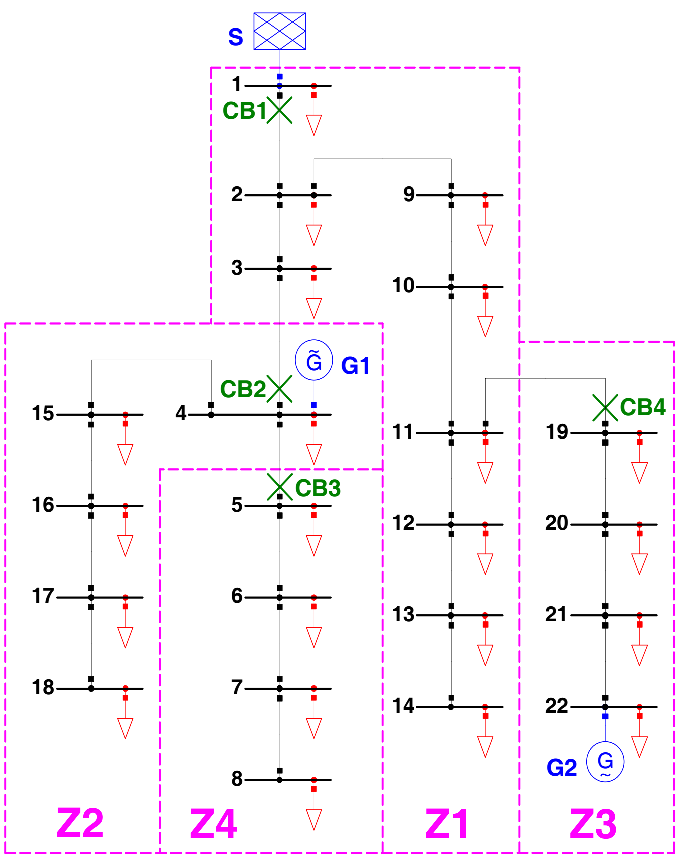

Fig. 6. Single line diagram of the studied distribution system after performing zoning approach

