A DNR and DG Sizing Simultaneously by Using EPSO

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Abstract—**Distribution network planning and operation require the identification of the best topological configuration that is able to fulfill the power demand with minimum power loss. This paper presents an efficient hybridization of both Particle Swarm Optimization (PSO) and Evolutionary Programming (EP) methods which is called the Evolutionary Particle Swarm Optimization (EPSO). The proposed method is used to find the optimal network reconfiguration and optimal size of Distribution Generation (DG) simultaneously. The main objective of this paper is to gain the lowest result of real power losses in the distribution network while improve the computational time as well as satisfying other operating constraints. A comprehensive performance analysis is carried out on IEEE 33 bus distribution system. The proposed method is applied and its impact on the network reconfiguration for real power loss is investigated. The results are presented and compared with the strategy of separated DG sizing and network reconfiguration.**

Keywords-evolutionary particle swarm optimization; particle swarm optimization; evolutionary programming; distribution generation

I. INTRODUCTION

Most of electrical distribution systems usually operate in a radial configuration due to lower short circuit, simple switching, lower cost of installation and protect equipment with lower reliability. Two types of switches are generally found in the system for both protection and configuration management which are sectionalizing switches (normally closed switches) and tie switches (normally opened switches). One of the most important control schemes in electrical distribution systems is "Distribution Network Reconfiguration" (DNR) which can bring optimal minimization of real loss, improve the voltage profile and relieve the overloads in the network. The DNR is affected more through the interconnection of DGs. The growth of DG insertion in distribution system is indeed in the increasing trend because of its vital contribution in the power system performance. According to the statistic in the literature review, [1] has reported that 70% of the total losses occur in the primary and secondary distribution system, while transmission and sub-transmission lines account for only 30% of the total losses. Therefore, considering the best DG insertion in the active distribution network is necessary.

The installation of DG and other devices will incur high cost. Therefore, determining the suitable DG sizing and its location prior to installation is essential to maintain the network stability and minimize the power loss in the distribution system. In the meantime, the reconfiguration technique is only required some additional line and controlling methods to improve the consistency of the system. Furthermore, the installation of reconfiguration network is much simple and cost efficient compared to other techniques. Various reconfiguration methods have been proposed in the research to foresee the strengths and weaknesses of each method. Many researchers have been focusing more on overcoming the reconfiguration problem through various approaches such as Tabu Search [2], Ant Search Colony (ASC) [3-4], Particle Swarm Optimization (PSO) [5-6], Genetic Algorithm [7], Plant Growth Algorithm (PGO) [8] and Bacterial Foraging Algorithm (BFA) [9]. However, there are only a few of them associate DG in their research and foresee DG's impact on the reconfiguration distribution network [2], [3] and [6]. On top of that, their reconfiguration system and DG sizing operate in different situation and organize separately.

In this work, the researcher is trying to solve the problem in finding the optimal network reconfiguration and optimal DG sizing simultaneously. Doing it simultaneously will further reduce the cost and increase its efficiency. In order to achieve that, EPSO has been proposed in reconfiguration problems due to its excellent capability for searching globally optimal solution to a complex problem and fast convergent. Five distinct cases have been manipulated to foresee their outcomes and results with the presence of DG as well as in the absence of DG. In experimenting the five cases, we only look for the best possible size of DG while the location of DG shall be set constant. The test result of EPSO algorithm is compared with the existing method as the conclusion for the minimization of losses and the decrease percentage is shown as the conformation for the success of this optimization.

The fundamental of PSO is being explained in section II. The particulars of this proposed method are discussed in Section III and IV. Meanwhile, Section V shows the simulation results in term of power loss and computing time and finally the last Section VI tells the discussion and conclusion of the study.

II. FUNDAMENTAL OF PARTICLE SWARM OPTIMIZATION

The PSO has been developed based on the behavior of social animals which live and move in group such as fish and bird. The birds or fish usually move in a group at a certain speed and position. Their design of movement is depending on their experience as well as the experience of others in the group (P_{best} and G_{best}). The new velocity, V_m^{t+1} and the new position, X_m^{t+1} for the fish or birds are obtained using Eq. (1) and (2).

