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Determination of optimal location and capacity of distributed generations based on artificial bee colony

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Abstract. This study aims at giving descriptive computation of determining the optimal location and capacity of Distributed Generation (DG) for the compensation of active and reactive power on the electric power system using Artificial Bee Colony and minimizing the power losses. It employed the IEEE 34-Bus Reliability Test System (RTS) as the case study focusing on the determination of the location and capacity of Distributed Generation using Artificial Bee Colony algorithm. The data analysis shows that the placement of DG on the IEEE 34-bus system employing ABC can reduce the real power losses and the real power losses at the optimal location and capacity is minimum.

1. Introduction
The needs of electrical energy as a source of energy to support all human activities have increased over time. It comes on the surface, that this is due to lifestyle changes and equipment used in carrying out the all life activities which absorbing large amounts of electricity. The consumer demand for electrical energy would have to be covered by the amount of electric power generated by the power system and electricity network capabilities. However, the fact remains that, at the moment, the load demand is not, directly proportional to the availability of electrical power and network capabilities. There are issues that need specific attention concerning electrical energy distribution, namely voltage drop, low power factor, and power losses [1, 2]. It is well understandable that the load on the power grid can be capacitive or inductive or both. Nevertheless, in the distribution network, of the high inductive load generally indicates the higher the conditions of reactive power peak load and inductive load will increasingly affect the voltage drop, enlarge power losses, and lower the power factor [3]. In electrical power distribution system, bus voltage can decrease when power flows from electrical substation directly to consumers [4]. Low voltage can happen in every part of the systems and it will change as the load flow. In regard to this matter, several studies have shown that at the distribution level, approximately 10-13% of the total power generated was power losses that would result in the increase in energy costs and a poor voltage profile [1, 2].

One of the advance methods commonly used to improve the voltage stability of the power system is the appropriate placement of Distributed Generation (DG). DG is a small capacity power plant located on the electricity distribution system, which is usually placed on the buses that relate directly to the load. The installation of DG has several advantages, namely it increases the efficiency and reliability of the system and improves power quality and voltage levels [5-7]. However, it also raises some drawbacks, such as it increases the number of short-circuit current source in the event of disruption in the system [8]. The placement and capacity size of DG can be said to be optimal if it is able to add the active and reactive power to the system, minimize power losses, and maintain the voltage level at normal conditions [5]. Therefore, an advance method is essential to solve the problems on the optimization of the location and capacity of the DG.

Optimization method used in this study is a metaheuristic method called Artificial Bee Colony (ABC). ABC is an optimization method inspired by the behavior of honey bees in searching for food which was firstly introduced by Karaboga in 2005 [9]. ABC algorithm has 4 advantages compared with other optimization methods, namely the concept and easy implementation, the few parameter used, very simple and flexible [9].

2. Distributed Generations

Based on some reviews of related literature, Distributed Generation (DG) can be defined as follows:

- International Council on Large Electricity Systems (CIGRE) defines DG as the generating unit with a maximum capacity of 50 MW to 100 MW, which is usually connected to the distribution net [10, 11],
- Institute of Electrical and Electronics Engineers (IEEE) defines DG as the generation of electrical energy with smaller equipment of power plants so as to enable their interconnection center in every point on the electric power system [12],
- The International Energy Agency (IEA) defines DG as an electric power generating unit to consumers and supplying electric power directly to the local distribution net [13].

DG has two main functions, they are: (1) it is a unit to anticipate the occurrence of disconnection of the power supply grid or stand-by units and (2) it is a unit supplying power in the peak hour load or peaking units. In addition, the installation of DG in the distribution network can improve the reliability of the electric power system since the DG is placed close to the load area [14]. Table 1 informs the classification of DG based on the characteristics of the active and reactive power generation

Table 1. DG Classification based on the active and reactive power generation

DG Type	Description
Type 1	able to inject the active power
Type 2	able to inject active and reactive power
Type 3	able to inject active power and absorb reactive power

3. The Proposed Methodology

In conjunction with the above mentioned issues, the researchers in this work used Artificial Bee Colony (ABC) method as an alternative solution to solve the determination of the optimal location and capacity of DG.

3.1 Power Flow Analysis

Power flow analysis is not only necessary in planning the electric power system in the future but also it is the basis for the study of power system[15]. The fundamental information obtained from the power flow study is power that flows in the form of active power (P) and reactive power (Q) from generation through transmission lines up to the load side. There are 4 purposes of power flow studies [16] as follows: knowing the characteristics of power flow as the effect of variations in load and losses in transmission lines, knowing the voltages at each node (bus) that exist in the system, knowing all the equipment specifications meet the specified boundaries to deliver the desired power and obtaining the initial condition on the planning of the new system.

The problem is the power flow calculation of the voltage and phase point at every bus in the power system with 4 conditions as follows [17]: three-phase system is balanced if the condition is steady-state and the system is stable sinusoidal; transmission network consists of constant, linear, and centralized branches; active and reactive power demand on each bus (load) and power plants are specified in each bus (generator) except for one bus generator.

