Volume : 3 | Issue : 9 | September 2014 • ISSN No 2277 - 8179

Research Paper

Application of Multi-Objective Reconfiguration to Reduce Losses in Distribution Networks and Improve Power Quality Parameters

Engineering

KEYWORDS : Multi-Objective, Reconfiguration, Parameters of Power Quality, SPEP

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ABSTRACT

In this paper multi-objective reconfiguration of distribution network is performed to minimize real losses and improve power quality parameters.

At first problem solve by using genetic algorithm method. Selection of weight coefficient in this approach is difficult and time consuming, therefore to fix this problem, Strength Pareto Evolutionary programming (SPEP) is used.in addition to this methods to investigate the constraints and restrictions of objective functions of the reconfiguration problem such as a radial distribution networks and transmission power to whole loads.

Graph theory and adjacency matrix corresponding to the distribution network were used.

Proposed methods were performed on 33 bus IEEE distribution system and observed SPEP method gives multi answers which user can select best answer based on his/her experience.

1. Introduction

Reconfiguration changes the transmission path of power by changing the mode of switches and switches, by meeting constraints such as keeping the distribution network radial and connecting buses in the system. Reconfiguration of problems in the distribution network, in order to reduce losses to active power, was first discussed in 1975 in [1]. In this paper all of the existent switches in the distribution network have been considered, and a suitable answer for the reconfiguration problem has been researched by exchanging different branches. Some disadvantages of this investigation include an assumption that all of the loads are active, and failing to consider network constraints such as voltage constraint and passing flow in each branch. In [2], the method of exchanging branches for solving the reconfiguration problem by selecting branches two by two is developed, so that in every ring one opens and the other closes. In [3], the study of network reconfiguration was performed seasonally or daily—as a function of time—and in different modes of load. In [4], an innovative method is presented to automatically eliminate inappropriate switches, so that selecting them stops the network from being radial. In this paper, only whole active losses of the network are defined as problematic. In [5] and [6], the ant algorithm is used for the first time to reconfiguration distribution systems with the objective of reducing total loss of power. This algorithm has provided very suitable answers for the travelling salesman problem and the sequential ordering problem. In addition, the ant algorithm has given Excellent results for solving the reconfiguration problem. In [7], the ant algorithm is used, in a parallel search, to minimize feeder losses and modify voltage levels. One of the advantages of a parallel search is the reduction of computing time. This paper has succeeded in finding global network minimums. In [8], an innovative method for solving the reconfiguration problem using the ant algorithm has been presented. In this method, firstly, all switches are considered closed, and then a switch is selected in every ring to be opened by determining rings of network graph. The entrance of nonlinear loads in the distribution network can have negative effects on the power quality problem. Reconfiguration is one way to modify parameters of power quality [9]. As a result, one of the reconfiguration objectives is to modify parameters of power quality, such as harmonics and voltage drop at the time of error. In this thesis, multi-objective reconfiguration of distribution networks towards reducing significant losses, and modification of parameters of power quality using intelligent methods is performed. In addition, the constraints and restrictions of objective function are investigated using other definitions and features of graph theory such as adjacency matrix. Different Methods to implement a variety of continuous and discrete functions and Pareto optimization approach (SPEA) because they have a good convergence of the objective function, is proposed as the preferred method. [10].

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In this paper, a daily reconfiguration Multi-objective distribution networks with the aim of minimizing real losses and modifying parameters of power quality parameters using intelligent methods are studied. Also, using other definitions and properties of the adjacency matrix of graph theory, graph constraints and objective functions are evaluated for this purpose we have used two approaches to solve the problem. In the first case, the weighting coefficients of the second approach using the Pareto method is carried out and the results are compared with each other.

2. Introduction to Objective Functions in the Reconfiguration Problem

In order to reconfiguration networks in the study and to use multi-objective optimization by the weighted sum method, the three stated objective functions in below must be minimized.

$$F_1 = Ploss \tag{1}$$

$$F_2 = \left(\sqrt{\sum_{i=1}^{npcc} \sum_{j=1}^{n} \left|V_{i,j}^{sag}\right|^2}\ \right)^{-1} \tag{2}$$

$$F_3 = \sqrt{\sum_{i=1}^{npcc} THD_i^{\ 2}} \tag{3}$$

Where:

$i \in$ Complex network of buses

In equations. (1)- (3) These equations are given again:

F1 include power loss,

F2 included npcc: (Number of buses sensitive to power quality),

THD: (total harmonic distortion),

and

$V_{i,j}^{sag}$

=bus numbers are sensitive to power quality

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3. Using Graph Theory to Investigate How to Produce Radial Distribution Networks and Non-Isolate Loads

This section states how to obtain a number of distribution network meshes and isolated loads using graph theory and adjacency matrix.

