An Empirical Metaheuristic Assessment for Solving of Multi-type Distributed Generation Allocation Problem

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***Abstract*—This paper aims to map the use of algorithms with a metaheuristic approach to find optimal solutions for Distributed Generation (DG) placement. This paper surveyed six (6) algorithms tested on the same object, namely the IEEE 30 bus system with various types of DG. The algorithms are Genetic Algorithm (GA), Human Opinion Development (HOD), Particle Swarm Optimization (PSO), Artificial Bee Colony Algorithm (ABC), Adaptive Real Coded Biogeography-Based Optimization (ARCBBO), and Firefly Algorithm (FA). The review of each reference articles is done by comparing the optimal solutions obtained on the basis of an assessment of the reduction of power loss, while still interpreting the constraints of each function. This is because almost all the objective functions of the algorithm use these parameters. The solution offered by the FA provides significant results compared to other algorithms.**

Keywords—Placement DG, Metaheuristic algorithm, FA, BGA, power loss, IEEE 30 bus

I. INTRODUCTION

Recently there is an increase of Distributed Generation (DG) integration into the electric power system. DG integration is considered a solution that has a positive impact on technical and non-technical aspects of energy problems. DG is a system for generating electricity from many small energy sources. DG generator unit has a maximum capacity of 50 MW to 100 MW which is generally connected to a distribution network [1]. The advantage of this system compared to a centralized electrical system is that it can operate independently, does not require large and complex operating areas, short transmission networks and can use to generate energy sources that correspond to the area to be electrified. Both in the analysis of calculations and in fact, in the field, the presence of DG is able to improve the quality of the network power system, including a reduction in power loss, improvement of the voltage profile and system stability [2,3]. Non-technically, the existence of DG as a source of power around the load is able to reduce emissions that have been caused by thermal plants [4]. Location, size, type are factors that must be considered appropriately. Application of classical optimization techniques resolves DG placement problems by considering an objective such as Linear Programming [5], Non-Linear Programming [6], Quadratic Programming [7]. These methods have deficiencies in terms of convergence. Departing from these shortcomings, studies on DG placement have been completed with an artificial intelligence-based optimization process known as the metaheuristic approach.

Metaheuristic is an algorithm that can solve complex optimization problems if solved by an exact algorithm. Based on Hillier and Lieberman [8] the heuristic method is the method used to find solutions to a problem where the solution found is the best feasible solution. In searching for an efficient and comprehensive solution, metaheuristic methods use mechanisms that mimic social behavior or strategies that exist in nature. Compared to traditional methods, metaheuristic algorithms have a better search speed for optimal solutions. This method also provides better results than the heuristic method because this method will always try to get out of the local optimal solution. Although there is no guarantee that the solution found is an optimal solution, metaheuristic methods that are well built can provide solutions that approach optimal solutions.

An important issue in the electrical system now is how to plan the distribution generation plan appropriately. Decision-making with a metaheuristic approach has resulted in better improvements and appropriate planning in the power plant scenario. In this paper, examines the optimal solutions generated by a metaheuristic approach using an IEEE 30 bus plant with various types of DG. The formalized DG type includes four (4) types P_+, Q_+, P_+Q_+, and P_-Q_+; clearly explained in the discussion section. This review is technically useful to see a comparison of the contribution of system improvements resulting from each optimal solution with a different algorithm approach. This is very useful to develop a new approach or to see the technical impact for further DG technology research.

The discussion in this paper is divided as follows. Sections 2 and 3 present a summary of research using metaheuristic algorithms with the discussion of optimal solutions. The final section presents trend algorithms that develop in the research and final conclusions.

II. METAHEURISTICS APPROACH

A. Population-Based Metaheuristics

The metaheuristic approach is an algorithm that is mostly inspired by events in nature or better known as the nature-inspired algorithm. The metaheuristic approach appears to answer the shortcomings of heuristic-based algorithms that require a long computational time. This algorithm is simple and easy to apply to computer programming languages so that it can provide solutions that are faster than heuristic algorithms [9]. Metaheuristic algorithm applications are a powerful method for solving many difficult optimization problems [10-12].

The results of mapping the use of metaheuristic algorithms in finding optimal solutions in the context of DG integration in the distribution network are summarized in table 1. The similarity of these studies is the use of the IEEE 30 bus test system as the object of research. This will make it easier to compare the optimal solution produced.

Table 1 represents five algorithms used by previous researchers: Artificial Bee Colony Algorithm (ABC), Adaptive Real Coded Biogeography-Based Optimization (ARCBBO), Genetic Algorithm (GA), Particle Swarm Optimization (PSO), Human Opinion Development (HOD), and Firefly Algorithm (FA).