To solve the problem of power flow, there are three the most common iteration methods used, namely the Gauss-Seidel method, Newton-Raphson method, and Fast Decoupled method [18]. In the process of installation of DG on the distribution system, it needs to know two things, they are the power flow in the distribution system and the similarities in the power flow analysis problems that is a nonlinear equation and it must be solved using iterative methods [19].

3.2 Artificial Bee Colony (ABC) Algorithm
ABC Algorithm is a type of artificial intelligence or artificial intelligent (AI) method seeking the optimal value by reflecting on the behaviour of bee colonies in looking for nectars (flowers). It is assumed that the ability of bee colonies to determine the food sources is divided into three groups, which are employees, onlookers and scouts. The employees' job is to find the food source and calculates the nectar. They provide information for onlookers by flying on dance area functioning as a meeting place for the bees. The onlookers are in charge of receiving information about the quality of the food source and choose the best one. The food source having more nectars has a greater chance to be selected by onlookers. After that, the employees in each food source then find another new food source in the neighbourhood. In the process of searching for a new source of food, the employees turned into scouts [20]. The three groups of bees perform task to determine the location and magnitude of a nectar, considering and comparing with other sources, which in turn they select a location with the most optimal source of nectar [21].

There are six major steps in solving optimization problems using ABC algorithm as follows [22]:

1. Initializing the position of the food source.
2. Moving the employees towards the food sources and determining the amount of nectar. For each employeee, a new food source is generated by using the following formula:

$$x'_{ij} = x_{ij} + \varphi_{ij}\,(x - x_{kj}) \tag{1}$$

3. Moving the onlookers towards the food sources and determining the amount of nectar. In this step, the onlookers choose a food source by using the probability calculation and obtaining a new food source in the area of chosen food source using the following formula:

$$P_i = \frac{Fitness_i}{\sum_{i=1}^{N} Fitness_i} \tag{2}$$

4. Determining the remaining food source to be abandoned and allocating the employees as the scout bee to find new food sources randomly using the following formula:

$$X_i^j = X_{min}^j + rand\,[0.1](X_{max}^j - X_{min}^j) \tag{3}$$

5. Recording the best food sources that have been found
6. Repeating steps 2-5 until the desired criteria are met.

4. Results and Discussions
This research employs the IEEE 34-bus system as case study where the study was focusing on the determination of the optimal location and capacity of DG type 1 and type 2 by using ABC algorhitm. The single line diagram system the IEEE 34-bus is shown in Fig. 1 with maximum active power of 3.805 MW, reactive power of 2.34 MVAr, losses of 22.18 kW and the minimum voltage is 0.9421 p.u. at the observed bus#27 [23].

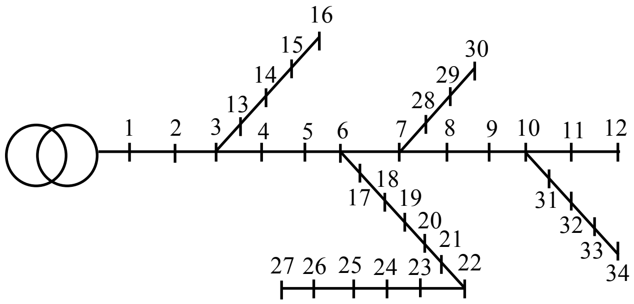

Figure 1. Single line diagram of the IEEE 34-bus radial distribution system

The results of simulations inform the optimal location and capacity for DG type 1 and DG type 2. Fig. 2 provides information on total power losses for DG type 1 placement. The best location for DG type 1 placement is bus#32 with optimal capacity of 500 kW and resulting in the lowest network losses of 168.24 kW with reduction of 23.93%. Fig. 3 shows the losses information for DG type 2 placement. It confirms that best location for this type of DG is at bus#30. The optimal capacity for DG type 2 is also 500 kW. With the placement of this DG, the losses drop to 133.96 kW with the reduction percentage of 39.43%. Table 2 and 3 inform the total power losses for each placement.

