Optimizing the Location of DG Using the Hybrid GA-PSO Optimization Techniques

Monica Verghese
M-Tech Scholar
Department of Electrical Engg
SSTC, Bhilai
CG, India

Tanu Rizvi
Assistant Professor
Department of Electrical Engg
SSTC, Bhilai
CG, India

Abstract

Distributed generation (DG) are small power plants that are connected to consumers in distribution systems for the purpose of improving the voltage profile, voltage regulation, stability, reduction of power losses and economic benefits. The above mentioned advantages can be achieved by optimal positioning of the DG. A novel nature-inspired algorithm called the Dragonfly algorithm is used to determine the optimal DG unit size in this paper. It was developed based on the special behavior of dragonflies in nature. This algorithm mainly focused on how dragonflies search for food or away from enemies. The proposed algorithm is tested on IEEE 33 and 69 test systems. The results obtained by the proposed algorithm are presented and compared. Compared to other algorithms, GAPSO based on harmony search has the best results.

Keywords: Harmony search; Distributed generation placement; Radial distribution system; Genetic Algorithm (GA), Particle Swarm Optimization (PSO).

I. Introduction

Interconnection of production, transmission and distribution systems, usually called the electricity system. Distribution systems are usually radial in nature and the energy flow is unidirectional [1]. Due to the ever-increasing demand, modern distribution networks face several challenges. With the installation of various distributed power sources such as distributed generation, capacitor banks, etc., several techniques for DG placement have been proposed in the literature. Most of the losses, about 70% of the losses, occur at the distribution level, which includes the primary and secondary distribution systems, while 30% of the losses occurred at the transmission level [2,3]. Distribution systems are therefore a major concern these days. Losses targeted at the distribution level are about 7.5%. By installing DG units in suitable positions, losses can be minimized. Photovoltaic (PV) energy, wind turbines, and other distributed generation power plants are typically located in remote areas and require operating systems fully integrated into the transmission and distribution grid. The aim of the DG is to integrate all production plants in order to reduce losses, costs and greenhouse gas emissions [4]. The main reason for using DG units in the power system is the technical and economic benefits, which were presented as follows. Some of the main advantages [5]:

- Reduced system losses
- Improvement of the voltage profile
- Frequency improvement
- Reduction of pollutant emissions
- Increased overall energy efficiency
- Improved system reliability and security
- Improved power quality
- Relieving transmission and distribution congestion

Some of the main economic benefits [6]:

- Deferred investment in equipment modernization
- Reduced fuel costs due to increased overall efficiency
- Reduced mandatory minimum reserves and related costs
- Increased security of critical loads.

A new harmony search algorithm is used in this paper to find the optimal DG size. The optimal size of the DG at different power factors is determined by the DA algorithm in order to reduce the power losses in the distribution system as much as possible and to improve the voltage profile of the system. An economic analysis of DG placement is also considered in this paper.

II. Proposed Optimal Planning Strategy

In our proposed methodology, the GA-PSO technique based on the search for harmony will be used for ideal estimation, as well as placement for one or more DGs to minimize active, reactive and apparent power losses in the distribution system [7,8]. the improvement strategy will be used to register the estimate of DG, location; this technique will initially determine a set of sites for DG placement and then the ideal size and location and cost of the DG task. The optimal power flow (OPF) problem [9,10] attempts to control the generation and utilization of loads in order to make specific destinations more efficient, for example to limit generation costs or energy losses in the system. It is gradually becoming necessary for distribution networks due to the developing DG and controllable load [11,12]. OPF was used to limit the aggregate production costs of C_G. Production costs remain characterized as a second-order polynomial production cost function. The cost function in light of active and reactive energy production costs 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 assessment, the jth serviceable load appears as a consistent power factor, so the ratio of reactive to real demand is constant [13,14]. At this point, the actual and reactive load utilization can be considered as a single/combined or packaged item. The valuation of the uniform nodal value can be communicated on a per MW (Mega Watt) or per MVAR (Mega Volt-Amp (reactive)) basis.

