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Power Loss Minimization In IEEE 33 Bus Network Through Optimal Location And Sizing Of Distributed Generation Using Particle Swarm Optimization Technic

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***Abstract*—In this study, power loss minimization in IEEE 33 bus network through optimal location and sizing of distributed generation using Particle Swarm Optimization technic is presented. Load flow analysis was conducted using the Newton Raphson method for the baseline scenario where there was no distributed generation (DG) in the network. The case study IEEE 33 bus has a total real power demand of 3715 kW and a total reactive power demand of 2300 kVar. 201.891 the total reactive power loss of 134.641kW which amounts to 5.853956522 % of the total real power is observed. The DG placement was done using the Particle Swarm Optimization (PSO) technic for 1 DG, 2DG and 3 DG. The PSO optimization at 30% penetration shows that the introduction of DGs considerably reduced the power losses and also improved on the voltage stability in the power system. The scenario with 2 DGs provides the most substantial improvements, balancing power loss reduction and voltage profile enhancement effectively. Specifically, the scenario with 2 DGs gave the highest (over 65 %) reduction in both reactive and reactive power with the lowest VDI of 2.61. The first DG of 567 kW was located at bus number while 14, while the second DG of 567 kW was located at bus number 32. In all, the PSO load placement and sizing showed remarkable reduction in the power losses and the best performance occurred with two DG scenario.**

Keywords— Loss Minimization, IEEE 33 Bus Network, Optimal Location and Sizing, Distributed Generation, Particle Swarm Optimization Technic

1. INTRODUCTION

Distributed Generation (DG) is as small-scale power generation technologies installed close to the utilisation point, and this includes solar photovoltaics, wind turbines, biomass systems and fuel cells, with each having its own strengths and applications [1,2,3]. Again, [4] and [5] stated that DG units can be installed as island grids, or they could also be linked with the existing grid, helping to increase energy security while facilitating the process of electrification and energy transition (towards renewable energy sources).

Importantly, DG plays a key role in modern power systems [7]. Firstly, DG improves energy security by reducing the dependency on centralised power plants for electricity generation [8,9]. Again, [10] went further to elaborate that DG reduces transmission and distribution losses because the generated power is always near their consumption points. Secondly, [11] contributed that DG enables more renewables integration into the energy system, which is vital for energy transition and shrinking the carbon footprint. Also, [12], highlighted that economically, adding DG defers the investments on building new large-scale power plants with high-capital outlays, creates jobs in local economies and stimulate technological innovation for smart grids and energy storage. Distributed generation can also be used to minimize power loss [13,4].