$$V_m^{t+1} = \omega \times V_m^t + wf_1 \times ran_1 \times (P_{bm}^t - X_m^t)$$
$$+ wf_2 \times ran_2 \times (G_b^t - X_m^t) \qquad (1)$$

$$X_m^{t+1} = X_m^t + V_m^{t+1} \qquad (2)$$

Where V_m^t is the velocity of particle m in iteration t, X_m^t is the position of particle m in iteration t, ran_1 and ran_2 are the random numbers between 0 and 1 [10]. P_{bm}^t is the best value of the fitness function that has been achieved by particle m before iteration t. G_b^t is the best value of the fitness function that has been achieved so far by any particle. Constants wf_1 and wf_2 are weighting factors of the random acceleration terms, which attract each particle towards P_{best} and G_{best} positions. Lower values of fitness function allow particles to move farther from the target region before they return. The inertia weight ω_i is typically set according to the following equation:

$$\omega_i(n+1) = \omega_i^{max} - \frac{\omega_i^{max} - \omega_i^{min}}{n_{max}} \times n \qquad (3)$$

In Eq. (3), n_{max} is the maximum number of iterations and n is the current iteration number. $\omega_{i\,max}$ and $\omega_{i\,min}$ are maximum and minimum of the inertia weights, respectively. The summary process of implementation of PSO algorithm is as follows:

Step A- Initialization- generate randomly all particles
Step B- Evaluate the fitness function
Step C- Determine P_{best} and G_{best} for all populations
Step D- Evaluate the new speed for each population
Step E- Update the existing position to a new position
Step F- Update the existing speed to the new speed
Step G- Check the stopping criteria –otherwise go to Step B.

In this work, the particles consist of the tie line *(S)* and DG size *(Pg)* as shown in Eq.(4).

$$X_{particle} = \{S_1, S_2, ..S_\beta, Pg_1, Pg_2, ...Pg_\alpha\} \qquad (4)$$

Where β is the number of tie line and α is the number of DG. If the case is only to find the optimum value of DG that can minimize the power losses, the particles can be written as:

$$x_{particle} = [p_{g1}, p_{g2}, ..., p_{g\alpha}] \qquad (5)$$

Only the particles that satisfy all the constraints bellow will be considered as the initial population.

A. Generator operation constraint:
All DG units are only allowed to operate within the acceptable limit where P_i^{min} and P_i^{max} are the lower and upper bound of DG output. Therefore, for the analysis that contained the DG units, the DGs size results must not exceed this limit.

B. Power injection constraint:
In the effort of avoiding power injection for its main grid (substation) from DG unit, the output of DG cannot be more than the total load and the total active power loss in the network.

C. Power balance constraint:
The amount of power generated within the network system which comes from the DG unit and the substation must be equal to the amount of total load plus the total power loss. This concept complies with the principle of equilibrium in generating power and demand concept.

D. Voltage bus constraint:
The voltage for each bus should operate within the acceptable limit which is in between 1.05 and 0.95(± 5).

E. Constraint of Radial configuration:
The configuration must be in radial to avoid excess current flow in 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.

EPSO is resembled to PSO in many ways. This is because EPSO has been developed based on PSO. However, their resemblances stop at step E and F where the new *Pbest* and new *Gbest* are determined. In the next subsection, EPSO will be discussed in greater detail.