Let us assume that the load is situated on the bus j and the costs of the genuine and the reactive power are λ_{AP_j} and λ_{RP_j} separately. In this way, the joined or packaged power χ can be expressed as,

$$\chi = \lambda_{AP_j} AP_{D_j} + \lambda_{RP_j} RP_{D_j} \tag{8}$$

$$\chi = \lambda_{AP_j} AP_{D_j} + \lambda_{RP_j}\left(\frac{RP_{D_j}}{AP_{D_j}}\right) AP_{D_j} \tag{9}$$

$$\chi = \left(\lambda_{AP_j} + \lambda_{RP_j} ct_j\right) AP_{D_j} \tag{10}$$

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

III. Optimal Planning of DG using Harmony Search Based Hybrid GA-PSO Techniques

Questions of the ideal location of the DG are planned as a problem of forced improvement of the Ministry of Defense. This paper uses a new harmony based on the combined genetic algorithm of integrated particle swarm optimization (GA-PSO) to solve ideal DG scheduling problems. The results were compared with PSO and GA [15].

This segment shows a new hybrid GA-PSO based on harmony search for solving ODGP problems. The inspiration for creating the PSO-GA approach [16,17] is the consolidation of the advantages of GA and PSO algorithms. Installing legacy administrators within a standard PSO will further strengthen investigative alignment and abuse capacity.

The proposed ideal location and DG methodology estimation was implemented in MATLAB and tested for several performance frameworks. The rated active power of the DG is 1.2 MW and the power factor is 1. The improvement was performed using a hybrid GA-PSO programming package based on harmony search, which was constructed to reproduce the ideal DG placement in any radial dissemination frame, whose detailed algorithm can be given as:

- Reading and entering system data (bus data, line data, generation data, etc.).

- Run and execute the Optimum Power Flow (OPF) results for the non-DG case.

- Initialize 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 butterfly swarm number.

- Now consider a for loop for buses up to the maximum number. system buses with the exception of slack and pv buses.

- Set the main while loop of the Hybrid G.A-PSO technique and set the number of iterations iteration=0 and also start with iteration= iteration+1.

- Update the sensitivity and probability values of the solution algorithm.

- Update butterfly particle velocities and positions according to the DG condition and check for constraint constraints.

- Then call the optimal power flow (OPF) and perform the results with the DG condition.

- Calculate the value of all indices for the multipurpose function with each butterfly swarm on each bus.

- Evaluate the fitness value for each particle position with respect to the multi-objective function as the fitness function on each bus.

- Compare the local best (l_{best}) of each particle and the global best (g_{best}) of the entire butterfly swarm.

- Find the global optimal value of the fitness function and the corresponding global optimal parameters or particle positions at each bus.

- And check the termination criteria, if it is different, repeat the algorithm from step 3 to step 12.

- Repeat this procedure up to the maximum number of buses.

- Record and store all system output data.

IV. 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.

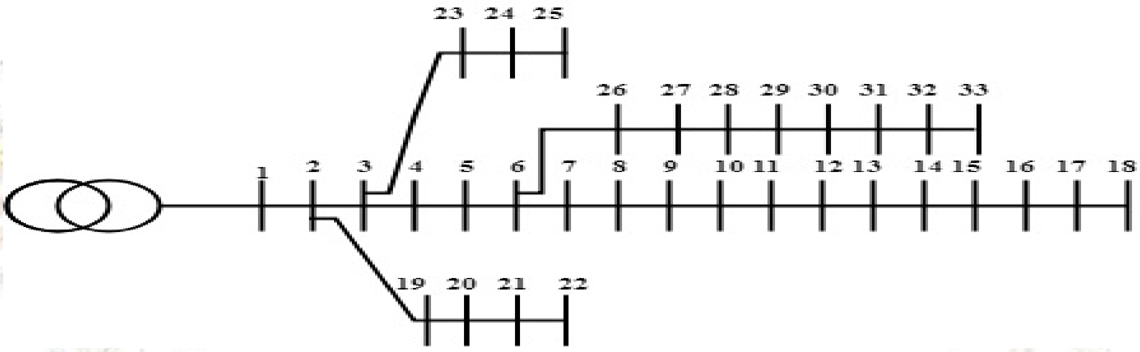
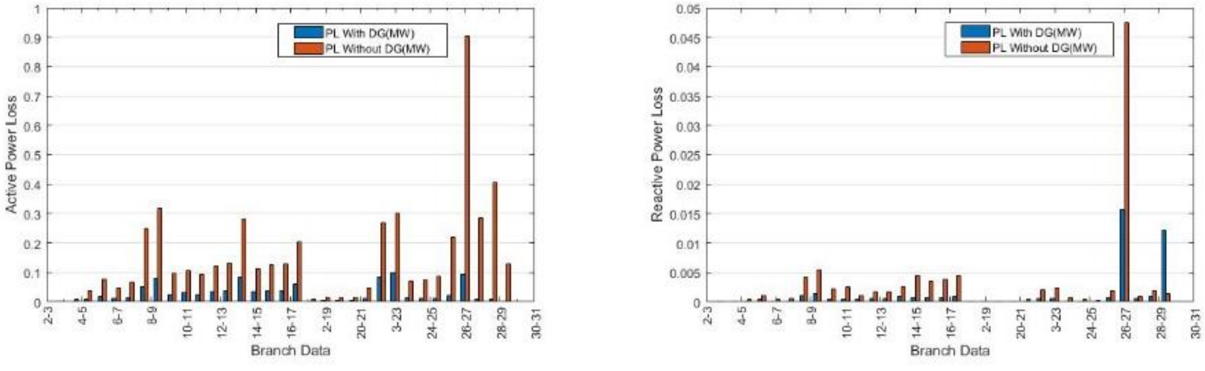


