J Electr Eng Technol Vol. 9, No. 4: 1229-1239, 2014
http://dx.doi.org/10.5370/JEET.2014.9.4.1229

ISSN(Print) 1975-0102
ISSN(Online) 2093-7423

Power Losses Reduction via Simultaneous Optimal Distributed Generation Output and Reconfiguration using ABC Optimization

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Abstract – Optimal Distributed Generation (DG) output and reconfiguration are among the well accepted approach to reduce power loss in a distribution network. In the past, most of the researchers employed optimal DG output and reconfiguration separately. In this work, a simultaneous DG output and reconfiguration analysis is proposed to maximize power loss reduction. The impact of the separated analysis and simultaneous analysis are investigated. The test result on the 33 bus distribution network with 3 units of DG operated in PV mode showed the simultaneous analysis gave the lowest power loss (global optimal) and faster results compared to other combined methods. All the analyses for optimizing the DG as well as reconfiguration are used the Artificial Bee Colony Optimization technique.

Keywords: Distributed generation, Optimization techniques, Power loss reduction, Reconfiguration, simultaneous analysis

1. Introduction

Power system is one of the most fundamental aspects of electrical engineering which consists of generation resources, transmission system and distribution system. The transmission system interconnects all major generating stations with the main load centres. Meanwhile, the distribution system is the final stage in distributing power to the individual customers. Among the three components, distribution system contributes the highest power loss due to its operation in low voltage level and single power source at the grid. The power loss in the system will be worsened if it is operated at high load demand and involve large scale system.

In order to reduce such power loss, great deals of researches have been conducted to improve the efficiency and reliability of distribution network. This is done by locating FACTS, capacitor bank and other devices in the distribution network as a control mechanism. However, these approaches are costly since requires expensive devices. Other well-known approaches are through finding optimal DG output and network reconfiguration. For instance, researchers in [1-7] used reconfiguration approach to improve overall network performance. Meanwhile, researchers in [8-12] minimise power loss by finding optimal location and output of DG units. Both approaches had been proven able to reduce power loss. However, from the literature review, none of the works performed simultaneous optimization process for DG output and network reconfiguration in order to give the lowest power loss. Artificial Bee Colony (ABC) optimization method is employed to solve the case study. This is due to the superiority of the algorithm in solving the complex optimization problem.

The remainder of the paper is organized as follows. Section 2 presents' related researches on the implementation of DG units and reconfiguration analysis in reducing the power loss and followed by the briefing on Artificial Bee Colony optimization method in the Section 3. The details of the case studies are discussed in the Section 4. Section 5 describes the superior performance of the simultaneous DG and reconfiguration optimization analysis compared to other approaches. Last but not least, Section 6 concludes the whole analysis of the study.

2. Related Work

Distribution network reconfiguration is a complicated combinatorial and non-differentiable constrained optimization problem. It involves with many candidate-switching combinations. These obstacles really put the reconfiguration process in difficulties to achieve the comprehensive optimal solution. The earliest researcher on reconfiguration was reported by Merlin and Back [1] in 1975. The researchers proposed a branch and bound type heuristic

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Received: August 14, 2012; Accepted: February 24, 2014

method in minimizing line loss of the network. They established a mesh network by switching "off" all the switches in the entire network. Those switches were then turned on one by one until the new radial reconfiguration was found. In the process, switches would be turned on/off to minimize the line loss. Meanwhile, Kashem [2] had proposed an efficient method of identifying the optimum configuration to minimize the power loss. The authors used the combination of tie-switch and sectionalizing for obtaining the best configuration for distribution network. All the infeasible combinations will be omitted from the analysis. This hectic searching was finally conducted by changing the one status switch at any one time, whether by moving to the left or right opened branch in selected configuration until maximum loss reduction is determined. Other methods, such as Genetic Algorithm based reconfiguration [4] and expert system [5-7], were applied as well in the network distribution configuration to accomplish their respective objectives.

The installation of DG at improper location with infeasible output will lead to the increase of power loss and operational cost of the power system. For that reason, it is necessary to find the suitable DG location and output. For instance, [8] applied two methods separately to reduce the power loss as well as improve the voltage profile in radial distribution system. In their research, the method of single DG placement has been used to figure out the optimal DG location whereby PSO method is applied to obtain optimal output of DG. In [9], the authors have used the GA approach to identify the DG placement and DG output in the electrical power system. Apart from that, other factors such as economic and geographic must also be taken into consideration.

Reconfiguration technique with DG gives tremendous impact in reducing the power loss. Thus, many researchers are focusing their research towards applying both variables. For example, the authors in [13] implemented the network reconfiguration process by using the Tie-Open Point Optimization (TOPO) technique, meanwhile, the optimal location of the Distributed Generation was identified using pre-determined sensitivity indices and output of DG is accomplished using Evolutionary Programming (EP) method. The implementation of network reconfiguration is done only upon the finding of the location and output of DG. In other words, they solve the problem separately. Apart from that, the researchers in [14] have emphasized the advantage of feeder reconfiguration of the distribution system in the presence of DG units for loss reduction and bus voltage improvement. The authors used the Tabu search technique in finding the DG output and analysed the impact of DG and reconfiguration based on four different cases. The results show the higher power loss reduction is occurring in Case 4 which is reconfiguration technique cooperate with DG compared reconfiguration without DG. The output of DG, however, is included in their work without any further discussion.

