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Optimal DG Placement Utilizing Harmony Search Based Hybrid GA-PSO Programming

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Abstract

Distributed generation (DG) refers to small-scale power generating facilities that are integrated into distribution systems to enhance the voltage profile, facilitate voltage regulation, improve stability, decrease power losses, and provide economic advantages. The aforementioned benefits can be attained through the strategic placement of DGs. In this manuscript, a novel nature-inspired optimization technique known as the Dragonfly algorithm is employed to ascertain the optimal size of DG units. This algorithm has been formulated based on the distinctive behavioural patterns exhibited by dragonflies in their natural environment. The primary focus of this algorithm is on the foraging behaviour of dragonflies, as well as their strategies for evading predators. The efficacy of the proposed algorithm is evaluated on the IEEE 33 and 69 test systems. The results generated by the proposed algorithm are subsequently presented and subjected to comparative analysis. When juxtaposed with other algorithms, the harmony search-based Genetic Algorithm-Particle Swarm Optimization (GA-PSO) demonstrates superior outcomes.

Keywords: Genetic Algorithm (GA), Particle Swarm Optimization (PSO); Harmony Search; Distributed Generation Placement; Radial Distribution System.

Introduction

Electric power systems are typically defined as the interconnection of generating, transmitting, and distributing systems. Power flow is typically unidirectional and distribution systems generally radial in form [1]. Modern distribution networks are dealing with a number of issues as a result of the constantly increasing demand. Numerous strategies for the deployment of distributed generators (DGs) have been suggested in the literature with the installation of various distributed power sources, such as capacitor banks and distributed generations. The majority of losses—roughly 70%—occur at the distribution level, which comprises the primary and secondary distribution systems, whereas 30% occur at the transmission level [2, 3].

Distribution systems are therefore the primary focus these days. At the distribution level, losses of roughly 7.5% are targeted. Losses can be reduced by placing DG units in strategic locations. Wind and photovoltaic (PV) energy. Due to their remote locations, dispersed generation units such as wind turbines and photovoltaic (PV) energy require operating systems that are fully linked into transmission and distribution networks. In order to lower loss, expense, and greenhouse gas emissions, the DG aims to interconnect all power plants [4]. The following technical and financial advantages are the primary justification for the use of DG units in power systems.

Among the principal benefits [5] are:

- A decrease in system losses
- Enhancement of the voltage profile
- An increase in frequency
- Lower pollution emissions
- A higher level of overall energy efficiency
- Improved system security and dependability
- Higher-quality power
- Reduced congestion in transmission and distribution

Several significant economic advantages [6] include:

- Postponed expenditures for facility improvements
- Lower fuel expenses as a result of improved overall efficiency
- Lower reserve requirements and related expenses
- Strengthened security for important cargoes.

In this study, the ideal DG size is determined using a unique harmony search algorithm. The DA algorithm determines the ideal DG size at various power factors in order to minimize power losses in the distribution system and improve the system's voltage profile. This research also considers the economic analysis of DG placement.

Proposed Strategy

In order to minimize active, reactive, and perceived power loss in the distribution system, our suggested methodology will make use of the harmony search-based GA-PSO technique for optimal estimates as well as the location for single and multiple DGs. [7, 8]. The DG estimate and position will be registered using an enhancement process, which first determines a selection of places for DG placement before determining the optimal size, location, and cost of the DG task. The Optimal Power Flow (OPF) [9,10] problem attempts to regulate the generation and usage of the loads in order to streamline particular destinations, such as limiting the system's power loss or generating cost. Due to the growing DG and the manageable burdens, it is becoming increasingly important for distribution networks [11,12]. The total generation cost has been kept to a minimum by using the OPF.

