

A DNR Using Evolutionary PSO for Power Loss Reduction

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Abstract—The total power losses in distribution network system can be minimized by network reconfiguration. In this area of research, most of the researchers have used multiple types of optimization technique to determine the optimal problem solving. In this paper, an efficient hybridization of heuristic method which is called as Evolutionary Particle Swarm Optimization (EPSO) is introduced to identify the open and closed switching operation plans for feeder network reconfiguration. The main objective is to reduce the power losses in the distribution network system and improve the voltage profile in the overall system meanwhile minimizing the computational time. The proposed combination of Particle Swarm Optimization (PSO) and Evolutionary Programming (EP) is introduced to make it faster to find the optimal solution. The proposed method is applied and its impact on the network reconfiguration for real power loss and voltage profiles is investigated. In network reconfiguration, the network topologies change through On/Off of the sectionalizing and tie switches in order to optimize network operation parameters. The aim is to find the best configuration which consists of switches that will contribute to a lower loss in the distribution network system. The method was tested on a IEEE 33-bus system to show the effectiveness of the EPSO method over the traditional PSO and EP method.

Index Terms—Distribution, Heuristic method, Distribution Network Reconfiguration (DNR), Evolutionary Particle Swarm Optimization (EPSO), Particle Swarm Optimization (PSO), Evolutionary Programming (EP).

I. INTRODUCTION

In order to make sure a reliable and secure the system economically, the high demand in power system has become as a challenging job to most of the power system engineers. This is due to the heavy loaded network that would increase the load current drawn from the source and at the same time, it leads to an increasing in voltage drop and system losses. Due to the dropping in voltage magnitude and intensification in distribution losses, the performances of distribution system

turn out to be incompetent. With this regards, changes in economic and commercial environment of power systems design and operation have necessitate the need to consider a smart distributed network by reconfigure the network. This would lead to the improvement of quality, reliability and economic such as in voltage profile, service restoration, energy efficiency, loss minimization and also load leveling.

The network reconfiguration is defined as altering the topological structures of distribution feeders by changing the open and closed states of normally-closed and normally-open switches. Under normal operating conditions, the network is reconfigured to reduce the power losses of system and to balance load in the feeders. Under conditions of permanent failure, the network is reconfigured to restore the service and bring to minimize the unrestored loads. Distribution systems usually is planned and built as weakly meshed network but in normal condition, it is operate as radial network and contains of groups of interconnected radial circuits.

There are two types of switches, which are sectionalizing switches and tie switches. These kinds of switches are being used for protection and configuration management in the primary distribution systems. Apart from that, the loss reduction and load balancing which is from the distribution network reconfiguration is a complicated combinatorial, non-differentiable, constraint optimization problem since this reconfiguration involves with many candidate-switching combinations. Ultimately, several constraints shall be considered during network reconfiguration which are:

1. Asseverate of radial structure for distribution system
2. Section of all users should need to be assisted
3. Feeder capacity should not be beat the limit
4. Feeder voltage profile should be sustained

Regarding to the issue, various methods have been developed to solve the network reconfiguration problem over the year. Based on [1-4], an improved method in refined Genetic Algorithm (GA) for distribution network reconfiguration application was presented. But the proposed GA is useable when it is implemented for huge network systems only and efficiently for the restoration system problem solving and load balancing study. A part from that, an

improved of optimization method such as Particle Swarm Optimization (PSO) for power losses minimization has been done in [5-8]. The simulation results for this optimization method have shown a good healthiness of the approach in term of power loss reduction but they are less optimal solution for computational time. Furthermore, an Evolutionary Programming (EP) is another method that has been widely used in solving the network reconfiguration problem. There is reported in [9-12]; the authors proposed a multi-objective Evolution Programming (EP) method for distribution network reconfiguration system. The ability of EP for network reconfiguration to balance the load, reduce the power losses, minimizing switching operations, certifying voltage quality, service reliability assurance and enhancement of voltage profile in distribution system has been looked as the advantages of this method. But the result of power loss reduction has shown that the ability of EP to propose the best result is not optimal when compared to the traditional PSO method.

Due to that, after many years of the algorithm application methods are introduced; the hybrid method for this research area is become more popular to apply. One of the powerful and applicable method that is being developed is Evolutionary Particle Swarm Optimization (EPSO) that has been introduced in [13]. There are several research has been reported in application of EPSO on power system according to [14-18]. But there is no paper research yet in distribution network reconfiguration. For latest report as in [19] and [20], the authors report that the new approach of EPSO has been implemented in power distribution network with Distribution Generation (DG). The performance of PSO and EPSO has been compared to the problem solving of DG sizing.

In this paper, the flow of explanation is organized as follows. In Section II, the modeled distribution network is tested by using commercial available simulation software. Section III discusses on how the hybrid method is designed. Analysis of simulation results and conclusion are discussed in section IV and V respectively.

