Loss Minimization Using Multi-stage Evolutionary Programming for Network Reconfiguration in Distribution System

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Abstract – **The occurrence of system loss due to line resistance in the distribution system can be minimized by changing its network reconfiguration. Therefore, network reconfiguration is an important issue for distribution system automation. The system loss minimization via network reconfiguration can be done by altering the topological structure of distribution feeders by changing open or closed status of sectionalizing and tie-switches to achieve different combinations of switching status. A stochastic optimization strategy of Multi-stage Evolutionary Programming MEP was proposed in this paper which can be used in distribution systems to solve network reconfiguration. The proposed method was simulated by using Matlab software and verified in an IEEE 69 bus distribution system.**

Keywords-Evolutionary Programming (EP), Multi-stage Evolutionary Programming (MEP) Network Reconfiguration, Distribution system. Loss minimization.

I. INTRODUCTION

Through network reconfiguration of distribution system, line losses of the network which increased proportionally with transmission of power energy can be minimized and moreover it also can be used to balance the load system of the feeder. This is proven in the recent studies which indicate that up to 13% of the total power generation is wasted in the form of line loss at the distribution level [1]. Therefore, in order to guide the search for configurations EP is required to follow the load flow calculations, in iterative. [2]

The purpose of this paper is to minimize total loss which occurs in the distribution system via changing the network reconfiguration in order to find the best tie line and sectionalizing switch pair in the IEEE 69 bus distribution system network. Thus, in order to solve the optimization problem in a distribution system which involve determining the open or closed status of switches by considering the rule of condition and then apply the value to the tie line in the interconnected systems, MEP was proposed. The network is reconfigured as operating condition of the switches change [3]. The fitness functions used for the network reconfiguration are to reduce the system real power losses and to improve the voltage profile of the system [4].

Evolutionary Programming is a stochastic optimization strategy which originally conceived by Lawrence J. Fogel in 1960. This method is quite similar to genetic algorithms, however the difference that EP emphasis on the behavioral linkage between parents and their offspring, rather than seeking to emulate specific genetic operators as observed in nature [3]. By comparing with other techniques for instance gradient descent or direct, analytical discovery and many locally optimal solutions are well suited for EP which makes EP is a useful method [5]

The use of search operations which were inspired by nature for instance recombination, mutation and tournament of the individuals in a population of satisfactorily represented potential solutions are the basic idea of all evolutionary algorithms that being propose in this paper. EP is powerful computational and general global optimization method and operates on real value and representation (1, 2, 3…). EP also involved fitness calculation, statistic, mutation and selection. The overall EP process is represented in Figure 1.

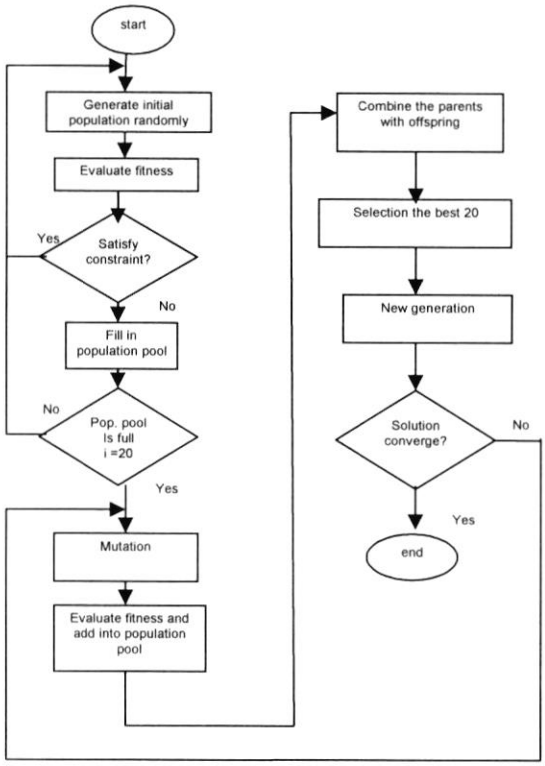


Figure 1: Programming flowchart

A. Initialization

The initial populations of trial solutions are generated randomly. The speed of optimization is highly depending on the number of solution in a population. However it doesn't display concrete answer as the number of appropriate solutions available and how many of them are just wasteful [6]. The initialization of the suitable tie line switch (S) and the suitable sectionalizing switch (R) were required in this problem searching for parent population. Each tie-line switch represents certain area in the network which contains several sectionalizing switches. Hence, the area of each tie-line is defined as in Table 1 below.