TABLE I. OPTIMAL SOLUTION DG METAHEURISTIC APPROACH RESULTS

Algorithm Proposed	Objective Function	DG Type	Optimal Solution
PSO [13]	Minimize total loss system	P+	15 (13.58 MW)
GA [14]	Minimize the total losses and improve the voltage profile	P+	22 (36.75 MW)
BGA [15]	Minimize power loss	P+	26 (15.30 MW)
Human opinion dynamics [16]	Minimum cost function reflecting the voltage profileand power loss	P+	4 (59.36 MW)
PSO [17]	Multi objective functions combine active and reactive power loss index, channel capacity, system short-circuit current, and voltage profile	P+and Q+	24 (31.21 MW+ j 7.96 MVar)
GA [18]	Minimize power loss and cost of investing the biomass	P+	5 (24 MW)
FA [19]	Minimize power loss	P+	2 (18,3 MW)
MPSO [20]	minimize economic and emission costs	P+Q+	11 (9,29 MW)
ABC[21]	Minimized operating times of the relays	P+Q+	12(10 MVA, 0.9 lagging power factor)
ARCBBO[22]	Minimization of fuel cost	P+	12(11.98 MW)
MOPSO[23]	Minimizing generation cost and minimized voltage stability	P-Q+	20(6.85 MW)

The metaheuristic algorithm approach resembles the natural phenomenon of 'swarm behaviors of animals' or 'evolution of species'.

B. Linkages of Metaheuristic Algorithms

Of the five methods described in the previous sub, there is a relationship between the algorithm approach. These five methods are optimization techniques with a population metaheuristic approach.

The difference between ARCBBO and GA lies in the search for the best generation. ARCBBO does not reproduce or produce children, as GA has done which results in the best solution from the best generation resulting from cross-breeding and mutation. ARCBBO is more similar to PSO in the process of finding solutions. Both are considered as velocity vectors in a space to find solutions by comparing results with their neighbors over time. The switching speed does not change but the changing point position represents a different value which is considered the best solution. The advantage of using intelligence swarm algorithm is a working system based on the interaction between agents of the same population and environment. The process of finding solutions is not random but based on people's decisions they use crowd decisions rather than random searches. This principle is also used in the FA. The FA's working principle in finding the optimal solution is to divide the population into sub-groups, and each group can surround each locality optimal. The process of exploration and exploitation in the FA can regulate randomness in iterations so as to accelerate convergence. FA and GA are both metaheuristic algorithms, but the work of the FA is based on a decrease in attractiveness and attractiveness with distance. Each group can cluster around each local mode or optimal to find all optima simultaneously. This is what differentiates it from GA in producing a new generation. The FA uses fewer variables than GA so it decreases the complexity of the model and speeds up the time needed for calculations. designations.

III. COMPARISON OF OPTIMAL SOLUTIONS RESULTS OF METAHEURISTIC OPTIMIZATION APPROACH

A. The contribution of Objective Function and Constraint Function

The issue of DG placement is very technical, requiring a metaheuristic approach because it is complex. Within a period of five years based on data from the results of previous research reviews [24] mapped as much as 85% more than analytical methods.

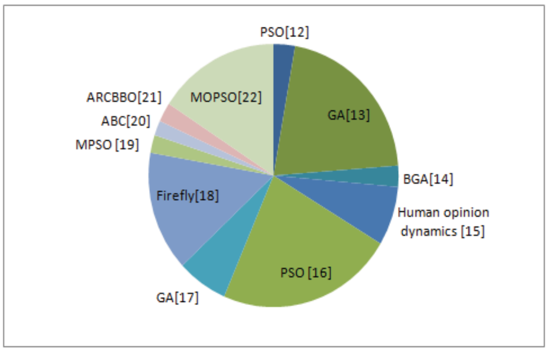

Fig 1. Comparison of the contribution of optimal solutions

In the optimization process of DG placement, objective functions, constraint functions, and optimization techniques are three basic models that greatly influence the process of finding optimal solutions. Almost objective functions of the optimization process that have been carried out by researchers have previously been based on the minimization of power losses in the network. The pair of DG bus-size locations varies depending on the algorithm approach used. The optimal solution produced has different contribution values on the system. By setting the power loss function as a basis for assessment, the graph in Figure 1 shows the percentage of contributions generated by each metaheuristic algorithm based optimal solution.

The contribution mapping based on the percentage reduction in power loss shows the PSO, GA and FA approaches have the potential to produce better solutions. Limitation of variables that must be met by the optimal value when operating is defined in the constraint function. This limit value is divided into equality and inequality that must not be violated by a single objective function or multi-objective function. In research [13,17] specifies the power balancingof load and generation as a constraint function that limits the optimal search for a location and DG size. The effect resulting from this solution is a decrease in power losses of 72.05 %. That is the case in research [14], the voltage magnitude and thermal limit of transmission lines control the optimization results generated in each iteration step. This methodproduces an optimal solution with a high decrease in power loss about 66.82 %. In the search for optimal solutions research uses the FA approach[19],a number of bus and voltage profile control the solution as constraint function. As a result, the solution was obtained by 47%.

In Jurado research [18], finding the optimal location and size of a biomass generator gas turbine was carried out in two steps. Determination of the size of the biomass plant is carried out at the first stage based on the maximum function of profit. in the second step using the minimum power loss function as the basis for determining the location of the biomass plant.