Table 1. Lists of various methods used by the previous researchers in solving the reconfiguration and DG problems

Researcher	Method	Optimal Reconfiguration	Optimal DG Sizing	Optimal Reconfiguration and DG Sizing	
				Separately	Simultaneously
[3]	Fuzzy & EP	✓			
[7]	ACO	✓			
[8]	Fuzzy & PSO		✓		
[9]	GA		✓		
[10]	GA & PSO		✓		
[11]	PSO		✓		
[12]	EP		✓		
[14]	TS			✓	
[15]	ACO			✓	
[16]	GA			✓	
[17]	Fuzzy & GA	✓			
[18]	ACO	✓			
[19]	BFO	✓			
[20]	PSO			✓	
Proposed Method	ABC				✓

* ABC = Artificial Bee Colony
* GA = Genetic Algorithm
* PSO = Particle Swarm Optimization
* EP = Evolutionary Programming
* TS = Tabu Search
* ACO = Ant Colony Optimization
* BFO = Bacteria Foraging Optimization

Other optimization methods had also been employed to solve the reconfiguration with the present of DG, such as Genetic Algorithm GA) [16], Particle Swarm Optimization (PSO) [20] and Ant Search Colony (ASC) [18]. Table 1 summarizes the various methods utilized by the previous researchers to solve the reconfiguration problem and DG output. From the table, it can be clearly seen that none of them tried to solve the reconfiguration problem simultaneously. Considering the existence limitation, we are now trying to solve the problem by putting greater emphasis on finding the optimal reconfiguration and DG output simultaneously via meta-heuristic optimization technique.

3. Implementation Artificial Bee Colony in Solving Optimal Reconfiguration and Optimal DG Output

The original Artificial Bee Colony (ABC) introduced by [21] is an optimization method that replicating the behaviour of the bees in searching food. The ABC consists of 3 groups of bees, which are the employed bees, onlooker bees and scout bees. At first, the initial scout bees were set out randomly to the area within the possible solution (food source position) is existed. After the initial solution was found, this information will be passed down to the employed bees. The employed bees will start to look for the solution that located near to the initial solutions' location (neighbourhood search). The comparison between initial solution and employed bees' solution will be done to select the best results (greedy selection). Next, the information regarding the best results is passed down to the onlooker bees, which will choose to find the next searching area based on the solution's fitness. Eq. (3) shows the formula for the solutions' fitness calculation in ABC algorithm. When there are no more solutions that are better than current solutions in the bee population, the onlooker bees will become the scout bees again and dispatched to search for new solution area randomly.

The whole process mentioned above will be repeated until the predetermine value is reached. Fig. 1 shows the general process of the ABC algorithm in looking the optimal solution. The summary of the proposed method in solving the optimal reconfiguration and DG output are based on the following steps:

Step 1 : Input Parameters

Input system data include network data, bus data, line data, pre-defined range of DG output, maximum iteration, population size and accuracy are inserted in the program.

Step 2 : Initialization

The initial population is determined by selecting the tie switches and DG output randomly from the set of the original population. The random populations of tie switches and DG output represent the 'Bees' which will provide a possible solution (food source position) to the optimization problem. The total position of food source is equal to the half of colony size (combination of employed bees and onlooker bees). The variable for tie-switches represented by D and DG output is represented by P_{dg}. The set of tie switches and DG output is written as follows:

$$F_{im} = \left[D_1, D_2, \ldots D_n, P_{dg1,} P_{dg2,\ldots} P_{dgk} \right] \tag{1}$$

where $i = 1, 2, 3 \ldots m$.

The variable m indicates the population size from a set of random distribution. n = number of tie switches and k = number of DG. If the method only to find the optimum value of DG output that can minimize power losses, the set of DG can be written as:

$$F_{im} = \left[P_{dg1,} P_{dg2,\ldots} P_{dgk} \right] \tag{2}$$

Only the set of tie-switches and DG output that satisfy all the constraints will be considered as the initial population.

Step 3: Fitness Evaluation Phase

The fitness value describes the quality of the solution. In ABC algorithm, the nectar amount of a food source directly proportional to the quality of the associated solution. The fitness value is formulated as follows:

$$Evaluate\,Fitness_{-i} = \frac{1}{1 + PowerLosses_{-i}} \tag{3}$$

After evaluating all the fitness value of each population,

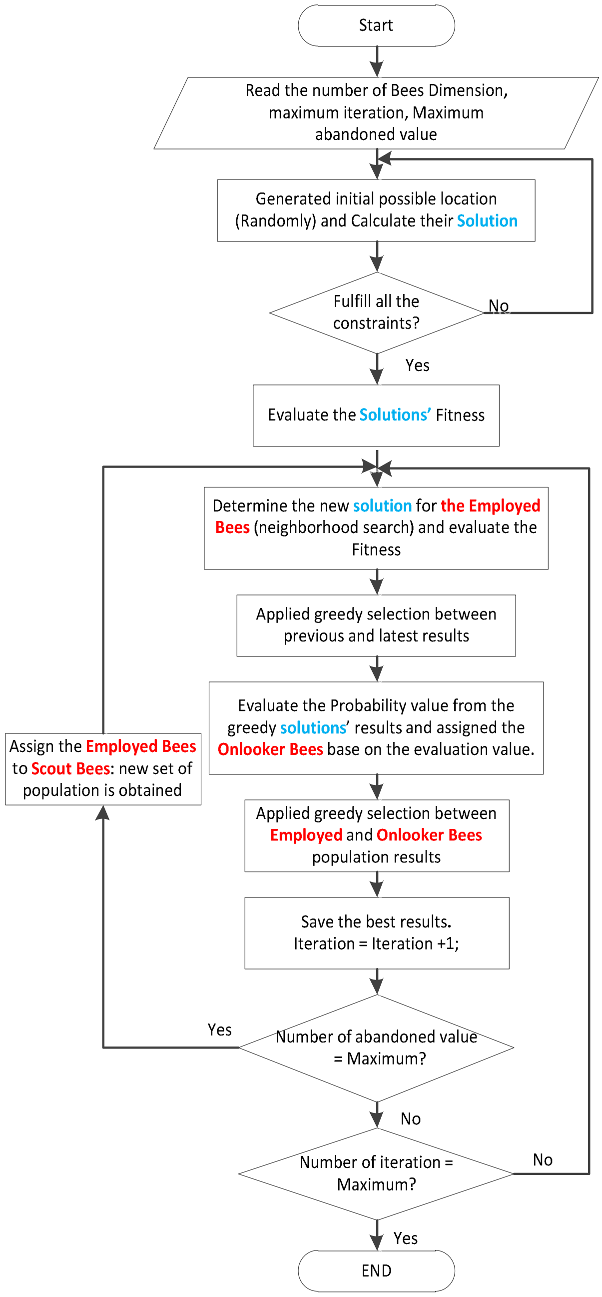

Fig. 1. The Artificial Bee Colony process to obtain the optimal results.

the best combination of open switches that give the highest value of fitness will be memorized.

Step 4 : Employed Bee Phase (generate new population)

For every iteration of the ABC algorithm, the employed bees will search randomly for a new combination opened switches and / or DG output of its selected solution. In order to determine the new population, the following equation has been implemented:

$$x_{ij}^{new} = x_{ij}^{old} + range * \left(x_{ij}^{old} - x_{kj} \right) \quad (4)$$

where x_{ij} = the value of i^{th} opened switches and / or DG output at random j^{th} dimension. x_{kj} = any k^{th} opened switches and/or DG output that is selected randomly from j^{th} dimension.

Step 5 : Greedy Selection Phase

In this phase, the greedy selection method is executed in order to compare the performance between the fitness of news solution and the current fitness in the memory. If the new fitness is better than the one in the memory, the employed bee will shift to this new solution, replacing the old one in the memory. Otherwise, the old fitness is kept in the memory and abandoning the new one.

Step 6 : Onlooker Bee Phase

The information regarding the best results gained by the employed bee will be evaluated by the onlooker bee. The onlooker bee will select the best solution according to Eq. (3).

Step 7 : Scout Bee Phase

If the solution is unable to be further improve and has exceeds the “limit” value, the ABC will eliminate the solution from the population. Subsequently the employed bee associated will become scout bee. The scout bee will be assigned to discover new areas of solution randomly and will replace the solution that has been abandoned with the new one using (4). The process continues until the solution converges.

For the reconfiguration analysis, the “Bees” in the ABC is set to *opened switches* in the distribution network and the “solution” (food source position) is the *power loss* value. However, for the optimal DG output cases, the “Bees” is the *DGs’ output* and the “solution” is still similar, which is the *power loss* value. Furthermore, the dimension for the bees depends on the number of variables that need to be solved. For example, for the reconfiguration problem, 5 switches in the network will be opened. Thus, the ‘Bees’ dimension of reconfiguration problem is equal to 5 (D=5). For the optimal DG output analysis, the dimension of the problem is equal to 3 due to the number of DG in the system is 3 units. In the simultaneous analysis, the Bees consist of two groups which are the *opened switches* as well as the *DG output*. Thus, the number of variable for the simultaneous analysis is equal to eight (5: opened switch, 3: DG output).

Some constraints needed to be considered in the reconfiguration and the DG output analysis. In the reconfiguration analysis, the configuration of the network should be maintained in the radial configuration after the optimal configuration is achieved. Furthermore, all buses in the system need to be energized after the reconfiguration process in order to make all loads in the network received the power sources. In other words, there is no load disconnected along the reconfiguration process. All these reconfiguration constraints are needed to maintain the behaviour of the distribution network. The constraints for the optimal DG output analysis are listed below:

a) Generator operation constraint:

$$P_i^{\min} \leq P_{DGi} \leq P_i^{\max} \quad (5)$$

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 output results must not exceed this limit.

b) Power injection constraint:

$$\sum_{i=1}^{k} P_{DG} < P_{Load} + P_{Losses}, \ k = no.of\ DG \quad (6)$$

In order to avoid the power injection to the main grid (Substation) from the DG units, the total power output of DG must be less than the total load in the network. There will be a power sending from the main grid to the distribution system.

c) Power balance constraint:

$$\sum_{i=1}^{k} P_{DG} + P_{Substation} = P_{Load} + P_{Losses} \quad (7)$$

Total power generated in the network which is from DG units and substation must be equal to the summation of total load and power loss. This is due to the principle of equilibrium in generating power and demand concept.

d) Voltage bus constraint:

$$V_{\min} \leq V_{bus} \leq V_{\max} \quad (8)$$

The voltage for each bus should operate within the acceptable limit, which is in between 0.95p.u. < V < 1.05p.u. (±5 % of voltage rated value).