The first, we constitute a corresponding graph of a distribution network, (A) constituted. Having the main bus (reference) of each feeder and considering a number of system feeders (K), we obtain matrix AK1 obtained. Its rows show the buses connected to each bus in the beginning of feeder, and to do this, according to the number of the main bus we move to the same row of the adjacency matrix and write down the column numbers corresponding to one. Then trace these numbers in rows for the number one to reach the repetitive number or the end of repetition. After eliminating the repetitive elements, the row matrix AK2 is obtained, resulting in two cases by comparing its nonzero elements with number of possible system buses:

1. Number of system buses is not equal to number of nonzero elements of the matrix (AK2):

This case shows that the graph is disconnected, and this difference introduces separate and isolated buses (except primary buses of each feeder).

2. Number of system buses is equal to number of nonzero elements of the matrix (AK2):

In this case after eliminating the first column of the matrix (AK1), (buses in the beginning of each feeder), the number of rows with zero elements show the number of buses in the beginning of each feeder that are isolated. If there is no zero row, the connectivity of the graph is guaranteed and the number of graph rings is obtained by the following equations:

Therefore

It is evident that if L is zero, the graph is a tree, and so the system is radial.

$$L = q - p + 1 + K' \qquad (4)$$

$$K' = K - 1 \qquad (5)$$

In equation. (4)

L: the tree graph, P: vertices of the graph and q: edges of the graph

4. Solving the Reconfiguration Problem using Weighted Coefficients

In order to solve the reconfiguration problem using weighted coefficients, the following objective function is suggested:

$$F = W_1 \cdot \left(\sqrt{\sum_{i=1}^{npcc} \sum_{j=1}^{n} \left|V_{i,j}^{sag}\right|^2}\right)^{-1} + W_2 \cdot \sqrt{\sum_{i=1}^{npcc} THD_i^{\,2}} + W_3 \cdot P_{loss} + C \qquad (7)$$

$$C = D \cdot Number(mesh) + E \cdot Number(isolated) \qquad (8)$$

In this equation. (7). w1, w2 and w3: weighted coefficients of the system

And C: fine coefficient

To solve the dimension problem by this method, consider the objective function F3 to be per unit. Using this, the problem of dimension is solved. On the other hand, by a suitable selection of weighted coefficients (w1 to w3) the effect of each these objective functions were determined. This action enables the beneficiary to choose these coefficients in order to highlight the most important objective function of the problem.

Considering constraints and restrictions in the reconfiguration of distribution networks -such as keeping a system radial, serving all of the loads, knowing the voltage of each bus and the flow amount of each branch in permissible range—answers that break the abovementioned constraints should be eliminated from the solution set. For this purpose, the parameter C is considered in every objective function and is introduced as follows:

In equation (9), D and E are fine coefficients of wrong selections. D is the fine coefficient of the number of network meshes, and E is the fine coefficient of number of system-isolated buses.

By lacing parameter C in objective functions, impossible solutions are eliminated from the search space and the algorithm converges to the optimum solution with a better speed. The constraint that the network is radial and with no isolated bus in the system is checked using graph theory.

5. Pareto multi-Objective Optimization Method

This algorithm was presented in 1999 by Zitzler and Thiele. SPEA uses Concepts which are top generation and dominate vector.

In each generation dominate collection keeps in archive titled external collection and in generate operation the fitness of each chromosome in the current population and external population depends on the number of dominating solutions [9].

SPEA algorithm is implemented as follows:

1. The initial generation chromosomes randomly generated and create a series called external set. (P')
2. Copy dominate solutions (p) in (p').
3. Solutions with other members who are covered delete it.
4. If the number of dominate solutions stored in more than a predetermined maximum was pruned using clustering external set length trimming.
5. Assignment the fitness of chromosome sets.
6. Selection next generation in (p + p') complex by using wheel or tournament methods.
7. Apply cross over and mutation.
8. If you make a stop condition terminates, otherwise go to 2.

In Step 5, the fitness of all chromosomes and a numerical value is determined. So it went on, how to allocate merit and clustering methods are described briefly discussed in Step 4.