II. TEST SYSTEM MODELLING

This type of network as shown in Figure 1 consists of 33 load nodes, one feeder, 32 normal closed tie line, 5 normally open tie switches (S33, S34, S35, S36 and S37) and 37 branches. The line data and also for load data for 33-bus system has been gain from [21]. The total load in the system is 3.715MW and the system load is expected to be constant and $S_{base} = 100MVA$. Same as other test system, a high resistance and high reactance value will be modified in R and X column in line data to simulate the open line. Apart from that, combination of state variables will be executed using Newton-Raphson power flow program and the optimization was done by using EPSO algorithm to find the most optimum losses in the system.

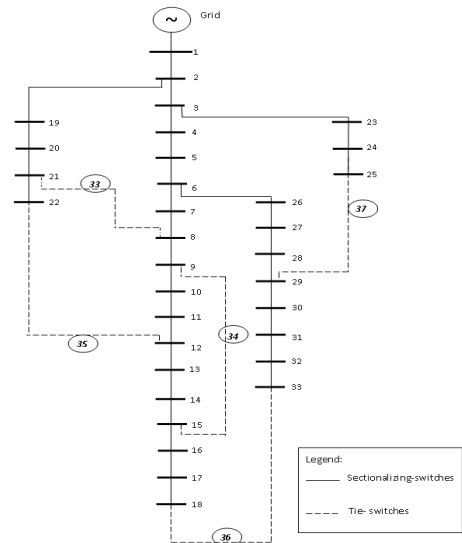


Figure 1: 33-bus radial distribution system

III. METHODOLOGY OF PROPOSED METHOD

A. Initialization

The flow chart of implemented EPSO algorithm by MATLAB programming is shown in Figure 2. The process is started with the initialization population which is determined by selecting tie switches from the set of original tie switches. Those variables will be generated by the system via a random generator available in the program and they will be utilized to compute the power losses in the next step.

The EPSO parameters are initialized such as number of particles N , weighting factors, C_1 and C_2 and maximum number of iteration. In order to ensure the radial network is maintained, several constraints need to be considered in the system. There are several rules have been adopted for the selection of switches.

1. Rule 1 : All switches that do not belong to any loop are to be closed
2. Rule 2 : All switches are connected to the sources are to be closed
3. Rule 3 : All switches contributed to a meshed network need to be closed

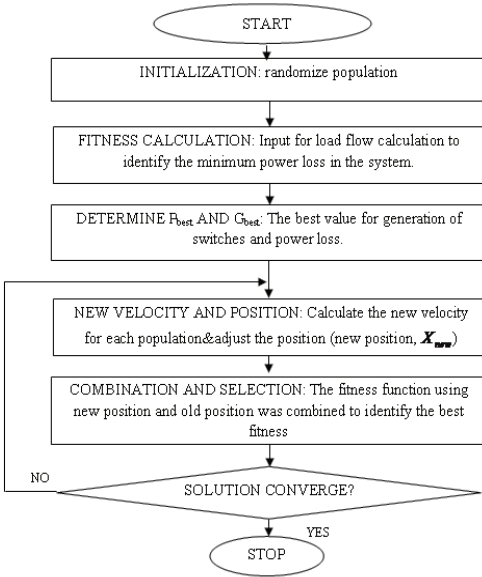


Figure 2: Flowchart of EPSO implemented in Network Reconfiguration

B. Fitness Calculation

An initial population of particles with random position, X and velocities, V on dimension in the solution space is randomly generated. For each particle that fulfills the constraints mentioned above, the power flow will be accomplished and the total power loss will be calculated using the Newton-Raphson load flow program.

The Newton-Raphson load flow equation at any given bus i and j are given as:

$$P_i = \sum_{j=1}^n |Y_i| |V_j| |Y_{ij}| \cos(\theta_{ij} - \delta_i + \delta_j) \quad (1)$$

$$Q_i = - \sum_{j=1}^n |V_i| |V_j| |Y_{ij}| \sin(\theta_{ij} - \delta_i + \delta_j) \quad (2)$$

where,

- V_i, V_j = the voltage magnitude of bus i and j respectively
- δ_i, δ_j = the voltage angle of bus i and bus j respectively
- Y_{ij}, θ_{ij} = the magnitude and angle of Y_{ij} element in the bus admittance matrix respectively.

The equations for the differences in real power (ΔP_i) and reactive power (ΔQ_i) for the i th bus are:

$$\Delta P_i = P_i^{SP} - P_i \quad (3)$$

$$\Delta Q_i = Q_i^{SP} - Q_i \quad (4)$$

where P_i^{SP} and Q_i^{SP} are the specified real and reactive power at bus i respectively.