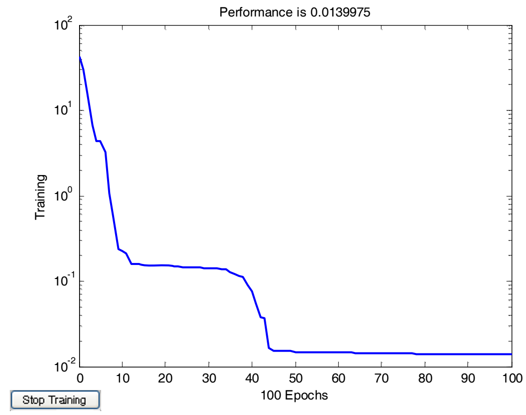

Fig. 7. Training result of neural network for 3-phase fault

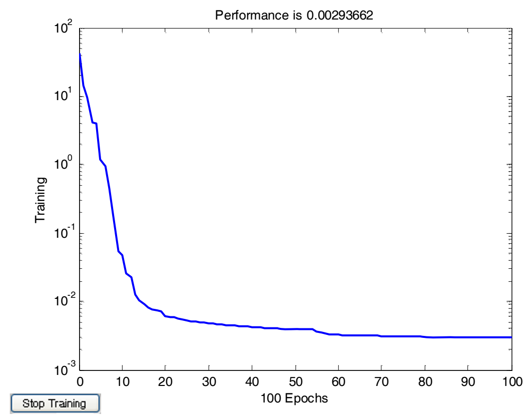

Fig. 8. Training result of neural network for 1-phase fault

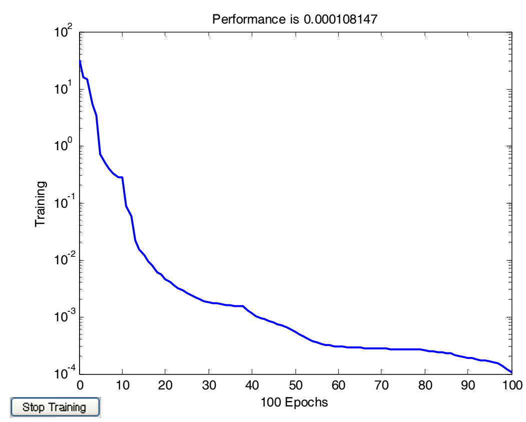

Fig. 9. Training result of neural network for 2-phase fault

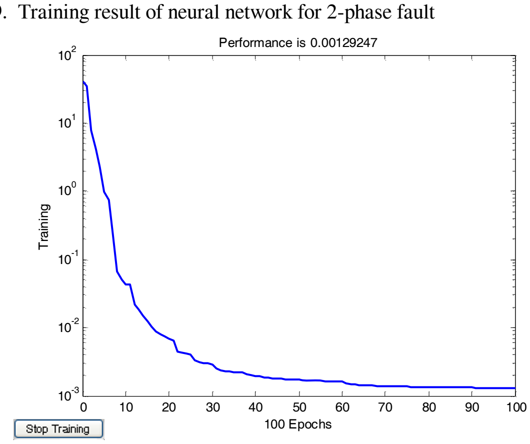

Fig. 10. Training result of neural network for 2-phase to ground fault

TABLE II
STRUCTURE AND ERROR OF TRAINED NEURAL NETWORKS

Fault Type	NN Structure	MSE
3-phase	[3 6 3]	0.0139975
1-phase	[3 5 3]	0.00293662
2-phase	[3 7 3]	0.000108147
2-phase to ground	[3 7 3]	0.00129247

According to the offline calculation results, the highest error of trained neural networks is about 20 meters. Regarding to 1km length of distribution lines in studied network and concerning the fact that recognizing the faulted line is the final goal of protection systems in distribution networks, the deviation in proposed method is passable and quite satisfying.

To make sure the main relay operates accurately; its operation has gone through detailed investigation with different faults. Due to the limited space, the detailed investigations are not shown in this paper. But, in order to presenting the sequence of the main relay's operation in case of fault occurrence along the feeder, the operations of the main relay in the case of following two faults are presented:

1. Single-phase to ground fault with the fault impedance of 25 ohm, at the middle of the line connecting buses 13 and 14;
2. Symmetrical three-phase fault with the fault impedance of 125 ohm at the middle of the line connecting buses 20 and 21;

A. Single-phase to ground fault on the line connecting buses 13 and 14

In this situation, the relay sends disconnection commands to all network CBs, immediately after it diagnoses fault type as well as it determines fault occurrence in the first zone (Z_1). Thus, Z_1 and Z_4 face power cut and Z_2 and Z_3 go on operating as an electric island. Then, to diagnose whether fault is temporary re-closing operation is done by CB_1. Obviously, there is no need to synchronize the network during re-closing operation, since Z_2 has faced power outage. If the fault is permanent, all CBs remain open. But, if the fault is temporary and is cleared during re-closing operation, the network must be restored. To make restoration, first, connection signal is sent to CB_1, then, CB_2 is closed with network synchronization operation, after that, connection signal is sent to CB_3, and finally connection signal with network synchronization operation is sent to CB_4.

To evaluate relay's load shedding algorithm, the above fault has to be simulated for two conditions; peak load and minimum load conditions. Simulation results indicate that at minimum load condition, relay's load shedding unit sends no command. But, at peak load condition the relay sends disconnection command to load break switches of substations 17, 18, and 19 in order to maintain the balance between generation and consumption in Z_2 and Z_3. Output result of relay simulation software application for the peak load regime is as follows:

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>>
The fault is single phase to ground fault.
The fault distance from network sources is: [6.5024; 7.5116; 6.4997;]
The faulted section is section 13 which connects bus 13 to 14.
The faulted zone is zone 1.
CB1 ==> Opened
CB2 ==> Opened
CB3 ==> Opened
CB4 ==> Opened
CB1 ==> Re-closed (fast mode)
For Temporary Fault:
    CB2 ==> Closed (with synchronizing function)
    CB3 ==> Closed
    CB4 ==> Closed (with synchronizing function)
For Permanent Fault:
    CB1 ==> Opened
    CB1 ==> Re-closed (slow mode)
    CB1 ==> Opened
    Load17==> Shed
    Load18==> Shed
    Load19==> Shed
>>
```

B. Symmetrical three-phase fault on the line connecting buses 20 and 21

In this situation, the relay sends disconnection commands to CB_4 and DG_2, immediately after it diagnoses fault type as well as it determines fault occurrence in the third zone (Z_3). Therefore, only Z_3 faces power cut and Z_1, Z_2 and Z_4 are still supplied through main source and DG_1. Then, to diagnose whether fault is temporary re-closing operation is done like what was done for previous situation, except that this time relay assigns this task to CB_4. If the fault is temporary and is cleared, relay sends re-closing signal to CB_4 to restore Z_4. Then, closing signal is sent to DG_2 in parallel with network synchronization operation to put it into operation and network restores completely. In the case that the fault is permanent and is not cleared, CB_4 remains open and Z_4 faces power outage. Like before, regarding the point that Z_4 has faced power outage, consequently re-closing operation will need no synchronization. Since there won't be any electric island, if the fault happens in the peak regime, relay's load shedding unit will not send any disconnection command. Output result of relay simulation software application is as follows:

