Optimal placement and Size of DG and DER for minimizing Power Loss and AEL in 69-bus distribution system by various Optimization Techniques

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Abstract - *In the electrical power distribution system the network feeds inductive loads for low voltage level, which lead to higher currents and power losses. Therefore, it is mandatory to improve the power system stability and reliability, power factor and voltage profile, which is done by placing active and reactive resources i.e., DG and Capacitor bank in the system. This paper presents the new optimization techniques for finding the optimal location and size of DG and capacitor bank in the electrical network. The results are generated by MATLAB R2015a software. Results are obtained for DG and DER placement in 69 bus system for different load levels-peak, normal and light load level. The study states that the best location and size of DG and DER is obtained by using MFO techniques for minimizing Power Loss and further minimizing AEL in the distribution system.*

***Key Words*: DG (Distributed generation), DER (Distributed Energy Resources), Optimization technique, MFO (Moth Flame Optimization), GOA (Grasshopper Optimization Algorithm), AEL (Annual Energy Loss).**

1. INTRODUCTION

The power system contains three major blocks i.e. power generation, power transmission, and power distribution. Power is generated at power generation stations and travels towards consumer area via transmission and distribution system. The type of distribution system used is of Radial Type because of its simplicity. In a radial distribution system, there are main feeders and lateral distributors. The main feeder originates from the substation and passes through different consumer loads. Laterals are connected to individual loads.[1]

The two major challenges that the modern power systems are facing are voltage and angle stabilities, expansion in electrical power network and increase in load demand which leads to the stability issues, voltage level and power losses issues. To obtain best from the existing network. i.e., to enhance voltage, minimize the losses compensation is done by placing the capacitor bank at a particular node in the system [2][3]. Nowadays Distributed generation is used, which are small sized power generating units near to the load center [4][5]. Which further increase its overall efficiency in the distribution system at optimal locations. DG is acronyms of Distributed generation and it is also called as a decentralized generation, embedded generation or dispersed generation.[6]The literal meaning of Optimization is the act of making the best or most effective use of a situation or resource. For starting any prototype in engineering design, both analysis and optimization are employed. An optimum solution for a problem is determined by the use of optimization methods.It is beneficial in reducing the losses effectively compared to other methods of loss reduction.[7] In this paper, optimal DG unit size and its placement using GOA and MFO algorithm are discuss.

2. Problem Formulation

The study is done for the active power loss minimization of the test power system. Consider the objective function for active power minimization as:

$$F_{ploss} = \sum_{i=1}^{N_b-1} k_i\, r_i \frac{P_i^2+Q_i^2}{V_i^2} \quad (1)$$

r_i resistance of line i
V_i voltage magnitude of bus i
P_i , Q_i real and reactive power injected to bus i
The power flow equations are given by:

$$P_i+P_{DGi}-P_{Li}-V_i \sum_{i=1}^{N_b-1} V_j[G_{ij}\cos(\theta_{ij}) + B_{ij}\sin(\theta_{ij})] = 0 \quad (2)$$

$$Q_i+Q_{DGi}-Q_{Li}-V_i \sum_{i=1}^{N_b-1} V_j[G_{ij}\sin(\theta_{ij}) + B_{ij}\cos(\theta_{ij})] = 0 \quad (3)$$

P_{DGi} , Q_{DGi} DG power generation at bus i .
P_{Li} , Q_{Li} Active, Reactive power load at bus i .
G_{ij} Conductance of the line (between bus i and bus j) .
B_{ij} Susceptance of the line (between bus i and bus j) .
θ_{ij} Angle between bus i and bus j .
DG Capacity limit $P_{DGi\,min} \le P_{DGi} \le P_{DGi\,max}$ (4)
$P_{DGi\,min}$ Lower limit
$P_{DGi\,max}$ Upper limit
$N_L = N_B - 1$ (5)
N_L Number of lines. [8]