The rectangular Newton-Raphson power flow is expressed as:

$$\begin{bmatrix} \Delta P \\ \Delta Q \end{bmatrix} = \begin{bmatrix} \frac{\partial P}{\partial \delta} & \frac{\partial P}{\partial V} \\ \frac{\partial Q}{\partial \delta} & \frac{\partial Q}{\partial V} \end{bmatrix} \begin{bmatrix} \Delta \delta \\ \Delta |V| \end{bmatrix} \quad (5)$$

Power loss can be calculated as in equation (6):

$$P_{loss} = \sum_{i=1}^n \sum_{j=1}^n A_{ij} (P_i P_j + Q_i Q_j) + B_{ij} (Q_i P_j - P_i Q_j) \quad (6)$$

$$A_{ij} = \frac{R_{ij} \cos(\delta_i - \delta_j)}{V_i V_j} \quad (7)$$

$$B_{ij} = \frac{R_{ij} \sin(\delta_i - \delta_j)}{V_i V_j} \quad (8)$$

where,

- P_i, Q_i = the real and reactive power of bus i respectively
- P_j, Q_j = the real and reactive power of bus j respectively
- R_{ij} = the line resistance between bus i and j
- V_i, V_j = the voltage magnitude of bus i and j respectively
- δ_i, δ_j = the voltage angle of bus i and j respectively

C. Determine P_{best} and G_{best}

During the searching process, the two best values are updated and recorded. It is related with the best solution that has been extended so far by each particle which retains path of its coordinate in the solution space. This value is noted as P_{best} and another best value to be verified is G_{best} , which is the whole best value so far by any particle. The P_{best} and G_{best} are representing the generation of tie-switches and power loss.

D. New Velocity and Position

In this step, the particles' velocity and position is updated by apply the equation (1) and (2). The particle's velocity signifies a switches movement. Meanwhile, the total power loss of all switches is evaluated by using the new position, X_{new} .

$$V_j^{k+1} = \omega \times V_j^k + C_1 \times rand_1 \times (P_{best}^k - X_j^k) + C_2 \times rand_2 \quad (9)$$

$$X_j^{k+1} = X_j^k + V_j^{k+1} \quad (10)$$

$$X_j^{k+1} = X_j^k + V_j^{k+1} \tag{11}$$

where,

- V_j^k is the velocity of particle j in iteration k
- X_j^k is the position of particle j in iteration k
- P_{bestj}^k is the best value of the fitness function that has been achieved by particle j before iteration k
- G_{best}^k is the best value among the fitness function value.
- C_1 and C_2 are constants that represent weighting factors of the random acceleration terms
- V_j^{k+1} is the new velocity
- X_j^{k+1} is the new position

E. Combination and Tournament Selection

After obtaining the new position X_{new} , the new fitness value (total power loss) is determined using the value of new position. Thus, the set of new position X_{new} and the old set position X will be combined together. This combination of new and old set position will be contested in a tournament. A position gains the score when its fitness is better than other contenders and this tournament is contested as randomly. The selection strategy in this process is using priority selection strategy. In this technique, the old set position X and the new position X_{new} were sorted in descending order according to power loss in the system.

F. Convergence Test

The new position set will be tested for convergence. If convergence is not achieved, the process will be repeated.

IV. RESULTS AND ANALYSIS

A. Losses Reduction

The losses for three different algorithms which are EP, PSO and EPSO were compared with the original network. In this paper, four cases are considered:

- Case 1: The system is without feeder reconfiguration(Initial).
- Case 2: The system is a network reconfiguration using PSO algorithm method.
- Case 3: The system is a network reconfiguration using EP algorithm method.
- Case 4: The system is a network reconfiguration using EPSO algorithm method.

Table 1 displays the performance of PSO, EP and EPSO that has been tested using 33-bus distribution system and summarizing with the numerical results for the four cases. The total power loss has been value in distribution system when the EPSO is applied as the network reconfiguration method and it is noticed as a considerable decrease. Thus, it is confirmed from Case 2 and Case 3 that the heuristic methods are able to minimize the system power loss after

reconfiguration from 202.7 kW to 126.4 kW for Case 2 and 125.2 kW for Case 3.

Table 1
Analysis Result of 33-Bus Test System

Parameters	Case 1	Case 2	Case 3	Case 4
Switch to be opened	33,34,35,36,37	7,10,28,14,32	17,7,10,3,7,13	11,28,32,34
Total Power Loss(kW)	202.7	126.4	125.2	120.7
Loss Reduction (kW)	-	76.3	77.5	82.0
Loss Reduction (%)	-	37.6	38.2	40.5

In the other hand, the percentage of power reduction for case 2 and case 3 are 37.6% and 38.2% respectively. The minimum power losses is observed in case 4 which is application of EPSO algorithm as the optimization method, the final total power loss is decreased from initial 202.7 kW to 120.7 kW. Thus, this EPSO method has lower loss reduction compare with other two methods (PSO and EP). From the perspective of losses, using the EPSO has positively impacted in the analyzed power distribution network, achieving value of 40.5% while the number of open switches is change to 11, 28, 32, 33, 34.

