A DNR by Using Rank Evolutionary Particle Swarm Optimization for Power Loss Minimization

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Abstract- **Distribution Network Reconfiguration (DNR) is required to identify the best topology network in order to fulfill the power demand with minimum power losses. This paper proposes a new method which is called as Rank Evolutionary Particle Swarm Optimization (REPSO). The proposed method is a combination of the Particle Swarm Optimization (PSO) and the traditional Evolutionary Programming (EP) algorithm with a rejuvenation of the additional of ranking element. The main objective of this paper is to reduce the power losses while improving the convergence time. The proposed method will be implemented and the real power losses in the IEEE 33-bus test system will be investigated and analyzed accordingly. The results are compared to the conventional PSO and hybridization EPSO method and it is hoped to help the power system engineer in securing the network with the less power loss in the future.**

Keywords – distribution network reconfiguration; rank evolutionary particle swarm optimization; particle swarm optimization; evolutionary programming

I. INTRODUCTION

Distribution Network Reconfiguration (DNR) 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. DNR has been used for many purposes and the main purpose of DNR is to minimize the power losses in distribution network system. Thus, DNR also comes in large scale and is designed in closed loop and opened loop. DNR is also 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 on/off of the sectionalizing and tie switches in order to get the optimal solution of the power losses.

Many researchers have been done the investigation on the combination of various methods and optimization techniques that seems to be able to help in reducing the power losses. The authors in [3] were the first proposed the distribution system reconfiguration for loss reduction. In the late 90's, the heuristics methods on large scale of distribution network appears 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] and the AMPSO that adds stochastic mutation in PSO was introduced in [11].

Unfortunately, in order to get the optimal value, the time taken for these methods is too long. The initial values of the optimization methods such as PSO are easily affecting the convergence result [12], [13]. Therefore, in this work, the concept of combination, selection and ranking will be implemented. The PSO algorithm will be combined with Evolutionary Programming (EP) to from a hybridization method called EPSO and hence, the Rank Evolutionary Particle Swarm Optimization (REPSO) is introduced from the ranking concept. REPSO is introduced in this work to help in finding the most suitable optimal opened switches and thus reducing the power losses in its fastest ways. The analysis performance will be done in the 33kV distribution network configuration and the results will be compared to previous methods which are PSO and EPSO.

In section II, the mathematical formulation and constraints will be discussed. The implementation of REPSO in the DNR, the simulation results and analysis for power losses and computational time and the conclusion will be discussed in Section III, VI and V respectively.

II. MATHEMATICAL FORMULATION AND CONSTRAINTS

The needed for the reconfigurtion of the distribution system in this study is to minimize the power losses in distribution network system. Therefore, the expression that can relate with the objective are as follow:

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

Where,

n is the number of branches
x is the continous control variable
v is the discrete control variable
losses is the power losses at classified at i branch.

There are some contraints that should be considered during the process of analysis. The constraints are:

A. The voltage constraints

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

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

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

B. Power flow constraints

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

C. 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.

III. RANK EVOLUTIONARY PARTICLE SWARM OPTIMIZATION

A. Hybridization and Implentation of 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 [14]. 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:

$$v^{i+1} = \omega v^{i} + c_i r_i \ (P_{best} - x_i) + c_2 r_2 \ (G_{best} - x^i) \qquad (3)$$
$$x^{i+1} = v^{i+1} + x^i \qquad (4)$$

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 Pbest.
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 EPSO 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 Figure 1.

B. Simulation of REPSO

Throughout this research, all the data and programming should be written and noted so that the entire work become easier. For this entire network, the data is taken from the network performance on test system 33kV IEEE test system. As the data is completely inserted into the data network, the proposed method consists of REPSO programming which consists of PSO and EPSO programming will be sitimulated into the Mathlab for analyzing the result. In order to verify either the power losses is really minimized or not, the comparison between the conventional results and the stimulation results have been done.

