

A 33kV Distribution Network Feeder Reconfiguration by Using REPSO for Voltage Profile Improvement

**¹M. F. Sulaima, ²S. N. Othman, M. H. Jali³, M. S. Jamri⁴, M. N. M. Nasir⁵,
Z. H. Bohari⁶**

*Faculty of Electrical Engineering
Universiti Teknikal Malaysia Melaka
Malacca, Malaysia.*

*¹fani@utem.edu.my, ²hairilatika@gmail.com, ³mohd.hafiz@utem.edu.my,
⁴saifuzam@utem.edu.my, ⁵mohamad.naim@utem.edu.my,
⁶zulhasrizal@utem.edu.my*

Abstract

The complexity of modern power system has contributed to the high power losses and over load in the distribution network. Due to that reason, Feeder Reconfiguration (FR) is required to identify the best topology network in order to fulfill the power demand with reduced power losses while stabilizing the magnitude of voltage. This paper addresses a new optimization method which is called as Rank Evolutionary Particle Swarm Optimization (REPSO). It has been produced by a hybridization of the conventional Particle Swarm Optimization (PSO) and the traditional Evolutionary Programming (EP) algorithm. The main objective of this paper is to improve the voltage profile while solves the overload problem by reducing the power losses respectively. The proposed method has been implemented and the real power losses in the 33kV distribution system has been investigated and analyzed accordingly. The results are compared to the conventional Genetic Algorithm (GA), EP and PSO techniques and it is hoped to help the power system engineer in securing the network in the future.

Keywords- Feeder reconfiguration, Rank evolutionary particle swarm optimization, Particle swarm optimization, Evolutionary programming, Genetic algorithm, Voltage profile, Power losses

INTRODUCTION

Feeder Reconfiguration (FR) is an important measure of changing the network

topology through the opening and closing the switches. It is also a key research of automatic operation. FR has been used for many purposes and the main purpose of FR is to minimize the power losses in distribution network system. Thus, FR also comes in large scale and is designed in closing the loop and opening the loop. FR is an effective way in order to balance the load, improve the voltage quality and enhance the system security as well [1]. During normal operation of a distribution network, the energy flow has a radial path and passes the normally close switches [2]. The network topologies in the distribution network reconfiguration change through the open /close of the sectionalizing and tie switches in order to get the optimal solution of the total power losses.

Many researchers have done the investigation on the combination of various methods and optimization techniques to reduce the power losses. The authors in [3] were the first to propose the distribution system reconfiguration for loss reduction. In the late 90's, the heuristics methods on large scale of distribution network appear to be the solution on reducing the power losses in a radial distribution networks [4]. Particle Swarm Optimization (PSO) is widely applied to various types of complex optimization problems. For example, the evolutionary PSO [5], modified PSO [6] and [8], hybrid PSO [7], multiple contingencies by using PSO [9], the distributed hierarchy structure in [10], mutation PSO [11] and the AMPSO that adds stochastic mutation in PSO was introduced in [12].

Unfortunately, in order to get the optimal value, the time taken for these methods to converge is too long. The initial values of the optimization methods such as PSO are easily affecting the convergence result [13-14]. Therefore, in this work, the concept of combination, selection and ranking have been implemented. The PSO algorithm is combined with the Evolutionary Programming (EP) from a hybridization method called EPSO as reported in [15], [16], [17], [20] and hence, the Rank Evolutionary Particle Swarm Optimization (REPSO) is introduced from the ranking concept. REPSO is introduced in this work to find the most suitable optimal opened switches and thus improving the voltage profile by reducing the power losses in its fastest ways. The analysis performance will be done in the 33kV distribution network configuration network and the results will be compared to previous methods which are GA, EP, PSO and EPSO.

In section II, the mathematical formulation and constraints will be discussed. The review of GA, EP, PSO and RREPSO is presented by the Section III while Section VI demonstrates the simulation process of REPSO. The simulation results which are consist of analysis of voltage profile, total power losses reduction, consistency, computational time will be in Section V and the conclusion has been made in Section IV respectively.

MATHEMATICAL FORMULATION AND CONSTRAINTS

In this study, the FR is to minimize the power losses in distribution network system. Therefore, the expression that relates to the objectives are as follow:

$$\text{Minimize } f_1(x, v) = \sum_{i=1}^n \text{Losses}_i \quad (1)$$

Where,

n is the number of branches

x is the continuous control variable

v is the discrete control variable

losses is the power losses at classified at i branch.