III. THE IMPLEMENTATION OF EPSO IN POWER DISTRIBUTION NETWORK RECONFIGURATION

Generally, the proposed EPSO undergoes the similar steps as the traditional PSO from step A to step D. However, the concept of the EP is then applied into step E (of the previous subsection), where the tournament selection process is done. Basically, EP employs a selection through the tournament scheme to choose the survivals for the next generation.
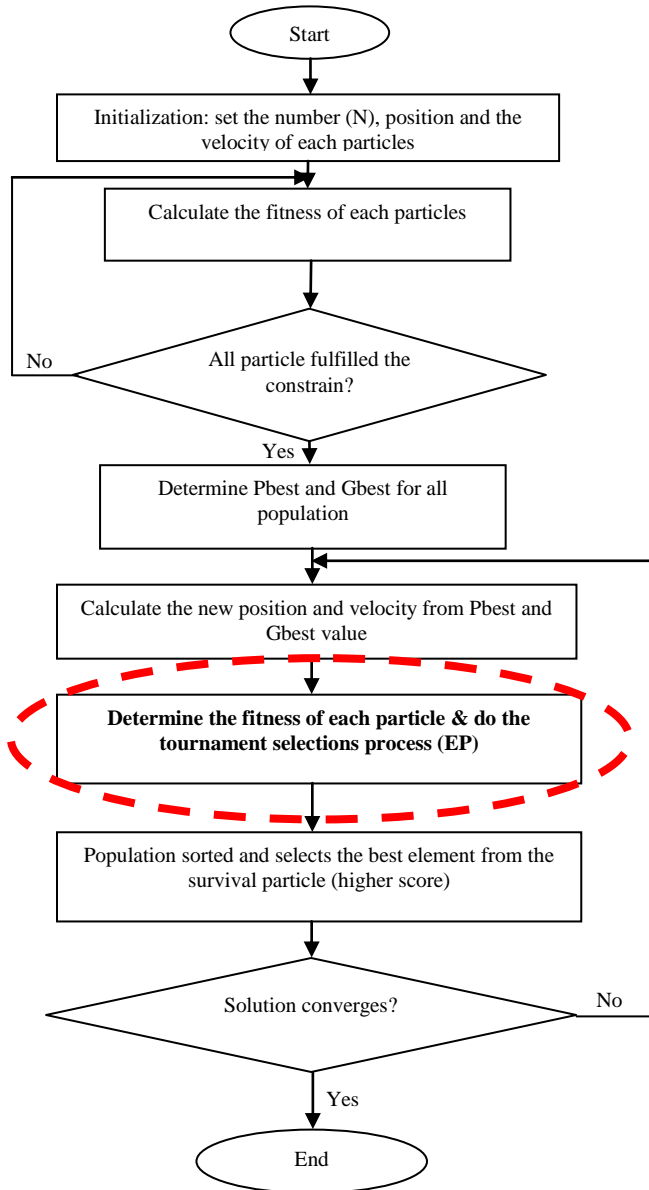
Figure 1. Flowchart for EPSO algorithm

This selection is used to identify the candidates that can be transcribed into the next generation of the combined population of the parents and offspring. In details for this EPSO, after obtaining the new position X_{new}, the new fitness value is determined by using the value of new positions. 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 as shown in red dotted line in flow chart. A position gains the score when its fitness is better than other contenders and this tournament is contested as randomly. This tournament selection is a part which is adapted from EP method that's different compare to the conventional Particle Swarm Optimization.

Meanwhile in step F, after the tournament and selection process, the positions will be sorted out in descending style,

starting with the highest score to the lowest score. The N numbers of positions with the best score from the results can be considered as survival positions which are used for the next iteration. These positions have been used as the newest P_{best} and the position with the highest score is used as the newest G_{best}.

Finally, in the last step, 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 (E) and (F) 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 EPSO is illustrated in the Figure 1.

IV.   SIMULATION AND CONSIDERATION

The test system for the case study is consisting of 33-bus radial distribution system as is shown in Figure 2. The system consists of one feeder, 32 normally closed tie line and five normally open tie lines (dotted line) and located on branch No. 33, 34, 35, 36 and 37. The system load is assumed to be constant and Sbase = 100MVA. The line and load data details can be referred in [10]. The total load on the system is 3715kW and 2300kVAr. The minimum and maximum voltages are set at 0.95 and 1.05p.u.respectively. All calculations for this method are carried out in the per-unit system. The convergence value is taken as 0.0001.

Five distinct cases have been executed to find out their reliability of having EPSO in the system to achieve the best configuration and the most optimal size of DG. Those cases are described as follows:

A. In this first case

The system follows the original network distribution of 33-bus without any alteration done.

B. In this second case

Reconfiguration technique is added to the existing system to foresee its effects of power loss reduction.

C. In this third case

Four DG units are stationed at the most optimal locations of buses 6, 18, 22 and 29 respectively. There is no reconfiguration done in this case. Then, the impacts of all these DGs are being analyzed.

D. In this fourth case

Both the reconfiguration and DG have been applied in the system. The system will find the optimal DG size first before conducting the reconfiguration. They are done separately.

E. In this fifth case

Both the reconfiguration and DG have been applied simultaneously in the system. Then we can make a better comparison between having used them separately or simultaneously.
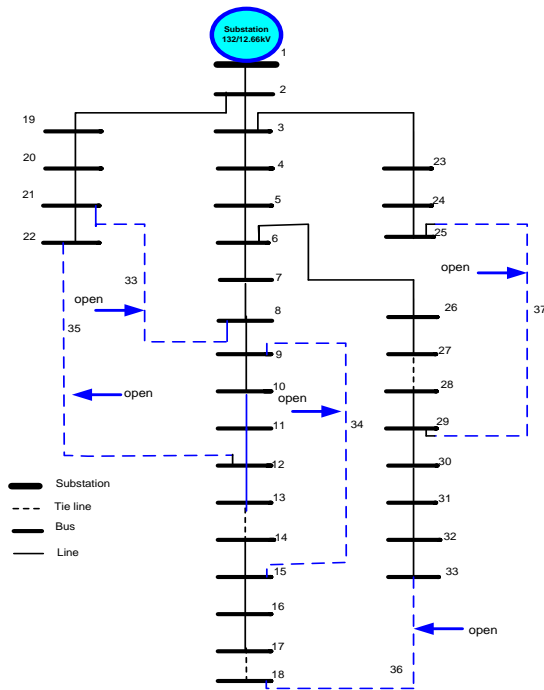
Figure 2. Initial configuration of the 33- bus radial distribution system

