Port Said Engineering Research Journal
Faculty of Engineering - Port Said University
Volume 26 No. 2 pp: 94:101

Optimal Size and Location of DG in the Distribution System for Power Loss and Voltage Deviation Minimization

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DOI: 10.21608/pserj.2021.87406.1130

Received 27-7-2021,
Revised 18-9-2021
Accepted 12-10-2021

ABSTRACT

Allocation of the distribution generator (DG) in the distribution system faces many challenges. The selection of the best location and capacity of the DG must be carefully selected as this affects the performance and stability of the system. This paper proposes the application of the Particle Swarm Optimization (PSO) technique to find the optimum location of DG in the distribution network for active and reactive power compensation to reduce the power losses and enhance the voltage profile. The main objective of the paper is to determine an appropriate location and size for different types of DG and investigate the impact of Battery Energy Storage System (BESS) in the distribution systems. The proposed technique is tested standard IEEE 33-bus and simulated in MATLAB to indicate the effectiveness of the PSO algorithm in solving the optimization problems of placement and sizing of multi-type DGs. and the obtained results are compared without distributed generation. The simulation results ensure the ability of the proposed algorithm for achieving the goals.

Keywords: Distributed generation, Particle swarm optimization, Distribution system, Battery Energy Storage System.

1. INTRODUCTION

To fulfill the ever-rising need in the rebuilt power network, distributed generations (DGs) are found as an effective other option to overcome the restrictions of established new power plants and transmission lines. Environmental considerations have encouraged the development and use of DGs. The addition of DG in distribution systems gives huge advantages to the power system such as reducing power loss, voltage improving, and increasing the stability of the power network. Conventional distribution systems are constructed to transfer power flow in one way from source to load. The installation of a new DG in power systems modifies the power flow and allows for different operating conditions in the distribution systems. This can cause many problems such as increasing fault impact, increasing voltage and reverse power flow [1]. The maximum size of DG should be consumable inside the limits of the substation distribution. Installing the DG with a high capacity to supply the load of the distribution system may cause reverse power flow and higher losses [1].

There are various types of techniques and resources that can be added to the system as DG such as, biomass, hydrogen, fuel cells, solar, and wind. Each DG type has a different impact on the power flow of the system, where DG is classified according to the injected power of DG to the system as follows [2]:

Type 1: DGs supply active power only to the system such as PV systems.
Type 2: DGs supply both active and reactive power to the system such as current controlled PV, synchronous generator, and fuel cell.
Type 3: DGs supply reactive power only to the system such as synchronous condenser.
Type 4: DGs supply active power and absorb reactive power such as wind turbines and induction generators.

Where type 1 DG and type 2 DG are used to satisfy the objectives of this paper. Therefore, before installing the DG source, the size and position must be selected correctly. It has been noted that the deployment of DGs of unsuitable size at non-optimal locations will lead to increased device losses and total costs. It highlights the significance of the optimum distribution of DGs. Even so, the choice of the most appropriate location and size of DG units represents a complex multi-objective optimization problem in large distribution systems, and it can be described as a nonlinear problem of mixed-integer optimization. Requirements for solving or goals vary from one application to another and are often subject to specific limitations. The difficulty of the optimization process increased with more targets and restrictions. Fig. 1 shows some of the different objectives of DG placement which are mentioned in many studies. Minimization of power loss, improvement of the bus voltage are objectives that are considered in this paper.

In general, a multi-objective function is taken into consideration to get a practical solution to this problem. Experiences in such problems have demonstrated that the objectives are considered to be conflicting in nature when framing the optimization problem. For these situations, weights are allocated to the individual objectives and those weights are determined crucially based on the relative importance given to the respective objectives. Frequently, these weights are determined by the operator's knowledge, previous experiences, research methods, and so on to aim for a better trade-off. Various methods for improving distribution network objectives have been introduced through the optimal positioning and rating of DG units such as Tabu Search (TS), Dynamic Programming (DP), Evolutionary Programming (EP), Fuzzy System (FS), Particle Swarm Optimization (PSO), Adaptive Weight Particle Swarm Optimization (AWPSO), Ant Bee Colony (ABC), Teaching Learning Based Optimization (TLBO), Genetic Algorithm (GA), Ant Colony Optimization (ACO), and so on.

