Modelling, Measurement and Control A
Vol. 91, No. 3, September, 2018, pp. 104-113
Journal homepage:http://iieta.org/Journals/MMC/MMC_A

Power loss reduction using distributed generation

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https://doi.org/10.18280/mmc_a.910302

Received: 15 June 2018
Accepted: 2 September 2018

Keywords:
forward/backward sweep analysis, bat algorithm, power losses, optimal placement

ABSTRACT

This research paper has been presenting a comparative analysis of power flow in radial distribution system before and after optimal locating and sizing of Distributed Generation (DG). In this paper the power flow analysis is using to obtain the real power loss and voltage at each bus with the BAT Algorithm (BA) and the conventional Gravitational Search Algorithm (GSA). Finally the conventional GSA has been comparing with the BA to prove that the BA will provide the better solution for optimal placement of DG and size. This research also presenting the optimal placement of DG and its size in order to reduce power loss and improve the voltage profile at each bus in the system. By using Forward and Backward (FW/BW) sweep analysis initially analysing the power losses in the system. Then by using GSA and BA the power loss and voltages at each bus will be calculate and also the optimal location and size of the DGs to reduce these losses will calculate. For this research the Photo Voltaic (PV) energy is considering as DG. All the methods for this research are computing by using MATLAB software and for the test the IEEE-33 radial bus system has considered.

1. INTRODUCTION

DG is the source of electrical energy which connects distribution system [1-2]. It produces a clean power because most of the DGs are renewable energy sources like PV models and Wind Turbine (WT) [3]. The important features of DG are power losses reducing, efficiency increasing, power quality enhancing, reliability of the system improving and fuel cost reducing fuel i.e. cost of maintenance and operating [4,5]. Though, wrong location and capacity of DG leads to more power loss and more cost than without DG [6].

Many techniques have been explained for optimal sitting and sizing of the DG through different optimization techniques enlightening technical and economical performances [7-10]. Tools like heuristic, deterministic and hybrid techniques are capable and still sprouting in this field. Certainly, Genetic Algorithm (GA), Taboo Search (TS), Particle Swarm Optimization (PSO) Algorithm, Direct Search Algorithm and Ant Colony Optimization (ACO) Algorithms were utilized to examine the optimal placement and sizing of DG. Most of the articles while locating the DGs importance were given on the minimization of power loss. Some of those have explained to improvement of the system voltage also [11-13].

The detailed explanation is presented in Section 5 and 6. Before that, the current research work is presented in Section 2. The experimental results and conversation are quantified in Section 8. Finally, the Section 9 finishes the document.

Recent work: A brief

Many of researchers have done work are formerly available in literature that on the basis of the optimal placing and capacity of DG in the power system. Some of the works are reviewed here.

Satish Kansal et al. [14] has done work on a hybrid method for optimal location of multiple DGs of different types. Their analytical methods may not be suitable for optimal location of multiple DGs alone. In their work, hybridization of analytical technique and heuristic search for the optimal placement of multiple DGs in power distribution system for minimization of power loss has been projected. In the method, the capacities of DGs were calculated at every bus by analytical method while the places were determined by PSO based technique. The objective performance has been reduced under operating constraints. The improvements in bus voltage profile and optimal power factor of the DGs have also been calculated. To validate their proposed hybrid method, results have been associated with PSO technique and available fast enhanced analytical (IA) method solutions.

Banaja Mohanty et al. [15] have proposed a Teaching Learning Based Optimization (TLBO) technique for finding the optimal capacity and place of DG in Radial Distribution Network (RDN). The optimal place and capacity of DG was examined considering Voltage Stability Index (VSI) as an objective function. The advantage of their proposed technique has been exposed by associating the results with GA and PSO techniques in RDN. The comparison was done with the help of system performances like the real power loss and voltage profile of RDS.

K. Muthukumar et al. [16] have projected a hybrid Harmony Search Algorithm for minimizing the power losses in radial distribution system and allows an improvement in bus voltage profile by important optimal places, optimal capacity distributed generators and shunt capacitors. To overawe the drawback of premature and slow convergence of Harmony Search Algorithm (HSA) over multi model fitness landscape, the Particle Artificial Bee Colony algorithm (PABC) was used to improve the harmony memory vector. In the first method, the formulation echoes the evaluation of loss sensitivity factor to resolve the candidate buses and thereafter resolves on the optimal rating through the usage of hybrid Algorithm.

Chengshan Wang et al. [17] have presented the long-term operation features of distributed generation; a mixed integer non-linear optimization issue was expressed to optimally regulate the location and capacity of Soft Open Points (SOPs) on the basis of the typical operation scenarios generated by Wasserstein distance. It was then malformed to and resolved as a mixed integer second-order programming model. The SOPs are power electronic devices fitted to replace generally open points in active electrical distribution schemes. SOPs could give active/reactive power flow control and voltage regulation under normal operating situations and also fast fault isolation and supply restoration under abnormal circumstances. The implementation of SOPs could progress the controllability of distribution schemes, thus further augments the economy, flexibility and reliability of the grid.

Lesiba Mokgonyana et al. [18] have presented a planning model for power distribution companies (DISCOs) to maximize profit. The model regulates optimal network place and size for renewable energy source, which are considered as Independent Power Production (IPP) and Self-Generation (SG). IPP refers to generators owned by third-party investors and linked to a quota obligation mechanism. SG includes smaller generators are reinforced by feed-in tariffs, that yield energy for local consumption, exporting any surplus generation to the distribution network. The attained optimal planning model was able to assess network capacity to maximize profit if the DISCO is gratified to give network access to SG and IPP. Distinct parts of the objective function, owed to the definition of SG, are revenue erosion, recovery and also the cost of excess energy.