A second order polynomial generation cost function is still used to describe the generation cost. Given the cost of producing both active and reactive power, the cost function is,

$$C(AP_G) = a + (b.AP_G) + (c.AP_G^2) \tag{1}$$

And also, the cost function identified with the receptive power generation can be spoken to as,

$$C(RP_G) = a' + (b'.RP_G) + (c'.RP_G^2) \tag{2}$$

At that point, the minimization capacity of the aggregate cost generation has been shown as,

$$C_G = min \sum_{k=1}^{G} [C(AP_{Gk}) + C(RP_{Gk})] \tag{3}$$

The power balance equations with-out DG at j^{th} bus (DG) is,

$$\sum AP_{D_j} + \sum AP_{L_j} - \sum_{i=1}^{n} |V_j||V_i||EM_{ji}| cos(\delta_{ij} + \theta_i - \theta_j) = 0 \tag{4}$$

$$\sum RP_{D_j} + \sum RP_{L_j} - \sum_{i=1}^{n} |V_j||V_i||EM_{ji}| sin(\delta_{ij} + \theta_i - \theta_j) = 0 \tag{5}$$

Consequently, the imperatives with-DG can be presented as,

$$\sum AP_{D_j} + \sum AP_{L_j} - AP_{DG_j} - \sum_{i=1}^{n} |V_j||V_i||EM_{ji}| cos(\delta_{ji} + \theta_i - \theta_j) = 0 \tag{6}$$

$$\sum RP_{D_j} + \sum RP_{L_j} - RP_{DG_j} - \sum_{i=1}^{n} |V_j||V_i||EM_{ji}| sin(\delta_{ji} + \theta_i - \theta_j) = 0 \tag{7}$$

$$\theta_{min} \leq \theta_j \leq \theta_{max}$$
$$V_{min} \leq V_j \leq V_{max}$$

$$AP_{min} \leq AP_j \leq AP_{max}$$
$$RP_{min} \leq RP_j \leq RP_{max}$$
$$AP_{DG_{min}} \leq AP_{DG_j} \leq AP_{DG_{max}}$$
$$RP_{DG_{min}} \leq RP_{DG_j} \leq RP_{DG_{max}}$$

By evaluating the jth dispatchable load, which is shown as a constant power factor, the percentage of reactive to actual demand remains constant [13,14]. At that moment, the load's actual and reactive power consumption might be considered as a single packed or integrated item. MW (Mega Watts) or MVAR (Mega Volt-Amps (reactive)) can be used to indicate the uniform nodal value esteem.

Assume for the moment that the load is located on the bus j and that the actual and reactive power are λ_{APj} and λ_{RPj}, respectively. The combined or bundled power χ can thus be written as,

$$\chi = \lambda_{AP_j} AP_{D_j} + \lambda_{RP_j} RP_{D_j} \quad \text{……………………………………………………….……………..} \ (8)$$

$$\chi = \lambda_{AP_j} AP_{D_j} + \lambda_{RP_j} \left(\frac{RP_{D_j}}{AP_{D_j}} \right) AP_{D_j} \quad \text{…………………………………………….…………} \ (9)$$

$$\chi = \left(\lambda_{AP_j} + \lambda_{RP_j} ct_j \right) AP_{D_j} \quad \text{……………………………………………………………..} \ (10)$$

Where,

$$ct_j = \frac{RP_{D_j}}{AP_{D_j}} = constant$$

In addition, the per MW cost of the packaged commodity is,

$$\lambda_{AP_j} + ct_j * \lambda_{RP_j}$$

Similarly, the per MVAR price has denoted as,

$$\frac{\lambda_{AP_j}}{ct_j} + \lambda_{RP_j}$$

Optimal Planning of DG Using Harmony Search Based Hybrid Ga-PSO Techniques

The DG's ideal placement concerns are planned as an improvement issue that is mandated by MO. In order to address the problems of optimal DG planning, this paper employs a novel harmony search based combination Genetic Algorithm integrated Particle Swarm Optimization (GA-PSO). PSO and GA were compared with the results [15].

The new harmony search-based hybridized GA-PSO for handling ODGP problems is demonstrated in this section. The goal of the PSO-GA [16,17] strategy is to combine the advantages of the PSO and GA algorithms. The harmony between the investigation and the abuse capacity is further improved by placing the hereditary administrators within the regular PSO.

