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OPTIMUM DNR AND DG SIZING FOR POWER LOSS REDUCTION USING IMPROVED META-HEURISTIC METHODS

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ABSTRACT

The main purpose of service restoration is to restore as many loads as possible by transferring loads in the out of service areas to other distribution feeders via changing the status of normally close and open switches which is known as Distribution Network Reconfiguration (DNR). In the event of any fault occurrence within the system, immediate restoration is indeed required in the particular area. Therefore, the distribution system must be equipped and planned in such a way that it will continuously supply the power without any interruption during the out-of-service condition. The primary idea in this work is to have the reconfiguration process embedded with Distributed Generation (DG) and being operated simultaneously to reduce power losses by using improved Meta-heuristics methods which is Evolutionary Particle Swarm Optimization (EPSO). A detail performance analysis is carried out in 33-bus systems demonstrate the effectiveness of the EPSO. The proposed method is adopted and its impacts on the network real power losses and voltage profiles are investigated as well as improving the voltage profile while fulfilling distribution constraints.

Keywords: network reconfiguration, distribution, distributed generator, PSO, power loss.

INTRODUCTION

The major issues nowadays that most power utilities are trying to achieve in power generation, transmission and distribution systems are service quality, reliability and efficiency of the overall power system. Since the distribution power system is the final stage of the distribution process from the source to the individual customer, it has contributed the greatest amount of power loss resulting in poor voltage magnitude. The performance of distribution system becomes inefficient due to the increase in the distribution of power loss and reduction in voltage magnitude, especially in the heavily loaded network.

One of the well-known techniques to minimize power loss is through network reconfiguration. However, the network reconfiguration technique has its own limitation. For the scenario of extreme power losses, the reconfiguration technique could only improve the performance by certain percentage only. Therefore, the implementation of Distributed Generation (DG) in the distribution network is still needed to improve the distribution system [1-2]. However, in order to ensure the effectiveness of DG in the distribution system, selecting the most appropriate location and optimal size of DG plays an important role in giving the greatest impact on the operations and control of the power system. Thus, the correct size of DG becomes a vital point in the network system in order to produce a lower amount of power waste. Therefore, in this work, the researcher is trying to solve the problem in service restoration via the optimal reconfiguration and DG sizing simultaneously after fault is isolated from the system.

MATHEMATICAL MODEL FOR DNR PROBLEM

Reconfiguration techniques in the distribution network will change the direction of power that flow throughout the network. In this study, the main objective for doing the reconfiguration is to obtain the minimum active power losses in the system based on active current formulation. Therefore, the objective function of this study is:

$$\text{Minimise} \quad \{P_{losses} = \Sigma_{l=1}^{n} |I_l|^2 \, k_l R_l\} \quad (1)$$

where I = number of lines in the system, I_I = Line real active current and R_I = line resistance and k_I = is the variable that represents the topology status of the branches (1=close, 0= open).

The power system constraints are also being considered during the analysis. The constraints are:

a) Distributed generator operation constraint

$$p_i^{\min} \le p_{dg,i} \le p_i^{\max} \quad (2)$$

where P_i^{min} and P_i^{max} are the lower and upper bound of DG output and all DG units shall function within the acceptable limit [3].

b) Power injection constraint

$$\sum_{i=1}^{k} P_{DG} < (P_{Load} + P_{Losses}) \quad (3)$$
$$k = no.of \quad DG$$

In order to avoid the power injection to the main grid (substation) from the DG units, the total power output of DG should be lower than the total load in the network.

So, there will be a power supplying from the main grid to the distribution system at all time.

c) Power balance constraint

$$\sum_{i=1}^{k} P_{DG} + P_{Substation} = P_{Load} + P_{Losses} \quad (4)$$

The sum of power generated from DG units and power from substation must be equal to the summation of power load and power losses. This is to comply with the principle of equilibrium in generating power and demand concept [3].

d) Voltage bus constraint

$$V_{\min} \le V_{bus} \le V_{\max} \quad (5)$$

The voltage for each bus should operate within the acceptable limit which is in between 1.05 and 0.95($\pm 5\%$ of rated value).

e) Radial configuration constraint

The configuration of the network should be maintained in the radial configuration after the reconfiguration process. Therefore, in order to ensure the radial network is maintained, several constraints need to be considered in the system. A set of rules has 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.

f) Isolation constraint

All nodes or buses in the system need to be energized after the reconfiguration process in order to make all loads in the network receive the power sources. In other word, there is no load being disconnected throughout the reconfiguration process.

All of the above constraints will be implemented using Meta-Heuristic methods which are discussed in great detail in the next chapter.

SIMULTANEOUS NETWORK RECONFIGURATION AND DG SIZING USING EPSO

In general, EP and PSO do possess their own strengths and specialties [4]. However, the merging of the two methods known as EPSO will definitely give greater impacts in the distribution system. EPSO is resemble to PSO in many ways because EPSO is developed based on PSO. Their resemblances stop at the steps E and F where the new P_{best} and new G_{best} are determined using CSS.