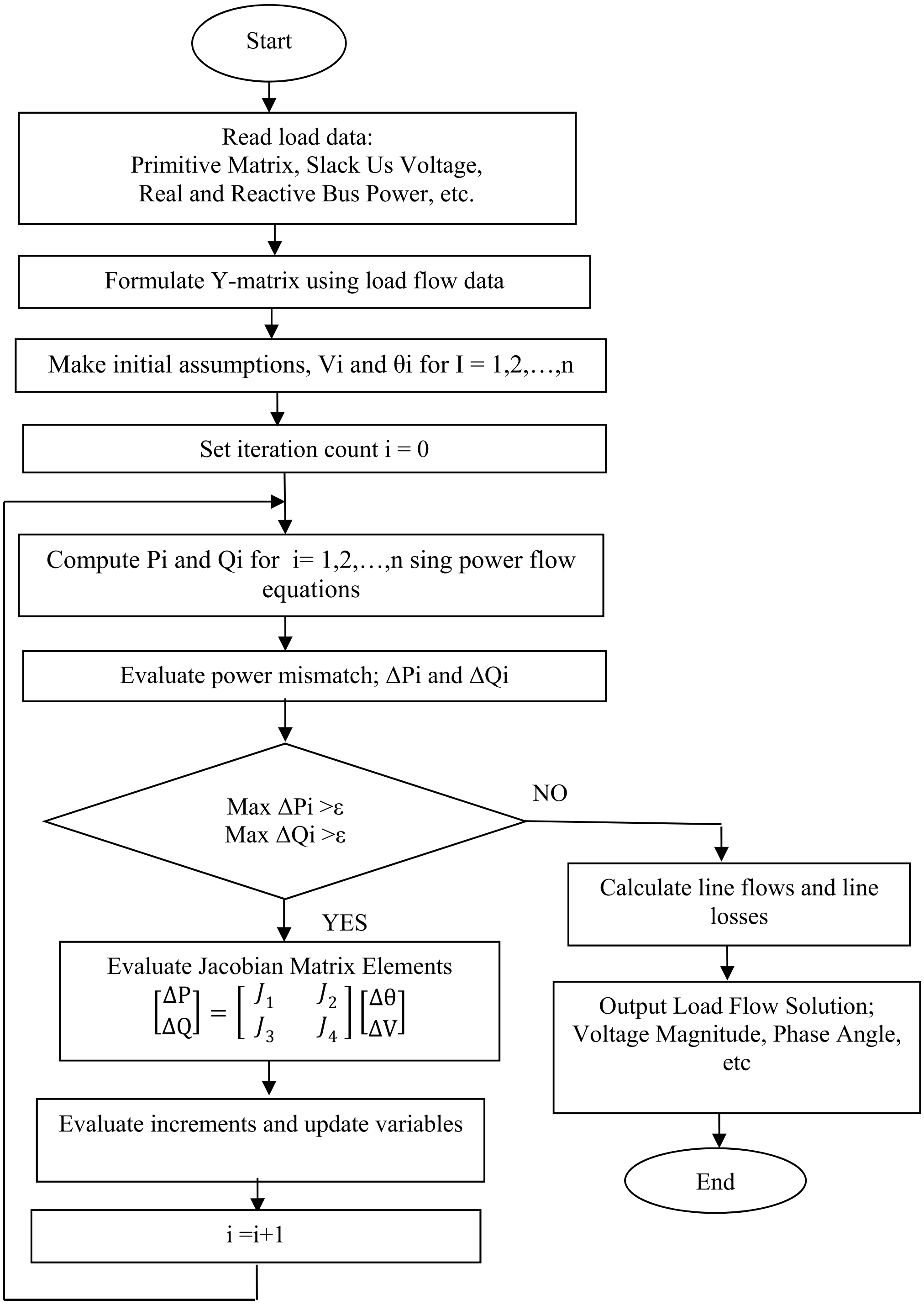
However, in order to realize the aforementioned benefits of DG in the power system, the DG must be optimally sized and optimally located within the power distribution network. Consequently, in this paper, loss minimization in IEEE 33 bus network through optimal location and sizing of DG using particle swarm optimization (PSO) technic is presented. The study considered the baseline low flow analysis where there is no DG. The Newton Raphson approach is used for the load flow. Further simulation are then conducted for different scenarios where 1 DG, 2 DG and 3 DGs are installed using the PSO to determine the optimal size and location of each of the DGs on the power distribution network. The results are presented and discussed; detailing the effectiveness of PSO to minimize the power loss and enhance voltage stability through optimal DG installation.

2. METHODOLOGY

2.1 The load flow analysis for the baseline scenario

Generally, the optimal placement and sizing of distributed generation on distribution network will lead to reduction in power. The actual percentage of reduction achieved depends on some factors among which is the approach used. In this study, the total power demand on the distribution network is determined for the baseline scenario where there is no distributed generation (DG) in the power network. The load flow analysis is conducted using the Newton Raphson method presented by [15] and the flowchart is shown in Figure 1.