Thus, the ABC algorithm will find the optimal result for the distribution network that fulfilled all the constraints. Since the main objective for the reconfiguration and DG output analysis is to obtain the minimum power loss value, the formulation for calculating the power loss in the network can be presented by:

$$P_{losses} = \sum_{i=1}^{n} \left| I_{ai}{}^{2} \right| R_i \tag{9}$$

where:

i = Number of lines in the system.
I_{ai} = Line real active current.
R_i = Line resistance.

4. Descriptions on Six Different Cases Studies

In this paper, the ABC algorithm is used to solve the reconfiguration of 33-bus distribution system with 3 units of DG that operating in PV mode (constant voltage) as shown in Fig. 2. The power MVA base and voltage base for the network are 10MVA and 132kV respectively. The line data and bus data for the network is shown in Appendix A. As mention earlier, the main contribution of this study is the implementation of simultaneous reconfiguration and DG output analysis. Thus, In order to validate the proposed approach, 5 other cases are introduced to compare with simultaneous analysis result. Thus, total case studies that will be analysed in this work are six as shown below:

Case 1: All the tie switches in the network are open and the DG units are carrying out of the system. This network is equal to an original 33 distribution network without any modification.

Case 2: Reconfiguration technique is employed in the system in Case 1 so that the improvement due to the reconfiguration technique can be observed.

Case 3: Three optimal DG output (using optimization technique) that operated in PV mode are placed on buses 6, 16 and 25. The impacts of all these DGs are analysed in the absence of reconfiguration.

Case 4: The conditions of the system are almost similar to Case 3, but the reconfiguration is present and has been carried out after the optimal DG output in PV mode is accomplished.

Case 5: Reverse from the concept in Case 4, the optimal configuration process will be done first, and followed by the process to find optimal DGs' output.

Case 6: The condition is again quite similar to Case 3 except that this case employs reconfiguration and optimal DG output simultaneously.

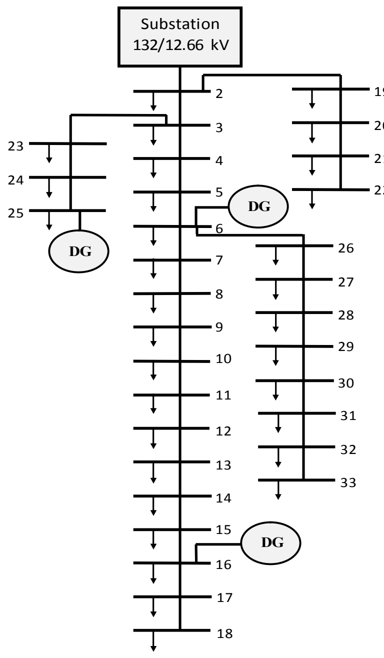

Fig. 2. 33-radial distribution system in existence of DG units operated in PV mode

5. Result and Discussion

In this section, the comparison between single technique (optimal configuration or optimal DG output only) and combined technique (optimal both configuration and DG output) will be discussed.

5.1 Impacts of DG and reconfiguration to the power losses improvement

Table 2 shows the power loss value after the reconfiguration and optimal DG output is obtained via ABC technique. From the results, with the presence of DG in PV mode (Case 3), the initial power loss has been decreased to the lower value as compared to the optimal reconfiguration result (Case 2). The optimal DG output has reduced the power loss from 1624.4W to 291.88W, which is nearly 82% from the initial power loss. Whereas, the optimal configuration can only reduce the power loss up to 34.1%. The injection of reactive power given by DG in PV mode has improved the voltage profile of the system and indirectly, reduced the power loss. Therefore, the optimal output of DG units has given better result compared to an optimal configuration. However, bearing in mind that the installation new DG will require an additional generation cost while the reconfiguration will not require additional

Table 2. Performance of optimal configuration versus optimal DG size in reducing the power losses

	Opened Switches					DG Sizes (MW)			Power Losses (W)
	SW 1	SW 2	SW 3	SW 4	SW 5	DG 1	DG 2	DG 3	
Case 1	33	34	35	36	37	-	-	-	1624.40
Case 2	7	9	14	31	37	-	-	-	1070.58
Case 3	33	34	35	36	37	1.6811	0.5446	0.7680	291.88

Table 3. Performance of optimal configuration versus optimal DG size in reducing the power losses

	Optimal Order		Opened Switches					DG Sizes (MW)			Power Losses (W)
	1st	2nd	SW 1	SW 2	SW 3	SW 4	SW 5	DG 1	DG 2	DG 3	
Case 4	DG	*Co	11	20	24	32	34	1.6811	0.5446	0.7680	160.85
Case 5	*Co	DG	11	20	24	32	34	1.2596	0.6342	1.0125	139.42
Case 6	Simultaneously		3	8	12	23	28	0.9301	0.7995	1.4237	102.61