Within this paper, the PSO approach is applied to find the optimal sizing and placement of DG in the distribution system. The PSO technique is mentioned later in more detail in this paper. In [3], TS is used to select the optimal location of DG, but TS is not a fast algorithm. Authors in [4] presented an analytical solution to determine the optimal location for many types of DGs according to the optimal DG size which satisfies minimum power loss. ABC algorithm is used in [5] to determine the impact of DG size which reduces the power loss. In [6], researchers are used GA to determine the suitable size and placement of DG to reduce the cost of the generated powers from the power system. EP is used to solve many optimization problems due to its good characteristics and not complex [7]. In [8], the authors are presented many types of PSO algorithm to solve many optimization problems of the power system. In [9], the PSO algorithm is used for optimal allocation of multiple DGs in the distribution system, where the obtained results indicated that the PSO method is efficient for power loss reduction and improving voltage stability. In [10], researchers are used both PSO and EP for the optimal location of DG, the obtained results indicated that both techniques have satisfied converging results. In [11], researchers used a new technique to determine the optimal location and size of DG for reducing the power losses and improving the voltage profile, this technique is used a fuzzy approach to determine the optimal location and used PSO to find the optimal DG size. In [12], the authors used hybrid GA-PSO methodology to find the optimal location and size of DG in radial distribution systems for getting the features of both techniques and solving with better optimization results.

In [13], the authors used TLBO and ABC algorithms to determine the optimal allocation of different types of DG, the obtained results indicated that ABC is more effective than TLBO for solving the optimization problems. The power losses were decreased with increasing the capacity of DG for a specific bus, and the installation of extremely high DGs in the network is not recommended in the distribution system [14]. The size of the distribution system in MW will impact the selection of the size of DG. Increasing the DG capacity caused higher losses because the distribution system was constructed where the power flows from the source to the load and the size of conductors from the sending end to the receiving end slowly decreases. In [15], a hybrid technique of ABC with the ACO algorithm is used to determine the optimal location and size of DG in the distribution system. A methodology for DG placement in electric power systems using the GA method is presented given the minimization of system power loss under various loading conditions in [16]. In [17], the GA algorithm is implemented with different load models to determine the suitable location and size of DG for satisfying multi-objective functions. In [18], a PSO is used to determine the optimal DG placement; a GA-based optimization technique and optimal power flow have been applied to reduce the cost of active and reactive power generation, taking into account the cost of installation of DG. In [19], a new approach based on nodal pricing has been proposed to determine the optimal allocating of DG in the radial distribution system. In [20], the authors have used the loss sensitivity factor with an analytical expression to determine the optimal allocating of DG for minimizing the power losses in the distribution system. Authors in [21] used GA with an optimal proposed approach (OPA) to satisfy multi objectives under many constraints for determining the optimal size and placement of DG.

The main objective of the paper is to determine an appropriate location and size for different types of DG and investigate the impact of Battery Energy Storage systems (BESS) in the system. PSO algorithm is used in this paper to obtain these objectives, while satisfying system constraints. The standard IEEE 33-bus is simulated in MATLAB to indicate the effectiveness of the PSO algorithm in solving the optimization problems of placement and sizing of multi-type DGs.

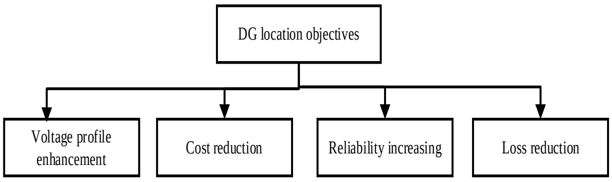

Figure 1: Different objectives of optimal sizing and location of DG.

2. PROBLEM FORMULATION

The problem of DG being optimally positioned and sized is described as a minimization problem. It is necessary to formulate the objective function of the problem to be optimized as well as satisfying the operating precautions. The optimization problem can be formulated in two types based on the number of objectives to be accomplished together, namely multi-objective optimization problems or single-objective optimization problems. In this paper, minimizing the voltage deviation and power loss reduction of the system are selected to be the objectives of the optimization problem.