Figure 1-Single line diagram of a 33-bus radial distribution network



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

The active and reactive power mishaps with DG obtain a lower value compared to the non-DG condition of the 33-bus radial frame shown in Figure 2. From the figures, the active and reactive power estimates with DG remain more remarkable than without DG.

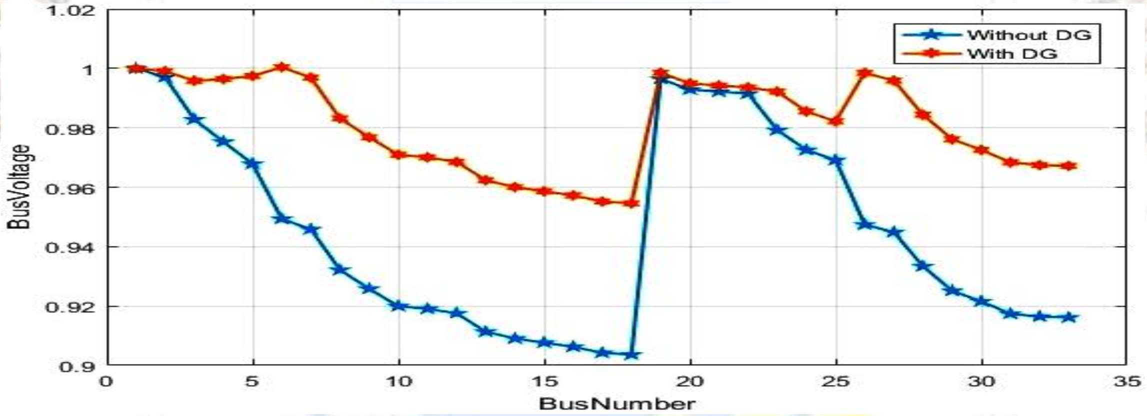
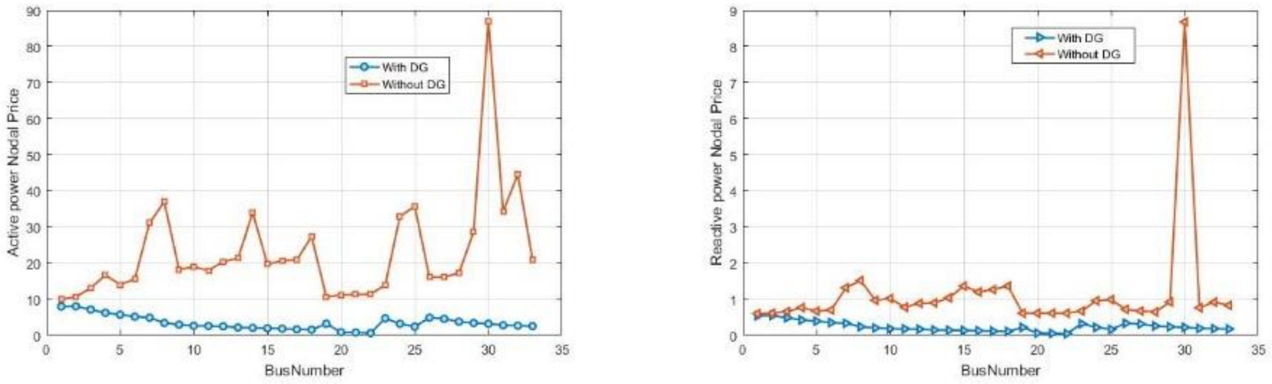