*Co = configuration

Table 4. Total DG capacity, Power losses and their ratio for all cases

		DG 1	DG 2	DG 3	Total DG capacity (MW)	Power loss improvement (W)	Ratio =Total DG (kW) / Power loss improvement	No of branches in the system
Single analysis	Case 1	-	-	-	-	-	-	4
	Case 2	-	-	-	-	553.82	-	5
	Case 3	1.6811	0.5446	0.7680	2.9937	1332.52	2.246645	4
Combined analysis	Case 4	1.6811	0.5446	0.7680	2.9937	1463.55	2.045506	6
	Case 5	1.2596	0.6342	1.0125	2.9063	1484.98	1.957131	6
	Case 6	0.9301	0.7995	1.4237	3.1532	1521.79	2.072034	6

cost.

Thus, the reconfiguration technique should be utilized in optimal DG analysis. Cases 4 to 6 (Table 3) show the results from the combination of both techniques in finding the lower power loss in the distribution network. The differences between Cases 4 to 6 is in the process to obtain the final optimal results (who's come first). For the Case 4, the process to find optimal reconfiguration is started after the optimal DG output is obtained. In this method, it has improved the power losses value to 160.85W, which is 44.89% lower than Case 3. Although the DG capacity in Case 3 is in an optimal value, with the adjustment (optimal) of configuration, the power loss can be further improved. Different approached is used for Case 5, the process to find the optimal DG output is coming later after the optimal configuration is obtained. Let the reconfiguration results obtained in Case 4 as a base case (optimally configured); the adjustment of the DG output is performed to obtain the optimal DGs' output. From the results, the power loss that are achieving in Case 5 is lower than Case 4 which is 139.42W. In other words, by adjusting the DG output after the optimal configuration is obtained, the power loss in the network can also be further improved.

From both analyses (Cases 4 and 5), the step by step optimization process could not guarantee for the system to have the lowest power loss value. The process of finding the optimal configuration with fixed DG output (or otherwise – fixed configuration) will only give the local optimal results. Thus, in the Case 6, both parameters are optimized simultaneously. The separated updating technique can be used in ABC algorithm, so that the ABC could handle these two variables (DG output and Switch number) simultaneously. From the results, Case 6 gave the lowest power loss in the system and different configuration compared to Cases 4 and 5. The power loss given by Cases 4 and 5 are 160.85W and 139.42W respectively, meanwhile the power loss in simultaneous results (case 6) is 102.61W. The simultaneous analysis for DG and reconfiguration gave nearly 93.68% of power loss reduction compared to initial power loss value.

The same results might be achieved by repeating the Case 4 and Case 5 alternately until reach the global optimal result; however, it may require too many steps. Therefore, the simultaneous DG and reconfiguration analysis is the best approach to determine the optimal operation for system, so that the power loss in the system is in the lowest value.

Fig. 3 shows the ability of the ABC algorithm in finding the optimum result for all cases (except Case 1 – no optimization is applied) in 10 samples analysis. In order to test the robustness and the efficiency of ABC algorithm, each sample analysis will use different initial random number. From the figures, the ABC algorithm is capable to give the optimal results in all cases within small number of iteration (<60 iteration). Furthermore, it can be said that the ABC is suitable to be used for solving the optimal DG or / and optimal reconfiguration problem due to the consistency in giving the optimal solution as shown in the results (Fig. 3).

5.2 Impacts of different optimal technique to the total DG capacity and number of branches

The adjustment on the individual DG output and configuration are not only affecting power loss value, but it also changes the total DG capacity in the system as well as the number of branches in the network. Since the cost of generation has a direct relationship with a total DG output, it is important to know the amount of generating power cost that need to be spent to reduce power losses in the system. Table 4 shows the individual DG output, total DG output, power loss improvement (refer to initial power loss value) and its ratio for all cases. There are no results for Cases 1 and 2 analyses due to the none of DG unit exist in both cases.