2.1. Objective functions

The primary objective of this optimization issue is to decide the best location and size of the DG with BESS, which will optimize different important variables relevant to the performance of the system.

- **First objective: minimizing the power loss (F_1)**

Overall active power losses expressed as follows [22]:

$$P_{loss} = \sum_{l=1}^{N_l} |I_l|^2 R_l \tag{1}$$

where, I_l is the current passing through line l, R_l is the resistance of the line l, and N_l is the total number of the system lines.

The objective function to minimize the power losses can be expressed as follows [23]:

$$F_1 = min\ [P_{loss}] \tag{2}$$

- **Second objective: minimizing the voltage deviation (F_2)**

The deviation between the bus voltage and the rated voltage is determined. The objective function to enhance the voltage stability is the sum of the voltage deviations for all buses, and the voltage deviation is improved by minimizing the obtained value of this algorithm [24]. The objective function of the voltage deviation is described as follows [24]:

$$\Delta V = \sum_{i=1}^{N_b} |V_i - V_r| \tag{3}$$

$$F_2 = min[\,\Delta V] \tag{4}$$

where ΔV is the voltage deviation, V_i is the voltage of bus i, V_r is the rated bus voltage, and N_b is the total system buses. Minimization of multi-objective function

$$F = min\ (w_l F_1 + w_v F_2) \tag{5}$$

where F is the objective function, w_l, $w_v$are the weighting factors for power losses and voltage deviation, respectively. Generally, it is hard to ascertain the correct values of the important factors. Heuristics and the expertise of distribution engineers can also be used wisely to achieve appropriate values. Also, the weighting factors should be flexible since electrical networks face different problems, such as voltage deviation and system loss. The value of weighting factors is determined according to the following equation [12]:

$$w_l + w_v = 1 \tag{6}$$

2.2. Constraints

A. Voltage constraints:

The next constraint is used to satisfy that the voltage at each bus in the network is inside the acceptable limits [12].

$$v_{i_{min}} \le |V_i| \le v_{i_{max}} \tag{7}$$

where $v_{i_{min}}$ is the minimum voltage of bus i , V_i is the voltage at bus i, and $v_{i_{max}}$ is the maximum voltage of bus$i$. The operating limits of the voltage system are regarded to be $\pm 10\%$ of the rated voltage [12].

B. DG constraints:

To get a significant effect of DG on the system and to prevent the issue of voltage increase, limitations are placed on the size of DGs. It is very important to take into consideration the minimum and maximum value of the generated power from DG; because of economic and technical reasons. The active and reactive powers created by DG are limited with lower and upper limits as follows [12]:

Active power generating limits of DG:

$$p_{DGi_{min}} \le P_{DGi} \le p_{DGi_{max}} \tag{8}$$

Reactive power generating limits of DG:

$$Q_{DGi_{min}} \le Q_{DGi} \le Q_{DGi_{max}} \tag{9}$$

where, P_{DGi}, Q_{DGi} are the generated active and reactive powers of DG at bus i (watt), $p_{DGi_{min}}$ is DG's minimum active power and is determined at 25% of the whole load (watt), $p_{DGi_{max}}$ is DG's maximum active power and is determined at 80% of the load (watt), $Q_{DGi_{min}}$is DG's minimum reactive power (watt), $Q_{DGi_{max}}$ is DG's maximum reactive power (watt) [9].

C. BESS constraints:

It is considered that BESS is connected via bidirectional DC/AC converters to an AC system [25]. To discharge or charge active power, it can work at any required power factor (leading /lagging). In other cases, during discharging times, BESS will act as a generator, and during charging periods will act as a load. It can also consume reactive power or insert it. In duration t, the BESS energy variance at bus *i* can be described as [26]:

$$Discharge: E_{Bi}(t) = E_{Bi}(t-1) - \frac{p_{Bi}^{D}}{\varepsilon_d}\Delta t \qquad (10)$$

$$Charge: E_{Bi}(t) = E_{Bi}(t-1) + \varepsilon_c p_{Bi}^{C}\,\Delta t \qquad (11)$$

where E_{Bi} is the whole stored energy in the BESS, p_{Bi}^{D} and p_{Bi}^{C} are the discharge and charge power of the BESS, respectively, ε_d and ε_c are the discharge and charge coefficient of the BESS, respectively, Δt is the duration of the period t.