B. *Solution Metaheuristic Based Population Analysis*

The benefit of metaheuristic algorithms as a modern mathematical optimization technique has been proven by the success of finding the optimal solution in each case. However, with the emergence of new approaches or hybrid techniques, the algorithm shows the lack of the algorithm.

In this study discussed the results of DG optimization for all types. Based on real and reactive power injection, DG can be divided into four types shown in table 2.

TABLE II. DG CATEGORYS[10, 25]

DG Type	Power injection	Technology
DG1	Real Power (P_+)	biogas,solar systems, photovoltaic cell etc
DG2	Reactive power (Q_+)	inductor bank, synchronous condenser, and capacitors bank etc
DG3	Real power (P_+) Reactive power (Q_+)	geothermal, wind, tidal, wave etc
DG4	Reactive power (Q_+) but absorbReal Power (P_-)	doubly fed induction generators based wind

From the results obtained can be analyzed that type DG does not significantly influence the location or number of bus searches. Type DG is more influential on the size of DG because it determines the value of active and reactive power needed for better system performance in accordance with the objective function that has been set.

In the PSO approach, a population that moves to find a solution consists of several individuals who are called particles that move to find the best solution. The particle *i* is denoted by: $x_i = (x_{i1}, x_{i2}, x_{i3}, ... x_{id})$. Positions that meet the criteria are denoted by: $pbest_i = (pbest_{i1}, pbest_{i2}, pbest_{i3}, ... pbest_{id})$. Notation d shows the number of initial particle numbers. The best value of each particle population denoted by *gbest* is recorded for the next iteration process. The movement of particles in each iteration stage is symbolized by $v_i = (v_{i1}, v_{i2}, v_{i3}, ... v_{id})$.

To move, this particle has a velocity so that the position of the particles will continue to be updated according to the boundary function that has been defined as the objective optimization equation. The new velocity and position of particle *i*described as Eq. 1 and Eq. 2 as follows:

$$v_{id}^{(t+1)} = w.v_{id}^{(t)} + c_1.r_1.(pbest_{id} - x_{id}) + c_2.r_2.(gbest_{id} - x_{id}) \quad (1)$$

$$x_{id}^{(t+1)} = x_{id}^{(t)} + v_{id}^{(t+1)} \quad (2)$$

In the GA approach, the population is a collection of chromosomes formed from constituent components called genes or individuals. In the case of DG optimization, the location of the bus uses binary numbers. In GA, the standard parameters used are population size, crossover probability, and mutation probability. In doing optimizationDG, used two optimization parameters, namely location parameters, and capacity parameters. So the genes in one chromosome contain two values. The first value is to determine the DG placement location variables encoded in the form of binary numbers (0 and 1). The value of both DG capacity variables is encoded in numbers real (float encoding) between -1 to 1. The value of the capacity of DG is actually obtained after the decoding process.

The firefly algorithm approach represents the brightness of fireflies as a fitness function. Almost the same as other swarm algorithms movement of fireflies shows the process of finding the optimal solution. Equation 3 shows the movement of a firefly to a brighter firefly [26]. At the end of each generation, fireflies are ranked according to their brightness so that the best fireflies are found in each generation.

$$x_i^* = x_i + \beta_0 e^{-\gamma r^2}(x_j - x_i) + \alpha \in_i \quad (3)$$

where x_i^* is the new position of firefly i, x_i is the initial position of firefly i, x_j is the position of firefly j, β_0 is the firefly's attractiveness, γ indicate the characteristic length, α is the randomization parameter,$\in$ is a vector of random numbers from Gaussian. For the next generation, fireflies are made to move by renewing the light intensity of each firefly to get a new fitness value. In the final stages of all generations, fireflies that have the highest brightness are fireflies with the best fitness value and are concluded as optimal solutions for DG.

Some studies also use multi-objective functions. This is certainly influential in determining the solution. The Pareto function is needed to determine which solution is the best because it must meet every objective function criteria[17]. The weight of each function is done with the Pareto function.

In other studies, modification of the existing algorithm is done to improve the quality of the search process for the optimal solution and computation time. This has been done in GA and PSO. GA modification[15] is done by modifying the crossover and mutation processes. This is the case with MOPSO which involves several objective functions so that the computational time needed is faster [20, 23].

IV. CONCLUSION

Mapping the use of metaheuristic algorithms for DG optimization cases has been carried out. The results of the research review focused on the same test object, IEEE 30 bus with several types of DG. The results obtained indicate that the use of metaheuristic algorithms is able to produce optimal solutions that vary in the range of 5.82% to 72.05%. The resulting solution is also influenced by the constraints set. From the results of this mapping also shows there are some metaheuristics approach that have not been applied to IEEE 30 bus for DG placement problem. These are whale algorithm, fruit fly algorithm, spring search algorithm, sun and leaf optimization, frog leaping algorithm, and hybrid algorithm. It can be the next research target.

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