For the Cases 3 and Case 4, although the total DG

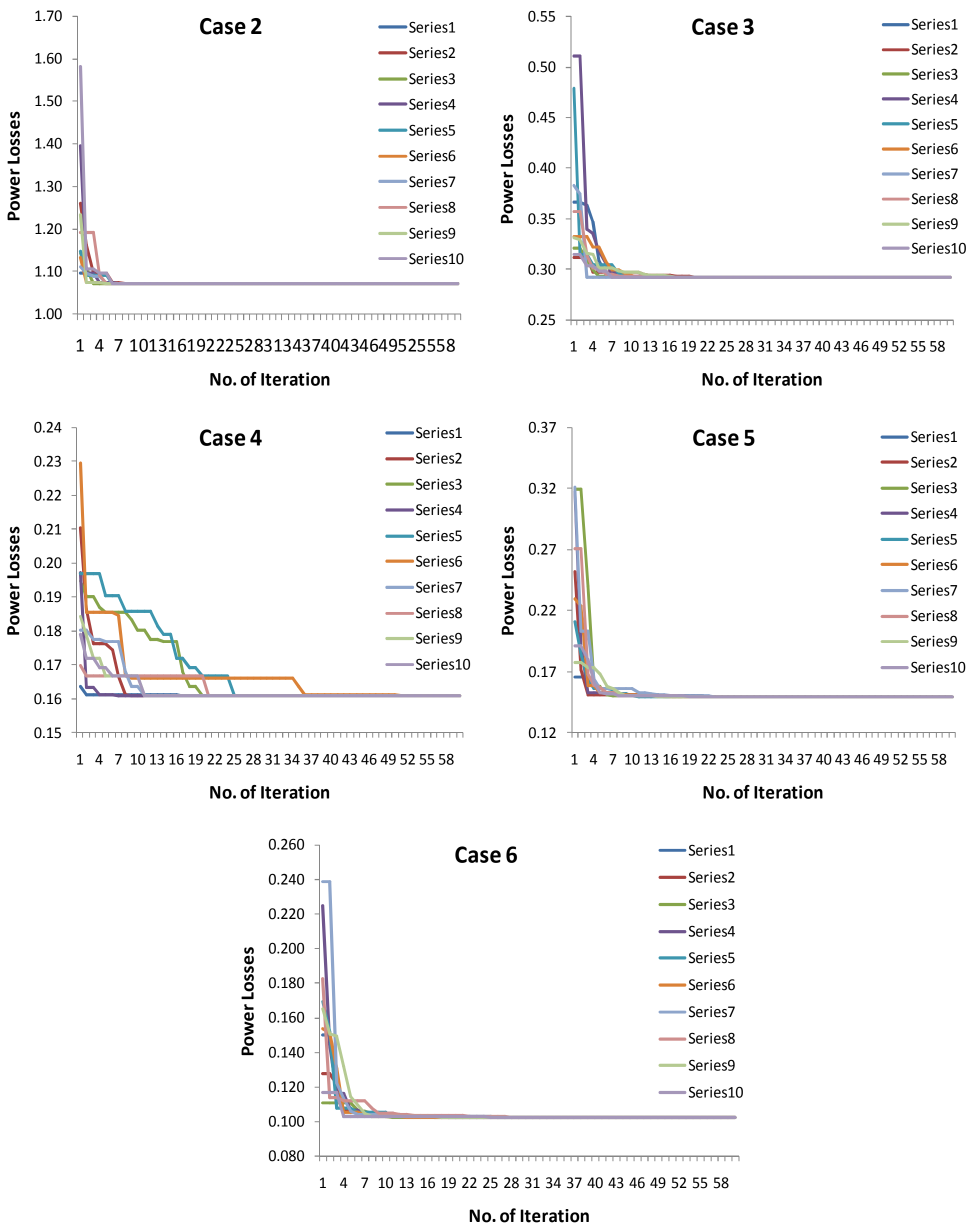

Fig. 3. The convergence of ABC in solving reconfiguration and optimal DG output for 33 bus system

capacity in both cases is similar, due to the reconfiguration process, the total power loss improvement in Case 4 is higher than Case 3. Indirectly, the ratio value for Case 4 has become lower than Case 3. The lower ratio value give an indication to the smaller amount of DG output required to improve per each unit of power loss in the system. The smallest total DG output and the highest ratio results can be seen in the Case 5 analysis. Although Case 5 gave the lowest DG output and ratio, but the simultaneous analysis (Case 6) gave the highest power loss improvement. Since the main objective of this study is to obtain the lowest power loss value, small differences in ratio and total DG output between Case 5 and Case 6 can be considered acceptable. On the other effects, by applying the reconfiguration process, it will change the number of branches in the system. From the Table 4, the original branches in the 33 bus distribution network are 3 and it has changed to 4 branches and 6 branches for Case 2 and Cases 4, 5 and 6 respectively.

On the other effects, by applying the reconfiguration process, it will change the number of branches in the system. From the Table 4, the original branches in the 33 bus distribution network are 3 and it has changed to 4 branches and 6 branches for Case 2 and Cases 4, 5 and 6 respectively. Fig. 4 shows the comparison between original configurations with a new configuration of the network after the simultaneous optimization process. It can be seen that the main branches for Case 6 (Green colour) had changed compared to the original network (Dark blue). With this change, the direction of power flow in the system