The DG placement is done using the Particle Swarm Optimization (PSO) technic. Three cases were considered in this study, namely, a case of 1 DG, another case of 2 DG and finally 3 DG. Each of the three cases were implemented using the PSO algorithm captured in the pseudo code given in section 2.2. The control parameters of the PSO algorithm used to conduct the study are presented in Table 1. The line data of the IEEE 33 bus are given in Table 2 while the load data are given in Table 3



$$\begin{bmatrix}\Delta P\\ \Delta Q\end{bmatrix} = \begin{bmatrix} J_1 & J_2 \\ J_3 & J_4 \end{bmatrix}\begin{bmatrix}\Delta \theta\\ \Delta V\end{bmatrix}$$

Figure 1 The flowchart for the Newton Raphson Algorithm-based load flow analysis for the baseline scenario without DG (Source: [1])

2.2 The Particle Swarm Optimization (PSO) Pseudocode for DG Placement and Sizing

```
i.     Initialize necessary parameters and candidate locations for DG;
ii.    while not termination do:
iii.   Generate particle swarm;
iv.    for each particle do:
v.     Select a candidate location for DG based on particle's position;
vi.    Determine the size of DG at the selected location;
vii.   End for
viii.  Evaluate the fitness of each solution (i.e., power loss and voltage stability for the given DG placement and sizing);
ix.    Update the best personal and global positions;
x.     Update particle positions and velocities based on the best found positions;
xi.    End while
xii.   Return the best solution found;
xiii.  End procedure.
```

Table 1: Control parameters of the PSO algorithm used to conduct the study

Parameters	**Values**	**Explanation**
Population size	50	Defines the number of search agents (particles) exploring the solution space simultaneously.
Maximum iterations	100	Sets the maximum number of times the PSO loop (particle movement and update) will be executed.
Minimum weight of inertia (ω_{max})	0.4	Controls the exploration-exploitation balance of particles. Higher ω_{max} allows wider exploration initially.
Maximum weight of inertia (ω_{min})	0.9	This value influences the exploitation behavior in later iterations, guiding particles towards promising regions of the search space.
Social acceleration coefficient (c_1)	1.5	Influences exploitation in later iterations, guiding particles towards promising regions.
Cognitive acceleration coefficient (c_2)	2.0	Controls the influence of a particle's personal best (Pbest) on its movement. Allows particles to explore promising regions based on their experiences.

Table 2: The line data of the IEEE 33 bus test system (Source :[16])

			Line Data	
S/N	**From Bus**	**To Bus**	**Line Resistance (Ω)**	**Line Reactance (Ω)**
1	1	2	0.0922	0.047
2	2	3	0.493	0.2511
3	3	4	0.366	0.1864
4	4	5	0.3811	0.1941
4	5	6	0.819	0.707
6	6	7	0.1872	0.6188
7	7	8	0.7114	0.2351
8	8	9	1.03	0.74
9	9	10	1.044	0.74
10	10	11	0.1966	0.065
11	11	12	0.3744	0.1238
12	12	13	1.468	1.155
13	13	14	0.5416	0.7129
14	14	15	0.591	0.526
15	15	16	0.7463	0.545
16	16	17	1.289	1.721
17	17	18	0.732	0.574
18	2	19	0.164	0.1565
19	19	20	1.5042	1.3554
20	20	21	0.4095	0.4784
21	21	22	0.7089	0.9373
22	3	23	0.4512	0.3083
23	23	24	0.898	0.7091
24	24	25	0.896	0.7011
25	6	26	0.203	0.1034
26	26	27	0.2842	0.1447
27	27	28	1.059	0.9337
28	28	29	0.8042	0.7006
29	29	30	0.5075	0.2585
30	30	31	0.9744	0.963
31	31	32	0.3105	0.3619
32	32	33	0.341	0.5302

Table 3: The load data of the IEEE 33 bus test system (Source :[16])