E.S. Ali et al. [19] have anticipated an Ant Lion Optimization Algorithm (ALOA) for optimal location and sizing of DG based renewable resources for various distribution schemes. The Photovoltaic (PV) and Wind Turbine (WT) are taken here as resources of DG. Location and sizing of DG have affected largely on the system losses. First the most candidate buses for installing DG are familiarized with the help of Loss Sensitivity Factors (LSFs). Then the projected ALOA is utilized to assume the locations and sizing of DG from the designated buses. The projected algorithm is tested on two IEEE radial distribution schemes. The attained results via the projected algorithm are associated with other algorithms to highlight its benefits in diminishing total power losses and accordingly increasing the net saving.

Subhodip Saha et al. [20] have projected a Chaotic Symbiotic Organisms Search (CSOS) algorithm to detect the optimal location and sizes of real power DGs in a radial distribution system (RDS) as constant load models. Distributed generators (DGs) play an imperative role to diminish the real power loss and to progress the voltage stability of the power system. This DG sitting and sizing problem is related to real power loss minimization and voltage stability enhancement objectives. Though, proper placement and sizing of DGs in the distribution network is a vital problem, as any improper location and size of DGs may upsurge the overall system loss.

Fazel Abbasi et al. [21] have projected a Distribution System Reconfiguration (DSR), in view of network configuration effect that runs in offline mode with constant loads and optimal DG distribution and sizing issues are studied concurrently to detect an optimal condition for distribution network on the basis of operational thresholds and reliability enhancements. The technique of calculating Energy Not Supplied (ENS) in DSR issue in the availability of DGs with storage schemes is elucidated and the impact of protective equipment is measured, as well. Optimal performance of power distribution networks significantly depends on network configuration, location and size of DGs units and storage systems.

Brendan Quinlan et al. [22] is presented in this work instrument used to measure tar concentration is an online tar testing apparatus that was designed and built by the authors. Using the online tar testing apparatus enables phenomena to be observed that previously could not using standard methods. The influence of tar concentration due to four scenarios is presented using the online tar testing apparatus: dynamic behavior at different testing locations, impact as electrical output applied to the engine increases or decreases, impact of refueling events, and impact of different gasifier reactor architectures. Dynamic behavior of tar concentration was captured over all scenarios. Consistent results were obtained and results proved to be nonlinear and sometimes unpredictable.

Power loss minimization and voltage stability enhancement is important arenas of power systems because of available transmission line contingency, financial loss of utility and power system blackouts. Optimal allocation (i.e. sitting and sizing) of DG is one amongst the best ways to strengthen the efficiency of power system among capacitor placement and network reconfiguration. Power system operators and researchers put forward their determinations to resolve the distribution system problem associated with power loss, energy loss, voltage profile, and voltage stability on the basis of optimal DG distribution. The review of the recent research work shows that, the dissimilar formulations have been utilized to resolve the problems, such as, calculus-based approaches, search-based methods and combinations of the previous methods. The calculus-based approaches include Linear Programming (LP), second-order algorithms and OPF-based methods. These optimization approaches treat the DG capacities as continuous variables while their locations remain fixed. Though, the issue of placing DG in practical networks belongs to the complexity category of Non-deterministic Polynomial (NP) complete, that is, it is almost firm that resolving for its global optimum cannot be done competently on a computer. Solutions can be attained by analytical methods only under abridging assumptions, namely placing a single DG. Search-based approaches have been projected to seek the optimal (or near-optimal) DG locations and capacities from candidate sites and sizes. The search-based approaches encompass numerous artificial intelligence methods like GA, combined fuzzy-GA, multi-objective evolutionary methods and tabu search. Combinations of search-based and calculus-based methods that handle discrete and continuous variables have been also projected to progress the modelling of DG sites and sizes. The GA based technique together with Optimal Power Flow (OPF) calculation was implemented to diminish the cost of dynamic and reactive power production. For multi-objective problems namely DG allocation, GA's are appropriate, and can present close to optimal significances, though, they are computationally demanding and slow in junction. Though, they also have shortcomings in some respects like computational time in resolving DG. Numerous heuristic algorithms have been accepted by the researchers to resolve complex optimization issues. Few modifications or improvisation of the algorithms by hybridizing the existing algorithms are necessary in order to balance and accelerate the exploration and exploitation ability of heuristic optimization algorithms for searching optimal solutions.

In this research, BA and conventional GSA were compared for the optimal location of DG in distribution system for power loss reduction of power loss and voltage profile improvement has been proposed. In this approach, the DG capacity is evaluated at every bus and the location is determined. Both the approaches BA and conventional GSA are tested on 33-bus test system and the obtained results are compared.

2. PROBLEM DESCRIPTION IN RADIAL DISTRIBUTION SYSTEM

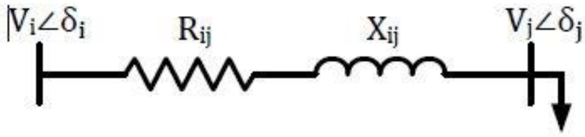

Figure 1. Radial distribution system with two-bus

The Fig.1 indicates a part of radial distribution system. This paper presents the comparative analysis of active power losses and improvement of voltage profile for the test system before and after introducing DGs in an optimal site with proper size. The system objective function for voltage profile improvement and the active power loss minimization are as follows:

$$F = \begin{cases} \max.\ voltage\ at\ each\ bus\ (f1) \\ \min.\ active\ power\ loss\ (f2) \\ \max.\ VSI\ (Voltage\ Stabilty\ Index)\ (f3) \end{cases} \quad (1)$$

The multi-objective optimization of above equation can be written individually as below:

2.1 To find voltage profile improvement:

$$f_1 = Voltage\ difference = \sum_{ni=1}^{n} \left(|V_{ref}| - |V_{ni}| \right) \quad (2)$$

where: V_{ni} is ni bus voltage and V_{ref} is $1\angle 0^0$ Per Unit.