The suggested optimal placement and calculation of DG methodology has been verified for a few power frameworks and implemented in MATLAB. The DG's power factor and active power ratings are 1.2 MW and 1, respectively. The improvement was made using the harmony search-based hybrid GA-PSO programming package, which was designed to simulate the optimal positioning of DG in any radial dispersion framework. The specific algorithm is as follows:

1. Read and input the system data (bus data, line data, generation data etc.).
2. Run and execute the optimal power flow (OPF) results in case of with-out DG.
3. Initialize the Hybrid G.A PSO parameters c1, c2, w, Pk, and Sk. And the butterfly particle positions can be defined as dg1 dg 2 DGs dg1 dg 2 DGs *x* 2 [P ,P ,......P ;*Q* ,*Q*,......*Q*] Where, s is the number of butterfly swarm.
4. Now, consider the for loop for the buses up to the maximum no. of buses of the system excluding the slack and pv buses.
5. Set-up the main while loop of the Hybrid G.A-PSO technique and sets iteration count= iteration=0, and also start with iteration= iteration+1.
6. Update the sensitivity and probability values of solution algorithm.
7. Update the butterfly particle velocity and the positions with-DG condition and check for constraints limit.
8. After that call the optimal power flow (OPF) and execute the of results with-DG condition.

9. Calculate the all indices value for the multi objective function with each butterfly swarm at each bus.
10. Evaluate the fitness value for each particle position considering the multi-objective function as a fitness function at each bus.
11. Compare the local best (lbest) of each particle and global best (gbest) in the whole butterfly swarm.
12. Find the global optimal value of the fitness function and the corresponding global optimal parameters or particle positions at every bus.
13. And check for termination criteria, if otherwise, repeat algorithm from step 3 to step 12.
14. Repeat this procedure up to maximum number of buses.
15. Record and save the all output data of the system.

Result & Discussions

Two systems taken for the verification of the above said analytical method such as,

I. **33-bus radial system -** A 33 bus radial dissemination framework with 33 branches has been considered with the aggregate active power load of 3.715 MW and a reactive load of 2.3 MVAR.

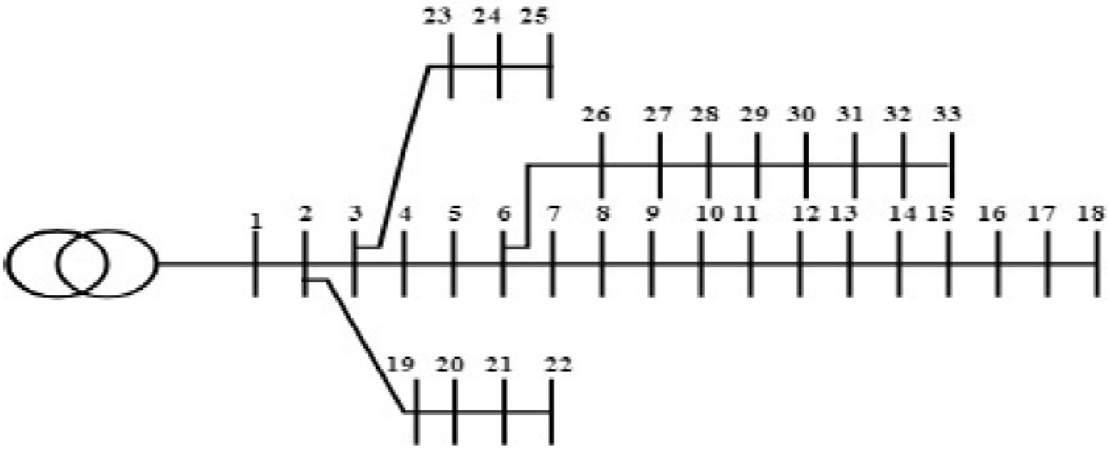
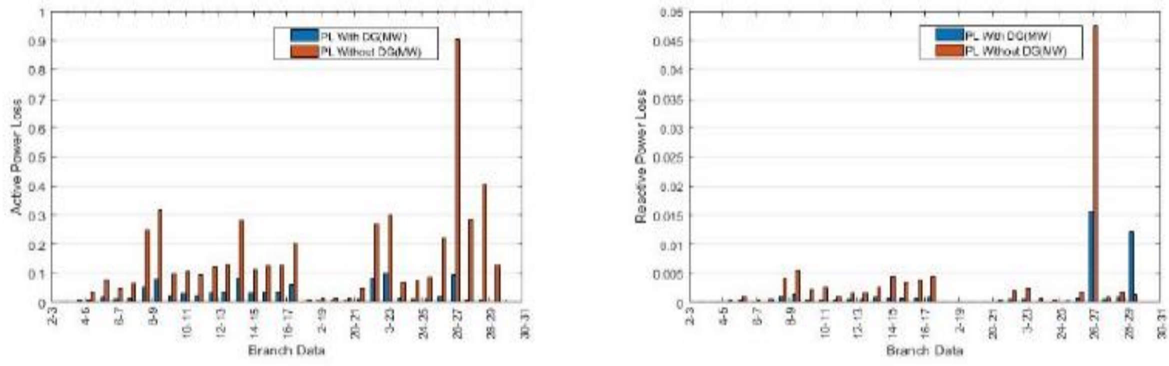