```
>>
The fault is single phase to ground fault.
The fault distance from network sources is: [6.4931; 7.5123; 1.5077;]
The faulted section is section 20 which connects bus 20 to 21.
The faulted zone is zone 3.
CB4 ==> Opened
DG2 ==> Opened
CB4 ==> Re-closed (fast mode)
For temporary Fault:
    DG2 ==> Closed (with synchronizing function)
For Permanent Fault:
    CB4 ==> Opened
    CB4 ==> Re-closed (slow mode)
    CB4 ==> Opened
Load shedding is not required in this situation
>>
```

VII. CONCLUSION

In this paper a novel fault location and protection scheme for distribution systems with DG using MLP neural network is presented. The algorithm uses network zoning approach, in which each zone is an independent section, capable of island operation whenever needed. After dividing distribution system into several independent zones, computer-based relay, installed in sub-transmission substation, diagnoses exact fault location using MLP neural networks which are trained through its offline calculations. Finally, the relay sends required commands and signals to protection devices in order to isolate the faulty zone from the rest of the network. Further work is in progress to improve the algorithm through adding features and capabilities to the proposed scheme, such as: optimal zoning approach considering a determined number of CBs and ultimately optimum utilization of zones in their island operation.

VIII. Appendix

For each load a three-step hourly load curve is considered, which is shown in Fig. 11. The peak load for all loads is 1 MW and the power factor for all of them and in every time is 0.92 (lag).

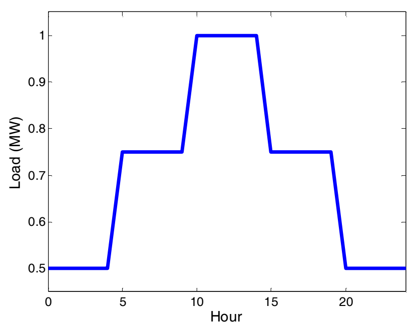

Fig. 11. Hourly load curve of the simulated feeder's loads

All the distribution conductors used in simulation are HYENA with 1 km length and technical information mentioned in table III.

TABLE III
TECHNICAL DATA OF DISTRIBUTION LINES

Conductor Name	Type	A
HYENA	ACSR	126 mm^2
Technical Data	**R (Ω)**	0.303
	X (Ω)	0.3383
	R_0 (Ω)	0.4509
	X_0 (Ω)	1.5866
	I_n (A)	250

Technical data of DGs are presented in tables IV.

TABLE IV
TECHNICAL DATA OF DGS

Machine Type	IEC 909	Salient Pole Series 1	
Voltage (kV)	20	**X'd (pu)**	0.256
Pn (MW)	2.8 , 3.6	**X"d (pu)**	0.168
PFn	0.8	**X0 (pu)**	0.1
Connection	YN	**X2 (pu)**	0.2
Xd (pu)	1.5	**R0=R2 (pu)**	0
Xq (pu)	0.75	**Rstr (pu)**	0.504

IX. References

[1] S.A.M. Javadian, M.-R. Haghifam, "Protection of Distribution Networks in Presence of DG Using Distribution Automation System Capabilities," Proc. 2008 IEEE Power Engineering Society General Meeting, 20-24 July 2008, pp.1-6.

[2] S.A.M. Javadian, and M.-R. Haghifam, "Implementation of a new protection scheme on a real distribution system in presence of DG," Proc. PowerCon 2008 and 2008 IEEE Power India Conference, 12-15 October 2008, New Delhi, India, pp. 1-7.

[3] N. Rezaei, M.-R. Haghifam, "Protection scheme for a distribution system with distributed generation using neural networks," International Journal of Electrical Power & Energy Systems, Volume 30, Issue 4, May 2008, pp. 235-241.

[4] P. P. Barker, R. W. de Mello, "Determining the impact of distributed generation on power systems: part1-radial distribution systems," IEEE Trans. Power Delivery, vol. 15, pp. 486–493, Apr. 2000.

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

[6] S.A.M. Javadian, M.-R. Haghifam, "Designing a New Protection System for Distribution Networks including DG," The 9th IET International conf. on Developments in Power System Protection, 17-20 March 2008, pp. 675-680.

[7] Farzanehrafat, S.A.M. Javadian, S.M.T. Bathaee, M.-R. Haghifam, "Maintaining the Recloser-Fuse Coordination in Distribution Systems in Presence of DG by Determining DG's Size," The 9th IET International conf. on Developments in Power System Protection, 17-20 March 2008, pp. 124-129.