2.2 To find active power loss:

$$f_2 = \text{Active power loss in branch ij}$$
$$= |Iij|^2\ \text{Rij} = \frac{P_{effj}^2 + Q_{effj}^2}{|V_j|^2} \quad (3)$$

where: I_{ij} is Current branch ij, R_{ij} is Resistance of branch ij, P_{effj} is effective active power fed bus j, Q_{effj} is effective reactive power fed bus j, V_j is voltage at bus j.

$$P_{effj} = \frac{|V_i||V_j|}{|Z_{ij}|} \cos\left(\varphi_{ij} - \delta_i + \delta_j\right) - \frac{|V_j|^2}{|Z_{ij}|} \cos\left(\varphi_{ij}\right) \quad (4)$$

$$Q_{effj} = \frac{|V_i||V_j|}{|Z_{ij}|} \sin\left(\varphi_{ij} - \delta_i + \delta_j\right) - \frac{|V_j|^2}{|Z_{ij}|} \sin\left(\varphi_{ij}\right) \quad (5)$$

where V_i is voltage at bus i, Z_{ij} is impedance of line i-j, φ_{ij} is angle of line i-j, δ_i is angle of V_i, and δ_j is angle of V_j.

2.3 To find Voltage Stability Index (VSI):

$$f_1 = VSI(j) = |V_i|^2 - 4\left[P_{effj} R_{ij} + Q_{effj} X_{ij}\right]|V_i|^2 - 4\left[\left(P - P_{effj}\right) X_{ij} + \left(Q - Q_{effj}\right) R_{ij}\right] \quad (6)$$

where V_i is voltage at bus i, P_{effj} is effective active power fed at bus j, R_{ij} is Resistance of branch ij, Q_{effj} is effective reactive power fed at bus j, X_{ij} is Reactance of branch ij, P is the real power and Q is the reactive power.

As the low VSI value will leads the system instable. Because of this reason it is required to find the minimum VSI point in the system.

$$\min(VSI(ni)) = \left(\frac{1}{VSI(ni)}\right);\ ni = \{1,2,\ldots,N_n\} \quad (7)$$

2.4 The inequality constraints in the system as follow:

2.4.1 Voltage constraints

$$V_{\min} \le V_i \le V_{\max} \quad (8)$$

2.4.2 DG constraints

$$P_{\min,i}^{dg} \le P_i^{dg} \le P_{\max,i}^{dg} \quad (9)$$

where: $P_{dgmin,i}$ is at bus i maximum real power and $P_{dgmin,j}$ is at bus i minimum real power, P_{dgi} is at bus i real power.

3. POWER FLOW ANALYSIS

The concept of power flow analysis is used as a basic tool in power system in order to find the values such as active and reactive power losses, voltage magnitudes and their phase angles at every bus in the system. In past the conventional methods like Gauss Seidel method, Newton Raphson method and Fast-Decoupled methods have been used for power flow analysis. But it is found that these all methods were not so useful in distribution side because of various reasons like distribution system having radial networks, poly phase systems, unbalanced operating conditions, continuously variable load, many number of nodes and branches. Because of these reasons the power flow analysis has done by using an effective method called FW/BW sweep analysis has been used on radial distribution bus system. FW/BW analysis has much lesser time of operation than any other approaches. FW/BW sweep approach will provide good outcomes when compared with other analysis in active and reactive power losses. The fig 2 shows the flowchart for FW/BW sweep approach.

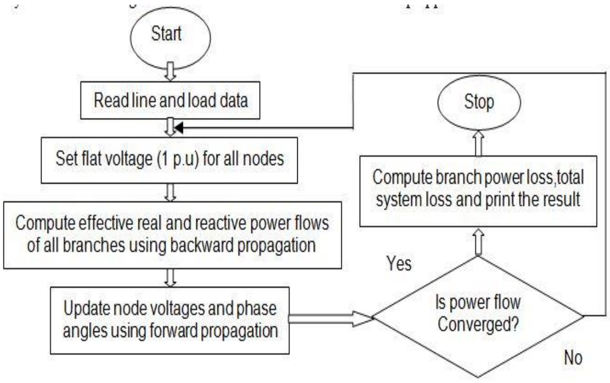

Figure 2. BW/FW sweep approach flow-chart

4. PERFORMANCE MODEL OF PV ARRAY

Highly improved control methods can support to reduce the operating costs and improve the PV cell plant performance. The important controlling challenges as follows:

(1) The most favorable healthy controlling techniques having capable of sustain working hotness as nearly close to finest as likely in spite of conflicts, like the level of irradiance of solar changed (because of clouds), reflectiveness of the mirror and some more working situations.

(2) The conventional algorithms and hybrid algorithms are used to find the optimally operating areas and methods and the commitments of production should consider. In addition, the radiation from the solar should be the level of expectation, the energy storage capacity and finally the electricity charges.

(3) Different types of techniques for predicting radiation from sun utilizing heterogeneous data like cameras, prediction of weather, satellites.

(4) Algorithms for the estimation of major procedure variables and also constraints from various and distributed quantities (oil hotness and radiation from sun at various sections on the ground, reflectivity of the mirror and thermal losses).

(5) Devices that cleans all the mirrors automatically. The major aspect degrading optical function of the concentrating mirrors are addition of dust over the surface of the mirror. Mirrors' cleaning is shows a significant cost for work force and the water is generally a rare source where PV stations were situated. Automatic equipment was required to be developed to reduce the utilization of water and reflective surface degradation.

(6) Reflectors were self-calibrated instruments. Reflectors were required rearrangement from time to time since all the errors in sun model, longitude and latitude of the location, reflector location on the ground, mechanical defaults, optical defaults and likewise. Reflector's re-calibration might be shown a very important charge in work force and the time when it done physically. Techniques were required for speed, online recalibration and atomization of reflectors.

Fault finding and parting in solar generating plants. Algorithms were needed to find and separate errors and malfunction in case of an electrical power plant, such as finding of hot locations.