The improvement of voltage profile in the network has the significant relationship to the power losses. The less losses, the more efficiency of voltage magnitude in network system. There are some constraints that should be considered during the process of analysis. They are:

THE VOLTAGE CONSTRAINTS

In order to maintain the power quality of the system, the voltage magnitude should be based on within its particular limits.

$$V_{\min} \leq V_{\text{bus}} \leq V_{\max} \quad (2)$$

The particular limits for voltage at each bus is within 1.05 and 0.95 (± 5).

POWER FLOW CONSTRAINTS

Each and every branch in the power flow has its own permissible range. This range should be followed clearly and the constraints are strictly lies within it.

RADIAL CONFIGURATION CONSTRAINTS

The constraints of the radial configuration should be considered to avoid any excess of current flow through the system. Therefore, in order to ensure the radial network to be maintained, several constraints must be taken into account. Several standard rules have been adopted for selection of switches. Those switches that do not belong to any loop, connected to the sources and contributed to a meshed network have to be closed.

REVIEW OF GA, EP, PSO AND REPSO TECHNIQUES

GENETIC ALGORITHM (GA)

GA has three important parts which are crossover, mutation and reproduction [21].

- i. Crossover: two crossover points are considered and selected randomly.
- ii. Mutation: identified digit is changed to a number excludes the element of leaf nodes to avoid local optimum.
- iii. Reproduction: the elitist strategy is employed to select a portion of individuals with best fitness value. The roulette wheel approach is used.

In solving the network reconfiguration problem in distribution system to minimize real power losses; the steps are taken as below;

Step 1-Read the bus data, line data, and switch data, and bus out data.

Step 2-The population size, crossover rate, and mutation rate for GA is estimated. Initial chromosomes are encoded by Prufer number randomly selected. The radial structure is reasonable.

Step 3-solve (MW power flow balance equations) and (MVAR power flow balance equations) to obtain system bus voltages for each chromosome.

Step 4-The line flows for each chromosomes compute.

Step 5-If line flow is violated, penalty function is augmented to the fitness function (the negative objective for maximization).

Step 6-The roulette wheel approach is used to reproduce new chromosomes (offspring).

Step 7-Convergent step. Stop if all new chromosomes are the same.

Step 8-Perform crossover and mutation operations in GA.

Step 9-Go to Step 3.

EVOLUTIONARY PROGRAMMING (EP)

The EP is an excellent method for searching optimal solution to a complex problem [22-23]. Generally, there are several steps for developing EP. The steps are:

- i. Random generation of initial population
- ii. Fitness computation
- iii. Mutation
- iv. Combination
- v. Tournament selection
- vi. Transcription of next generation

Step 1: Random generation of initial population

The process for the optimal solution is done by determining a population of candidate solution over a number of generations randomly.

Step 2: Fitness computation

The strength of each candidate solution is determined by its fitness function which is evaluated based on the constraint in the objective function of the optimization process.

Step 3: Mutation

Others will combine through a process of mutation to breed a new population.

Step 4: Combination

Combination process will occur after the mutation that will combine the parent and offspring.

Step 5: Tournament Selection

Tournament selection is choosing the survival to next generation.

Step 6: Transcription of next generation

The new population is evaluated and the process is repeated.

PARTICLE SWARM OPTIMIZATION (PSO)

Particle swarm optimization has been found to be successful in a wide variety of optimization tasks [19]. The movement of birds seeking food happen in certain speed and position depends on their own experience and experience from their friends which known as the P_{best} and G_{best} . The value of P_{best} and G_{best} obtained are used to calculate the new velocity and the new position. The main steps for the PSO algorithm is:

- i. Initialization-randomize population (x).

Repeat:

- ii. Calculate fitness ($f(x)$).
- iii. Find P_{best} and G_{best} for all population.
- iv. Calculate the new velocity for each population.
- v. Adjust the position (new position, X_{new}).
- vi. Requirement fulfilled? - No: Repeat
- vii. End.

RANK EVOLUTIONARY PARTICLE SWARM OPTIMIZATION (REPSO)

For the hybridization, it is started with the proposed algorithm which is based on the traditional particle swarm optimization (PSO) and the evolutionary programming (EP).