- **Calculation for DG/DER penetration for peak load:**

$$\%\ \text{DG Penetration} = \frac{Sum\ of\ 3\ DGs\ sizes(MW)}{Centralised\ generation + Sum\ of\ 3\ DGs\ sizes(MW)} \times 100$$
$$= \frac{Sum\ of\ 3\ DGs\ sizes(MW)}{1.6\sqrt{P^2+Q^2}} \times 100$$

(1.6 Multiplication factor is used for peak load level)

% DER Penetration =

$$\frac{\sqrt{(Sum\ of\ DGs\ sizes\ in\ MW)^2 + (Sum\ of\ SCs\ sizes\ in\ MVAr)^2}}{1.6\sqrt{P^2 + Q^2}} \times 100$$

(1.6 Multiplication factor is used for peak load level)

- **AEL=**
  (Losses × Load duration)$_{\text{at peak load}}$ + (Losses × Load duration)$_{\text{at normal load}}$ + (Losses × Load duration)$_{\text{at light load}}$

- **Cost (USD)=**

(Losses × Load duration × Cost in USD/MWh)$_{\text{at peak load}}$ + (Losses × Load duration × Cost in USD/MWh)$_{\text{at normal load}}$ + (Losses × Load duration × Cost in USD/MWh)$_{\text{at light load}}$

3. GOA (Grasshopper Optimization Algorithm)

The flow chart of GOA is show in Figure 1

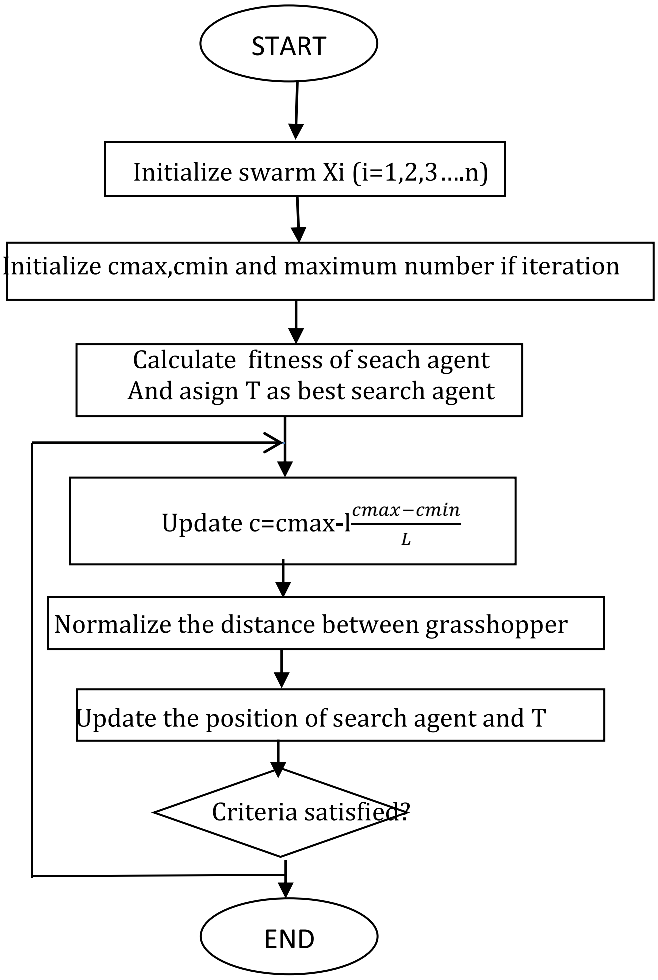

Fig -1: Algorithm for GOA.[8][9]

Grass hopper Optimization is a Meta heuristic algorithm that works on the swarming behavior of grasshoppers. It is an insect with long hind legs .These insects have special social interaction which equip them with the predatory strategy. The social interaction have the two type of forces attractive forces that exploit local search and reputation force to explore search space.[8]This algorithm is run for 200 iterations for finding the results for different load level .

4. MFO (Moth Flame Optimization)

The navigation method of moths is the main inspiration of this optimizer. Moths have a very effective mechanism of flying at night and traveling in a straight line by maintaining a fixed angle with respect to the moon. . [9][10][14]. The below flow chart Figure 2, of MFO will explain the mechanism of this algorithm.