Figure 1. The development and implementation of REPSO

IV. SIMULATION RESULTS AND ANALYSIS

To verify the effectiveness of the proposed REPSO method in reducing power losses, a comprehensive analysis is being implemented in the 33bus radial initial network configuration system as shown in the Figure 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 are consists of one feeder, 32 normally closed tie line and five 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.
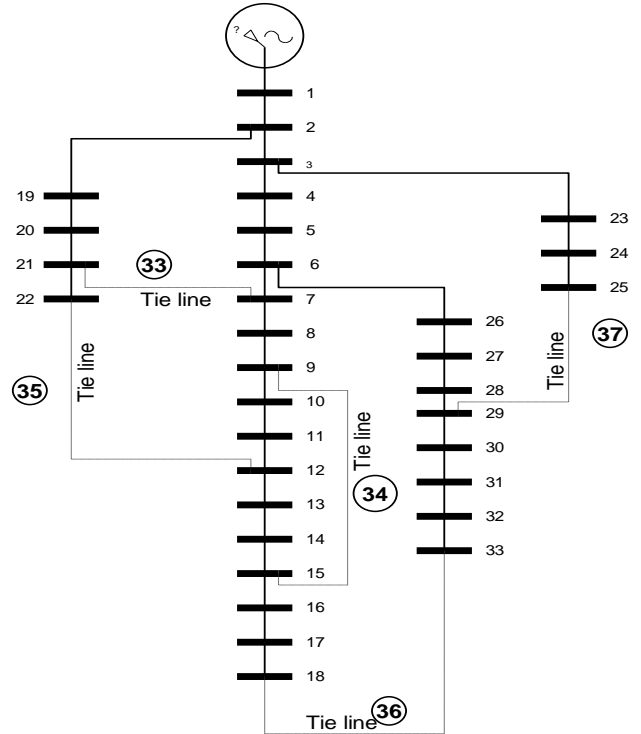

Figure 2. The 33bus radial initial configuration

In order to prove that REPSO is one of the fastest ways in reducing the power losses, a comprehensive performance of PSO and EPSO are also being done in the 33-bus distribution system. The analysis is separated into four cases which consist of:

Case 1: The original 33bus initial network reconfiguration with all the open switches will be remained at their original location.
Case 2: The reconfiguration of the distribution network system by using PSO.
Case 3: The reconfiguration of distribution network system by using EPSO.
Case 4: The reconfiguration of the distribution network system by using REPSO.

The numerical results for the four cases are summarized in the Table 1 while the Table 2 represents the convergence time

as well. In contributing to the finding of getting the optimal solution for the power losses, the important parameters should be focused on switches, power losses reduction and the convergence time for each method used.

TABLE 1: THE PERFORMANE ANALYSIS ON THE 33 BUS SYSTEMS BY USING PSO, EPSO AND REPSO

Parameters	Switch to be opened	Total power losses (kW)	Loss reduction (kW)
Case 1: Original initial network	33,34,35,36,37	202.7	-
Case 2: After reconfiguration using PSO.	33,6,14,28,34	146.1	56.6
Case 3: After reconfiguration using EPSO.	14,33,17,26,8	131.1	71.6
Case 4: after reconfiguration using REPSO	32,28,11,33,34	120.7	82

TABLE 2: THE CONVERGENCE TIME ANALYSIS FOR SIMULATION

Parameters	Convergence time (s)
Case 2:PSO	28.65
Case 3:EPSO	13.62
Case 4: REPSO	9.97

From the Table 1, it can be seen that when the PSO, EPSO and REPSO are applied to the system, the value of power losses reduction are considerable decreased. For Case 1, the PSO algorithm is able to reduce from 202.7kW to 146.1kW which gives a reduction of 56.6kW. For the Case 2, EPSO algorithm successfully reduces the power losses from 202.7kW to 131.1kW, gives the reduction of 71.6kW. For case 4, which is the main concern of this work, REPSO is successfully reduces the power losses from 202.7kW to 120.7kW which bring the total reduction of 82kW, the highest among the three algorithm. Therefore, REPSO is proved to be better in reducing the power losses compared to PSO and EPSO. Moreover, in term of convergence time comparison as shown in Table 2; REPSO perform the shortest time taken which is 9.97 seconds only. Meanwhile the time for PSO and EPSO to converge are 13.62s and 28.65s respectively. The integration of selection, combination, tournament and ranking element have produced the newest P_{best} and newest G_{best} in good condition manner.