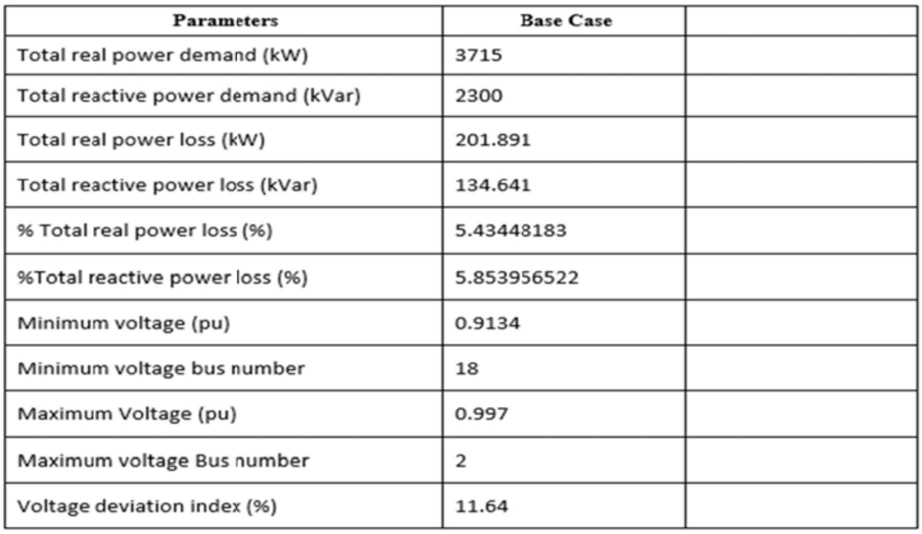
Bus Number	Real Power Demand (kW)	Reactive Power Demand (kVar)	Bus Number	Real Power Demand (kW)	Reactive Power Demand (kVar)
1	0	0	18	90	40
2	100	60	19	90	40
3	90	40	20	90	40
4	120	80	21	90	40
5	60	30	22	90	40
6	60	20	23	90	50
7	200	100	24	420	200
8	200	100	25	420	200
9	60	20	26	60	25
10	60	20	27	60	25
11	45	30	28	60	20
12	60	35	29	120	70
13	60	35	30	200	600
14	120	80	31	150	70
15	60	10	32	210	100
16	60	20	33	60	40
17	60	20	17	60	20
Total				**3715**	**2300**

3. RESULTS AND DISCUSSIONS

3.1 The results on the baseline case without DG

The Newton Raphson load flow analysis The key parameters of the bus network obtained from the Newton Raphson load flow analysis are shown in Table 4. The results in Table 4 shows a total real power demand of 3715 kW and a total reactive power demand of 2300 kVar. 201.891the total reactive power loss of 134.641kW which amounts to 5.853956522 % of the total real power is observed.

Table 4 The key parameters of the bus network obtained from the Newton Raphson load flow analysis



Parameters	Base Case	
Total real power demand (kW)	3715	
Total reactive power demand (kVar)	2300	
Total real power loss (kW)	201.891	
Total reactive power loss (kVar)	134.641	
% Total real power loss (%)	5.43448183	
%Total reactive power loss (%)	5.853956522	
Minimum voltage (pu)	0.9134	
Minimum voltage bus number	18	
Maximum Voltage (pu)	0.997	
Maximum voltage Bus number	2	
Voltage deviation index (%)	11.64	

3.2 The results on the DG sizing and placement using PSO

The results in Table 5 presents the outcomes of optimizing Distributed Generation (DG) placement in a power system using Particle Swarm Optimization (PSO) which is implemented at a 30% level of penetration. The results are compared across four scenarios: the base case (no DGs) and cases with 1, 2, and 3 DG units. The PSO optimization at 30% penetration shows that the introduction of DGs considerably reduced the power losses and also improved on the voltage stability in the power system. The scenario with 2 DGs provides the most substantial improvements, balancing power loss reduction and voltage profile enhancement effectively. Specifically, the scenario with 2 DGs gave the highest (over 65 %) reduction in both reactive and reactive power with the lowest VDI of 2.61. The first DG of 567 kW was located at bus number while 14, while the second DG of 567 kW was located at bus number 32.