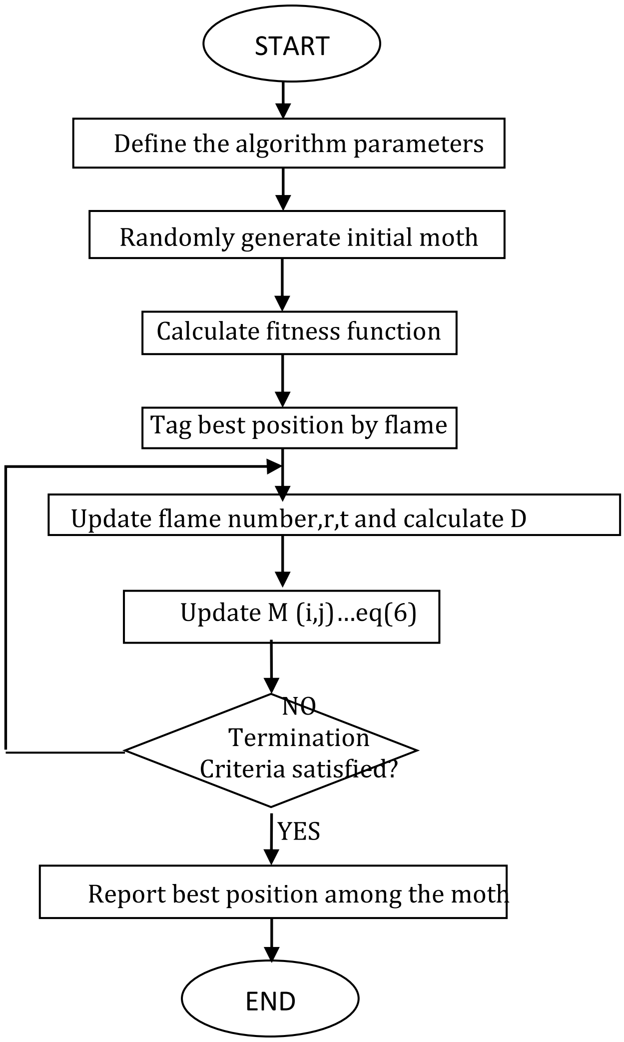

Fig -2: Algorithm for MFO. [9][10][13]

Moths are insects that belonged to the family of butterflies. The special navigation method of these insects is developed to fly at night using moon light. The moth flies by maintaining a fixed angle with the moon, this mechanism called transverse orientation for navigation. But, When moths see an artificial light, the light is extremely close compared to moon, so they try to maintain a similar angle with the light to fly in straight line. However, maintaining a similar angle to the light source causes a useless or deadly spiral fly path for moths, Equation 6 is the representation of moth in matrix form

$$M=\begin{bmatrix} m_{1,2} & \cdots & m_{1,d} \\ \vdots & \ddots & \vdots \\ m_{n,2}, & \cdots & m_{n,d} \end{bmatrix} \quad (6)$$

$$F=\begin{bmatrix} F_{1,2} & \cdots & F_{1,d} \\ \vdots & \ddots & \vdots \\ F_{n,1} & \cdots & F_{n,d} \end{bmatrix} \quad (7)$$

Flame matrix similar to moth matrix.

$$S(M_i, F_j) = D_i \cdot e^{bt} \cdot \cos(2\pi t) + F_j \quad (8)$$

D_i- distance of the i-th moth for the j-th flame,
b- constant for defining the shape of the logarithmic spiral
t -random number in [-1,1].

$$D_i = |F_j - M_i| \quad (9)$$

n -number of moths
d - number of variables (dimension).
M_i- i-th moth,F_j - j-th flame, and D_i- distance of the ith moth for the j-th flame. [11][12].