B. Computing Time

Meanwhile, regarding to the Table II, the computing time for the EPSO method is 12.2 seconds faster as compared to EP and PSO method. For the traditional PSO, it requires 54th iterations before it can converge while the EPSO which implements the competition concept of EP requires only 39th number of iteration before it converges.

Table 2
Performance Of Computing Time

Parameters	EP	PSO	EPSO
CPU time (secs)	55.0	16.0	12.2
No.of iteration		54 th	39 th

Figure 3 details illustrate the comparison of CPU time based and the number of iteration of PSO and EPSO to converge. As compared to the other EP and PSO methods during the simulation, EPSO algorithm is accomplished of solving faster and converge them quickly within a short period of time.

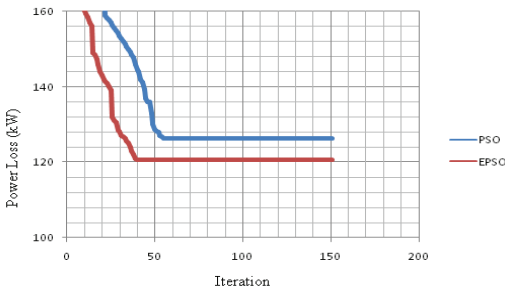


Figure 3: Convergence performances of the PSO and EPSO

Apart of that, the EPSO algorithm is also beneficial in term of consistency of the simulation results when it is compared to conventional PSO. Figure 4 shows the comparison of the consistency for both methods after 12 times simulation of the programming.

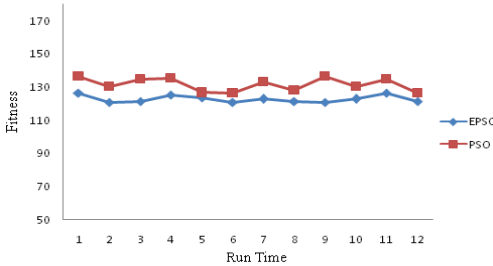


Figure 4: Consistency of simulation results between PSO and EPSO

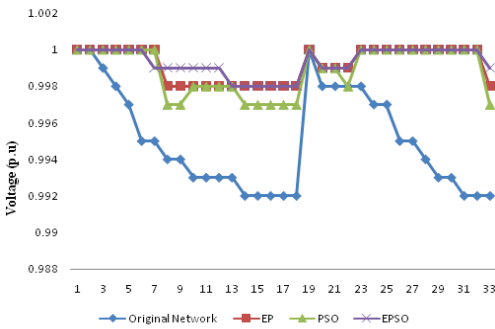


Figure 5: Performance of Voltage Profile for 33-bus radial distribution

C. Voltage Profile

Meanwhile, for the reconfiguration distribution network using EPSO, this proposed method does not only give the lowermost total of losses, but also improves the voltage profile in the overall network system. The voltage profile for the network after reconfiguration is demonstrated a significant improvement as illustrated in Figure 5. It also seen that bus voltages for all cases are within the allowable range. Regarding to the Figure 5, there are some improvements of

12.5% on voltage value between buses 7 until 13 when EPSO is compared to PSO and EP. The increment of voltage value also can be seen in bus 33 as improvement of 12.5% and the rest is equal between EP and EPSO.

The relationship between power losses with three heuristic methods is shown in Figure 6. The EPSO shoes a great different after reconfiguration. It can be decided that the suggested method EPSO is a better method for reconfiguration process since, the EPSO provides the better result compared to others and its performance is better than traditional method

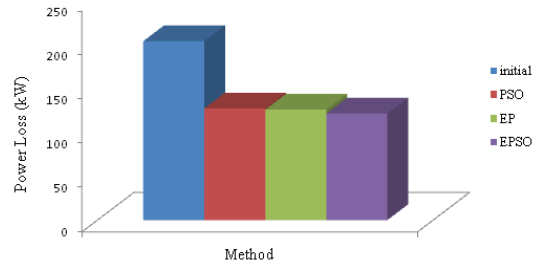


Figure 6: Comparisons of power losses between PSO, EP and EPSO

V. CONCLUSION

As a conclusion, the EPSO was successfully tested in IEEE 33-bus original distribution system and it showed a better performance in term of power loss reduction and voltage profile. Meanwhile, the proposed method requires less number of iteration and computing time to converge and also has the better consistency for the simulation results. The conventional Particle Swarm Algorithm (PSO) algorithm is modified by substituting the concept of combination and selection method from Evolutionary Programming (EP) algorithm that made it faster to find the optimal solution. Thus, it can be said that this hybridization method is more effective and has better performance for network reconfiguration when it compared to PSO and EP method.

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