The comparison of real (active) and reactive power losses across different scenarios of DG placement in a power system is illustrated in Figure 3. The scenarios include the base case (no DGs) and cases with 1, 2, and 3 DGs, optimized using PSO. The chart effectively demonstrates that the integration of DGs using PSO optimization leads to a significant reduction in both real and reactive power losses, with the most pronounced benefits observed when two DGs are optimally placed.

The comparison of the voltage profiles across different bus numbers for various scenarios of DG penetration, optimized using PSO is presented in Figure 4. The results demonstrates that increasing DG penetration through optimal placement using PSO significantly enhances the voltage profile of the system. The most considerable improvement is observed with the integration of two DGs, which provides the best voltage regulation across the network. Adding a third DG still improves the voltage profile but does not offer as significant an advantage as the second DG.

Table 5: PSO-Optimized DG Placement Results Implemented at 30% Penetration)

Parameter	Base Case	1 DG	2 DGs	3 DGs
Total real power loss (kW)	201.891	86	70	74
Total reactive power loss (kVAR)	134.641	59	46	48
Real power loss reduction (%)	-	57.4	65.3	64.3
% Reactive power loss reduction	-	56.1	65.8	64.3
Minimum voltage (pu)	0.9134	0.936067	0.959644	0.9543035
Minimum voltage bus number	18	18	30	31
Maximum voltage (pu)	0.9834	0.997931	0.997942	0.9979402
Maximum voltage bus number	2	2	2	2
Voltage deviation index, VDI (%)	11.28	4.32	2.61	2.62
DG Location (Bus No.)	-	30	14, 32	32, 11, 16
DG Real Power Size (kW)	-	1115	567, 567	372, 372, 372
DG Reactive Power Size (kVAR)	-	540	270, 270	180, 180, 180