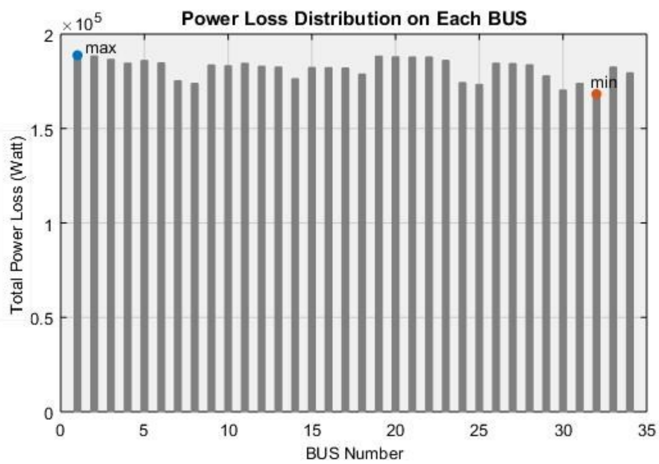

Figure 2. Total Real Power Losses for DG Type 1 Placement

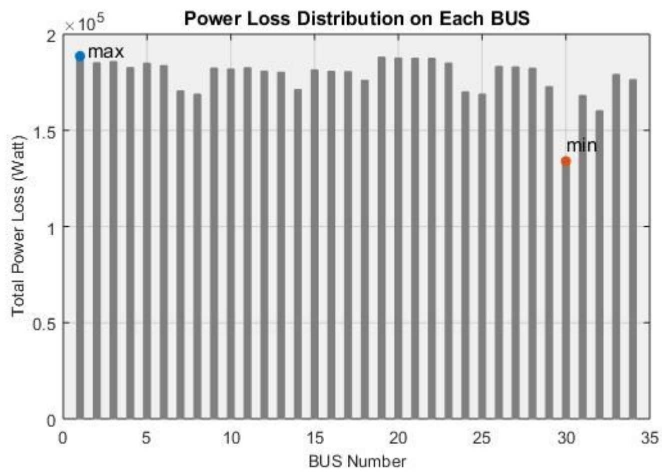

Figure 3. Total Real Power Losses for DG Type 2 Placement

Table 2. The Result for Optimal Placement DG type 1

Location (Bus)	Losses (kW)	Gap (kW)	Percentage (%)
NO DG	221.18	-	-
1	188,794317	32,385683	14,64
2	188,362298	32,817702	14,84
3	186,577867	34,602133	15,64
4	184,610847	36,569153	16,53
5	186,060617	35,119383	15,88
6	184,763712	36,416288	16,46
7	175,279281	45,900719	20,75
8	173,903313	47,276687	21,37
9	183,669766	37,510234	16,96
10	183,212499	37,967501	17,17
11	184,527587	36,652413	16,57
12	183,000668	38,179332	17,26
13	182,539043	38,640957	17,47
14	176,337915	44,842085	20,27
15	182,286866	38,893134	17,58
16	182,186289	38,993711	17,63
17	182,070478	39,109522	17,68
18	178,845597	42,334403	19,14
19	188,346964	32,833036	14,84
20	187,966868	33,213132	15,02
21	187,904783	33,275217	15,04
22	187,868956	33,311044	15,06
23	186,129413	35,050587	15,85
24	174,289308	46,890692	21,20
25	173,303166	47,876834	21,65
26	184,614763	36,565237	16,53
27	184,419003	36,760997	16,62
28	183,737122	37,442878	16,93
29	177,918775	43,261225	19,56
30	170,345202	50,834798	22,98
31	173,9297	47,2503	21,36
32	***168,246768***	***52,933232***	***23,93***
33	182,539517	38,640483	17,47
34	179,470372	41,709628	18,86

Table 3. The Result for Optimal Placement DG type 2

Location (Bus)	Losses (kW)	Gap (kW)	Percentage (%)
NO DG	221.18	-	-
1	188,5931748	32,58682525	14,73
2	188,0016933	33,17830667	15,00
3	185,7531961	35,42680388	16,02
4	182,5933934	38,58660662	17,45
5	184,9504618	36,22953824	16,38
6	183,6462577	37,53374231	16,97
7	170,496505	50,68349498	22,92
8	168,8009581	52,3790419	23,68
9	182,3808172	38,79918284	17,54
10	181,8505955	39,32940453	17,78
11	182,5761272	38,60387277	17,45
12	180,7269149	40,4530851	18,29
13	180,1450752	41,03492475	18,55
14	171,2152006	49,96479944	22,59
15	181,430609	39,74939104	17,97
16	180,6722312	40,5077688	18,31
17	180,5403359	40,63966411	18,37
18	176,0307132	45,14928684	20,41
19	188,0275935	33,15240653	14,99
20	187,5724169	33,60758312	15,19
21	187,4980671	33,68193286	15,23
22	187,455164	33,72483602	15,25
23	185,0310423	36,14895772	16,34
24	170,020901	51,15909901	23,13
25	168,8111448	52,3688552	23,68
26	183,2080056	37,97199437	17,17
27	182,9277964	38,25220362	17,29
28	182,2564883	38,92351168	17,60
29	172,6984747	48,48152531	21,92
30	***133,9646162***	***87,2153838***	***39,43***
31	168,1651176	53,01488236	23,97
32	160,1594842	61,02051584	27,59
33	179,0794568	42,10054324	19,03
34	176,3617967	44,81820327	20,26

5. Conclusions

The simulation results in this study with the IEEE 34-bus system have shown that the optimal capacity for both DG type 1 and type 2 is 500 kW. Whereas the optimal location by using Artificial Bee Colony for DG type 1 is bus#32 and for DG type 2 is bus#30 and both placement show the smallest network losses.

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