Table 1: Tie Line and Sectionalizing Switches

Tie-line switch (S)	Sectionalizing Switch (R)
S1: 8 – 43	R1: 36 – 43
S2: 10 – 46	R2: 36 – 46
S3: 12 – 21	R3: 13 – 21
S4: 27 – 65	R4: 13 – 27 , 53 – 64
S5: 50 – 59	R5: 47 – 50 , 53 – 59

B. Mutation

The replication of each solution into a new population where each of these offspring solutions were mutated according to a distribution of mutation types, ranging from minor to extreme with a continuum of mutation types between. It is all depend on the basis of functional change that was applied to parents which will affect the mutation severity [6]. An offspring vector P_i' is created from each parent P_i by adding to each component of Pi a Gaussian random variable and using the equation (1) and (2).

$$\eta_i'(j) = \eta_i(j)\exp\tau' N(0,1) + \tau N_j(0,1) \quad (1)$$

$$P_i'(j) = P_i(j) + \eta_i'(j)N_j(0,1) \quad (2)$$

Where:

$$\tau = \left(\left(2(n)^{1/2}\right)^{1/2}\right)^{-1} \text{ and } \tau' = \left((2n)^{1/2}\right)^{-1} \quad (3)$$

P_i (j), P_i' (j), ηi (j) and η_i' (j) is i^{th} component of the respective vector.

N (0, 1) is a normally distributed one dimensional random number with mean 0 and 1.

N_j (0, 1) indicates that the random number will be a new for each value of j.

C. Combination

After mutation process, a combination (reproductive population) population is formed from the union all parent population and offspring population.

D. Selection

In order to pick the best reconfiguration in the system, the mutated pool obtained before are ranked in ascending number referring to the multi objective solution. The best 20 among the mutated pool are chosen. The process will continue until the stopping criterion met. For this research, the stopping criterion is the convergence test. Once the fitness approaching 0.0001, the process will stop.

Based on Figure 1, the programming flowchart consists of index formulation, statistical evaluation, fitness calculation, mutation and new generation resulted from the tournament selection. In order to develop an MEP for network reconfiguration in distribution system, the implementation of procedure below need to be done.

I. Set the initialize condition for the tie line ,S1,S2,S3,S4 and S5, (S=0,open tie line & S=1, close tie line)
II. Set the initialize sectionalizing switch (parent) for each associated loop. Let's R1, R2, R3, R4 and R5

represent the initialize random of switches. Let i =1,2,3,4 and 5

III. The generated xi will replace into the load flow program and tested for the fitness (F1) which is the total loss. If the voltage magnitude at the bar is kept within its constraint ($0.95 \leq Vm \leq 1.05$ and $0 \leq Tloss \leq 1$), the value tie line and the fitness total loss will be kept in a population otherwise it will be repeated to generate the random value again. This process will be continued until the population contains 20 individual. This population is chosen to be candidate for mutate of the parents in the mutation process.

IV. Check for constraint violations. If constraints violated, go to next step (mutation), otherwise go to second step again

V. At the mutation process, there is 3% of tie line to be mutated. The R1, R2, R3, R4 and R5 switches also have to mutate (offspring) and represent as Rm1, Rm2, Rm3, Rm4 and Rm5. The generated Rm will replace into the load flow program and tested too. All the Rm must followed the mutation condition requirement, constraint violation (consider $0.95 \leq Vm \leq 1.05$ and $0 \leq Tloss \leq 1$) and the mutation fitness too (Fm1).

VI. Fill in mutation population until 20 generation, if not repeated the mutation process again.

VII. Combine parents and offsprings.

VIII. Perform selection of best 20 by tournament process

IX. Rank the selection with the highest value of sectionalizing switches is the best. This used for new generation.

X. If solution is not converged, repeated step V until IX but if meet converged end the program

XI. End

II. EVOLUTIONARY PROGRAMMING BASED NETWORK RECONFIGURATION

By using this method, the nodes (switch) can be triggered to be switch either on or off via different paths that connect with other feeders and/or connecting the nodes which place on a same feeder. In distribution networks, radial topological structure was generally use where the changing open/closed status of sectionalizing and tie switches to achieve different combinations of switching status must be made considering this constraint [7]. Each status of switch is naturally represented by a binary control parameter 0 or 1. For instance, when the switch is open its binary control will be represented as 0 and when the switch is closed its binary control will be represented as 1. Let ***S*** as a tie line switch (normally open) and ***R*** represent sectionalizing switch (normally close).

The determination an order switching list of the status of current tie lines and sectionalizing switches is the objectives for network reconfiguration. However this order of switching list must be done without jeopardize the operational and topological constraints. This work modifies the solution methodology requires to fulfill a large amount of load flow calculations, and due to the great computational effort involved, for a real sized distribution system it results impractical[7]. This version allows estimating the electrical condition of the system with a reasonable accuracy.

The determination of switching action to minimize the network losses can be shown through the algorithm. The basic idea of the search scheme when using the "branch exchange" method consists on starting with a feasible tree (parent tree) and successively creating new trees (offspring trees) when doing "one" branch exchange at a time; this operation is always made from the parent tree [7]. Each open switch will originate as many offspring trees as closed switches exist in the respective associated loop; that is to say, the amount of branch exchanges that can be made from the parent tree is equal to the number of closed switches that belong to the loops associated to the open switches [8].