The BESS's lower and upper power limits should be met as follows [25]:

$$p_{Bi_{min}} \leq p_{Bi}(t) \leq p_{Bi_{max}} \qquad (12)$$

where $p_{Bi_{min}}$and $p_{Bi_{max}}$ are the lower and upper power limits of the BESS, respectively. In this paper, the lower and upper limits are estimated to account for 15% and 80% of the total load, respectively [27].

3. PARTICLE SWARM OPTIMIZATION (PSO)

The selection of an effective optimization technique is very critical for a nonlinear system with different operating constraints. Researchers have widely used different algorithms for overcoming nonlinear programming problems, particle swarm optimization (PSO) is used in this paper to obtain better optimization results. PSO is one of the most recent progressive algorithms designed by Eberhard and Kennedy [28, 29]. PSO is influenced by social experiences of fish schooling or bird flocking. The first edition of PSO was designed to deal with continuous nonlinear optimization problems only. Nevertheless, several developments in PSO growth have improved its ability to face a wide variety of complex problems in engineering and science optimization. Researchers developed various variants of the PSO algorithm. PSO is an evolutionary computing strategy not adversely influenced by the problem's scale and nonlinearity. PSO has the following merits over alternative population-based evolutionary algorithm GA:

1- PSO is easier to incorporate, and fewer adjustment parameters are needed.
2- Has greater memory capacities than the GA.
3- In PSO, all particles, which are referred to as potential solutions, are used the knowledge concerning the most productive particle to boost it, however in GA, the worst solutions are rejected and only saved the good ones.

PSO is a parallel multi-agent evolutionary algorithm. Particles are mathematical structures moving around multidimensional search spaces. At any given moment, each particle has its velocity and location. The positioning of a particle vector concerning the origin of the search space is an experimental solution to the search problem. Initially, a particle population is adjusted with random locations and random velocity.

A d-dimensional search space assumes that a swarm has n particles. The fundamental template of PSO can be represented in mathematical terms as follows:

The primary random n position of the particles is as follows:

$$p = \begin{bmatrix} p_1{}^{k} = (p_{11}{}^{k}, p_{12}{}^{k}, \dots\dots\dots\dots., p_{1d}{}^{k}) \\ p_2{}^{k} = (p_{21}{}^{k}, p_{22}{}^{k}, \dots\dots\dots\dots., p_{2d}{}^{k}) \\ P_i{}^{k} = (p_{i1}{}^{k}, p_{i2}{}^{k}, \dots\dots\dots \quad \dots., p_{id}{}^{k}) \\ P_n{}^{k} = (p_{n1}{}^{k}, p_{n2}{}^{k}, \dots\dots\dots\dots., p_{nd}{}^{k}) \end{bmatrix} \qquad (13)$$

The primary random n velocity of the particles as follows:

$$v = \begin{bmatrix} v_1{}^{k} = (v_{11}{}^{k}, v_{12}{}^{k}, \dots\dots\dots\dots., v_{1d}{}^{k}) \\ v_2{}^{k} = (v_{21}{}^{k}, v_{22}{}^{k}, \dots\dots\dots\dots., v_{2d}{}^{k}) \\ v_i{}^{k} = (v_{i1}{}^{k}, v_{i2}{}^{k}, \dots\dots\dots \quad \dots., v_{id}{}^{k}) \\ v_n{}^{k} = (v_{n1}{}^{k}, v_{n2}{}^{k}, \dots\dots\dots\dots., v_{nd}{}^{k}) \end{bmatrix} \qquad (14)$$

where, $p_{id}{}^{k} = (p_{i1}{}^{k}, P_{i2}{}^{k}, \dots\dots\dots \quad \dots., p_{id}{}^{k})$ refers to the position of the particle (i^{th}) at the iteration (k^{th}), so the previous best position is determined as follows:

$$(p_{best})_{id}{}^{k} = ((p_{best})_{i1}{}^{k}, (p_{best})_{i2}{}^{k}, \dots, \ (p_{best})_{id}{}^{k})$$