The ideas of developing PSO are originally from Kenedy and Eberhart in 1975 [18]. These ideas are inspired from the choreography of a bird flock when they seek for food. The birds will move in certain speed and position to get the food. The movements that has been made are based on their experiences and also as well as their friends' experience which can be concluded as P_{best} and G_{best} . As they move, they have their own velocity and the new velocity which is known as the $v^{(i+1)}$ and the new position $x^{(i+1)}$ can be obtained by the expression below:

$$v^{i+1} = \omega v^i + c_1 r_1 (P_{best} - x_i) + c_2 r_2 (G_{best} - x^i) \quad (3)$$

$$x^{i+1} = v^{i+1} + x^i \quad (4)$$

In REPSO, among the particles in a population, the best particles will move to the new position and the empty position that they left will be replaced by other particles. The selection of the new position of these particles are much more different if to be compared with PSO algorithm as they are being done using the concept of combination, ranking and selection technique in evolutionary programming. For the REPSO, the flow process of the new algorithm is as follow:

- i. Step 1: Define the number (N), position (x) and velocity.
- ii. Step 2: Determine the fitness of each particle and find the P_{best} and G_{best} .
- iii. Step 3: fulfilled the constraints? If not, REPEAT. If yes. CONTINUE.
- iv. Step 4: find the new position (x^{i+1}) and new velocity (v^{i+1}) from the value of P_{best} .
- v. Step 5: Determine the new fitness of each particle.
- vi. Step 6: Do the tournament selection process.
- vii. Step 7: Population sorted based on the highest score.
- viii. Step 8: Select N best particles from the results.
- ix. Step 9: Choose best rank in the tournament.
- x. Step 10: Solution converges? If no, REPEAT.
- xi. If yes, END.

In order to obtain the REPSO, the EP is needed to be integrated in PSO. Thus, from the process, the EP is integrated in Step 6 after the selection process is done. The integration of EP will produced the new method which is called as REPSO After the newest P_{best} and newest G_{best} are set, the best rank element that won in the tournament is set to be the best element to converge. The concept of ranking is presented in Step 9.

Meanwhile in Step 10, the convergence test is required to determine the stopping criteria of this optimization search process. The new position set will be tested for convergence. If convergence is not achieved, the process will be repeated by calculating a new velocity and position by using equations in Step 4 and Step 5 based on the new local best (P_{best}) and global best (G_{best}). If convergence is achieved, then the optimization process is terminated. The overall flow of REPSO is illustrated in the Fig. 1.

THE SIMULATION OF REPSO

Throughout this study, all the data and programming should be written and noted so that the entire work becomes easier. For this entire network, the data is taken from the network performance on 33-bus IEEE test system. As the data is completely inserted into the data network, the proposed method consists of REPSO programming will be simulated into the Matlab environment to analyze the results. In order to verify either the voltage profile is really improve or not, the results comparison between the conventional and the proposed method has been done accordingly.