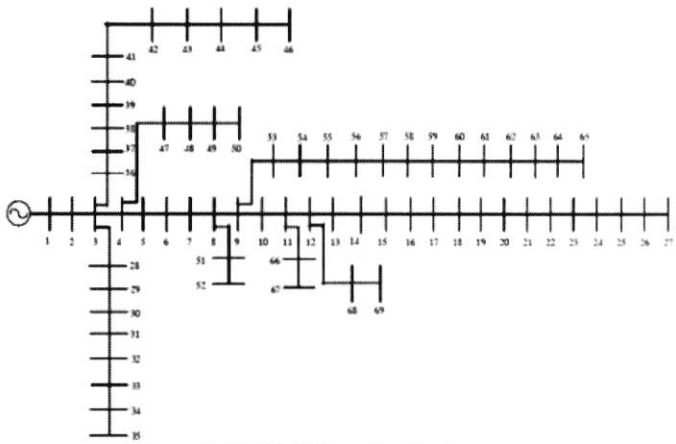


Figure 2: IEEE 69 bus distribution system

In Figure 2, it shows how IEEE 69 bus distribution system looks like. The objectives of designation of tie line are for protection where it will isolate the faulty part from healthy system when fault occur and configuration management to reconfigure the network.

III. RESULT AND DISCUSSION

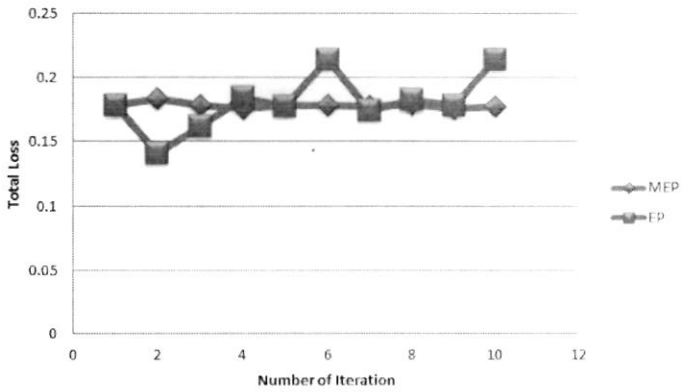


Figure 3: Comparison between MEP and EP for consistency test

Based on Figure 3, the result shows the total loss obtained by MEP and EP optimization technique which were generated from 10 simulations. Both techniques were repeated 10 times in order to evaluate the consistency of each technique. Within 10 simulations, the results shown in Figure 3 prove that the best losses values for MEP that was represented by blue line produces more consistency in total loss as compared to EP which was represented by the red line. Although there is minority of time where EP produces much lower total loss compared to MEP however there is no consistency when it was tested in 10 test run.

Table 2: Total Loss for MEP and EP

No of Simulation	Total Loss	
	MEP	EP
1	0.178466	0.178045
2	0.183183	0.141238
3	0.178189	0.161496
4	0.175859	0.184078
5	0.178074	0.177769
6	0.178483	0.214113
7	0.177243	0.173913
8	0.17949	0.182867
9	0.175757	0.178172
10	0.177424	0.213672
Average	**0.178217**	**0.180536**

In order to calculate the losses in the IEEE 69 bus distribution system which is shown in Table 2 above, power flow analysis was used. Based on Table 2, the lowest total loss which was produced by using MEP method is 0.175757 at 9^{th} simulation and for the total loss which was produced by using EP method is 0.141238 at 2^{nd} simulation. Although EP produced the lowest total loss, however it also provide the highest total loss which is 0.214113 at 6^{th} simulation whereas the highest total loss being produced by MEP is 0.183183 at 2^{nd} simulation. By comparing the results obtained from MEP and EP method in Table 2, it is shown that average of total loss for MEP is slightly lower than average of total loss for EP.

IV. CONCLUSION

This paper proposed a Multi-stage Evolutionary Programming MEP to solve the problem of network reconfiguration in distribution system. The proposed of Multi-stage Evolutionary Programming MEP has been tested in order to evaluate its performance in term of total loss and time taken to complete run the coding. Moreover, in order to analyze its performance, evolutionary programming EP was chosen as comparison. Since MEP and EP differ only in their programming flowchart, it is quite easy to apply MEP to solve network reconfiguration problem. The MEP was proposed to improve the loss minimization compared to EP. This paper proves the effectiveness of the proposed method which is MEP when being compared with EP. Moreover, the result also demonstrated that MEP outperforms EP in term of consistency. The majority of this paper focused on minimizes losses by using MEP. Therefore for future development, this method should be used to improve voltage stability and perform in a larger system in order to get sufficient data for improving network reconfiguration in distribution system.

ACKNOWLEDGMENT

First and foremost I would like to express my gratitude to ALL S.W.T for giving me strength, patience and idea in completing my project. To my final year project supervisor, I am deeply indebted and my deepest appreciation goes to Miss Norlee Husnafeza Binti Ahmad for her tireless support, patience and encouragement in guiding and helping me to solve the Multistage Evolutionary Programming method in the Matlab software and complete the project with confidence. Last but not least, I would like to express my utmost gratitude to my parent and friends who provide the moral support and helping me complete ths project successfully. May Allah S.W.T bless all these beautiful people with good health, happiness and prosperity.

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