4.1 PV panels

PV panels are the equipment, which converts temperature into electrical energy. Most of the house owners showing interest to install PV panels at their location (generally on the top of the roof) in order to minimize their electrical energy usage bills and to minimize their carbon footprint. The charge for PV panels differs considerably. However, a survey shown by the National Renewable Energy Lab (NREL) in 2010 assessed that the national average charge of PV (Photo Voltaic) systems was about $7.61 per watt. Hence, a typical 6-Kw system could be charge is about $40,000. For any state or local discounts would minimize this charge, as would be about 35% PV tax credit.

All the costumers should keep in their mind that we have three various types of PV panel systems. The very first one is the on-grid battery system. Evidently, all these systems were associated to grid but also have batteries, which can store additional generated energy. They are can still drive various additional energy will be out to the grid. On-grid systems without a battery are easy and less expensive to set up, but the system will be shut down if the power goes out in your zone. In conclusion, we have off-grid PV power systems also. Houses, which utilize this kind of systems, are not at all connected to the power grid and produce all of their electrical energy individually. This choice is not at all typically suggested unless you are staying in a heavily remote place.

Parallel and series combinations of PV cells increase the current and voltage to tailor PV array output. For a PV array having of NSXNP PV modules, the maximum power output will be calculated as equation (10),

$$P_{pv} = N_S N_P P_{md} \tag{10}$$

Here, P_{md} is maximum power produced by PV cell which will be formulated as in the equation (11),

$$P_{md} = FF * V_{OC} * I_{SC} \tag{11}$$

where, V_{OC}, I_{SC} and FF are voltage when the circuit is open, current when the circuit is short and the Fill Factor (FF) of PV cell respectively. V_{OC}, I_{SC} and FF are the function of solar irradiance and PV cell temperature; also, these are attained as in the equations (12), (13) and (14),

$$V_{OC} = \frac{V_{NOC}}{1 + c_2 * \ln \frac{G_N}{G_a}} \left(\frac{T_N}{T_a} \right)^{c_1} \tag{12}$$

$$I_{SC} = I_{NSC} \left(\frac{G_a}{G_N} \right)^{c_3} \tag{13}$$

$$FF = \left(1 - \frac{R_s}{V_{OC}/I_{SC}} \right) \frac{\frac{V_{OC}}{nKT/q} - \ln\left(\frac{V_{OC}}{nKT/q} + 0.72 \right)}{1 + \frac{V_{OC}}{nKT/q}} \tag{14}$$

where, G_N and G_a are the nominal and actual solar irradiance on PV cell, T_N and T_a are nominal and actual PV cell temperature, V_{NOC} and I_{NSC} are nominal open circuit voltage and nominal short circuit current of PV cell, R_S is the series resistance of PV cell, c_1, c_2 and c_3 are the three various constants which are introduced to have non-linear relationship in between solar, photo-current and PV cell temperature. η is density factor, T is the PV cell temperature (in Kelvin), K is the Boltzmann's constant (1.38 X 10^{-23} J/K) and q is the charge of electron (1.6 X 10^{-19} C).

5. GRAVITATIONAL SEARCH ALGORITHM

This methodology was first proposed by Rashedi in 2009. GSA is the heuristic stochastic swarm based search algorithm [23]. This algorithm has been proposed by laws of Newton's gravitational force. In GSA approach the objects are selected in such a way that whose performance is to find by their masses. All these objects will get attract by one another due to the force of gravity. Because of this attraction force between the objects will cause a movement towards heavier mass objects. The solution of the problem will be determined by the position of an each object. The objects which are having heavy mass will gives a better results than light mass objects which moves faster than heavier mass objects.

5.1 GSA formulation

In this system having N agents, the position of i^{th} agent can be determined by:

$$X_i = \left(x_i^1, ..., x_i^d, ..., x_i^n\right) \; for \; i \; = \; \{1, 2, ..., N\} \tag{15}$$

where x_{di} is i^{th} agent position in the d^{th} dimension and η is search space dimension.

From j mass the force acts on i mass at t time is given by:

$$F_{ij}^d = G(t) \frac{M_{pi}(t) X M_{aj}(t)}{R_{ij} + \varepsilon} (x_j^d(t) - x_i^d(t)) \tag{16}$$

where $G(t)$ is at t time the gravitational constant, $M_{aj}(t)$ is active gravitational mass of j^{th} agent, $M_{pi}(t)$ is passive gravitational mass of i^{th} agent, $R_{ij}$is Euclidian distance between i^{th} and j^{th} agents, ε is constant.

Velocity and position of agent can be determined by:

$$v_i^d(t=1) = rand_i v_i^d(t) + a_i^d(t) \tag{17}$$

$$x_i^d(t=1) = x_i^d(t) + v_i^d(t=1) \tag{18}$$

where: $rand_i$ is in the interval [0 1] uniform random variables, $a^d_i(t)$ is in time t and in the d^{th} dimension acceleration related to i^{th} mass.

Inertial mass and gravitational mass are updated as,

$$m_i(t) = \frac{fit_i(t) - worst(t)}{best(t) - worst(t)} \tag{19}$$

$$M_i = \frac{m_i(t)}{\sum_{j=1}^{N} m_j(t)} \tag{20}$$

where, fit is value of fitness at i^{th} agent at t time, $worst$ is higher power loss, best means lower power loss, i is 1, 2 n.