Assign fitness value of chromosomes

Assignable fitness of chromosomes consists of two stages. First, external set dominate chromosomes sort, then chromosomes of P series are initialized Eq. (9).

Degree of strength defined as below:

$$s_i = (n/(N+1)) \qquad (9)$$

Where:

$$f_i = s_i \qquad (10)$$

Chromosomal fitness, are equal to degree of strength.

Fitness value of each chromosome cover, the total degree of dominate external solutions.

Cover is calculated. Here we are collecting the resulting number to guarantee that a member has a better fitness than are members. The aim here is to be careful of is minimization.

$$f_j = 1 + \sum_{i, i \succ = j} s_i \qquad (11)$$

In this paper, to optimize the multi-functional reconfiguration, three functions which f1, f2, f3 function, subject to a minimum to minimize the THD and Voltage Sag.

Executable flowchart presented in Fig.1.

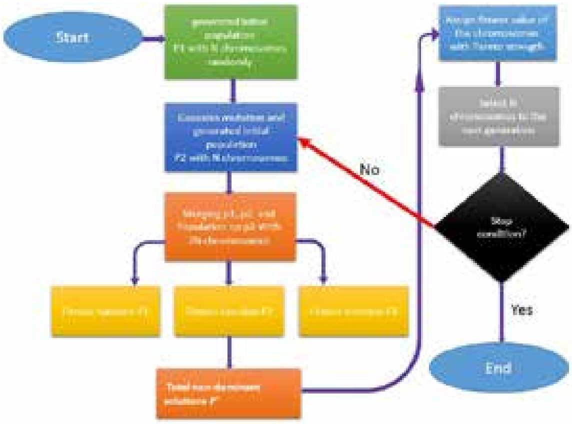

Figure. 1. Executive Graph Algorithms SPEP

6. Implementation of the Network of Study Using Evolutionary Algorithms, Weighted Sum and SPEA

In this section, objective functions are implemented by binary genetic algorithm (BGA) [10]. The system in use is a distribution network with 33 buses and a nominal voltage of 12.66-kV. A single-line diagram of this system is plotted in the figure. (2). In addition, it is assumed that nonlinear loads are in the network according to table. 1.

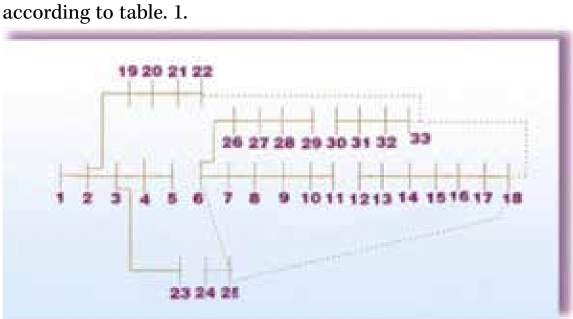

Figure. 2. 33-Buses Test System

6.1. The simulation method of weighting coefficients

Before simulation, it is assumed that switches related to the lines 33-37 are open. In addition, buses with loads sensitive to voltage drop and harmonics are 28, 24, 20, and 12. In this case, objective function values related to parameters of power quality are as follows:

$$fit2 = \left(1 \Big/ \sqrt{\sum_{i=1}^{npcc} \sum_{j=1}^{n} \left| V_{i,j}^{sag} \right|^2} \right) = 0.0694 \tag{12}$$

$$fit3 = \sqrt{\sum_{i=1}^{npcc} THD_i^{\,2}} = 0.2906 \tag{13}$$

In the implementation of this network with the BGA algorithm—since there are five meshes in the network that are caused by closing all of its switches—chromosomes are considered to be five gene ones, and each chromosome is defined as [Switch 1 to 5]. In this program, the number of chromosomes is chosen as 20 and the number of algorithm repetition as 200. Crossover coefficient is chosen as 0.9 and contact coefficient as 0.05. In the first case, coefficients chosen for objective and fine functions are D=E=500, w2=1, w1=1, w3=1. Results are summarized in table.2 and figures. 3 and 4.