Figure 1: Single line diagram of a 33-bus radial distribution network



a) Active Power Loss **b) Reactive Power Loss**

Figure 2: Active and reactive power loss with and without DG for the 33-bus radial

System

When compared to the 33-bus radial framework's without-DG condition, which is shown in figure 2, the active and reactive power misfortunes with-DG gain a lower value. The estimates of active and reactive power with DG are still more notable than those without DG, according to the numbers.

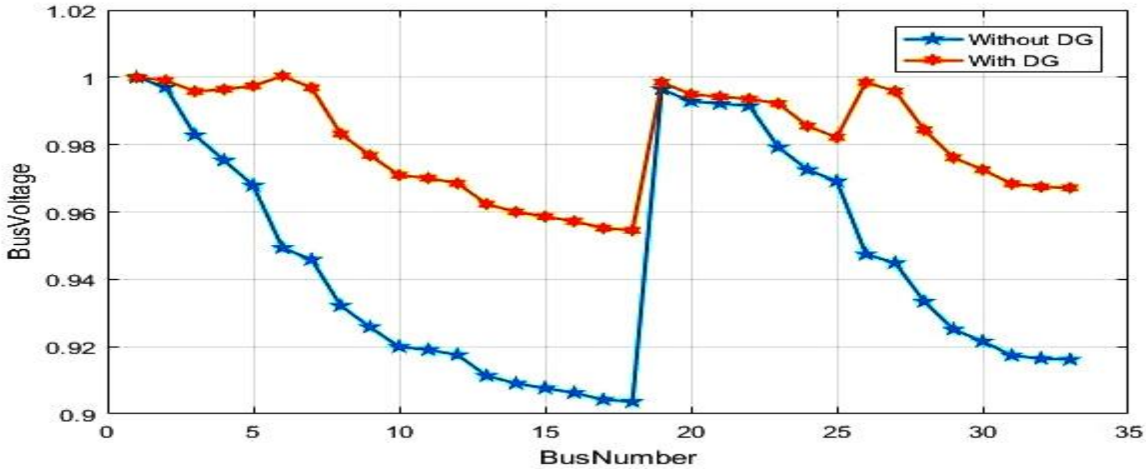
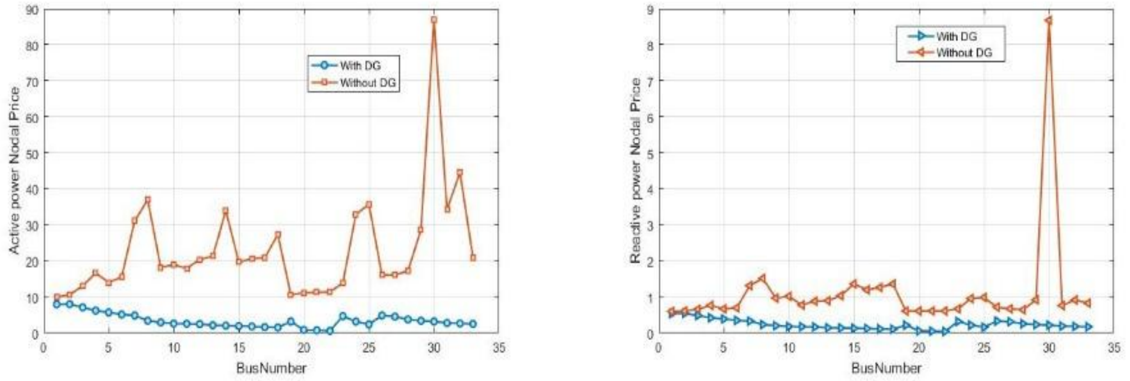


Figure 3: The voltage profile in per unit with and without DG for 33- bus radial system

The voltage profile estimates for the 33-bus radial system with and without DG are shown in Figure 3. When compared to the 33-bus radial system's without-DG condition, the voltage profile values with-DG are higher. It shows that the voltage profile with DG is estimated to be greater than the voltage profile without DG.



a) Nodal Price for active power **b) Nodal Price for reactive power**

Figure 4: The nodal price of active and reactive power with and without DG for the 33- bus radial system

The 33-bus radial system's nodal costs for both active and reactive power with and without DG are examined in Figure 4. When compared to the 33-bus radial system's without-DG condition, the nodal price value for active and reactive power with-DG gets a lower value.