5. CASE STUDY:

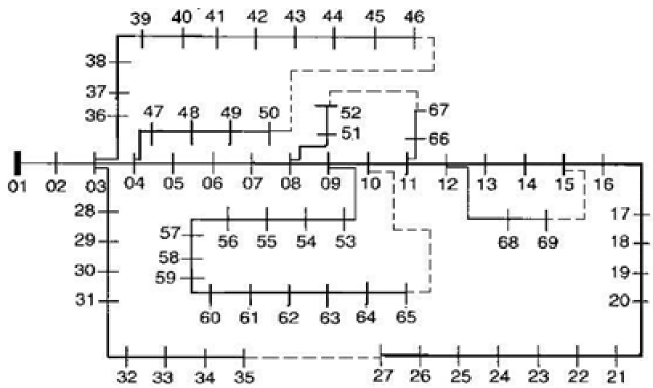

Fig -3: 69-bus RDS.

Table -2: Different Load Levels with Load duration and Cost.[17][18]

LOAD LEVEL	mf	LOAD DURATION(h)	USD/MWh
Peak(P)	1.6	1500	120
Normal(N)	1.0	5256	72
Light(L)	0.5	2000	55

Optimal locations of DG and DER are analyzed using GOA and MFO techniques for different load levels. Parameters for different load levels are taken from Table [17][18]. Both the algorithms are run for 200 iterations. Table no. 3 show the optimal locations and sizes of DGs and DERs, losses in each techniques, minimum voltage value and DG and DER Penetration percentage for both techniques.

The generated results are best when MFO is used and hence different graphs are plotted using these results. Figure 4 and Figure 5 shows plot for Voltage (pu) on each bus for DG and DER placement respectively. A comparison of Voltage values at each bus is shown in Figure 6, both for DG and DER placement .And Figure 7 shows bar graph showing the losses for different load conditions. This bar graph shows that the losses are maximum at base case, i.e., when DG/DER(s) are not installed, and the losses in the system are greatly reduces by placing DG/DER .Losses minimization is more when DER is placed in the system.

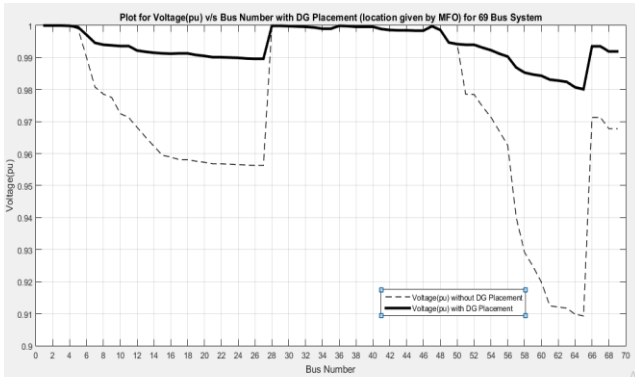

Fig -4: Voltage (pu) at each bus for DG placement in 69 bus system.

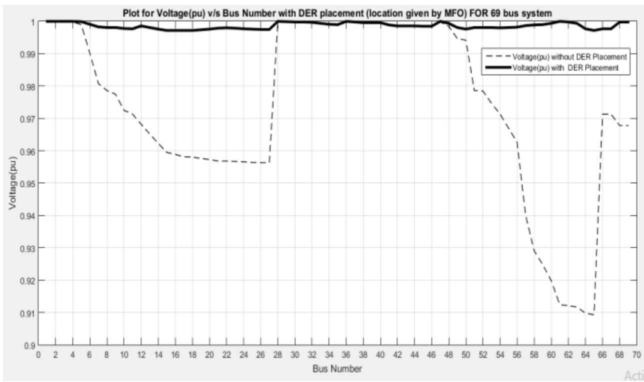

Fig -5: Voltage (pu) at each bus for DER placement in 69 bus system

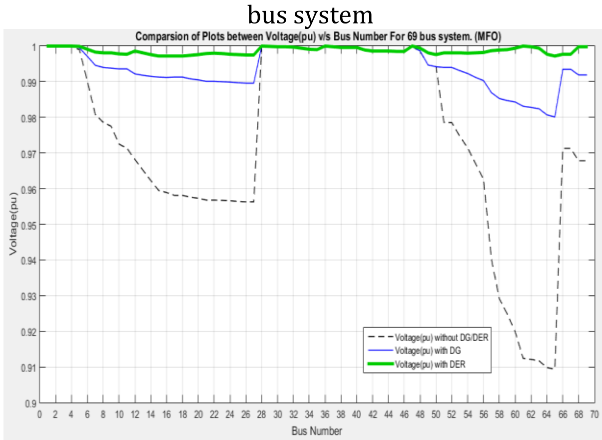

Fig 6:Comparison of Plot between Voltage (pu) on each bus of 69 –bus RDS with DG and DER placement using MFO technique.