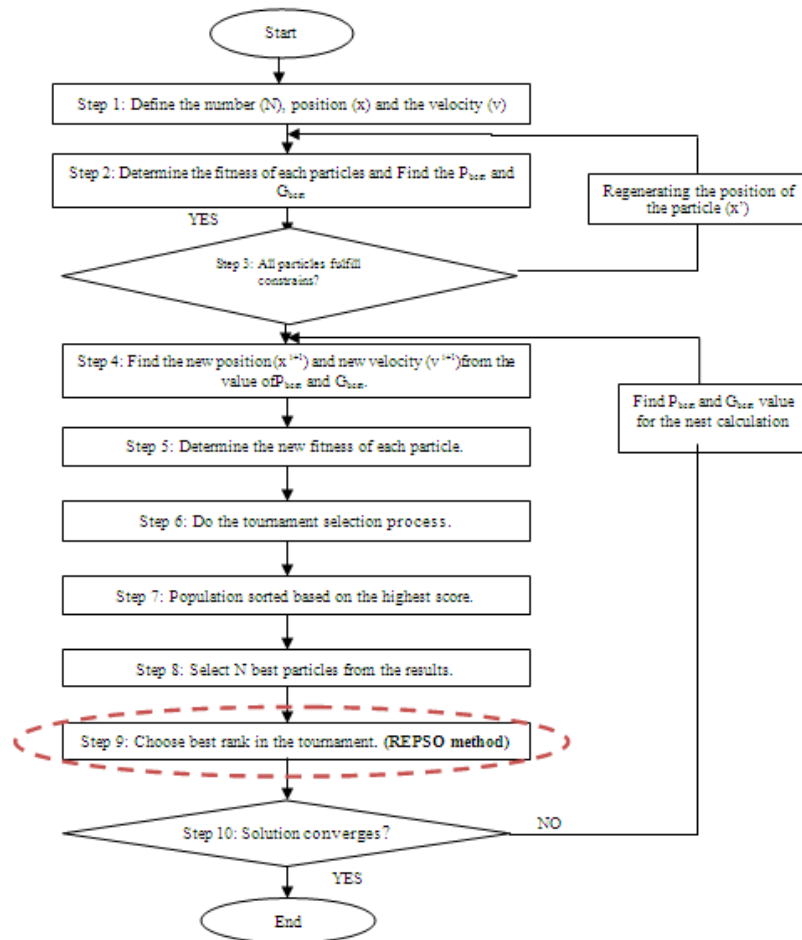


Fig. 1. The development and implementation of REPSO

RESULTS AND ANALYSIS

To verify the effectiveness of the proposed REPSO method in improving the voltage profile and reducing power losses, a comprehensive simulation is being implemented in the 33-bus radial initial network configuration system as shown in the Fig. 2. The load is assumed to be constant throughout the system and the base apparent power is set to be 100MVA. In this system, the original initial configuration consists of 1 feeder, 32 normally closed tie line and 5 normally open tie lines (open-switches). The open-switches are normally represented by the dotted lines and located at no. 33, 34, 35, 36 and 37 branches.

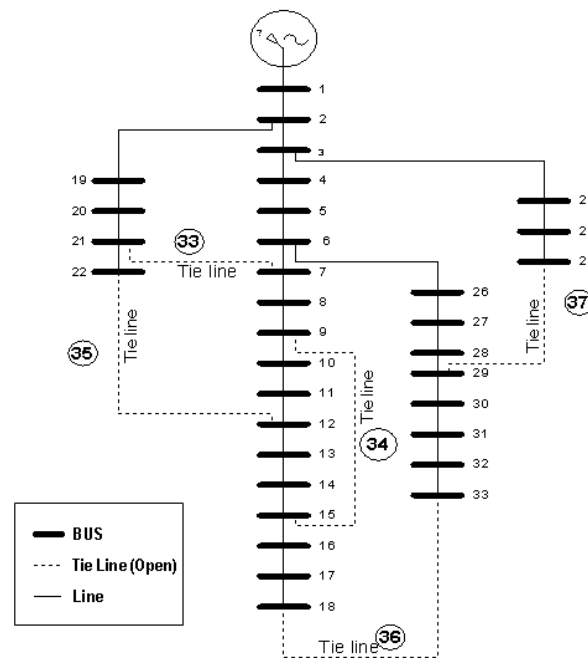


Fig. 2. The 33-bus radial initial configuration

In order to prove that comparison REPSO is a superior technique to optimum the solution, a comprehensive performance of GA, EP and PSO has been done. The analysis is separated into five cases which are consisting of:

Case 1: The original 33bus initial network reconfiguration with all the open switches will be remained at their original location.

Case 2: The FR of the distribution network system by using GA.

Case 3: The FR of the distribution network system by using EP.

Case 4: The FR of the distribution network system by using PSO.

Case 5: The FR of the distribution network system by using REPSO.

There are three important parts will be discussed in this section. For part A is the summary of the voltage profile improvement while the Part B represents the numerical results for the five cases in terms of the total power losses and convergence time.

VOLTAGE PROFILE IMPROVEMENT

The Fig. 3 shows the voltage profile analysis for Case 2, Case 3, Case 4 and Case 5 respectively. In this result, the improvement is taken and the comparison is made based on the three conventional algorithms and one hybridization method simultaneously. The overall view; REPSO technique (Case 5) has a better value for voltage magnitude if to be compared to others methods. It is clearly seen by looking at the data for bus number 8 to 18; the profile value for REPSO is highest due to the ability of the combination, selection and ranking concept process. Meanwhile, to change the certain buses, the value of voltage profile for PSO (Case 4) and REPSO are the same. This phenomenon can be seen at the bus number 19 and 20. The values for voltage profile are the same for all the techniques at the buses number 1 until 4 because of the searching and arrangement process of heuristic method that using the similar technique in order to initial the population. Thus, the Case 5 which is the REPSO technique by the concept of hybridization and rank factor has contributed to the superior voltage profile improvement for the test system 33kV distribution network feeder reconfiguration.