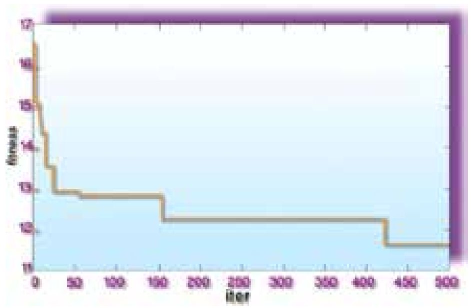

Figure. 3. How to Get to the Best Solution of the Objective Function by BGA for 33-Buses System with (w1=w2=w3=1)

Table 1: Properties of Nonlinear Loads of the 33-Buses Test System Harmonics Components

	Harmonics Components																	
Bus number	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
33	0	0	0	0.2	0	0.143	0	0	0	0.0910	0	0.077	0	0	0.059	0	0	0.035
22	0	0	0	0.2	0	0.143	0	0	0	0.0910	0	0.077	0	0	0.059	0	0	0.035
18	0	0	0	0.2	0	0.143	0	0	0	0.0910	0	0.077	0	0	0.059	0	0	0.035
25	0	0	0	0.2	0	0.143	0	0	0	0.0910	0	0.077	0	0	0.059	0	0	0.035
12	0	0	0	0.2	0	0.143	0	0	0	0.0910	0	0.077	0	0	0.059	0	0	0.035
4	0	0	0	0.0192	0	0.132	0	0	0	0.0910	0	0.057	0	0	0.0035	0	0	0.0027

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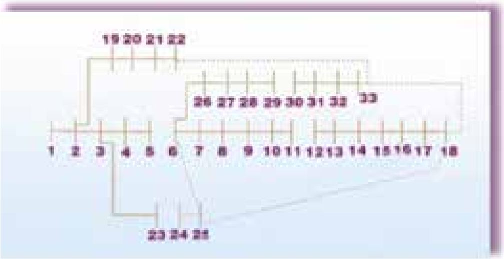

Figure. 4. 33-Buses System after Reconfiguration: Case One

Table .2. Reconfiguration Results by BGA for 33-Buses System with (w1=w2=w3=1)

Modification Percentage	Objective Function Value Before Reconfiguration	Best Chosen Switches	Merit Function	Network Status
89.36	2.0268	29,23,33,11,5	F1=0.2155	Reconfiguration With BGA
27	0.0694		F2=0.0506	
76.6	0.2906		F3=0.0679	

The final single-line diagram of the system after reconfiguration is plotted in the figure. 4. The figure shows that, after reconfiguration, the network has remained radial and continuous the restriction that the system remains radial has been met and the optimization method has converted to a correct solution.

To simulate, use weight coefficient as illustrate in table .3. At first case weight coefficient of 2 first aim functions, power loss and voltage sag, considered equal. Actually these 2 aim functions have more importance to user. Results of this simulation presented in table .4, table. 4.1. Answers of this case are same in comparison with another case that is considering all weight coefficients equal to 1.Therefore to improve effect of 2 first aim functions weight coefficient increased based on as demonstrated in table 3.

Table. 3. Weighting Coefficients Used in the Reconfiguration

Number	W_1	W_2	W_3
1	2	2	1
2	5	5	1
3	1	5	5

Table. 3.1. Reconfiguration Results by BGA for 33-Buses System for Weighted Coefficients: Case Two (w1=w2=1, w3=10)

Modification Percentage	Objective Function Value Before Reconfiguration	Best Chosen Switches	Merit Function	Network Status
86.9	2.0268	29,24,33,11,5	F1=0.2648	Reconfiguration With BGA
14.6	0.0694		F2=0.0592	
87.8	0.2906		F3=0.0352	

Table. 4. Reconfiguration Results by BGA for 33-Buses System for Weighted Coefficients (w1=w2=2, w3=1) from table.5: Case Two

Modification Percentage	Objective Function Value Before Reconfiguration	Best Chosen Switches	Merit Function	Network Status
89.36	2.0268	29,23,33,11,5	F_1=0.2155	Reconfiguration With BGA
27	0.0694		F_2=0.0506	
76.6	0.2906		F_3=0.0679	

Table. 4.1. Reconfiguration Results by BGA for 33-Buses System for Weighted Coefficients (w1=w2=5, w3=1) from Table. 5: Case Three

Modification Percentage	Objective Function Value Before Reconfiguration	Best Chosen Switches	Merit Function	Network Status
91.66	2.0268	29,33,5,2,12	F_1=0.2648	Reconfiguration With BGA
38.7	0.0694		F_2=0.0592	
17.4	0.2906		F_3=0.0352	

To explain further, we use several different weight coefficients.

It is assumed that reducing losses is more important than two other objective functions. In this case, weighted coefficients can be considered as follows, for example:

W1=w2=1, w3=10.