Figure 3-The voltage profile in per unit with and without DG for 33- bus radial system

Figure 3 shows voltage profile estimates with and without DG in a 33-bus radial system. The s-DG voltage profile is more in contrast to the condition of the no-DG radial system with 33 buses. It shows that the estimates of the voltage profile with DG are higher 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

Figure 4 shows the nodal cost investigation for both active and reactive power with and without DG for a 33-bus radial system. The value of nodal cost for active and reactive power with-DG becomes lower compared to the case of no-DG radial system with 33 buses.

Figure 5 shows the curve for the aggregate production cost of DG buses for the 33-bus outspread framework. Production costs were determined for each bus within the 33 buses.

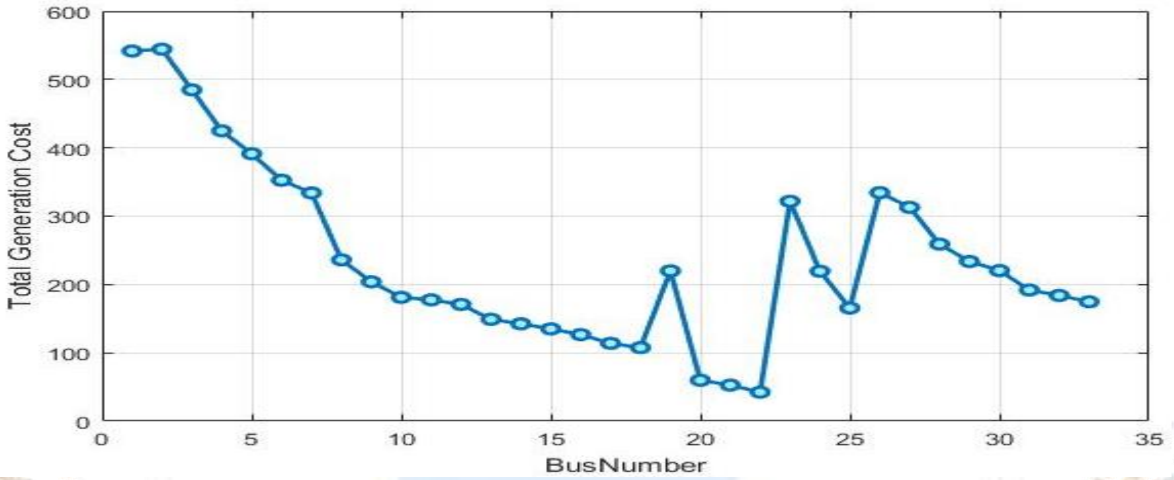


Figure 5-The total generation cost curve at buses with-DG for the 33-bus radial system