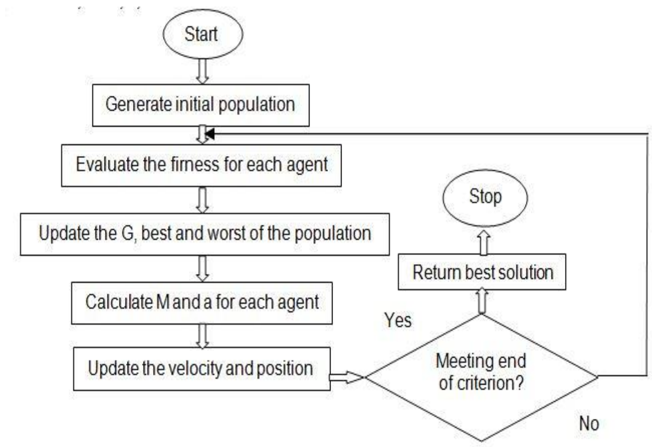

Figure 3. GSA analysis flow chart

6. BAT ALGORITHM (BA)

BA is a nature inspired algorithm proposed by Xin-She Yang in 2010 [24]. The algorithm exploits the so called echo location of the bat [25]. This research presents that the optimal allocation of DGs over a period of 24 hours in the system. The real and reactive power losses will be determined by using BA after placing DGs in the system. The following flowchart is the process to find the optimal location and size of the DGs in the system.

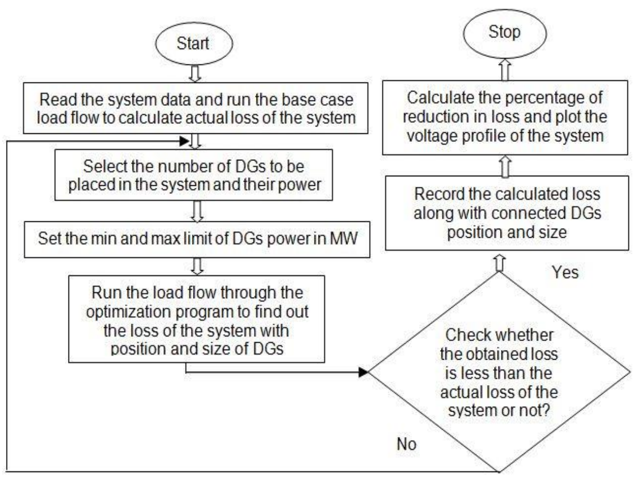

Figure 4. Bat algorithm analysis flowchart

7. DISCUSSION

This research presents an effective and efficient comparison analysis to find the best location and capacity of DGs using BA over a period of 24 hours. The results of this BA are compared with BW/FW sweep analysis and GSA analysis. This is implemented using MATLAB software. For this research IEEE 33 radial system has considered. The IEEE 33 radial system has shown in fig. 5. For location of DGs, system real power losses are considered.

To analyses the power losses in the system using BA, initially the size of population, pulse rate, frequency and loudness etc. parameters are considered.

IEEE 33 bus radial distribution system consists of 32 branches and 33 nodes with the base MVA is 100 and the base KV is 12.62 kV.

8. RESULT

The performance results of the BW/FW sweep analysis before DG placement, GSA analysis on load condition and BA analysis on load condition on IEEE 33 bus are as shown in table.1 and table 2.

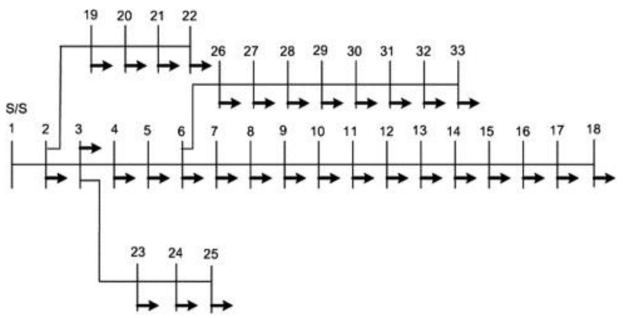

Figure 5. Radial distribution IEEE 33 bus system

Initially, the FW/BW sweep method is explained to study the power flow line distribution network. The bus and line data of distribution network is examined, which include 33 nodes and 32 branches. It is contrast by available technique like BW/FW sweep, GSA and BA. In this section, the performances of the techniques are inspected in terms of the current, voltage, actual and immediate power of IEEE 33 bus distribution scheme. The power losses are determined in different hours and demonstrated in Fig. 6, 7, 8, 9 and 10.