The best rank element that won in the tournament is set to be the best element to converge in a short time. Due to that reason, the REPSO can be seemed as the fastest searching method if to be compared to PSO and EPSO. The results obtained for the total power losses reduction and the convergence time are plotted in graphs as shown in Figure 4 and Figure 5 accordingly.
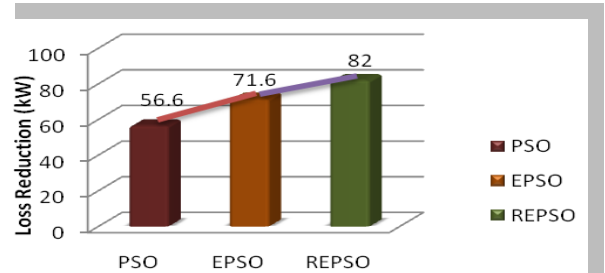

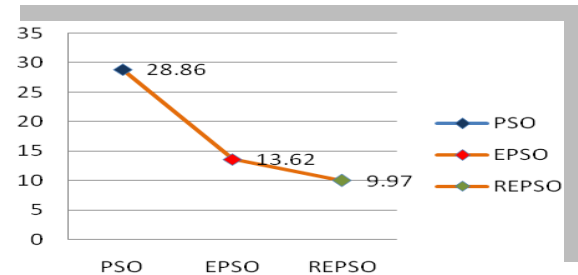Figure 4. The comparison of total loss reduction between PSO, EPSO and REPSO algorithm

Figure 5. The comparison of the convergence time between PSO, EPSO and REPSO algorithm

For the sectionalizing switches, the original switches opened are at 33, 34, 35, 36 and 37. Nevertheless, after the reconfiguration is done, the sectionalizing switches opened are different for PSO, EPSO and REPSO algorithm. For case 2, the sectionalizing switches to be opened are 33, 6, 14, 28, and 34. The radial network after reconfiguration with PSO is shown in Figure 6. In the meantime, for Case 3, the sectionalizing switches opened are at 14, 33, 17, 26, and 8. The radial network after reconfiguration with EPSO is shown in Figure7. To end with Case 4, after reconfiguration by using REPSO algorithm, the sectionalizing switches opened are 32, 28, 11, 33 and 34 as presented in Figure 8.
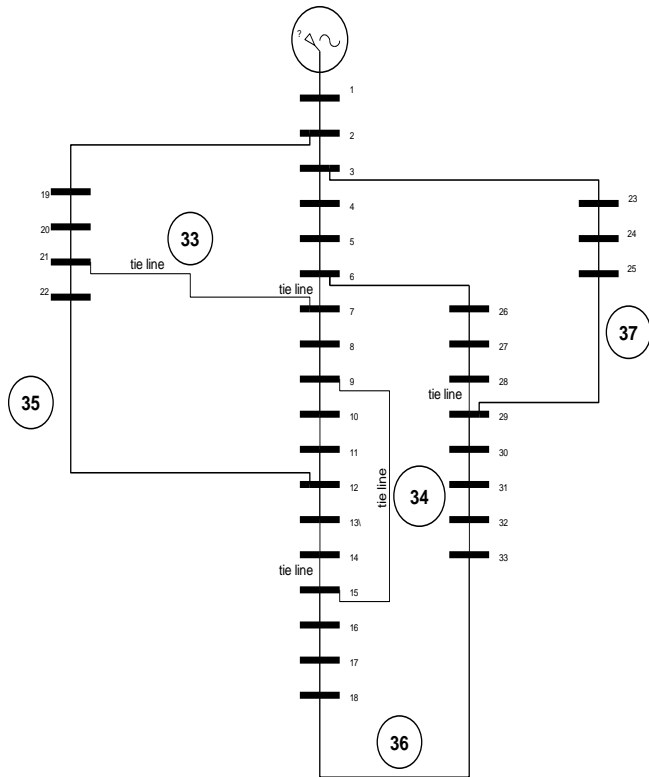
Figure 6: The radial network after reconfiguration by using PSO
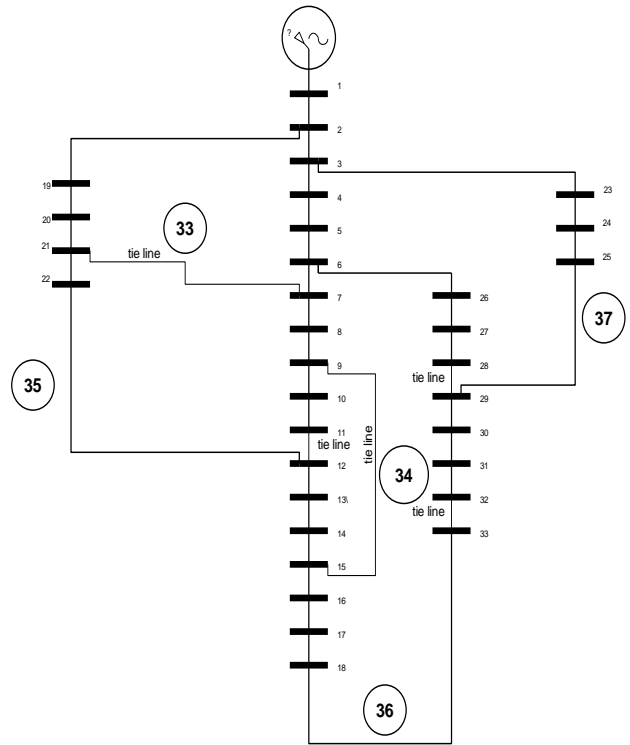