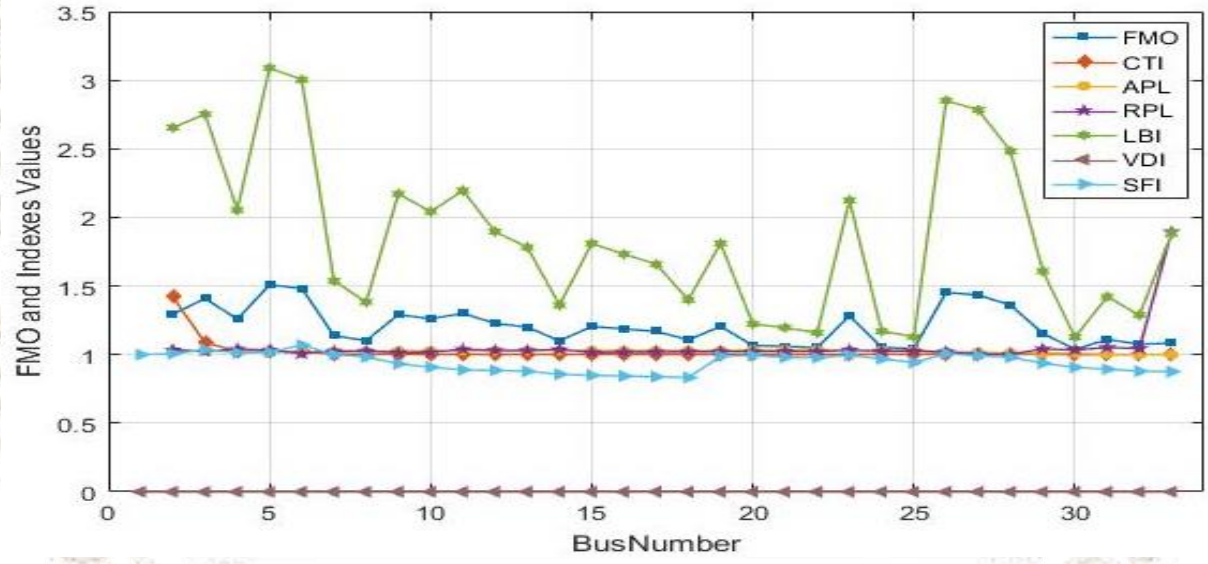


Figure 6- The variation of MO function and various indices at different buses for the 33-bus radial system

The MO function and diversity indices appeared in Figure 6 for the characteristic number of buses in a 33-bus radial system. Similarly, it defines the variety of each index that was placed in the MO function. The MO function with different DG dimensions and with different frame accidents determined for a 33-bus radial frame is plotted in Figure 7.

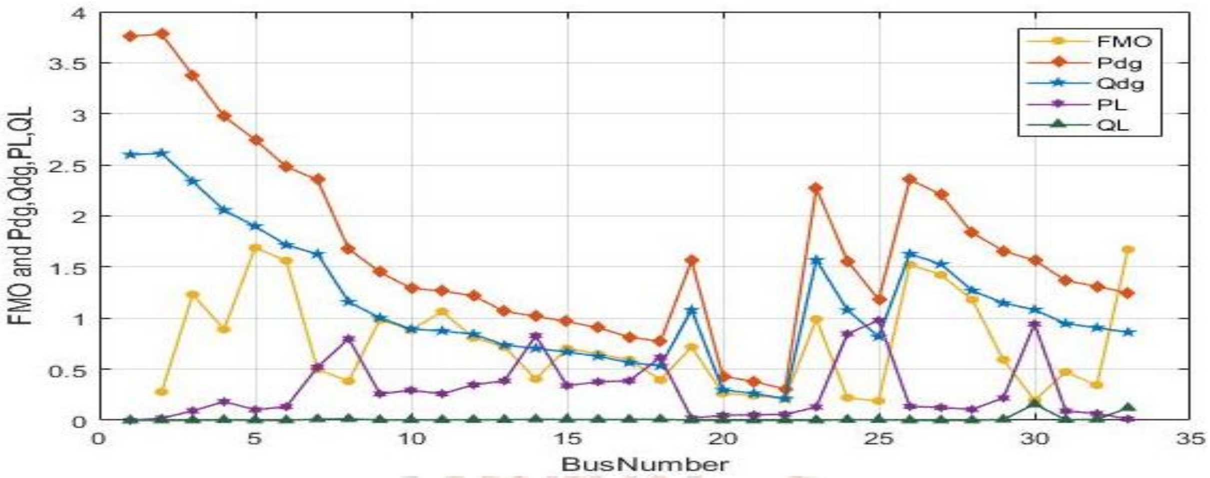


Figure 8: The variation of DG size, and system losses with MO function forthe 33-bus radial system

The possible optimal solution results of the developed GA-PSO hybrid optimization technique based on harmony search on each bus except the free bus within a 33-bus radial system are investigated. These results conclude that the optimal value of the multi-objective function is 1 on bus-1, which is the most optimal value among all buses. The corresponding multi-objective function values such as CTI, APL, RPL, LBI, VDI and SFI values are obtained as , , 1.7924, ∞, 0 and 1 respectively at bus-1

II.69-bus radial system - The developed technique was validated on a 69-bus radial transport system as shown in Figure 10. A 69-bus radial distribution system contains 69 branches. The combined actual power loads and reactive power storages on the 69-radial allocation frame are 3.80 MW and 2.69 MVAR respectively.