V. ANALYSIS OF THE RESULTS

As mentioned in the previous section, the analysis of reconfiguration involved the network with and without DG units. In the case of a network with DG, the optimal size of DG units is obtained from the simulation in which both parameters DG size and the switches opened (in equation (4)) are adjusted during simulation simultaneously. The size of each DG is already set with the limitation range less than 5MW in the program. In this work, the location of DG is fixed. DG location shall be constant as a controlled measure in order to observe the responding changes of DG sizing. Tie switch and sectionalizing switch are considered as the main control variables. The optimal power losses are based on flexible switches while the optimal size of DG depends on the optimum power losses value. The programming is run randomly and takes approximately 100 times by using MATLAB software. Then, only the minimum power loss with optimal DG size is selected. The results obtained consist of the five opened switches, total power loss and four optimal DG sizing. Analysis of the network reconfiguration and DGs installation technique has been divided as follows:

A. Impact on power loss

Since the reconfiguration technique has changed the original configuration network as well as a number of feeders, the impacts of this technique to the power losses and voltage profile of the system need to be studied and analyzed. The operation of the system by using EPSO method in the initial case (case 1) shows that the network of 33-bus system runs without the presence reconfiguration and

DG. The network has given the initial total power loss of 202.3kW through five initial open switches of 33, 34, 35, 36 and 37. While in case 2 where the reconfiguration is employed in the network of 33-bus system, the power loss reduction has been improved by 40.4% (202.3kW to 120.5kW). At the same time, the newly opened switches are also shifted to 7, 10, 13, 16 and 25 after the reconfiguration. The open switches and overall performance of the test is summarized in Table I and Table II.

Meanwhile, in case 3 where the network of 33-bus system is operated by having only DG which is placed on bus number 6, 18, 22 and 29. In this case, reconfiguration is taken out so that we can clearly observe the impact of DG. After the analysis, it is found that the presence of DG does give lower power loss as compared to case 2. The total power loss is reduced by 93.3kW or 46.1% (from 202.3kW to 109kW). From the improved network system, the sizes of DG are also become optimal; 0.731MW, 0.840MW, 1.827MW, 2.435MW respectively. Figure 3 and Figure 4 show the diagram of the network after reconfiguration and DG installation in the distribution system.

In case 4, the operation is conducted in both reconfiguration and DG. However, reconfiguration process is only being done after the right size of DG has been determined. In other word, both processes run separately. The results reveal even greater power loss reduction by 105.2kW or 52% as compared to case 2 and case 3. Thus, the presence of both DG and reconfiguration in the process has indeed led to the reduction of power loss. The new diagram of the network reconfiguration operates with DGs in splitting and simultaneous mode is illustrated in Figure 4.

TABLE I: TIE SWITCHES TOPOLOGY

No. Case	Opened Switch				
Case 1	33	34	35	36	37
Case 2	16	7	10	25	13
Case 3	33	34	35	36	37
Case 4	36	33	9	7	37
Case 5	28	16	13	10	6

TABLE II: THE OVERALL PERFORMANCE OF THE CASE STUDY

No. Case	Size of DG (MW)				Total Loss (kW)	Loss Reduction (%)
Case 1	-	-	-	-	202.3	-
Case 2	-	-	-	-	120.5	40.4
Case 3	0.731	0.840	1.827	2.335	109	46.1
Case 4	0.729	0.800	1.827	2.250	97.1	52.0
Case 5	0.720	0.741	1.733	2.235	89.3	55.9