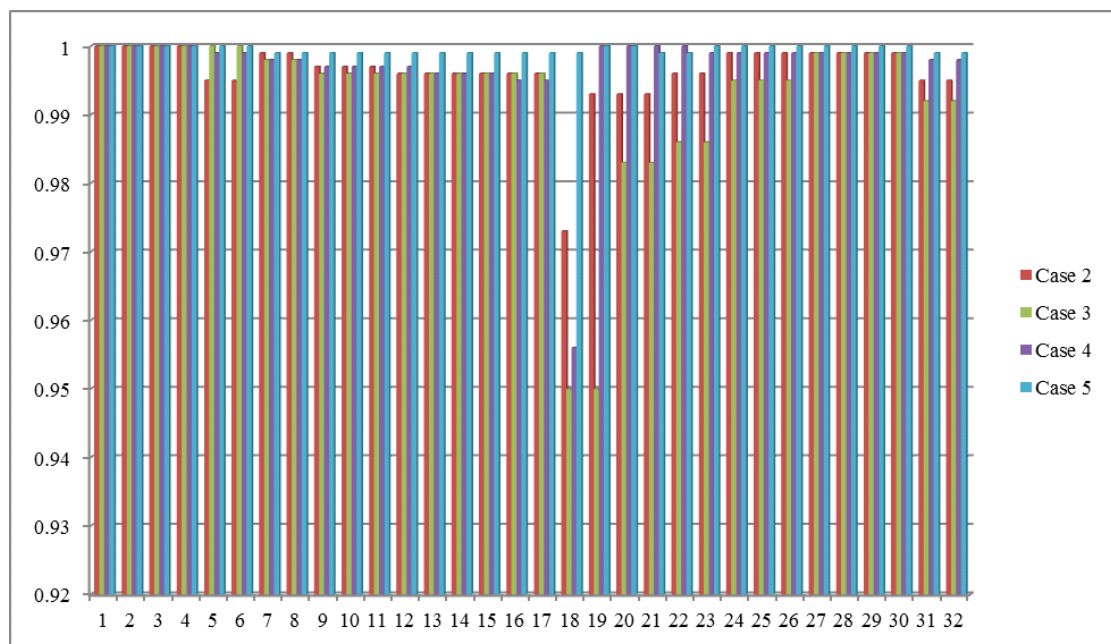


Fig. 3. Voltage profile improvement by GA, EP, PSO and REPSO

TOTAL POWER LOSSES & CONVERGENCE TIME

Table 1 indicates the results for overall performance of the 5 cases accordingly. In contributing to the finding of getting the optimal solution for the total power losses, the important parameters should be focused on switches to be opened, power losses reduction and the convergence time for each case.

TABLE 1 The performance analysis on the 33 bus systems by using GA, EP, PSO and REPSO

Parameters	Switch to be opened	Total power losses (kW)	Loss reduction (kW)	Convergence Time (s)
Case 1: Original initial network	33, 34, 35, 36, 37	202. 7	-	-
Case 2: After reconfiguration using GA [25]	7, 9, 14, 32, 37	137. 0	65. 7	24. 0
Case 3: After reconfiguration using EP[23], [26]	7, 9, 14, 32, 37	139. 5	63. 2	13. 9
Case 4: After reconfiguration using PSO [24]	7, 10, 14, 28, 31	126. 5	76. 2	18. 0
Case 5: After reconfiguration using REPSO	32, 28, 11, 33, 34	120. 7	82	9. 0