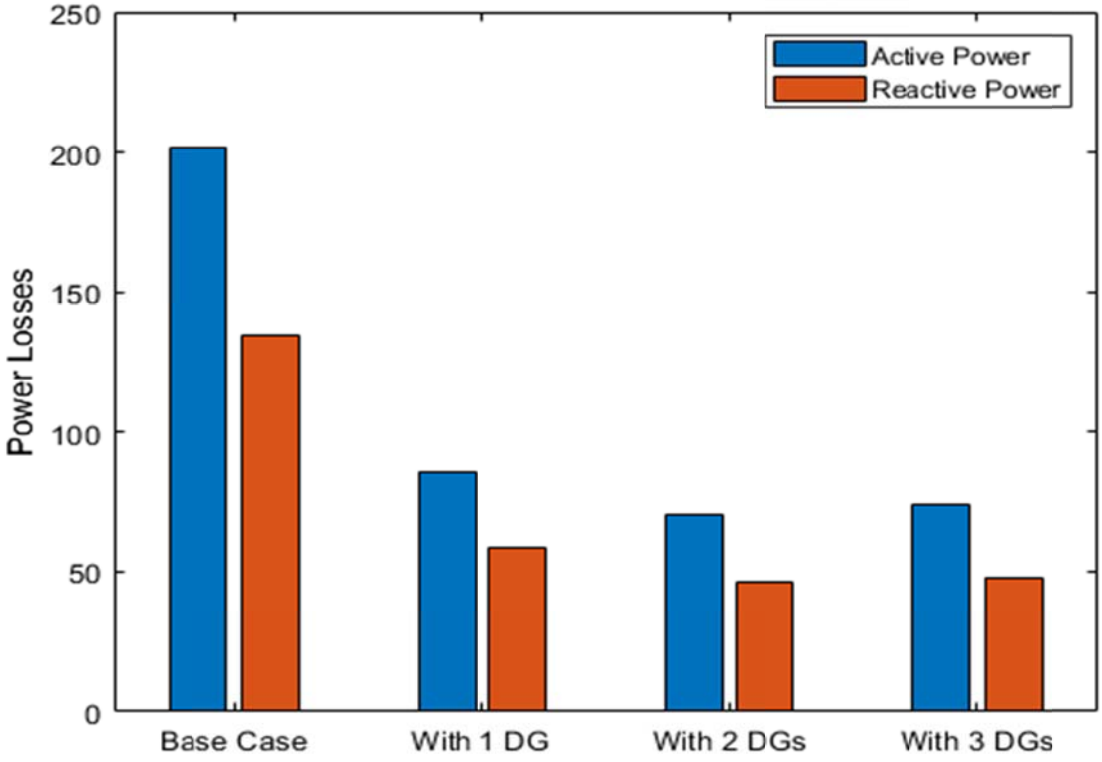


Figure 3:Real and reactive power losses for all scenarios using PSO.

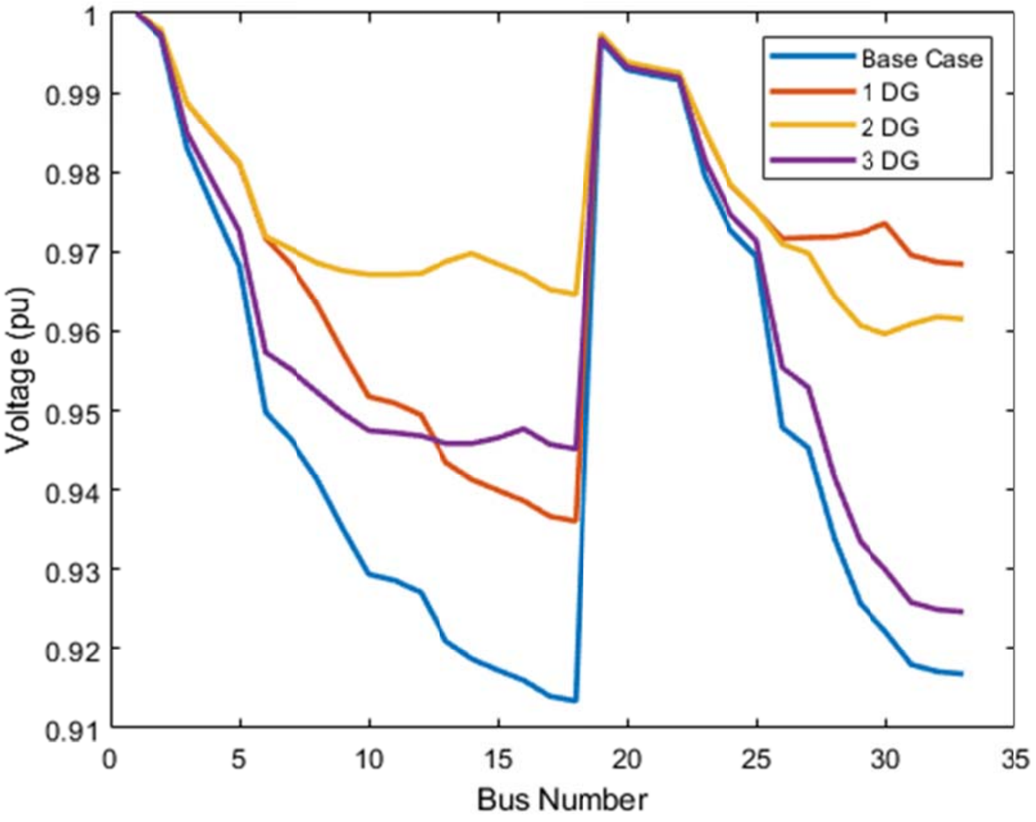


Figure 4: Voltage profile comparison with increasing DG penetration using PSO.

4. CONCLUSION

A study of power reduction in IEEE 33 bus network based on distributed generation sizing and placement using Particle Swarm Optimization (PSO). Newton Raphson method was used in the load flow analysis to determine the power losses and voltage profile and other relevant parameters of the bus network under the condition of no distributed generation on the bus. The PSO load placement and sizing showed remarkable reduction in the power losses and the best performance occurred with two DG scenario.

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