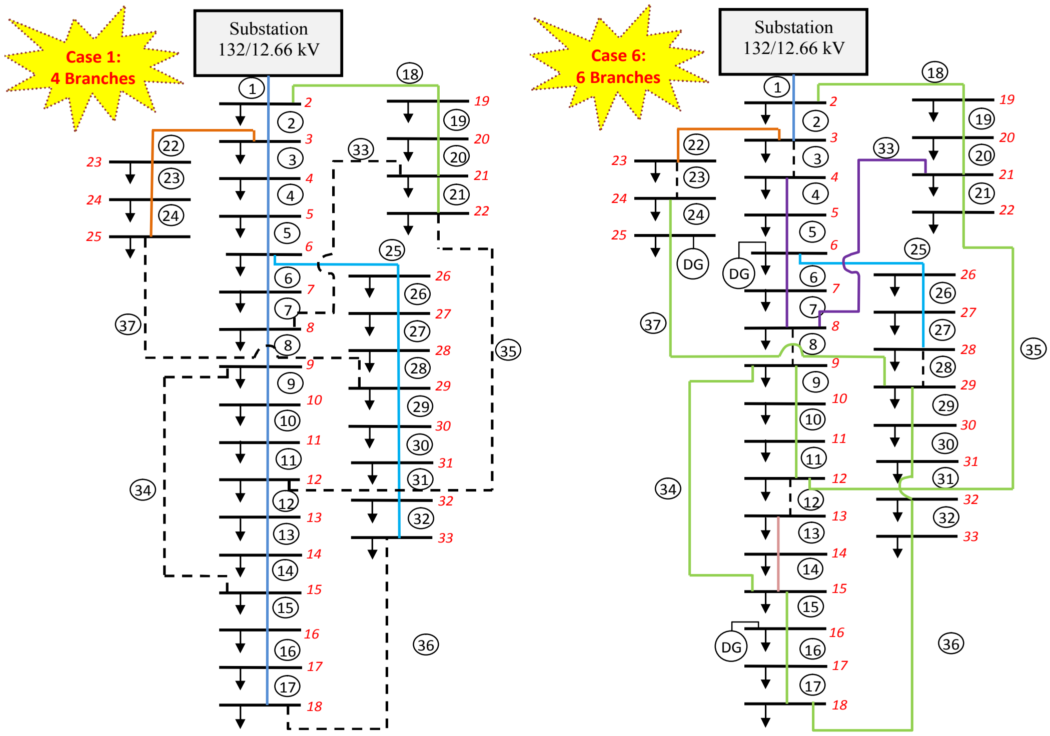

Fig. 4. The comparison of network configuration before and after optimization process

Table 5. The differences of V_{min} and V_{max} values in the system with respect to DG output and opened switches

	DG 1 (MW)	DG 2 (MW)	DG 3 (MW)	Opened switches	V_{min} (p.u)	V_{max} (p.u)
Case 1	-	-	-	33, 34, 35, 36, 37	0.999235	1.00
Case 2	-	-	-	7, 9, 14, 31, 37	0.999525	1.00
Case 3	1.6811	0.5446	0.7680	33, 34, 35, 36, 37	0.999720	1.00
Case 4	1.6811	0.5446	0.7680	11, 20, 24, 32, 34	0.999900	1.00
Case 5	1.2596	0.6342	1.0125	11, 20, 24, 32, 34	0.999903	1.00
Case 6	0.9301	0.7995	1.4237	3, 8, 12, 23, 28	0.999925	1.00

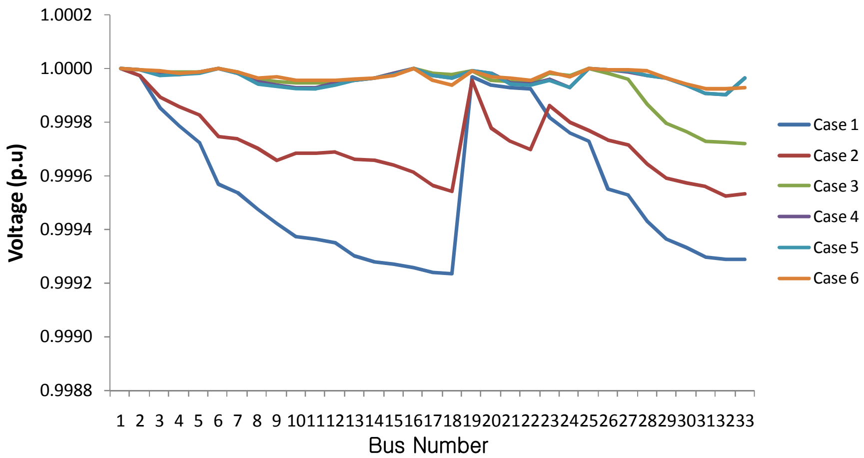

Fig. 5. The voltage profile after the reconfiguration and DG output adjustment

has also changed and the amount of power loss will be difference based on current flow and resistance values (I^2R).

Since the simultaneous analysis give the lowest power loss, the best configuration for the network with suitable DG output can be obtained by using this technique. Besides generating the low power loss, the network reconfiguration also improves the overall voltage profile of the distribution system. Fig. 5 illustrates the performance of the voltage profile on 33-bus distribution system for all cases. There is an obvious improvement on voltage value for Case 4, Case 5 and Case 6 as compared to the other cases. The minimum bus voltage at base case is equal 0.999235p.u (Case 1). After the process of optimal reconfiguration and DG output are done, the minimum bus voltage has raised to nearly 0.999925p.u. (Case 6). Bear in mind that the reconfiguration process itself has improve the voltage profile as shown in Table 5. Thus, in general, the reconfiguration and suitable DG output will help the network to have better voltage profile as compared to the initial condition.

6. Conclusion

The main contribution of this paper is on the employment of simultaneous analysis for reconfiguration and DG output in order to find minimum power loss. The applied Artificial Bee Colony (ABC) algorithm in this work proves its capability to solve the simultaneous analysis. A 33-bus distribution system with 3 DG units operating in PV mode is used to show the effectiveness of the proposed method.

