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# Power Distribution Network Reconfiguration by Using EPSO for Loss Minimizing

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**Keywords:** Distribution; Heuristic method; Distribution Network Reconfiguration (DNR); Evolutionary Particle Swarm Optimization (EPSO); Particle Swarm Optimization (PSO); Evolutionary Programming (EP).

**Abstract.** Due to the complexity of modern power distribution network, a 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 network reconfiguration. The objectives of this work are to reduce the power losses 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 in order to find the optimal solution. The proposed method is applied and it impacts to the network reconfiguration for real power loss and voltage profiles is investigated respectively. The proposed method is tested on a IEEE 33-bus system and it is compared to the traditional PSO and EP method accordingly. The results of this study is hoped to help the power engineer to configure the smart and less lossed network in the future.

## 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.

Ultimately, several constraints shall be considered during network reconfiguration which are asseverate of radial structure for distribution system, section of all users should need to be assisted, feeder capacity should not be beat the limit and 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.

**Testing and Modeling**

This type of network 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 as in Fig. 1. The line data and also for load data for 33-bus system has been gain from [19-23]. The total load in the system is 3.715MW and the system load is expected to be constant and Sbase = 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.

**Methodology and Proposed Method**

**Initialization.** The flow chart of implemented EPSO algorithm by MATLAB programming is shown in Fig. 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, C1 and C2 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.

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

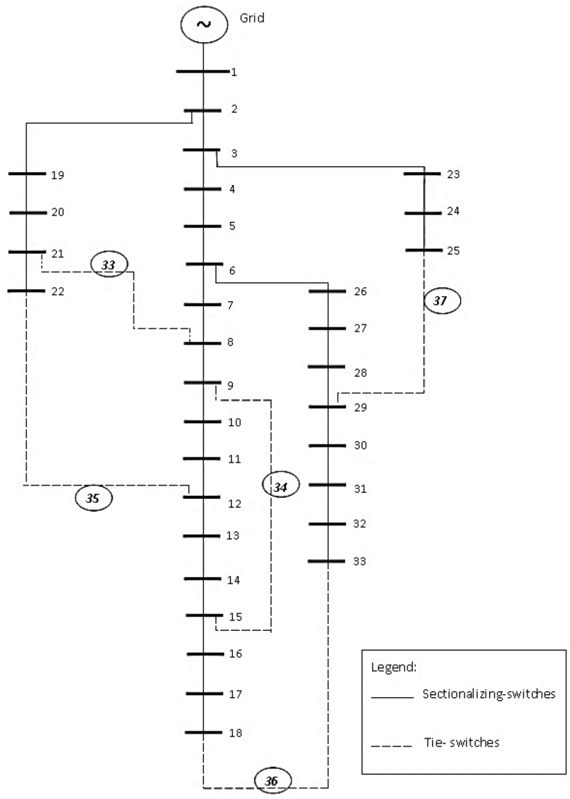


Fig. 1. 33-bus radial distribution system

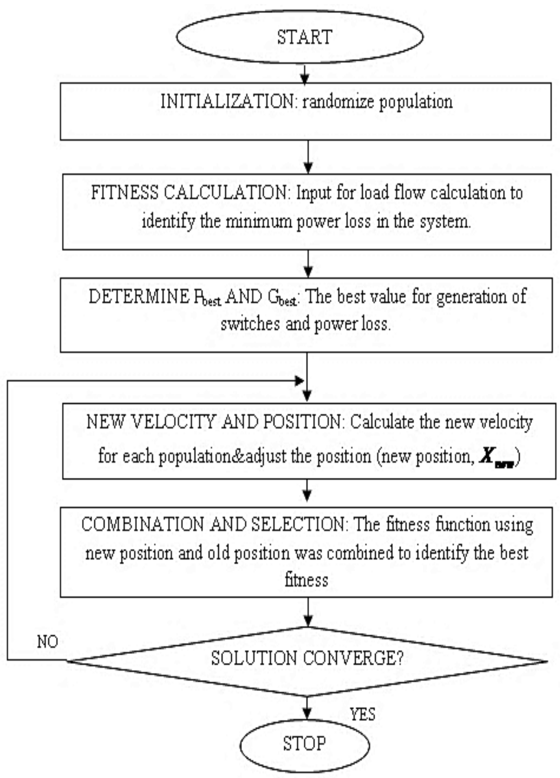


Fig. 2. Flowchart of EPSO implementation

**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.

**Determine Pbest and Gbest.** 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 Pbest and another best value to be verified is Gbest, which is the whole best value so far by any particle. The Pbest and Gbest are representing the generation of tie-switches and power loss.

**New Velocity and Position.** In this step, the particles' velocity and position is updated by apply the Eqs. 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, $X_{new}$.

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

$$X_j^{k+1} = X_j^k + V_j^{k+1} \quad (2)$$

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

**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.

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

## Result and Analysis

**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. 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 | 17,7,10,37,13 | 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 |

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.

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.

**Computing Time.** Meanwhile, regarding to the Table 2, 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** | | $54^{th}$ | $39^{th}$ |

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

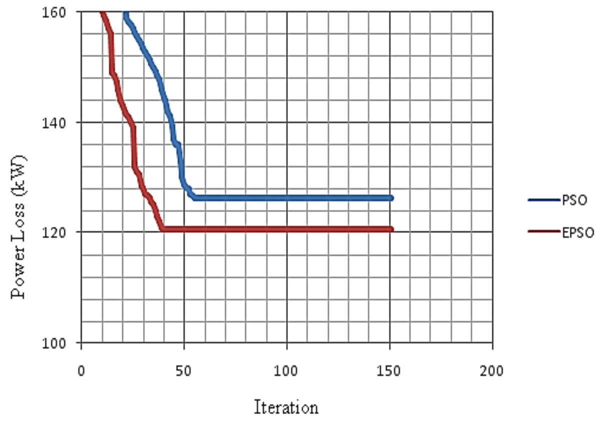


Fig. 3. Convergence performances

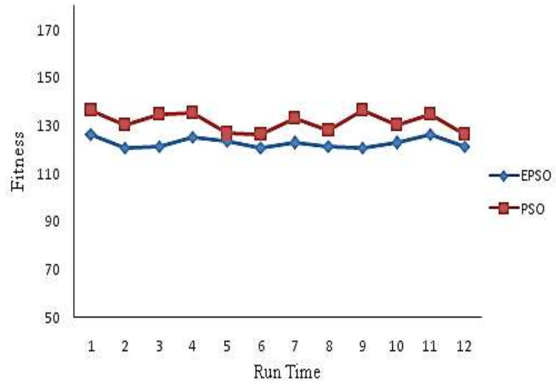


Fig. 4. Consistency of simulation results

**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 Fig. 5. It also seen that bus voltages for all cases are within the allowable range (0.99 to 1.00). Regarding to the Fig. 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.

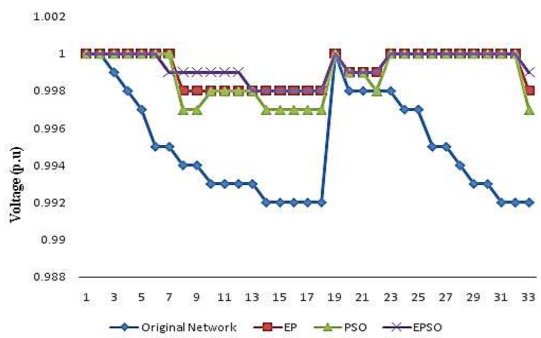


Fig. 5. Voltage profile for 33-bus

## 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 Optimization (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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