Choosing these coefficients and simulating them obtained the results shown in the table. 3.1 The table shows losses to have reduced by 86.9 percent, while two objective functions saw less modification. In fact, by increasing the weighted coefficient of the third objective function, this objective function decreased more than two other objective functions within the problem. This demonstrates the extent to which changing weighted coefficients affects the final solution of the optimization algorithm, and makes it difficult to choose these coefficients.

The final single-line diagram of the system after reconfiguration is plotted in figure. 5. The figure shows that, after reconfiguration, the network has remained radial and continuous that is require to remain the system radial and the optimization method has converged to a correct solution.

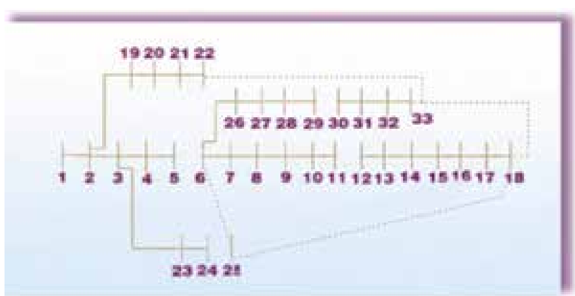

Figure. 5. 33-Buses System after Reconfiguration: Case Two

In the third case, weighted coefficients choose as follows: W1=w3=1, w2=10.

By choosing these coefficients and simulating them, results are obtained as in table. 5. The table. 5 shows that second objective function has seen a reduction of almost 29 percent, and has decreased more than the two previous cases. In fact, by increasing the weighted coefficient of the second objective function, this objective function has experienced a greater reduction in the optimization problem.

Table. 5. Reconfiguration Results by BGA for 33-Buses System for Weighted Coefficients: Case Three (w1=w3=1, w2=10)

Modification Percentage	Objective Function Value Before Reconfiguration	Best Chosen Switches	Merit Function	Network Status
89	2.0268	29,22,33,11,5	F1=0.2228	Reconfiguration With BGA
29	0.0694		F2=0.0489	
76	0.2906		F3=0.068	

The final single-line diagram of the system after reconfiguration in this case is plotted in figure. (6). the figure shows that, after reconfiguration, the network has remained radial and continuous that is the required to converge optimization method to a correct solution.

These discussions show that choosing weighted coefficients has significant effect in solving multi-objective optimization problems, and that by changing these coefficients, the output solution of the optimization problem will experience considerable changes.

For more information about reconfiguration results in Table 8.
Results of presented Table. 3 highlight in green, for weights (w1=w3=1, w2=10,) highlight in yellow and for weights (w1= w2=1, w3=10) highlight in blue.

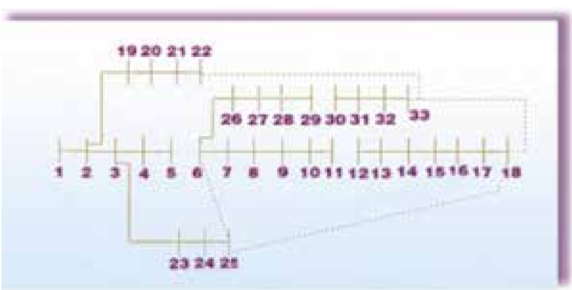

Figure. 6. 33-Buses System after Reconfiguration: Case Three

6.2. The problem implementation by the SPEP method
In the last section Multi-objective reconfiguration problem with sum method of weighted coefficients is carried out. In this section, reconfiguration with strong Pareto Evolutionary programming (SPEP) is implemented. Objective functions to optimizing, Osmic losses in the system and parameters of power quality are considered. On SPEP algorithm of selecting 50 chromosomes with the 200 repeating loop, created the results of Fig. 7 and Table. 7.

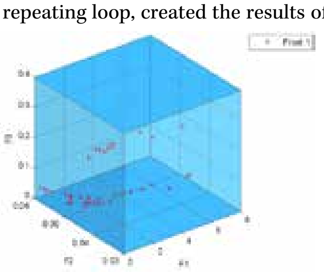

Figure. 7. Members Archive in the Purpose the Three-dimensional Space F1, F2 and F3

Table. 7. Stored non-defeated solutions on archive of the three-dimensional space Purpose of F1, F2 and F3

