Power Distribution Network Reconfiguration by Using EPSO for Loss Minimizing

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Abstract. The total power losses in distribution network system can be minimized by network reconfiguration. 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.

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 [1,2,3,4], 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 [5,6,7,8]. 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 [9,10,11,12]; 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 [14,15,16,17,18]. 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]. 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

a. 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
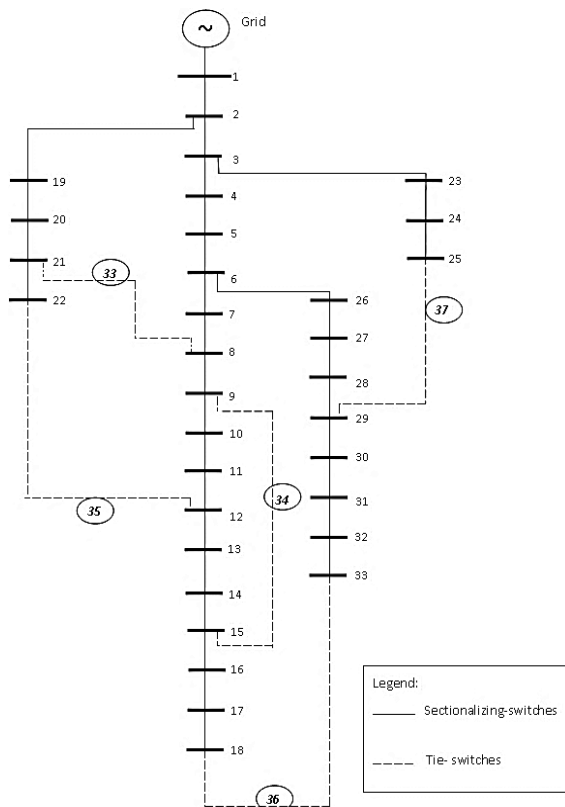Rule 3 : All switches contributed to a meshed network need to be closed

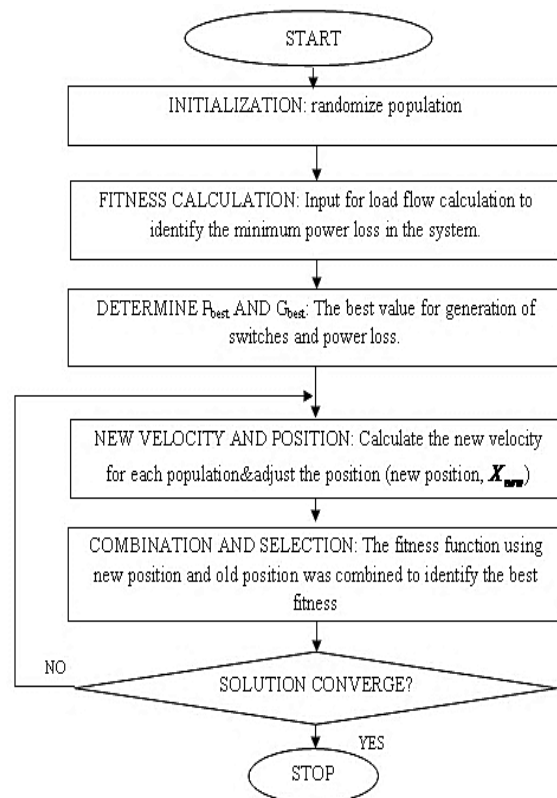Fig. 1: 33-bus radial distribution system

Fig. 2: flowchart of EPSO implementation

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.

c. 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.

d. New Velocity and Position

In this step, the particles' velocity and position is updated by apply the Eq. (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}.

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

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

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

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.

Result 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. 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.

b. 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		54th	39th

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.
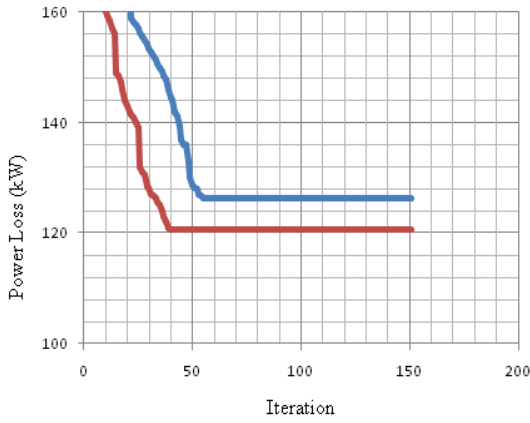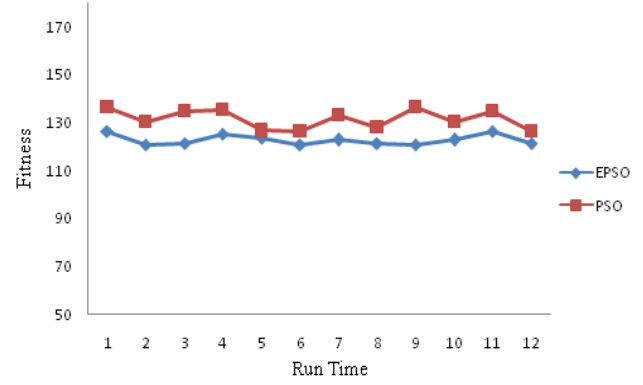
Fig. 3: Convergence performances

Fig. 4: Consistency of simulation results

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 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.

The relationship between power losses with three heuristic methods is shown in Fig. 6. The EPSO shows 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
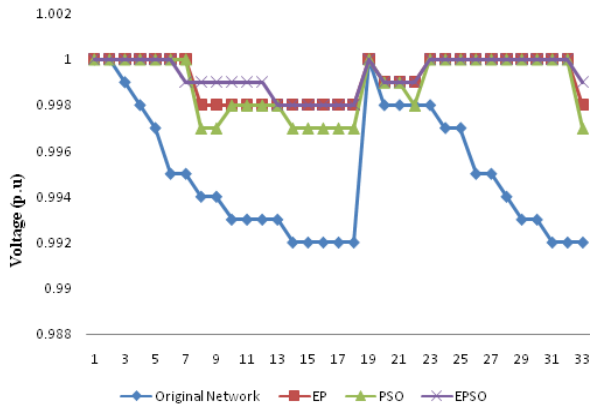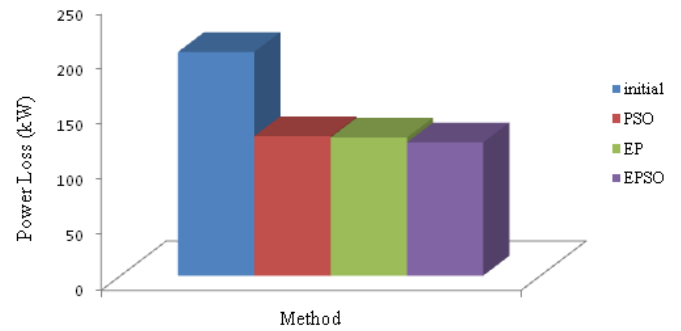

Fig. 5: Voltage Profile for 33-bus

Fig. 6: Comparisons of power losses

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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