The network condition of case 5 study is almost identical to case 4 except that this time both reconfiguration and DG are being organized simultaneously.
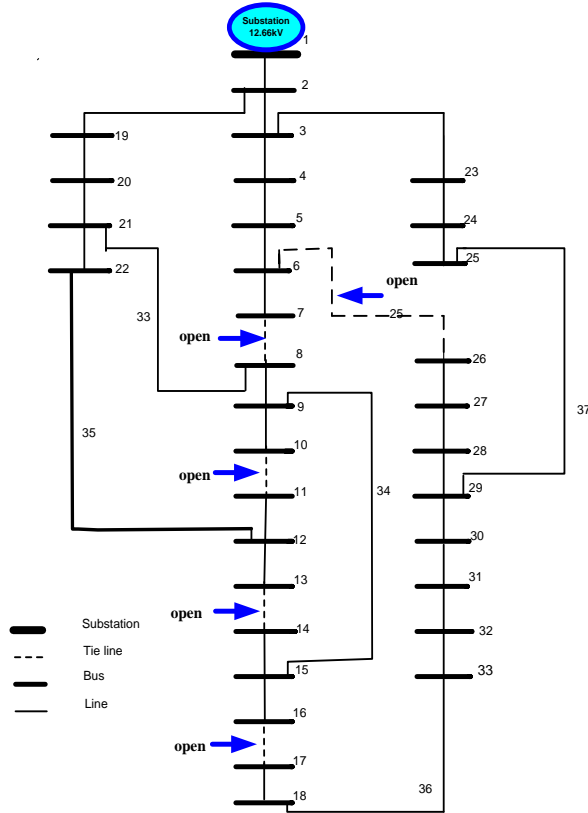
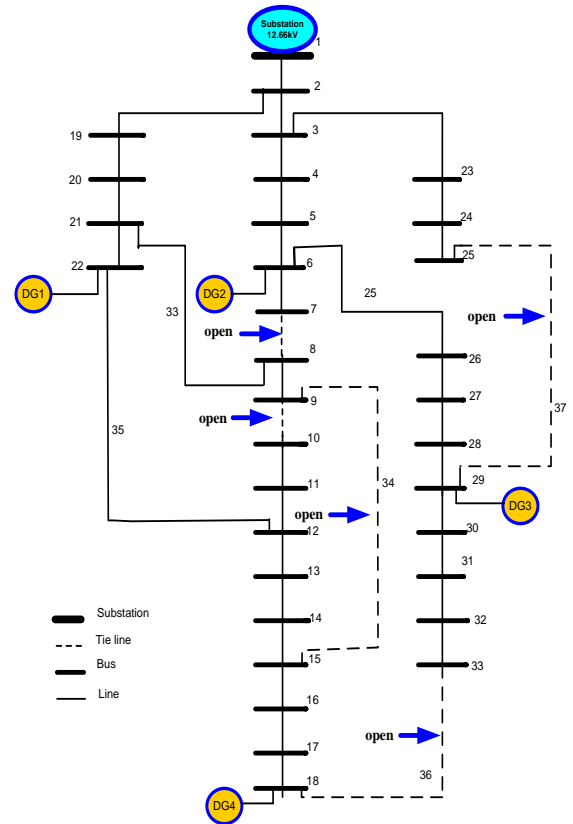Figure 3. Case 2: after network reconfiguration without DGs

Figure 5. Case 4: network reconfiguration and DGs sizing separately
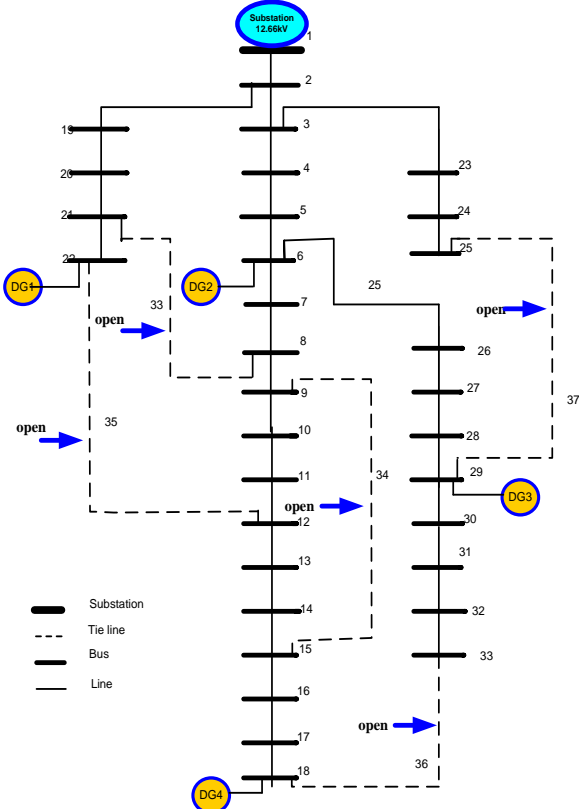