The curve for the total generating cost of buses with DG for the 33-bus outspread framework is shown in Figure 5. For every bus in the 33-bus framework, the generation cost has been determined.

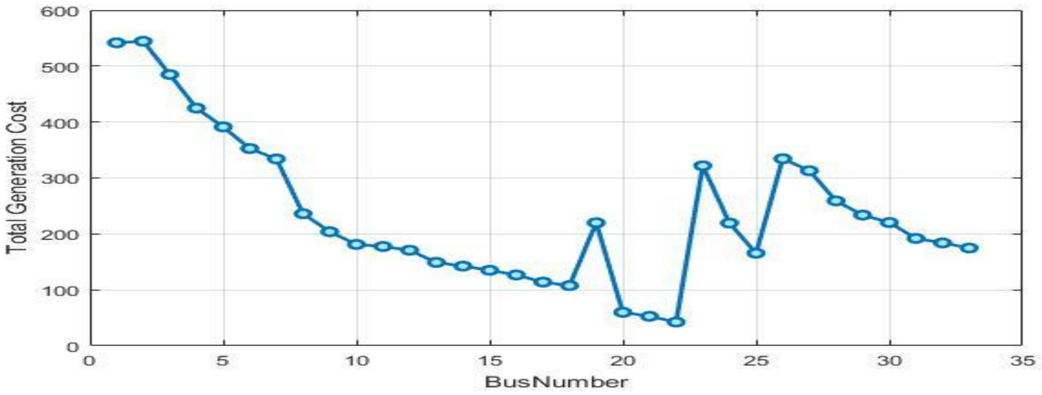


Figure 5: The total generation cost curve at buses with-DG for the 33-bus radial system

Figure 6 shows the MO function and diversity indices for the unique bus count in the 33-bus radial system. Additionally, it describes the range of each index found in the MO function. Figure 7 shows the MO function for the 33-bus radial framework with different DG dimensions and different framework misfortunes.

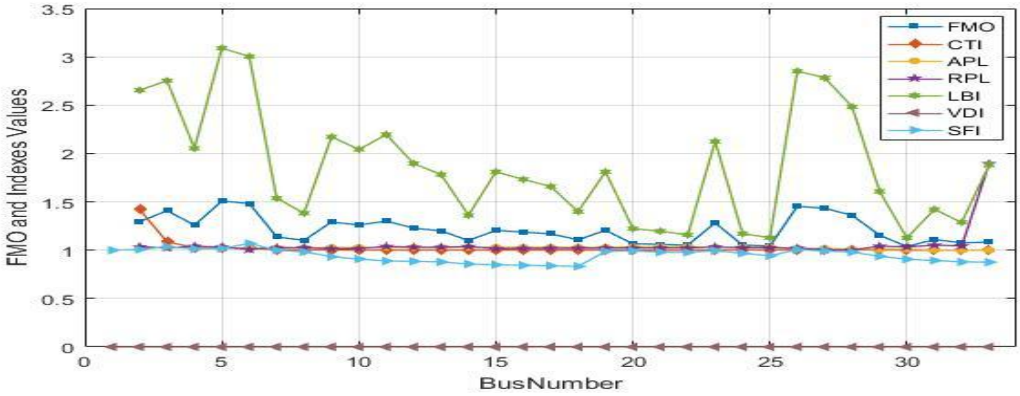


Figure 6: The variation of MO function and various indices at different buses for the 33-bus radial system