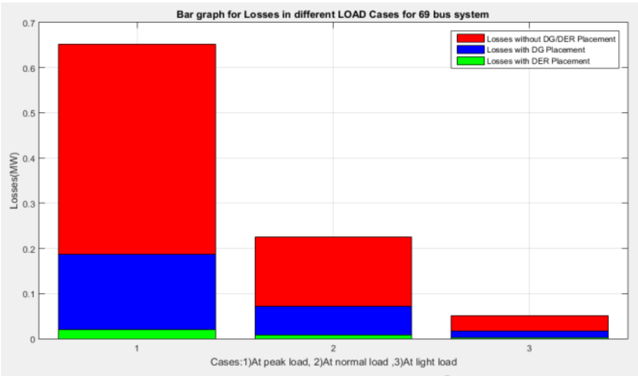

Fig -7: Bar graph showing the losses for different load conditions in 69 bus system.

6. CONCLUSIONS

This paper presents the optimization techniques to get the optimal locations and sizes of DG and DER for benchmark 69 test bus system shown in Figure 3. The techniques used are GOA and MFO. The MFO Techniques shows the better result for DG and DER placement over GOA. The best location analyzed by MFO for DGs placement is at 61,11,18 bus number that reduces losses from 0.2200MW to 0.0695MW at normal load condition with DG penetration 59.48%-calculated for peak load condition. For DER placement, DGs at bus number 69,61,22 with Shunt Capacitors location at bus number 61,49,12.In this case the losses reduces from 0.2200MW to 0.0054MW at normal load condition with DER penetration 72.27% -calculated for peak load condition. The above graphs and Tables-3 shows that the location analyzed by proposed MFO techniques greatly minimizes the losses, further the annual energy losses (AEL) from 2265.45 MWh, at base case to 674.22 MWh for DGs and 2265.45 MWh, at base case to 52.004 MWh for DERs placement which further reduces the Cost (USD) as well as boost up the voltage of the 69 bus system, that justifies their placement in the powersystem.

Table 3:Optimal location and size of DG and DER in 69-bus system.

Sno.	METHOD Used Optimization technique	OPTIMAL DG Location	At mf	OPTIMAL DG SIZE(MW)			LOSSES (MW)	Vmin	DG Penetration% / AEL(MWh) / COST(USD)
1	Base Case	X	P	X			0.6525	0.8445	X
			N				0.2200	0.9092	2265.45MWh
			L				0.0516	0.9567	208338 USD
2	MFO	61 11 18	P	3.0000	0.8244	0.6105	0.1831	0.9736	59.48%
			N	1.7522	0.5272	0.3804	0.0695	0.9801	674.22 MWh
			L	0.8560	0.2550	0.1897	0.0170	0.9896	61149.04 USD
Sno.	**METHOD Used Optimization technique**	**OPTIMAL DER Location**	**At mf**	**OPTIMAL DER SIZE (MW &MVAr)**			**LOSSES (MW)**	**Vmin**	**DG Penetration% / AEL(MWh) / COST(USD)**
				DG [0.5545	2.72411	0.5685]			

1	MFO	DG [69 61 22] SC {61 49 12}	P					0.0140	0.995 2	72.27% 52.004 MWh 4708.088 USD
				SC	{2.0000	0.9407	0.8218}			
			N	DG	[0.3424	1.7066	0.3586]	0.0054	0.997 2	
				SC	{1.2074	0.5682	0.5415}			
			L	DG	[0.1707	0.8522	0.1788]	0.0013	0.998 5	
				SC	{0.6032	0.2830	0.2703}			

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