Member Archive	Switches Choice	F_1	F_2	F_3
1	2 17 32 33 36	1.2053	0.0323	0.2835
2	2 5 33 29 12	0.1690	0.0425	0.2400
3	2 24 28 11 36	0.4251	0.0506	0.0352
4	2 11 33 23 35	6.9411	0.0418	0.0679
5	5 11 33 24 29	0.2648	0.0592	0.0352
6	2 11 33 29 36	0.4356	0.0452	0.0684
7	5 11 33 23 29	0.2155	0.0506	0.0679
8	3 11 33 24 28	0.4232	0.0566	0.0352
9	2 12 33 35 36	4.1156	0.0447	0.0352
10	2 12 33 24 35	6.3333	0.0414	0.2407
11	4 11 33 24 28	0.2949	0.0581	0.0352
12	2 11 33 24 35	5.7672	0.0431	0.0352
13	5 11 33 22 29	0.2228	0.0489	0.0680
14	2 11 33 23 35	6.9411	0.0418	0.0679
15	2 8 33 35 36	3.4780	0.0417	0.2717

Figure.7 Shows Pareto optimal solutions that is stored in Specified archive on three-dimensional space.

The archives contain 45 members that all these solutions are acceptable. But here are just 15 answers provided. The important point is that All solutions are optimized in such a way and exploiter Can With its discretion Choose One of these solutions. However, that on method of weighting coefficients there was only one optimal solution and there was no selection right. The Table. 7 Shows that specified Answer in the table is the same results from method of weighting coefficients. This shows that the obtained answer By way of weighting coefficients in different modes is available on the obtained answers as the best way to approach the Pareto. But with Pareto method we can act more, For example, if for the exploiter the minimum being of Active power losses is important can select one of the answers of 2, 11. Also above table shows that among the obtained response, Reply Number 1 Have the best condition for voltage sag and the response of 3, 5, 11 and 12 have the minimum THD. So if for system exploiter these parameters are more important can select each of these solutions.

It is clear that in this way, other weighting coefficients Have no place and system operator without worrying about the correct selecting of weighting coefficients easily choose his desired response.

7. Conclusion:
In this chapter the problem of multi-reconfiguration with the objective functions of Osmic losses in the system and improving parameters of power quality, two methods of Total Weighted and SPEP were studied. In the SPEP Problem Solving is not a unique solution and will lead to an archive of Pareto optimal solutions on a Purpose space multi-dimensional.

Optimization Problem Solving In the multi-objective space Than the single-objective space, Gives Wider perspective Towards Problem Solving From the idea that Among the Pareto optimal solutions, the Quantity of Which of the variables Impacts On which of the optimization objective function.

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REFERENCE

[1] Merlin, A., & Back, H. (1975). Search for a minimal loss operating spanning tree configuration for an urban power distribution system. Proceedings of the 5th Power System Computation Conference (PSOC), Cambridge, 1-18. | [2] Civanlar, S., J Grainger, J., Yin,H., & Lee, H. (1988). Distribution feeder reconfiguration for loss reduction. IEEE Transactions on Power Delivery, (3)3, 1217-1223. | [3] P Broadwater, R., Khan A.H., Shalaan, H.E., & Lee, R.E. (1993).T ime varying load analysis to reduce distribution losses through reconfiguration. IEEE Transactions on Power Delivery, (8)1, 294-300. | [4] Safri, R.J., Salama, N.M.A., & Chickani, A.Y. (1994). Distribution system reconfiguration for loss reduction: a new algorithm based on a set of quantified heuristic rules. Proceedings of Electrical and Computer Engineering, Canada, (1), 125-130. | [5] Carpaneto, E., & Chicco, G. (2004).Ant colony search based minimum losses reconfiguration of distribution systems, IEEE MELECON, 971-974. | [6] Ahuja, A., & Pahwa, A. (2005). Using ant colony optimization for loss minimization in distribution networks, Proceedings of the 37th Annual North American on Power symposium, 470-474. | [7] Su, C.T & Chung, C. F. (2005). Distribution network reconfiguration for loss reduction by ant colony search algorithm, Electric Power System Research, Elsevier, 190-199. | [8] Wu, Y., Lee, C. (2010). study of reconfiguration for distribution system with distributed generation, IEEE Transaction on Power Delivery, (25)3, 1678-1685. | [9] Jazebi, Saeed. & Vahidi, Behrooz. (2012). Reconfiguration of distribution networks to mitigate utilities power quality Disturbances. Electric Power Systems Research, 9-17 | [10] P. Melo, M.A. (1999). Multi-objective reconfiguration for loss reduction and service restoration using simulated annealing. IEEE Int. Conf. Electric Power Engineering, 213-218.