Additionally, the best location between all the particles is defined by

$$(g_{best})_{d}{}^{k} = \left((g_{best})_{1}{}^{k}, (g_{best})_{2}{}^{k}, \dots, (g_{best})_{d}{}^{k}\right)$$

where, $v_{id}{}^{k} = (v_{i1}{}^{k}, v_{i2}{}^{k}, \dots\dots\dots \quad \dots., v_{id}{}^{k})$ refers to the velocity of the particle (i^{th}). At first, the g_{best} and p_{best} settings for all the particles are $x^{k=0}$. After initializing all particles, a repetitive process of optimization starts, where the velocities and positions of all particles are modified according to the following repeating equations. The equations have introduced the velocity and position of the i^{th} particle for the d^{th} dimension.

The velocity (v_{id}) and the position (p_{id}) of the particle (i^{th}) is determined according to the following equations respectively:

$$v_{id}{}^{k+1} = x_2 z_2\left({g_{best}}_d{}^k - p_{id}{}^k\right) + x_1 z_1\left({p_{best}}_{id}{}^k - p_{id}{}^k\right) + w v_{id}{}^k \qquad (15$$

$$p_{id}{}^{k+1} = p_{id}{}^k + v_{id}{}^{k+1} \qquad (16)$$

$$w = w_{max} - \left(\frac{w_{max}-w_{min}}{k_{max}}\right) * k \qquad (17)$$

where, x_1, x_2 are acceleration factors (usual x_1, x_2=2), z_1, z_2 variable numbers among 0&1, w is the weight of inertia, ${g_{best}}_d{}^k$ is global best of the group at iteration k, ${p_{best}}_{id}{}^k$ personal best of particle i^{th} at iteration k, $v_{id}{}^{k+1}$ is the updated velocity of a particle i^{th}, $v_{id}{}^k$ is the present velocity of a particle i^{th}, $p_{id}{}^{k+1}$is the updated position of a particle i^{th}, and $p_{id}{}^k$ is the present position of a particle i^{th}. x_1, x_2 are identified as "self-assurance" and "swarm assurance" respectively, w_{max} and w_{min} are the final and initial weight, k is the current iteration and k_{max} is the maximum iteration. These terms give vision from the social point of view. The factor x_1 depends on the experience of a particle and the factor x_2 refers to the direction of the particle in the global path, which observes the movement of all particles in the previous iteration of the program. As mentioned previously, the issues of optimization associated with the control and operation of the distribution system are complex and can be defined in terms of objective function or restrictions. The following are the characteristics of the PSO algorithm which make it desirable:

1- This algorithm has limited parameters.
2- It is free of derivatives.
3- It's very effective in carrying out international searches.
4- Compared with other methods it is easy to apply.
5- The objective function is used explicitly in PSO as an optimization problem.

These best characteristics make the PSO a multipurpose optimizer that handles a broad range of electric distribution systems optimization problems.

4. PROBLEM SOLUTION ALGORITHM

Determining the optimal allocating of DG with BESS to satisfy many objectives by using the PSO algorithm according to the following steps:

1- Input the data of the system
2- Execute a population of particles in solution space with random locations and velocities on dimensions, and consider the iteration$(k = 0$).
3- Using a Newton Raphson distribution load flow method to determine the bus voltage for each particle if it is inside the limits as indicated above, calculate the total loss or else, this particle is not possible.
4- Determine the objective optimization function for each particle.
5- Compare the objective function of each particle with the individual best. If the objective function value is lower than the past p_{best}, subsequently, put current p_{best} to present position.
6- Select the particle which has a minimum p_{best} of all particles, and consider this value is the present best overall g_{best} .
7- Upgrade the position and velocity of a particle according to Equations (15) and (16).
8- Determine the objective function of each particle and update the p_{best}, g_{best}.
9- Go to step 10, when the number of iteration exceeds the permissible limit. Or else, go to step 7 and apply iteration factor $k = k + 1$.
10- Print the results of the optimal solution to the problem. The best place involves DG's optimum positions and size that satisfy multi-objective functions.