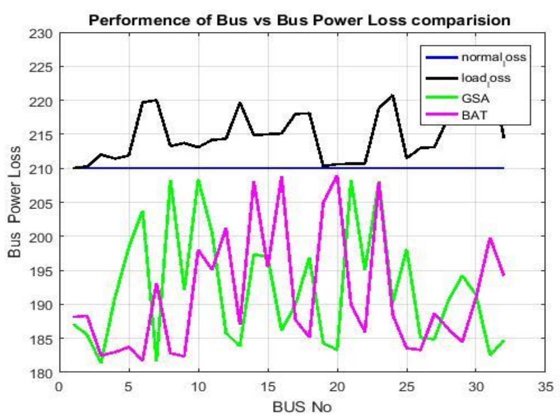

Figure 6. Performance of Power Loss by different algorithms at hour 7

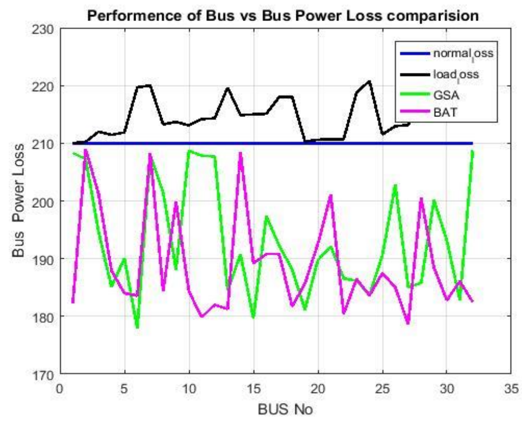

Figure 7. Performance of Power Loss by different algorithms at hour 8

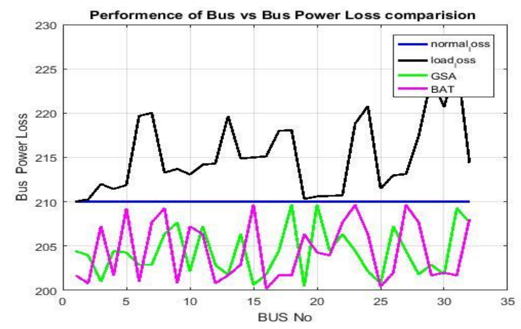

Figure 8. Performance of Power Loss by different algorithms at hour 9

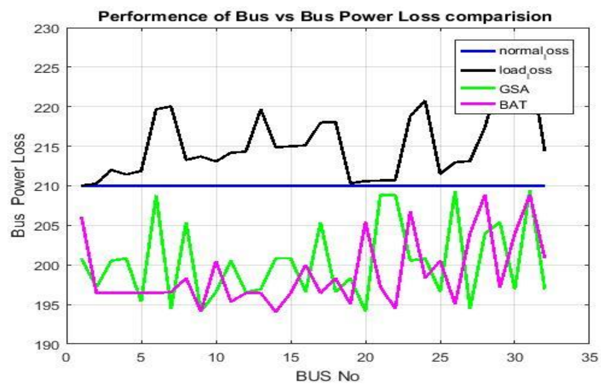

Figure 9. Performance of Power Loss by different algorithms at hour 12

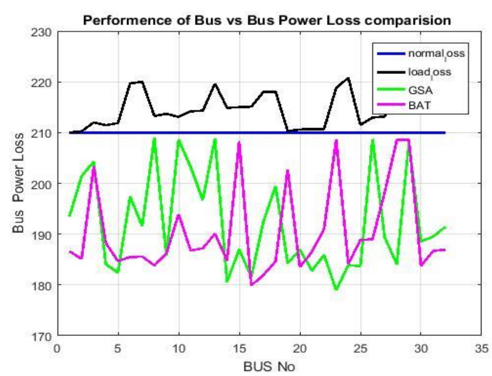

Figure 10. Performance of Power Loss by different algorithms at hour 16

During 24 hours in a day the sufficient PV energy will be available only from 7th to 16th hours only. From the result it is very clear that the BA analysis is effective and efficient algorithm to reduce power losses and gives an optimal location and optimal size of the DG.

By using the projected method, the voltage stability index, voltage profiles, and the power loss of the system is also assessed. Later the difference voltage values are contrast by those of the BW/FW sweep, GSA and BA. Now, the expected method VSI is 0.0208. The finest position and capability of DG is investigated in the diverse position is tabularized in table 2 and 3.

Table 1. Power loss comparison

Methods	**Power Loss (kW)**	**VSI (p.u)**
Bat algorithm	79.2159	0.0208
GSA method	170.8819	0.9064
Biogeography-Based Optimization (BBO) [26]	150.91	-
Particle Swarm Optimization (PSO) [26]	108.78	-
Genetic Algorithm (GA) [26]	78.55	-
multi objective particle swarm optimization (MOPSO) [27]	39.82	0.028
Strength Pareto Evolutionary Algorithm (SPEA) [27]	140.5	0.032
Non-dominated Sorting Genetic Algorithm (NSGA) [27]	64.74	0.033
Multi-Objective Differential Evolution (MODE) [27]	54.1	0.025
Imperialist Competitive Algorithm and Genetic Algorithm (ICA/GA) [27]	50.44	0.018

Table 2. Power loss comparison of BW/FW sweep analysis and GSA analysis

PL Loss Normal(kw)				**210.016**									
Hour				7	8	9	10	11	12	13	14	15	16
PL Loss Load (kw)	Load added (kw)	Load added Bus No											
210	50	1	PL GSA (KW)	191	185	204	172	178	195	207	193	208	189
			PV Bus	8	12	6	12	29	11	16	4	12	8
			Capacity (KW)	5	12	60	85	100	100	85	60	12	5
			Loss Deviation	19	25	6.3	38	32	15	2.7	17	1.9	20.9
220	100	7	PL GSA (KW)	187	185	209	192	187	194	206	180	208	186
			PV Bus	11	10	10	7	5	14	5	11	4	9
			Capacity (KW)	5	12	60	85	100	100	85	60	12	5
			Loss Deviation	33	35	11	28	33	26	14	40	12	33.9
213	210	24	PL GSA (KW)	183	179	202	170	181	201	202	209	208	186
			PV Bus	11	17	28	18	6	16	3	2	11	9
			Capacity (KW)	5	12	60	85	100	100	85	60	12	5
			Loss Deviation	29	33	11	42	31	12	11	3.9	4.7	26.3
221	100	29	PL GSA (KW)	186	189	202	186	188	200	205	180	209	180
			PV Bus	13	9	7	29	4	14	12	10	7	14
			Capacity (KW)	5	12	60	85	100	100	85	60	12	5
			Loss Deviation	35	32	20	36	33	22	17	41	12	41.5

Table 3. Power Loss comparison of BW/FW sweep analysis and BAT analysis

PL Loss Normal(kw)				**210.016**									
Hour				7	8	9	10	11	12	13	14	15	16
PL Loss Load (kw)	Load added (kw)	Load added Bus No											
202	45	2	PL BAT (KW)	188	187	202	187	208	201	210	190	209	187
			PV Bus	12	28	19	29	19	2	20	7	22	11