A radial 69-bus framework remains under review to demonstrate that this technique locates audio for higher bus systems as well. Simulation work is performed on 69-bus spread traffic feeders to validate the viability of the developed strategy.

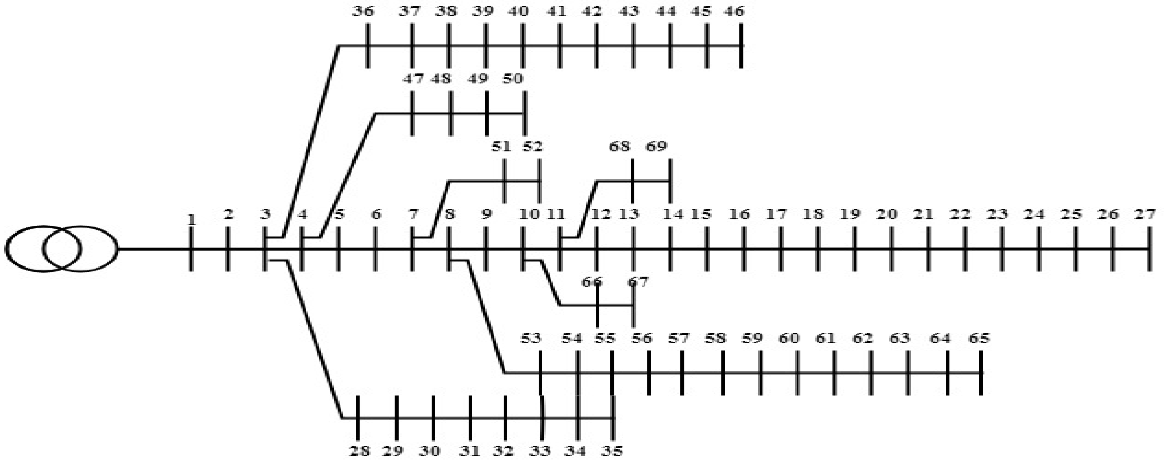


Figure10: Single line diagram of a 69-bus radial distribution network

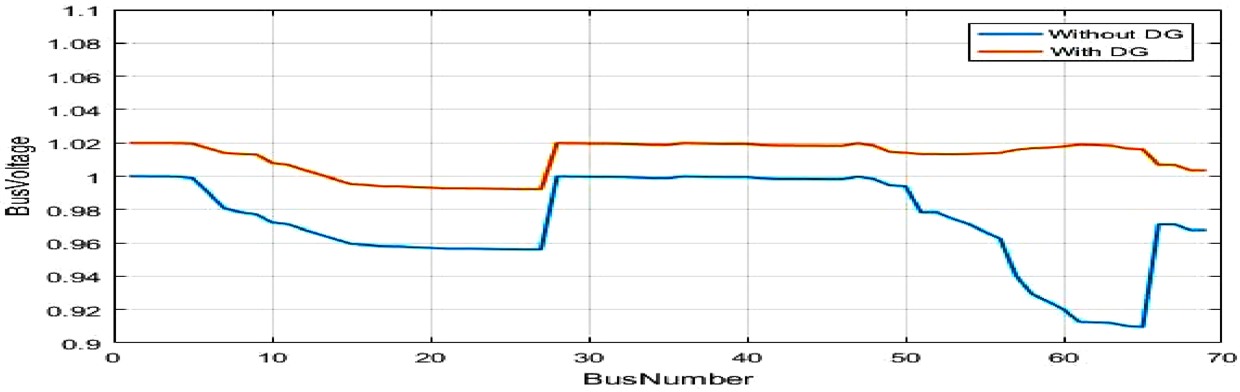
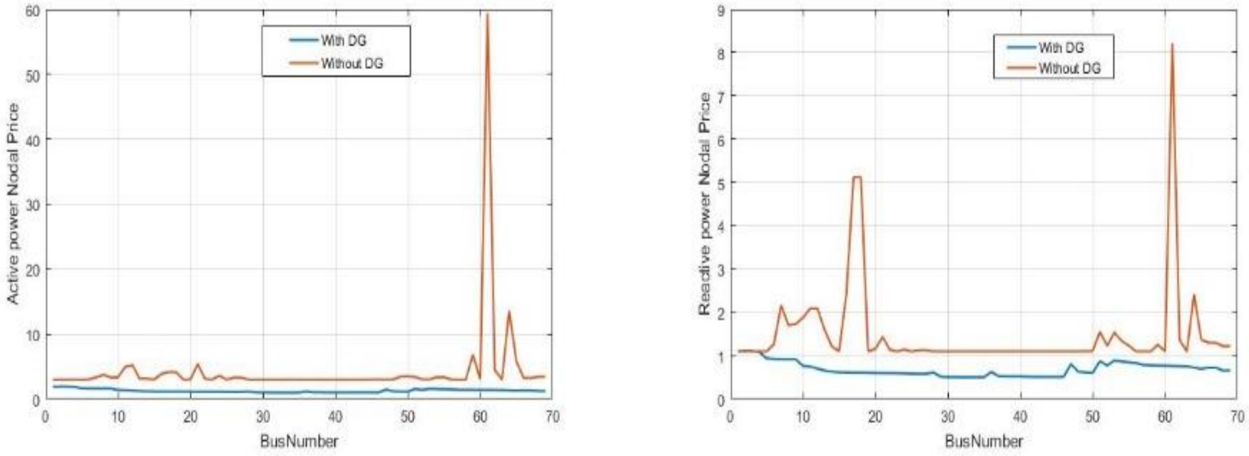