The basic flow chart of the solution algorithm is shown in Fig. 2.

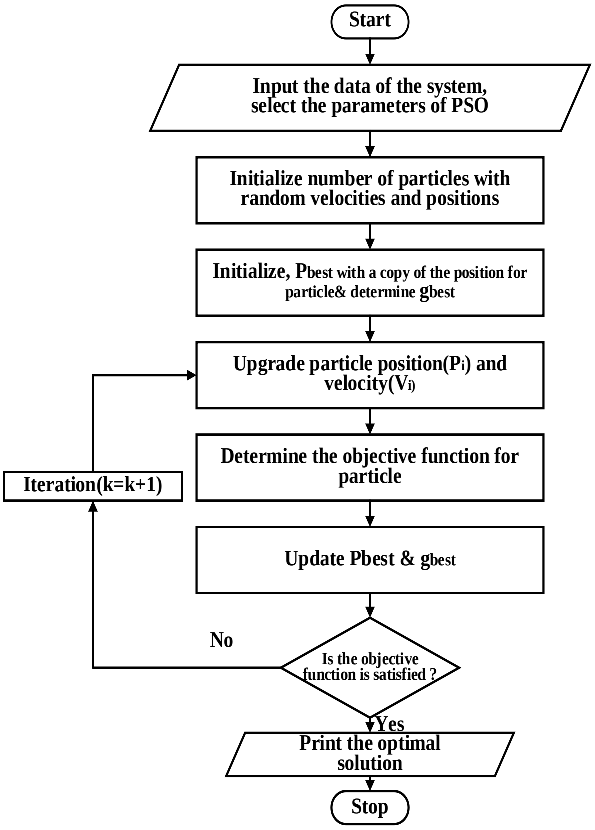

Figure 2: Flow chart of PSO algorithm

5. CASE STUDY

Minimizing the total power losses and enhancing the voltage deviation in the distribution systems are the main objective functions for studying the optimal location and size of DG. The standard IEEE 33-bus is simulated in MATLAB to indicate the effectiveness of the PSO algorithm in solving the optimization problem of placement and sizing of DG with BESS [9, 10, 23, 30, and 31]. Fig. 3 shows the single line diagram of the standard IEEE 33-bus. Table 1 shows the parameters of the PSO algorithm used in this paper and the detailed Data of the IEEE 33-bus system was shown in table 2. The overall active and reactive powers of the system are 3715 kW and 2300 kVAR respectively [32]. Where the power losses of the system without DG are 210.99 kW and the minimum voltage is 0.904pu at bus 18. The data of the loads are constant and base voltage ($V_{base} = 12.66\ kv$). Where, the base apparent power is 100 MVA, the loads and lines data are discussed in [30]. The upper and lower limits for voltages are determined to 1.1 pu and 0.90 pu respectively. The maximum real power from both DG and ESS is considered 2972 kW to avoid the negative impact of the increased DG size on the voltage limits [9], where DG is classified according to the injected power as follows:

Type 1: DG injects active power only.

Type 2: DG injects both active and reactive power.

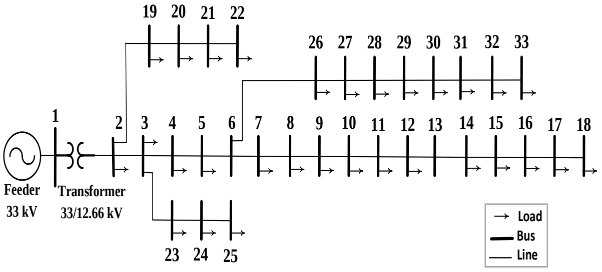

Figure 3: Single line diagram of the standard IEEE 33-bus.

6. SIMULATION RESULYS

6.1. Case 1: the optimal allocating of type 1 DG with BESS

The optimal allocating of type 1 DG is analyzed in this case according to values of weighting factors for both power loss and voltage deviation as shown in equation (5) and equation (6). Where the value of the weighting factors refers to the importance of each objective function.