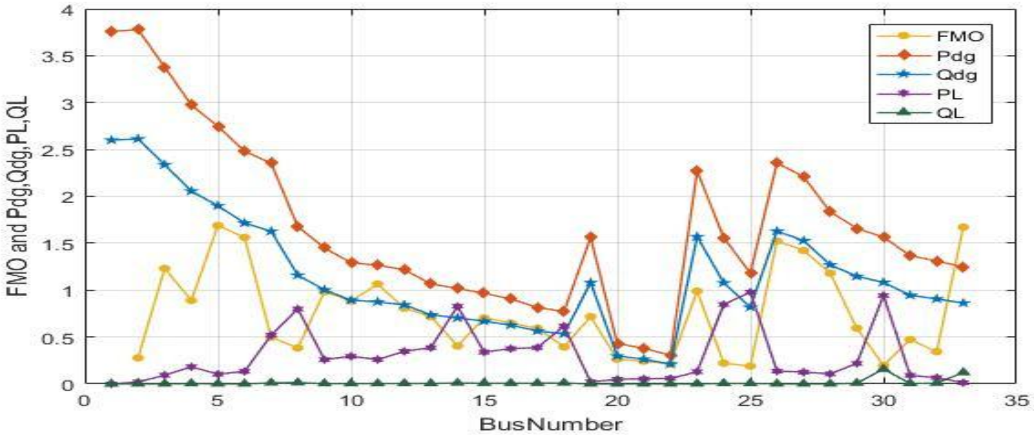


Figure 7: The variation of DG size, and system losses with MO function forthe 33-bus radial system

The created harmony search-based hybrid GA-PSO optimization technique's potential optimal solution findings are examined for every bus in the 33-bus radial system, with the exception of the slack bus. According to these findings, the multi-objective function's optimal value is 1 at bus-1, which is the bus with the best value overall. At bus-1, the appropriate values of the multi-objective functions, such as CTI, APL, RPL, LBI, VDI, and SFI, are obtained as ∞, 1.7924, ∞, 0, and 1, respectively.

II. 69-bus radial system: As shown in Figure 8, the developed technique has been validated on a 69-bus radial conveyance framework. There are 69 branches in a 69-bus radial distribution system. On the 69-radial appropriation framework, the total actual power loads and reactive power stacks are 3.80 MW and 2.69 MVAR, respectively.

To show that the method finds sound for higher bus systems as well, the radial 69-bus structure is still evaluated. To verify the feasibility of the presented technique, simulation work is conducted on a 69-bus outspread conveyance feeder.