Figure 11: The voltage profile with and without DG for the 69-bus radial system

Figure 11 shows voltage profile estimates with and without DG in a 69-bus radial system. The s-DG voltage profile is more compared to the non-DG 69-bus radial system condition. It is believed that the estimates of the voltage profile with DG are higher than the voltage profile without DG.

The nodal cost correlation for active and reactive power with and without DG for the 69-bus outspread system appeared in Figure 12.



a) Nodal price for active power

b) Nodal price for reactive power

Figure 12-The Nodal price of active and reactive power with and without DG for the 69-bus radial network

In the figure, the active and reactive power estimates with DG are more remarkable than without DG. The nodal cost value for the active and reactive power mishap with-DG becomes lower compared to the no-DG condition for the 69-bus outspread frame.

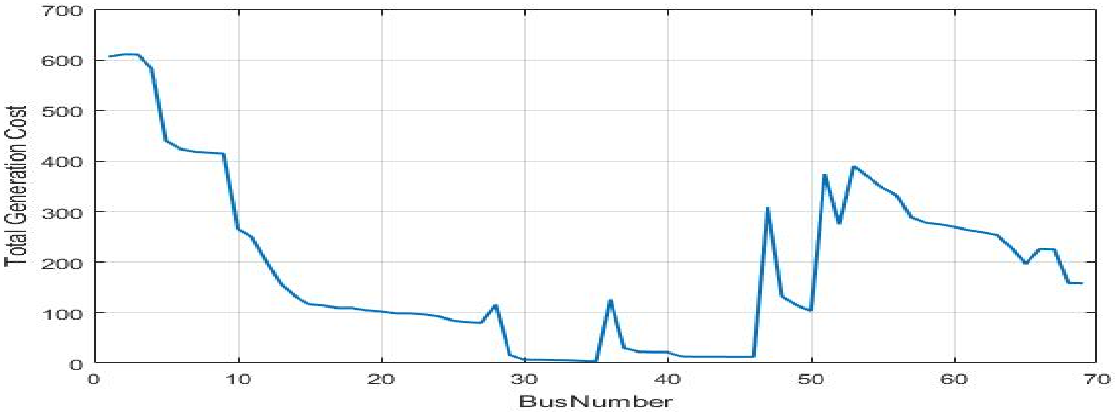


Figure 13-The total generation cost curve at buses with-DG for the 69-bus radial system

Figure 13 shows the aggregate production cost curve of various DG buses for a 69-bus radial frame. The generation price was determined for each bus in the 69-bus system.