It is can be seen that when the techniques of GA, EP, PSO and REPSO are applied to the system, the value of total power losses are considerable decreased. For Case 2, the GA algorithm is able to reduce from 202. 7kW to 137. 0kW which gives a reduction of 65. 7kW. For the Case 3, EP technique is successfully reduces the power losses from 202. 7kW to 139. 5kW, gives the reduction of 63. 2kW. The both techniques GA and EP have the similarity in terms of the mutation and crossover concept but in two different way operations. For the Case 4, PSO has shown the ability to search the optimum value which is the reduction of losses is 76. 2kW. The total power losses have fall to 126. 5kW obviously. Thus, for the Case 5, which is the main concern of this work; the REPSO method is successfully reduces the power losses from 202. 7kW to 120. 7kW which presents the total reduction of 82kW. This is the highest among the 4 cases technique that have been tested. Therefore, REPSO has proved to be a chosen technique in order to reduce the power losses for feeder reconfiguration system. The Fig. 4 summaries the total power losses for Case 2, Case 3, Case 4 and Case 5 respectively.

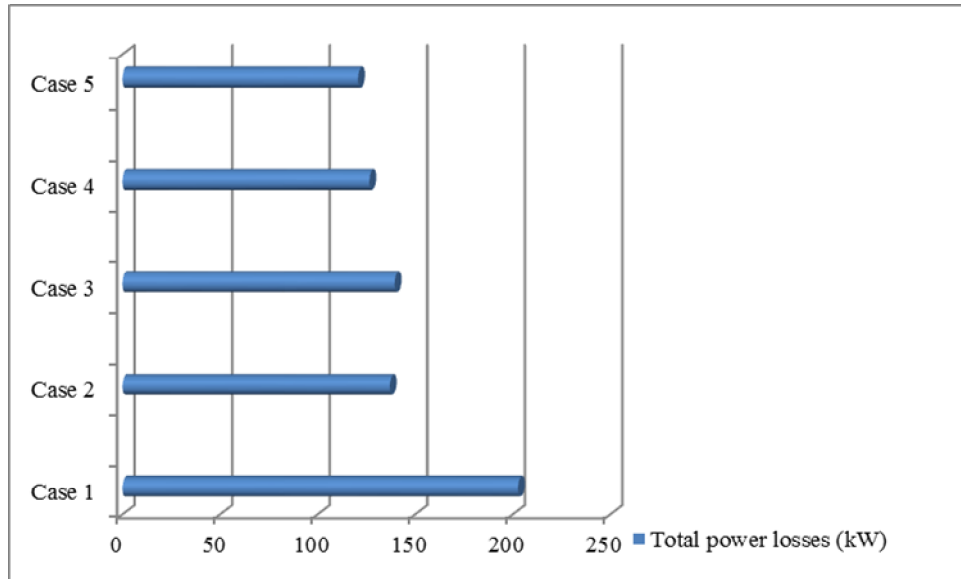


Fig. 4. The comparison of total power losses

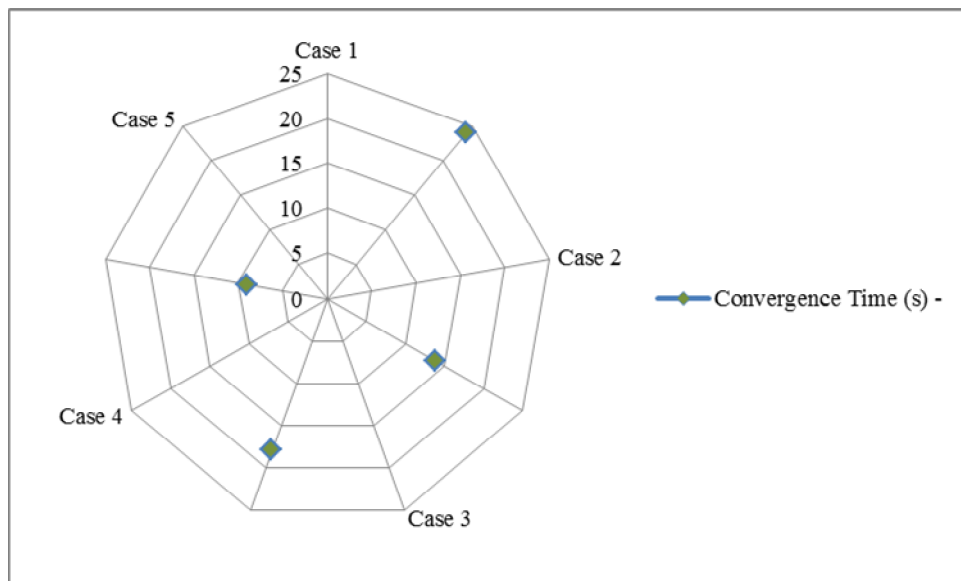


Fig. 5. The convergence time for 5 cases

The analysis of convergence time is demonstrated by Fig. 5 clearly. From the comparison study of this part, the Case 5 has shown the great results with minimum time to converge in order to get the optimal results. The number time is given by superior REPSO technique is 9 seconds. The conventional