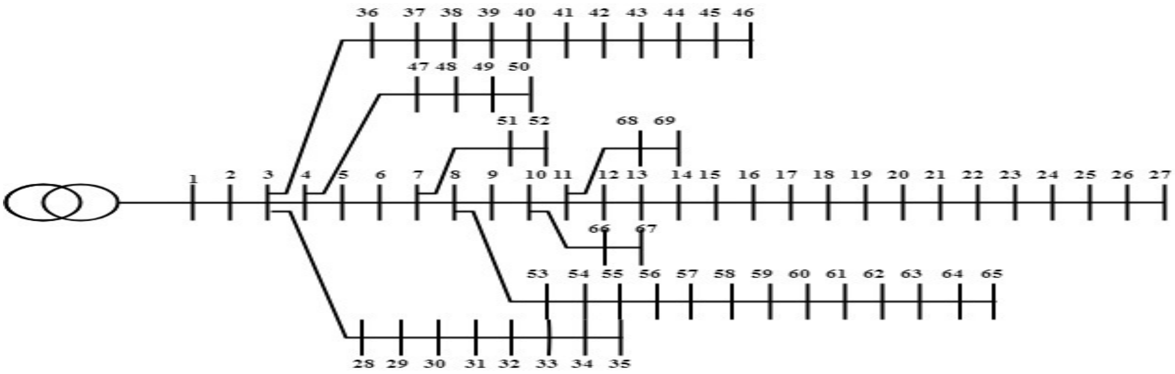


Figure 8: Single line diagram of a 69-bus radial distribution network

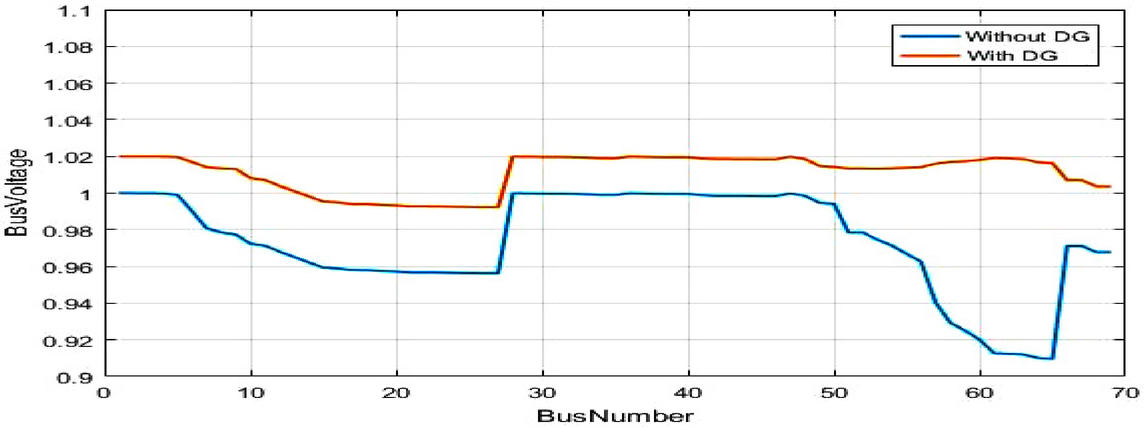
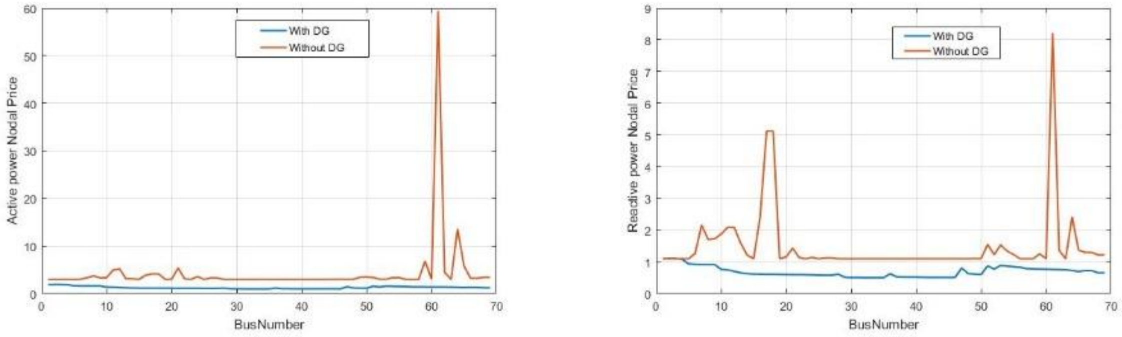


Figure 9: The voltage profile with and without DG for the 69-bus radial system

The voltage profile estimates for the 69-bus radial system with and without DG are shown in Figure 9. When compared to the 69-bus radial system's state without DG, the voltage profile values with DG are higher. The voltage profile with DG is estimated to be greater than the voltage profile without DG.

Figure 10 shows the relationship between the nodal price for both active and reactive power with and without DG for the 69-bus outspread system.



a) Nodal price for active power **b) Nodal price for reactive power**

Figure 10: The Nodal price of active and reactive power with and without DG for the 69-bus radial network

The active and reactive power estimates in the figure with DG are more notable than those without DG. When compared to the 69-bus outspread framework's without-DG condition, the nodal price value for active and reactive power misfortune with-DG acquires the lower value.

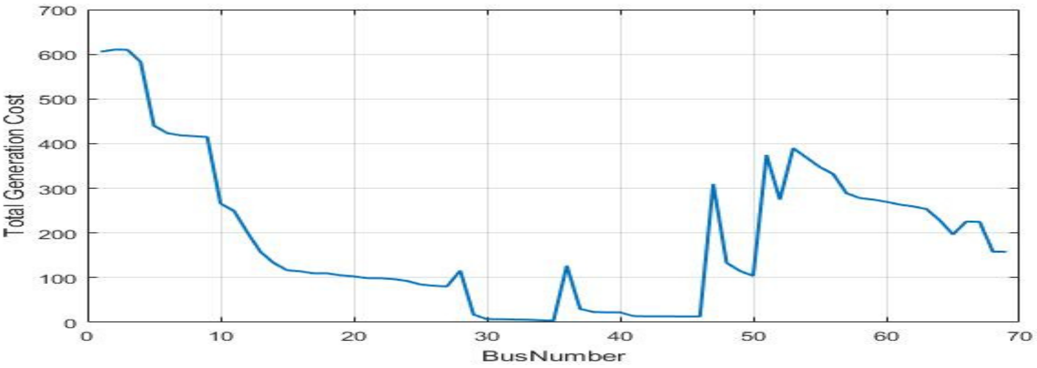


Figure 11: The total generation cost curve at buses with-DG for the 69-bus radial system