PSO algorithm is used to determine the optimal location and size of type 1 DG which injects active power only to the tested power system. As shown in Table 2, the power loss is reduced with the addition of more DGs with BESS to the distribution system at the optimal location and with a suitable size. Where the power loss for the system without DG is 210.99 kW, but the power loss is 123 kW with the addition of a single DG at bus 6 with a DG size is 1812.72 kW. Adding the BESS to the single DG at the same bus reduced the power loss more to than 111kW (47.39% power loss reduction). Adding two DGs with BESS to the power system at buses 6 and 24 with a total DG and BESS size is 2648.6 kW reduced the power loss to 91.30 kW (56.73% power loss reduction). Adding three DGs at the buses 11, 24, and 29 with a total DG and BESS size is 2954.4 kW reduced the power loss to 74.1 kW (64.88% power loss reduction). Table 2 shows the optimal sizing and location of type 1 DG with BESS for the standard IEEE 33–bus system.

Table 1. Parameters of PSO algorithm

parameters	value
Maximum weight ($w_{\max}$)	1
Minimum weight($w_{\min}$)	0
Weighting factor (x_1)	2
Weighting factor (x_2)	2
Number of sources	100
Population size	50

As shown in Table 2, the voltage deviation is minimized with the addition of DGs of type 1 with BESS to the distribution system. Where the lowest value of the voltage is 0.904pu at bus 18 and the system without DG.

Table 2. The optimal allocation of type 1 DG for 33-bus network

Case	Without DG	1 DG	2 DG	3 DG
DG size (kW)	-----------	1812.72	1198.7 & 655.3	991&686.1&489.9
Power loss (kW) [with DG]		123	107	91
BESS size (kW)		776.88	588&206.6	400&203&184.4
Total size (kW) [DG + BESS]		2589.6	2648.6	2954.4
At Bus		6	6&24	11&24&29
Power loss (kW) [DG+ BESS]	210.99	111	91.3	74.1
Loss reduction (%)	-----------	47.39	56.73	64.88
Minimum voltage (pu) at bus	0.904 at bus 18	0.941at bus 18	0.954at bus 33	0.968at bus 33
Maximum voltage (pu) at bus 1	1	1	1	1

The voltage at bus 18 remained the minimum value, which equals 0.941pu with the addition of a single DG with BESS. The minimum voltage is 0.954pu at bus 33 with the addition of two DGs to the system, while the minimum voltage is 0.968pu at bus 33 with the addition of three DGs with BESS. Fig.4 shows the voltage deviation at different buses with the addition of multi DGs with BESS to the distribution system.

6.2. Case 2: the optimal allocating of type 2 DG with BESS

The optimal allocating of type 2 DG with BESS is analyzed in case two according to values of weighting factors for both power loss and voltage deviation as shown in (5) and (6). Where the value of the weighting factors refers to the importance of each objective function.

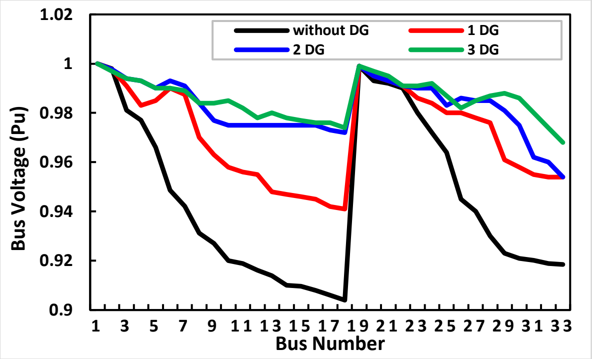

Figure 4: The voltage at buses with the addition of multi-type 1 DGs.

PSO algorithm is used to determine the optimal site and size of type 2 DG which injects both active and reactive powers to the tested system. As shown in table 3, the power loss is reduced with the addition of more DGs to the system at the optimal location and with a suitable size. Where the power loss for the system without DG is 210.99 kW, but the power loss is 84 kW with the addition of a single DG at bus 6 with a DG size 1790.7 kW/1318.1 kVAR.