[8] Jiang J-A, Liu Y-H, Liu C-W, Yang J-Z, Too T-M, "An adaptive fault locator system for transmission lines," IEEE PES summer meeting, vol. 2, 1999. pp. 930–936.

[9] A. Meshal, A. Al-shaher, M. Manar, B. Sabry, S. Ahmad, S. Saleh, "Fault location in multi-ring distribution network using artificial neural network," Electric Power Systems Research, vol. 64, 2003 pp. 87–92.

[10] M. Ehsan, A. Soroudi, "An Introduction to Heuristic Search Algorithms for Optimization of Engineering Problems," International Conference on Genetic and Evolutionary Methods, USA, June 25-28, 2007.

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

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

[13] A. Girgis, S. Brahma, "Effect of Distributed Generation on Protective Device Coordination in Distribution System," Power Engineering, LESCOPE'01. 2001 Large Engineering Systems Conference, 11-13 July 2001, pp. 115 – 119.

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

[15] T. M. de Britto, D. R. Morais, M. A. Marin, J. G. Rolim, H. H. Zuirn and R. F. Buendgens, "Distributed generation impacts on the coordination of protection systems in distribution networks," in Proc. EEE Power Engineering Societ, Transmission and Distribution Latin America, Sao Paulo, pp. 623-628, 2004.

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

[17] S. Brahma, A. Girgis, "Microprocessor-Based Reclosing to Coordinate Fuse and Recloser in a System with High Penetration of Distributed Generation," IEEE PES Winter Meeting, 2002, Vol.1, pp. 453 – 458.

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

[19] M. Baran, I. El-Markabi, "Adaptive over current protection for distribution feeders with distributed generators," in Proc. EEE Power engineering Society Power Systems Conference and Exposition, pp. 715-719,2004.

[20] I. Chilvers, N. Jenkins and P. Crossley, "Development of distribution network protection schemes to maximize the connection of distributed generation," in Proc. 2003 CIRED, 17th International Conference on Electricity Distribution, Barcelona, 12-15 May.

[21] M. E. Baran and I. El-Markaby, "Fault analysis on distribution feeders with distributed generators," IEEE Transactions on Power Systems, vol. 20 (4), pp. 1757-1764, 2005.
[22] M.-R. Haghifam, H. Falaghi, O. P. Malik, "Risk-based distributed generation placement," IET Generation Transmission Distribution, 2008, 2, (2), pp. 252-260.
[23] X. Wu, Y. Lu, J. Du, "Wide area current protection for distribution feeders with distributed generation," DPRT 2008, 6-8 April 2008, Nanjing, China, pp. 2558-2563.
[24] L. Comassetto, D. P. Bernardon, L. N. Canha, A. R. Abaide, "Software for automatic coordination of protection devices in distribution system," IEEE Transaction on Power Delivery, Vol. 23, NO. 4, October 2008, pp. 2241-2246.
[25] N. Prera, A. D. Rajapakse, T. E. Buchholzer, "Isolation of faults in distribution networks with distributed generators," IEEE Transaction on Power Delivery, Vol. 23, NO. 4, October 2008, pp. 2347-2355.
[26] S. Chaitusaney, A. Yokoyama, "Prevention of reliability degradation from recloser-fuse miscoordination due to distributed generation," IEEE Transaction on Power Delivery, Vol. 23, NO. 4, October 2008, pp. 2545-2554.
[27] S. Haykin, "Neural Networks a comprehensive foundation," Second edition, Prentice-Hall, Inc. 1999.
[28] K. Y. Lee, M. A. El-Sharkawi, "Modern Heuristic Optimization Techniques, Theory and Applications to Power Systems," John Wiley & Sons Inc., 2008.
[29] IEEE Standard for Interconnecting Distributed Resources with Electric Power Systems, IEEE Std. 1547-2003, Jul. 2003.
[30] IEEE Guide for Monitoring, Information Exchange, and Control of Distributed Resources Interconnected with Electric Power Systems, IEEE Std 1547.3, Nov. 2007.

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