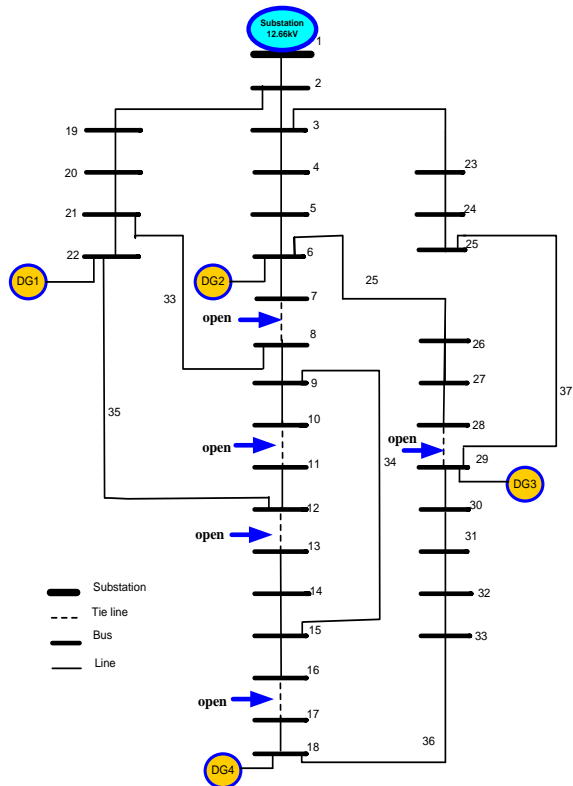
Figure 4. Case 3: network with DGs installation

Figure 6. Case 5: reconfiguration with DGs sizing simultaneously

In other words, the switches will be opened and the size of DG is determined simultaneously during simulation. The results for the network of 33-bus system show the greatest improvement on power loss reduction of 55.9% (202.3kW to 89.3kW). The optimal size of DG is slightly different from case 4 which are 0.720MW, 0.741MW, 1.733MW and 2.235MW. The analysis of this case has proven that the simultaneous presence of reconfiguration and DG yields a much better rate of power loss. The comparison of power losses of all cases is depicted in Figure 7.
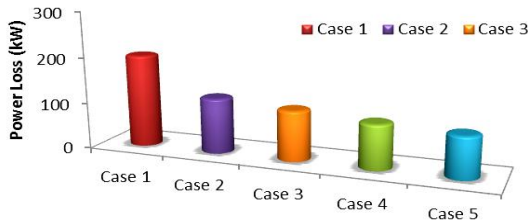

Figure 7. Power losses against cases between with and without reconfiguration and DGs installation

B. Computing time

The computing time taken in case 5 only 46 seconds instead of 57 seconds in case 4 to perform two processes together as shown in Table 3. Hence, case 5 gives better results in term of Computer Processing Unit (CPU) time to reach the optimal result with the percentage of improve is 19.3%.

TABLE III: THE COMPUTATIONAL TIME

No. Case	CPU time (s)	Improvement [%]
Case 4	57	-
Case 5	46	19.3

The differential of CPU time is due to the concept used in EPSO which only maintains survival particles. The survival particles are the particles among the population set that given the lowest fitness value when the optimization process is running. So that, it has made the process of convergence becomes faster and consistence. While Case 4 needs longer time because the organization of the two processes has to be done twice and separately. The results of CPU time are illustrated in Figure 8.
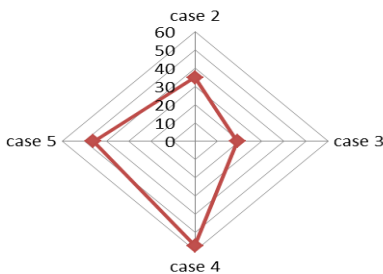

Figure 8. The performance of CPU time of EPSO algorithm

VI. CONCLUSION

A reconfiguration method of EPSO technique has been introduced. The prime aim of this paper is to reduce the amount of power loss to the lowest possible and at the same time improve the computing time is positively done. The applying a reconfiguration technique with the presence of DG and with the absence of DG has successfully analyzed. Thus, the simultaneous implementation of DG and reconfiguration by using the EPSO algorithm is certainly giving great impacts to the whole distribution system.

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