The implementation of both methods (DG output and network reconfiguration) in the system gave better power loss value compared to single approaches (DG or reconfiguration only). However, although the implementation of both methods gave better results compared to single approach, the power loss value might trap in the local optimal solution. This is due to the process of finding the minimum power loss is through step by step technique (e.g.: find the optimal DG first and followed by optimal reconfiguration). Thus, the used of simultaneous optimization on both approaches gave the superior result by avoiding trap in the local optimal. The results show that the simultaneous analysis (Case 6) reduced up to 93 percent of initial power losses whereas the step by step approach had improved the power loss up to 90 and 91 percent for Cases 4 and Case 5 respectively. The one by one approach might achieve the similar results by repeating the process for several times. However, it might take a long simulation process.

Therefore, the simultaneous network reconfiguration and DG output does not only gave the lowest power loss value, but it also can save a computing time (without repeating the process).

Acknowledgements

This work is supported by Universiti Teknologi Malaysia under the Potential Academic Staff (PAS), Grant Code: Q.J130000.2723.00K88

Appendix

Bus Data

BaseMVA = 100; Vbase(kV)=132;

---Load---- ---Gen----
No Volt Angle MW MvarMW Mvar
busdata=

No	Volt	Angle	MW	Mvar	MW	Mvar
1	1.00	0.0	0.000	0.000	0.000	0.000
2	1.00	0.0	0.100	0.060	0.000	0.000
3	1.00	0.0	0.090	0.040	0.000	0.000
4	1.00	0.0	0.120	0.080	0.000	0.000
5	1.00	0.0	0.060	0.030	0.000	0.000
6	1.00	0.0	0.060	0.020	0.000	0.000
7	1.00	0.0	0.200	0.100	0.000	0.000
8	1.00	0.0	0.200	0.100	0.000	0.000
9	1.00	0.0	0.060	0.020	0.000	0.000
10	1.00	0.0	0.060	0.020	0.000	0.000
11	1.00	0.0	0.045	0.030	0.000	0.000
12	1.00	0.0	0.060	0.035	0.000	0.000
13	1.00	0.0	0.060	0.035	0.000	0.000
14	1.00	0.0	0.120	0.080	0.000	0.000
15	1.00	0.0	0.060	0.010	0.000	0.000
16	1.00	0.0	0.060	0.020	0.000	0.000
17	1.00	0.0	0.060	0.020	0.000	0.000
18	1.00	0.0	0.090	0.040	0.000	0.000
19	1.00	0.0	0.090	0.040	0.000	0.000
20	1.00	0.0	0.090	0.040	0.000	0.000
21	1.00	0.0	0.090	0.040	0.000	0.000
22	1.00	0.0	0.090	0.040	0.000	0.000
23	1.00	0.0	0.090	0.050	0.000	0.000
24	1.00	0.0	0.420	0.200	0.000	0.000
25	1.00	0.0	0.420	0.200	0.000	0.000
26	1.00	0.0	0.060	0.025	0.000	0.000
27	1.00	0.0	0.060	0.025	0.000	0.000
28	1.00	0.0	0.060	0.020	0.000	0.000
29	1.00	0.0	0.120	0.070	0.000	0.000
30	1.00	0.0	0.200	0.600	0.000	0.000
31	1.00	0.0	0.150	0.070	0.000	0.000
32	1.00	0.0	0.210	0.100	0.000	0.000
33	1.00	0.0	0.060	0.040	0.000	0.000

Line Data

Bus BusR X
nlnr p.up.u
linedata=

nl	nr	R (p.u)	X (p.u)
1	2	0.000529155	0.000356061
2	3	0.002829431	0.001903030
3	4	0.002101125	0.001412121
4	5	0.002187213	0.001470455
5	6	0.004700413	0.005356061
6	7	0.001074380	0.004687879
7	8	0.004083448	0.001781061
8	9	0.005910813	0.005606061
9	10	0.005991736	0.005606061
10	11	0.001128903	0.000493182
11	12	0.002148760	0.000983333
12	13	0.008425161	0.008749242
13	14	0.003108356	0.005400758

14	15	0.003391299	0.003984848
15	16	0.004282599	0.000303030
16	17	0.007397268	0.013037879
17	18	0.004201102	0.004347727
2	19	0.000941230	0.001185606
19	20	0.008632920	0.010268939
20	21	0.002350207	0.003624242
21	22	0.004068526	0.007100758
3	23	0.002589532	0.002336364
23	24	0.005153811	0.005371970
24	25	0.005141758	0.005356818
6	26	0.001165634	0.000783333
26	27	0.001631084	0.001096212
27	28	0.006077250	0.007074242
28	29	0.004616047	0.005307576
29	30	0.002912075	0.001958333
30	31	0.005592860	0.007294697
31	32	0.001782025	0.002741667
32	33	0.001957645	0.004016667
8	21	0.001957645	0.004016667
9	15	0.001957645	0.004016667
12	22	0.001957645	0.004016667
18	33	0.001957645	0.004016667
25	29	0.001957645	0.004016667

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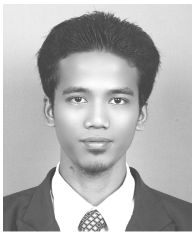

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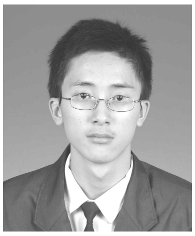

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