			Capacity (KW)	5	12	60	85	100	100	85	60	12	5
			Loss Deviation	13	15	0.2	15	-6	1.1	-8	12	-7	15
210.9	60	3	PL BAT (KW)	202	204	202	208	208	197	196	191	208	182
			PV Bus	4	23	23	20	21	2	22	26	32	16
			Capacity (KW)	5	12	60	85	100	100	85	60	12	5
			Loss Deviation	8.6	7.1	9.2	3.1	3.3	14	15	19	2.6	29
210.8	30	5	PL BAT (KW)	184	184	209	204	201	196	198	181	210	185
			PV Bus	11	13	30	21	23	20	2	15	13	10
			Capacity (KW)	5	12	60	85	100	100	85	60	12	5
			Loss Deviation	27	27	1.6	6.6	9.5	14	12	30	1	26
190	30	11	PL BAT (KW)	182	184	201	190	187	196	202	186	208	185
			PV Bus	14	32	16	4	14	27	11	14	14	32
			Capacity (KW)	5	12	60	85	100	100	85	60	12	5
			Loss Deviation	8.3	6.4	-11	-0	3.2	-6	-12	3.8	-18	4.5
216.4	45	18	PL BAT (KW)	187	208	201	208	185	198	209	184	208	79
			PV Bus	6	13	7	2	20	7	7	12	18	15
			Capacity (KW)	5	12	60	85	100	100	85	60	12	5
			Loss Deviation	30	8	16	8.5	31	18	7.4	32	8.4	137

Initially, the vulnerable buses are identified on the maximum power loss and VSI. After the DG is placed and expected their capability by different methods. The above tables 1, 2 and 3 prove that the different location and capacity of DG. In the table prove their power loss reducing and DG capacity. In the base condition, the loss is 210.016 kW. The performances are comparing by the BW/FW sweep method, GSA and BA technique. In the BA method, the base losses are reduced up to 79.3619 kW.

9. CONCLUSION

Firstly finding the power losses from power flow analysis using BW/FW sweep analysis on IEEE 33 bus radial system. After that BA is used to find the optimal location and size of the DG in order to reduce the power losses and optimize the voltage. These methods implemented on MATLAB/Simulink software under normal and loaded conditions. By the comparison of different algorithms it is clearly shown that the BA analysis is the efficient and effective power flow analysis for the radial power distribution networks.

REFERENCES

[1] Ackermann T, Andersson G, Soder L. (2001). Distributed generation: a definition. Electr. Power Syst. Res 57(3): 195-204. https://doi.org/10.1016/S0378-7796(01)00101-8

[2] Pepermans G, Driesen J, Haeseldonckx D, Belmans R, D'Haeseleer W. (2005). Distributed generation: definition, benefits and issue. Energy Policy 33(6): 787-798. https://doi.org/10.1016/j.enpol.2003.10.004

[3] Mithulananthan N, Than O, Phu LV. (2004). Distributed generator placement in power distribution system using genetic algorithm to reduce losses. TIJSAT 9 (3): 55-62. https://doi.org/10.7227/IJEEE.43.2.2

[4] Georgilakis PS, Hatziargyriou ND. (2013). Optimal distributed generation placement in power distribution networks: models, methods and future research. IEEE Trans. Power Syst. 28(3): 3420-3428. https://doi.org/10.1109/TPWRS.2012.2237043

[5] Naik SG, Khatod DK, Sharma MP. (2012). Optimal allocation of combined DG and capacitor for real power loss minimization in distribution networks. Int. J. Emerg. Technol. Adv. Eng. 2(9): 381-388. https://doi.org/10.1016/j.ijepes.2013.06.008

[6] Griffin T, Tomsovic K, Secrest D, Law A. (2000). Placement of dispersed generation systems for reduced losses. 33th Proceeding Hawaii Int. Conf. On System Sciences, pp. 1-9. https://doi.org/10.1109/HICSS.2000.926773

[7] El-Zonkoly AM. (2011). Optimal placement of multi-distributed generation units including different load models using particle swarm optimization. IET Generation, Transmission, Distribution 5(7): 760–771. https://doi.org/10.1049/iet-gtd.2010.0676

[8] Tan WS, Hassan MY, Rahman HA, Abdullah P, Hussin F. (2013). Multi-distributed generation planning using hybrid particle swarm optimisation- gravitational search algorithm including voltage rise issue. IET Generation Transmission, Distribution 7(9): 929–942. https://doi.org/10.1049/iet-gtd.2013.0050

[9] Gopiya Naik SN, Kumar Khatod D, Sharma MP. (2015). Analytical approach for optimal siting and sizing of distributed generation in radial distribution networks.