(Combine Sort → Select) →

In this work, a novel Evolutionary Particle Swarm Optimization known as EPSO is proposed to improve and enhance the convergence speed of classical PSO [5-6]. Basically, the proposed EPSO undergoes the similar steps as the traditional PSO. However, the concept of the EP is then applied into steps E (of the previous subsection), where the tournament selection process is done. EP employs a selection through the tournament scheme to choose the survivals for the next generation. 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. The concept of EP is included in the PSO algorithm, so that the particles can move quickly to the optimal point compared to the classical PSO.

In details for this EPSO, after obtaining the new position X_{new}, the new fitness value is determined 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 indicated in red dotted line in the flow chart is as shown in Figure-1. 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 which is different compare to the conventional PSO. In comparing the results obtained, the parameter used is set the same as PSO and EP. Meanwhile, in step F, after the tournament and selection process, 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}.

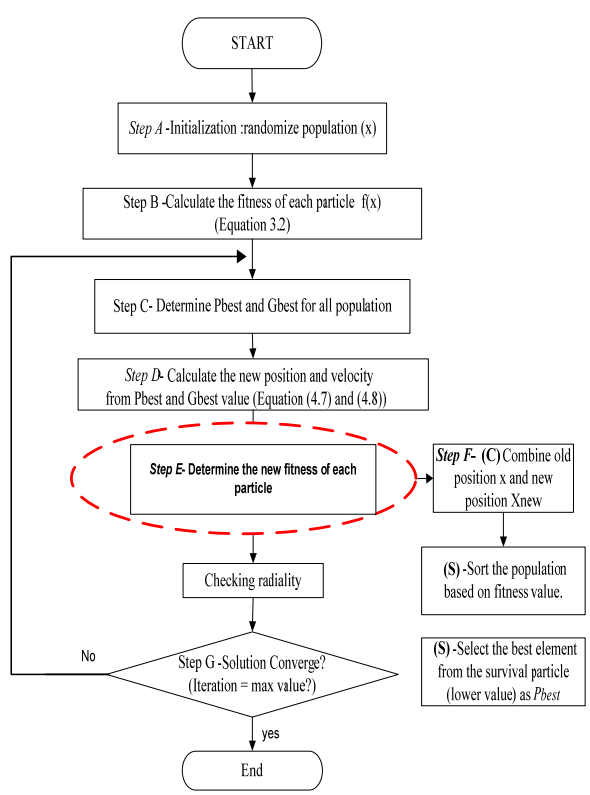

Figure-1. Flowchart for EPSO algorithm.

The convergence test is required to determine the stopping criteria of this optimization search process. The new position set will be tested for convergence and checking the radiality.

If convergence and radiality are not achieved, the process will be repeated by calculating a new velocity and position by using Equations.(6) and (7) based on the new local best (P_{best}) and global best (G_{best}). If convergence is achieved, then the optimization process is terminated. Finally, in the last step, check the end condition, If all population give the similar values, then stop and show the optimal results. If the iteration number > iter max, then stop and show the optimal results. Otherwise, repeat steps 3-6 until the end conditions are satisfied.

The new velocity, V_j^{k+1} and the new position, X_j^{k+1} the fish or birds are obtained using Equations.(6) and (7).

$$V_j^{k+1} = \omega^{(t+1)} V_j^k + C_1 \times rand_1 \times (P_{bestj}^k - X_j^k) + C_2 \times rand_2 \times (G_{best}^k - X_j^k) \quad (6)$$

$$X_j^{k+1} = X_j^k + V_j^{k+1} \quad (7)$$

where V_j^k = velocity of particle j in iteration k, X_j^k = position of particle j in iteration k, $rand_1$ and $rand_2$ = random numbers between 0 and 1, P_{bestj}^k = The best value of the fitness function that has been achieved by particle j before iteration k, G_{best}^k = The best value of the fitness function that has been achieved so far by any particle, C_1 and C_2 = acceleration coefficient for cognitive and social components, X_j^{k+1} = new particle position, V_j^{k+1} = new velocity of particle and V_j^k = initial velocity of particle.

The hybridization process between EP and PSO gives great advantages of reaching the optimal solution faster than the conventional PSO, since it requires less number of iterations and small deviation in solving the problem. Throughout the process, EPSO will ensure only the highest potential particles will be selected for the next iteration. Thus, the results obtained will be the nearest to the optimum solution.

ANALYSIS OF THE RESULTS ON POWER LOSS

In this paper, the problem is solved and analyzed into four scenarios as shown in Table-1 which is service restoration with and without DG. The standard 33-bus radial distribution systems are considered to test the effectiveness of the algorithms. Initial diagrams of 33-bus [7] is applied in the reconfiguration distribution systems are illustrated in Figure-2. The network consists of 33 buses, 38 lines, 5 switches and 3 branches (excluding the main branch). The total load of the system is 37.15 MW, while the initial system power loss 202.6 kW.The size of the population used is 50. The location of DG used in this analysis are 6, 16 and 25[8].

Table-1. Descriptions on five different scenario studies.