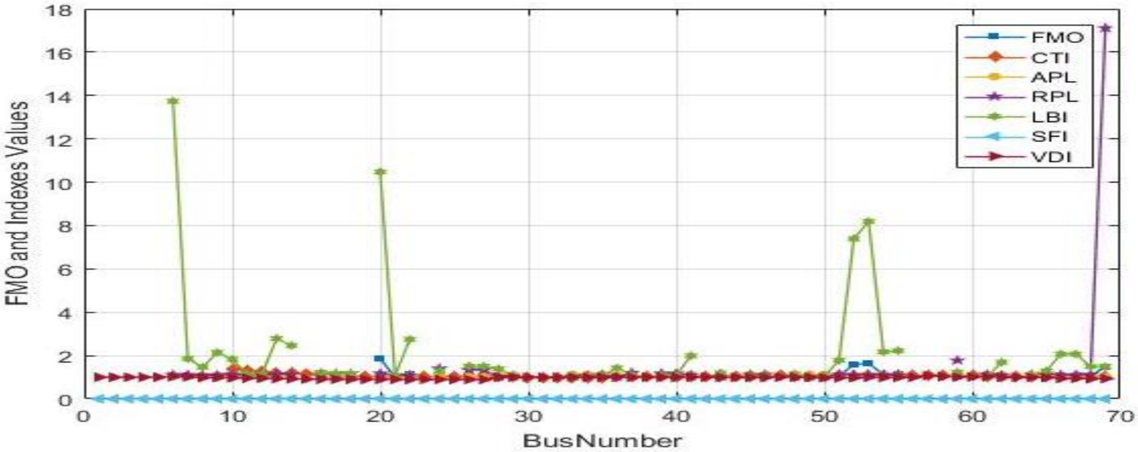


Figure 14-The variation of MO function and various indices at different buses for the 69-bus radial system

Figure 14 shows the MO function and diversity indices for different numbers of buses in a radial frame of 69 buses. Moreover, it represents the diversity of each index that was placed in the MO function of our developed methodology.

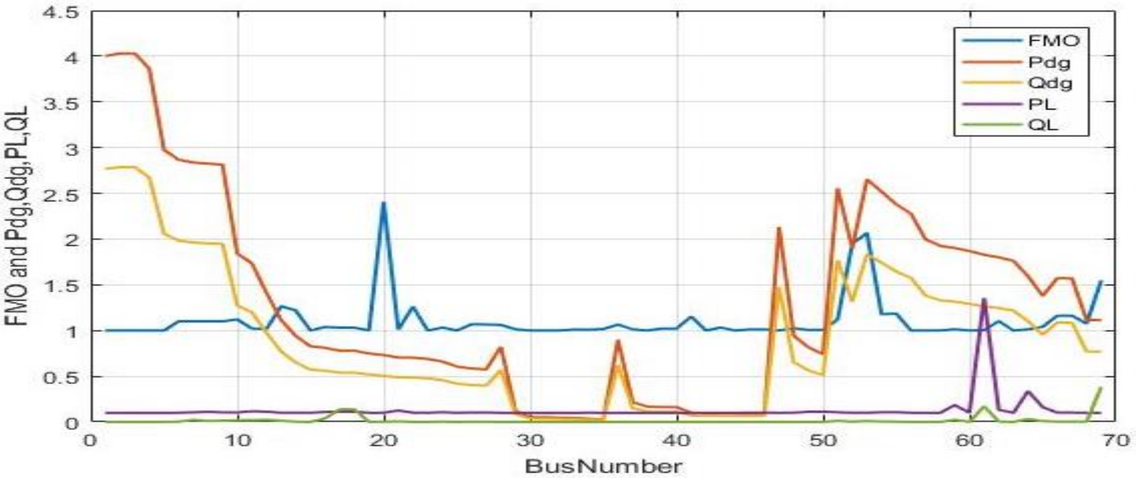


Figure 15: The variation of DG size, and system losses with MO function value of the 69-bus radial system

Figure 15 shows our MO function with many DG sizes and also with different accidents for a 69-bus radial system. Possible optimal solution results are obtained for each bus except the free bus within the radial system of 69 buses.

V. Conclusion

DGs are continuously integrated into distribution systems. DG sizing and placement have a significant effect on the framework, which reduces power losses and improves the voltage profile of extended DGs. Power loss reduction with distributed generation which is 84.28% compared to non-distributed generation, voltage profile improvement with DG is 65.28% compared to non-DG, increased load balancing capacity, cost minimization with DG is 75.89% compared to no DG and the optimal value of shift factor therefore increases ATC and reduces MVA flows and MVA consumption which is 2.4532 MVA from 33 bus radial distribution network.

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