Adding the BESS to the single DG at the same bus reduced the power loss more to 67.86kW (67.8% power loss reduction). Adding two DGs with BESS to the distribution system at the bus 11 and 30 with a total size 2596.6kW/1855.1kVAR reduced the power loss to 40.82 kW (80.65% power loss reduction) and adding three DGs with BESS at the buses 13, 24, and 30 with the total size 2837 kW/2158.8kVAR reduced the power loss to 19.63kW (90.70% power loss reduction)

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As shown in Table 3, the voltage deviation is minimized with the addition of multi-DGs of type 2 with BESS to the distribution system. Where the lowest value of the voltage is 0.904pu at bus 18 and the system without DG. The voltage at bus 33 is minimum which equals 0.956pu with the addition of a single DG and BESS with a total size is 2558.2 kW/1761.1 kVAR at bus 6. The minimum voltage is 0.981pu at bus 25 with the addition of two DGs and BESS to the system at bus 11 and 30 with a total size is 2596.6 kW/1855.1kVAR, while the minimum voltage is 0.983pu at bus 18 with the addition of 2837 kW/2158.8 kVAR from three DGs with BESS at bus 13, 24, and 30. Fig. 5 shows the voltage of different buses with the addition of multi DGs with BESS to the system.

Table 3. The optimal allocation of type 2 DG for 33-bus network

Case	Without DG	1 DG	2 DG	3 DG
DG size (kW/kVAR)	-----------	1790.7/1318.1	1275/977.4 & 548.6/325.7	841/721.8 &689/416 &552/387
Power loss (kW) [with DG]		84	62	34
BESS size (kW/kVAR)		767.5/443	518/367 & 255/185	321/292 &211/189 &223/153
Total size (kW/kVAR) [DG + BESS]		2558.2/1761.1	2596.6/1855.1	2837/2158.8
At Bus		6	11 & 30	13 &24 &30
Power loss (kW) [DG+BESS]	210.99	67.86	40.82	19.63
Loss reduction (%)	-----------	67.8	80.65	90.7
Minimum voltage (pu) at bus	0.904at bus 18	0.956at bus 33	0.981at bus 25	0.983at bus 18
Maximum voltage (pu) at bus 1	1	1	1	1

6.CONCLUSION

This paper has presented the importance of using an optimization technique to determine the optimal location and size of DGs in distributed systems. PSO is used in this paper to satisfy multi-objectives such as reducing power loss and minimizing the voltage deviation. Where, the obtained results show that the optimal allocating of (DG) according to a single- objective is different from one objective to another according to the weighting factor which indicates the importance of each objective. In addition, the impact of DG on the power system stability during disturbances. Two types of DGs are added to the tested IEEE-33 bus system. The obtained results show that the power loss of the system is reduced with the addition of DG and BESS to the system at the optimal location and size. The power loss of the system is reduced by adding type 2 DGs which provide the system with both active and. more than type 1 DGs which provide the system with active power only under the same conditions. The voltage deviation is minimized more with the addition of type 2 DG to the system; because type 2 DG provided the system with additional reactive power. The voltage deviation is reactive powers minimized by increasing the penetration level of DGs. The obtained results show that the power loss is reduced and voltage deviation is minimized with the addition of multi- DGs and BESS to the distribution system.

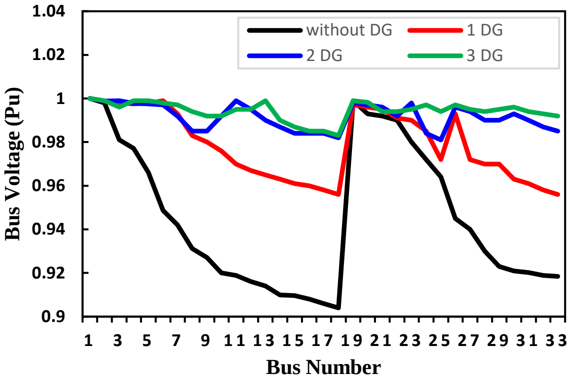

Figure 5: The voltage at buses with the addition of multi type 2 DGs.

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