Scenario 1	Optimal network reconfiguration
Scenario 2	Optimal DG sizing
Scenario 3	Optimal reconfiguration and DG sizing based on sequential approach
Scenario 4	Optimal reconfiguration and DG sizing based on simultaneous approach

Table-2. The overall performance of simulation results of 33-bus distribution system.

	Method	Opened Switches	Power Loss (MW)	Loss Reduction (%)	DG Size (MW)		
					6	16	25
Scenario 1	PSO	7, 10, 28, 14, 32	136.4	32.58	-	-	-
	EPSO	7, 10, 13, 16, 25	130.5	35.49	-	-	-
Scenario 2	PSO	33, 34, 35, 36, 37	109.6	45.82	1.0038	0.9004	0.5167
	EPSO	33, 34, 35, 36, 37	102.5	49.33	0.7310	0.6564	1.1560
Scenario 3	PSO	7, 10,14, 28, 32	95.5	53.78	1.0439	0.9061	0.7012
	EPSO	7, 9, 33, 36, 37	94.2	53.44	1.1127	0.918	0.729
Scenario 4	PSO	7, 9, 14, 28, 32	92.3	54.37	1.1523	0.9545	0.6312
	EPSO	6, 10, 13, 16, 28	89.4	55.81	1.1590	0.9747	0.6632

From the base system, four different scenarios are formed and analyzed to test the strength, robustness and efficiency of the proposed methods in obtaining the best configuration. The lists of scenarios are shown in Table-1. The results obtained from this operation shall then be compared to viewing the difference. This simulation is executed repeatedly thirty times and then only the minimum power loss with correspond to specific DG size is selected. The overall performance of meta-heuristics method is summarized in Table-2.

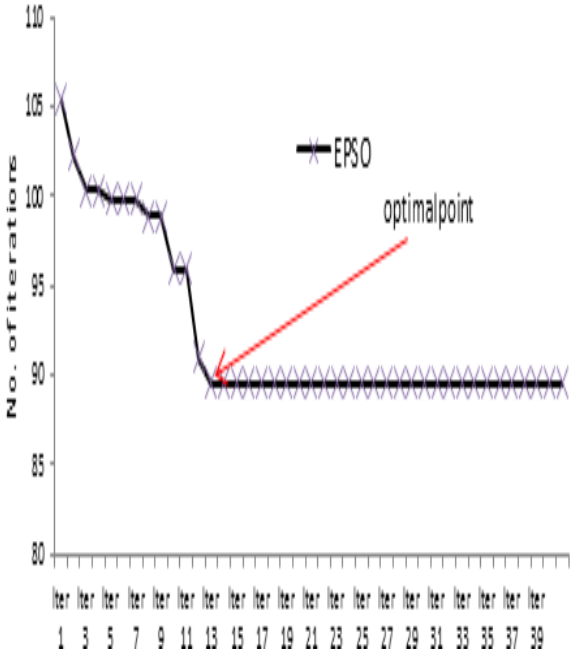

Figure-2. Voltage profile for optimal reconfiguration and DG sizing based on simultaneous approach.

Their impact on the voltage profile for scenario 4 of the system operate using the proposed method is depicted in Figure-1. By observing the results, we can conclude that the voltage profile has been improved and the average bus voltages have reached 0.995983p.u. from the base scenario 0.9131 p.u. In scenario 4, the system which is operated with reconfiguration and DG simultaneously, the voltage profile of the system has been improved considerably with a minimum node voltage of 0.987692p.u.

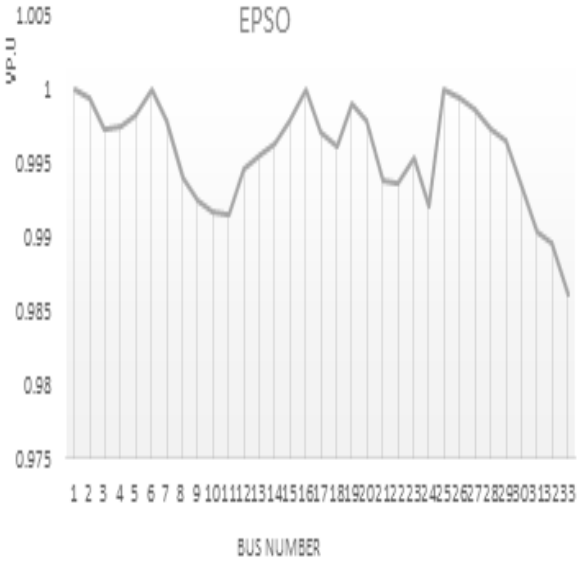

Figure-3. Convergence characteristics of the proposed method.

Figure-3 shows the convergence characteristics of the proposed method of 33-bus system. The convergence curve summarizes the capability and efficiency of the method and the speed of the algorithm in reaching the optimal point (iteration 13). With the updated technique, the value of power loss is improved until the best solution is reached.

CONCLUSIONS

The results obtained clearly show that the improved meta-heuristics methods are able to further minimize power loss as well as improve the voltage profile. Therefore, the efficiency of the algorithm plays a vital role in reaching the optimal result in the shortest computing time possible. EPSO seems to show a better reading of power loss, less the computation time and less the number of iterations compared to the conventional method.

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