technique such as PSO has converged within 18 seconds, EP is 13.9 seconds and GA is 24 seconds respectively. The hybridization of PSO and EP concept in REPSO technique has contributed to the faster model of optimization algorithm with the accurate value and full fills all the constraint set at the beginning, as well.

For the sectionalizing switches, the original switches are opened at 33, 34, 35, 36 and 37. Nevertheless, after the reconfiguration is done, the sectionalizing switches opened are different for GA, EP, PSO and REPSO algorithm. For Case 2 and 3, the sectionalizing switches to be opened are 7, 9, 14, 32 and 37 while the Case 4 is 7, 10, 14, 28 and 31. The switches to be opened for Case 5 is 32, 28, 11, 33 and 34 as presented in Fig. 6 (remain the radial network topology).

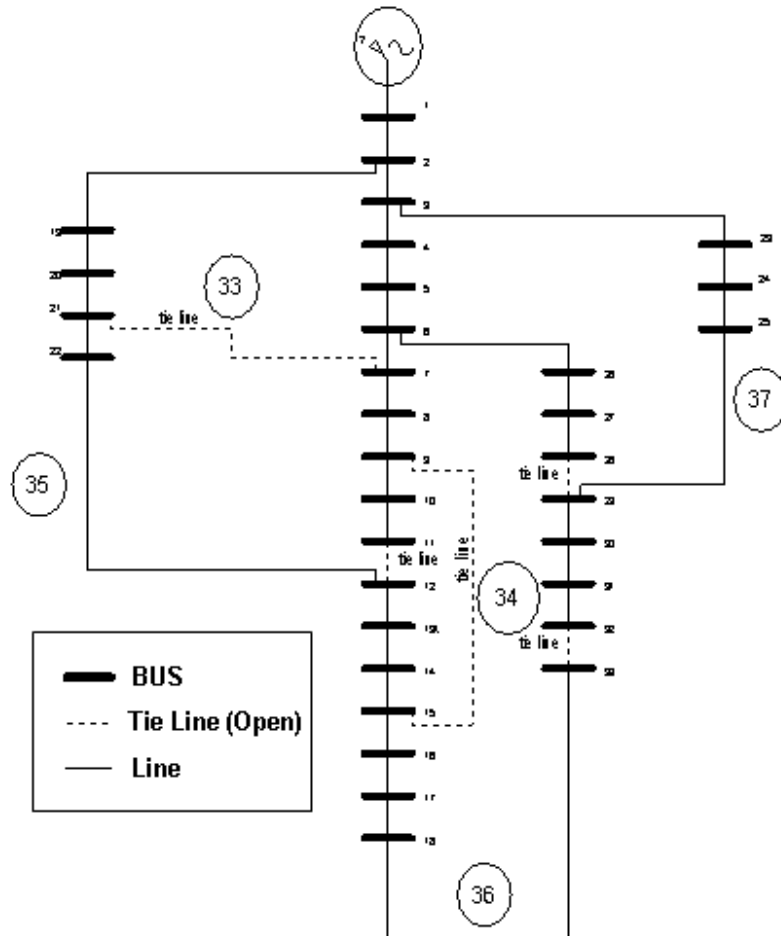


Fig. 6. The radial network after reconfiguration by using REPSO

CONCLUSION

In this paper, a distribution network feeder reconfiguration which is based on REPSO technique has been introduced. The main goal of this work is to improve the voltage profile and minimize the power losses while improve the computing time are successfully analyzed. This is done by comparing the three optimization methods which are GA, EP, PSO and REPSO correspondingly. The power losses are positively being reduced and affect the voltage profile value. The best optimal value has been achieved by REPSO algorithm and is can be conclude that the implementation of

REPSO has given the great impact for the whole 33kV power distribution feeder reconfiguration system.

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