IET Generation Transmission, Distribution 9(3): 209–220. https://doi.org/10.1049/iet-gtd.2014.060
[10] Narayanan K, Shahbaz AS, Manoj F. (2015). Identification and reduction of impact of islanding using hybrid method with distributed generation. In Proceedings of IEEE Power & Energy Society General Meeting, pp. 1-5. https://doi.org/10.1109/PESGM.2015.7286467
[11] Gomez-Gonzalez M, Lopez A, Jurado F. (2012). Optimization of distributed generation systems using a new discrete PSO and OPF. An International Journal of Electric Power Systems Research 84: 174–180. https://doi.org/10.1016/j.epsr.2011.11.016
[12] Pavlos SG, Nikos DH. (2013). Optimal distributed generation placement in power distribution networks: Models, methods, and future research. IEEE Transactions on Power Systems. 28(3). https://doi.org/10.1109/TPWRS.2012.2237043
[13] Prakash P, Dheeraj KK. (2016). Optimal sizing and siting techniques for distributed generation in distribution systems: A review. An International Journal of Renewable and Sustainable Energy Reviews 57: 111–130. https://doi.org/10.1016/j.rser.2015.12.099
[14] Kansal S, Kumar V, Tyagi B. (2016). Hybrid approach for optimal placement of multiple DGs of multiple types in distribution networks. An International Journal of Electrical Power and Energy Systems 75: 226–235. https://doi.org/10.1016/j.ijepes.2015.09.002
[15] Mohanty B, Tripathy S. (2016). A teaching learning based optimization technique for optimal location and size of DG in distribution network. An International Journal of Electrical Systems and Information Technology 3: 33–44. https://doi.org/10.1016/j.jesit.2015.11.007
[16] Muthukumar K, Jayalalitha S. (2016). Optimal placement and sizing of distributed generators and shunt capacitors for power loss minimization in radial distribution networks using hybrid heuristic search optimization technique. An International Journal of Electrical Power and Energy Systems 78: 299–319. https://doi.org/10.1016/j.ijepes.2015.11.019
[17] Wang CS, Song GY, Li P, Ji HR, Zhao JL, Wu JZ. (2017). Optimal siting and sizing of soft open points in active electrical distribution networks. An International Journal of Applied Energy 189: 301–309. https://doi.org/10.1016/j.apenergy.2016.12.075
[18] Daud S, Kadir AFA, Lada MY, Gan CK. (2016). A review: Optimal distributed generation planning and power quality issues. International Review of Electrical Engineering. 11(2): 208. https://doi.org/10.15866/iree.v11i2.5806
[19] Ali ES, Abd Elazim SM, Abdelaziz AY. (2017). Ant lion optimization algorithm for optimal location and sizing of renewable distributed generations. An International Journal of Renewable Energy 101: 1311-1324. https://doi.org/10.1016/j.renene.2016.09.023
[20] Saha S, Mukherjee V. (2016). Optimal placement and sizing of DGs in RDS using chaos embedded SOS algorithm. IET Generation, Transmission and Distribution 10(14): 3671-3680. https://doi.org/10.1049/iet-gtd.2016.0151
[21] Abbasi F, Hosseini SM. (2016). Optimal DG allocation and sizing in presence of storage systems considering network configuration effects in distribution systems. IET Generation, Transmission and Distribution 10(3): 617-624. https://doi.org/10.1049/iet-gtd.2015.0367
[22] Quinlan B, Kaufmann B, Allesina G, Pedrazzi S, Whipple S. (2017). Application of OLTT in gasification power systems. International Journal of Heat and Technology 35(4): 773-778. https://doi.org/10.18280/ijht.350411
[23] Jamian JJ, Mustafa MW, Mokhlis H, Baharudin MA, Abdilahi AM. (2014). Gravitational search algorithm for optimal distributed generation operation in autonomous network. Arabian Journal for Science and Engineering 39: 7183–7188. https://doi.org/10.1007/s13369-014-1279-0
[24] Abd-Elazim SM, Ali ES. (2016). Load frequency controller design via BAT algorithm for nonlinear interconnected power system. International Journal of Electrical Power & Energy Systems 77: 166-77. https://doi.org/10.1016/j.ijepes.2015.11.029
[25] Sudabattula SK, Kowsalya M. (2016). Optimal allocation of solar based distributed generators in distribution system using Bat algorithm. Perspectives in Science 8: 270-275. https://doi.org/10.1016/j.pisc.2016.04.048
[26] Ghaffarzadeh N, Sadeghi H. (2016). A new efficient BBO based method for simultaneous placement of inverter-based DG units and capacitors considering harmonic limit. Electrical Power and Energy Systems 80: 37–45. https://doi.org/10.1016/j.ijepes.2016.01.030
[27] Zeinalzadeh A, Mohammadi Y, Moradi MH. (2015). Optimal multi objective placement and sizing of multiple DGs and shunt capacitor banks simultaneously considering load uncertainty via MOPSO approach. Electrical Power and Energy Systems 67: 336–349. https://doi.org/10.1016/j.ijepes.2014.12.010

NOMENCLATURE

V_{ni}	ni bus voltage
$V_{specified}$	Specified Voltage ($1\angle 0^0$ Per Unit)
P_{gi}	Generator active power output at i^{th} bus
P_{di}	Active power demand at i^{th} bus
V_{mi}	mi bus voltage
Y_{mni}	admittance of branch between mi and ni bus
N	total number of buses
N_i	bus number of receiving end
M_i	bus number of sending end
i	branch number

Greek symbols

δ_{mi}	mi bus voltage phase angle
δ_{ni}	ni bus voltage phase angle
θ_{ni}	angle of admittance of$Y_i = Y_{ni}\angle\theta_{ni}$
H	density factor
$P_{ni}(ni)Q_{ni}(ni)$	Total real power fed through bus ni
R_{ni}	Total reactive power through bus ni
X_{ni}	i^{th} branch resistance
$VSI\ (ni)$	i^{th} branch reactance
V_{max}	VSI of ni node
V_{min}	Maximum Voltage
$S^{dg}{}_{max}$	Minimum Voltage
$S^{dg}{}_{min}$	at bus ni maximum apparent power
$S^{dg}{}_{ni}$	at bus ni minimum apparent power
P_{PV}	at bus ni apparent power

P_{md}	
N_S	PV array output Power
N_P	maximum power produced by PV
V_{OC}	Series PV modules
I_{SC}	Parallel PV modules
FF	voltage when the circuit is open
G_N	current when the circuit is short
G_a	Fill Factor of PV cell
T_N	nominal solar irradiance on PV cell
T_a	actual solar irradiance on PV cell
V_{NOC}	nominal PV cell temperature
I_{NSC}	actual PV cell temperature
R_S	nominal open circuit voltage of PV cell
c_1, c_2 and c_3	nominal short circuit current of PV cell
T	series resistance of PV cell
K	three various constants
q	
GF	PV cell temperature (in Kelvin)
GC	Boltzmann's constant (1.38 X 10^{-23} J/K)
M_i	charge of electron (1.6 X 10^{-19} C)
M_j	Gravitational Force
D	Gravitational Constant
fit	Mass of object i
Bad	Mass of object j
Good	Distance between objects
d	fitness

Abbreviations

BA	BAT Algorithm
GSA	Gravitational Search Algorithm
DG	Distributed Generation
FW/BW	Forward and Backward
PV	Photo Voltaic
PL	Power Losses
PDS	Power Distribution System
PQ	Power Quality
CPD	Custom Power Devices
VSI	Voltage Stability Index
CSP	Concentrated Solar Plant
LCOE	Levelized Charge Of Energy
NREL	National Renewable Energy Lab
FF	Fill Factor