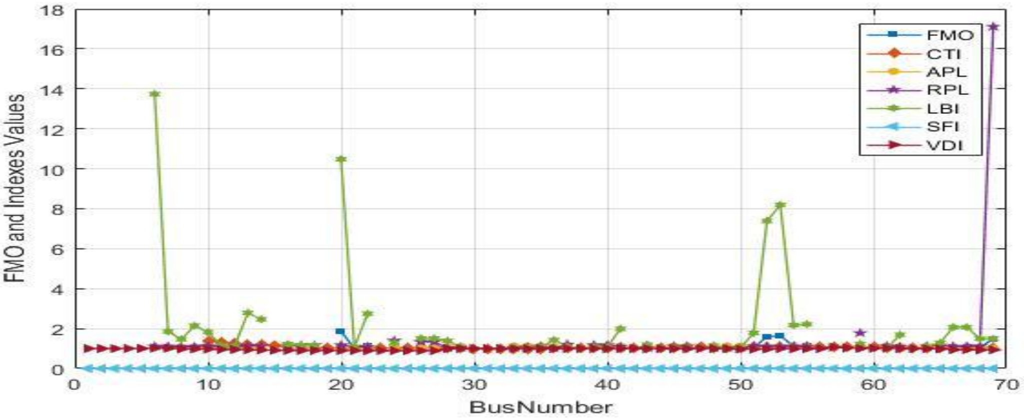


Figure 12-The variation of MO function and various indices at different buses for the 69-bus radial system

The MO function and diversity indices for different bus counts in the 69-bus radial structure are shown in Figure 12. It also shows the variation of each index that has been placed in our designed methodology's MO function.

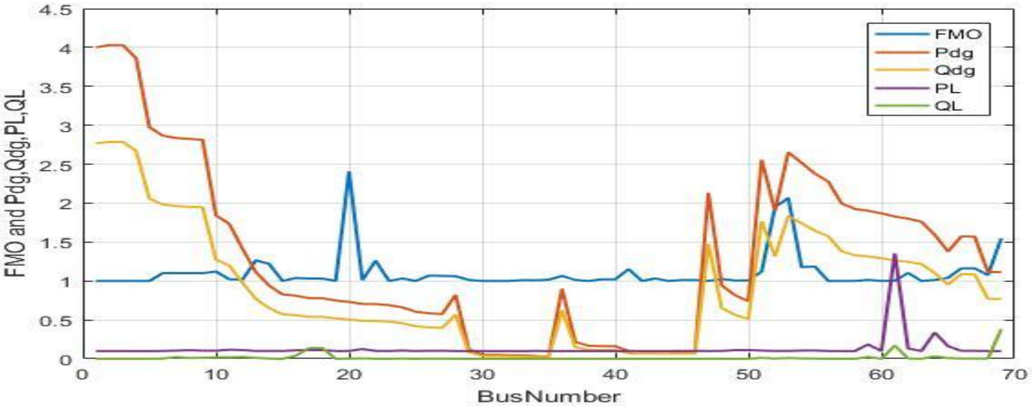


Figure 13: The variation of DG size, and system losses with MO function value of the 69-bus radial system

Our MO function for the 69-bus radial system is shown in Figure 13 with a variety of DG sizes and misfortunes. The 69-bus radial system's potential optimal solution results are achieved for every bus, with the exception of the slack bus.

Conclusion

The integration of DGs into distribution systems has been ongoing. DG location and size have a big impact on the framework, which improves the voltage profile and reduces power losses in distributed DGs. Distributed generation reduces power loss by 84.28% when compared to the absence of distribution generation; improves voltage profiles by 65.28% when compared to the absence of distribution generation; increases load balancing capacity; minimizes costs by 75.89% when compared to the absence of distributed generation; and has an optimal shift factor value, which raises ATC and reduces MVA streams and MVA consumption by 2.4532MVA from the 33-bus radial distribution network.

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