Figure 8: The radial network after reconfiguration by using REPSO

V. CONCLUSION

A distribution network reconfiguration method which is based on REPSO technique has been introduced. The main goal of this work is to minimize the power losses and improve the computing time is successfully analyzed. This is done by implementation of the three optimization methods which are PSO, EPSO and REPSO correspondingly. The power losses are positively being reduced and the best optimal value has been achieved by REPSO algorithm. Thus, the implementation of REPSO is proved to give the great impact for the whole network reconfiguration system.

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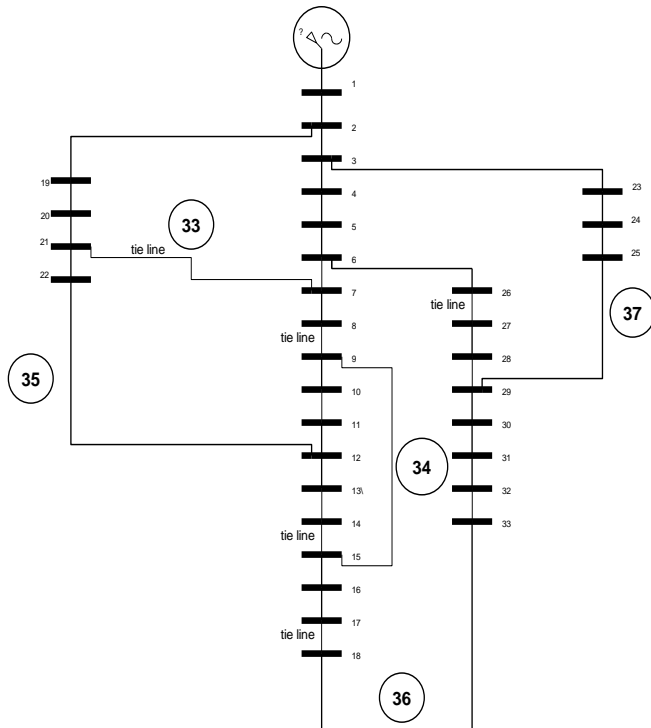

Figure 7: The radial network after reconfiguration by using EPSO

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