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Optimal allocation and sizing of renewable energy distributed generation using a modified particle swarm optimization method for power loss reduction

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Abstract

In this paper, a modified PSO (MPSO) technique was used to determine the optimal size and location of Distributed Generation (DG) in Onitsha distribution system in the Nigeria power network. This technique mitigates the drawback of the conventional PSO method by speeding up the convergence, ensuring that the search algorithm does not get trapped in local optima thereby reducing the computational time. The algorithm was implemented using the MATPOWER 5.1 toolbox. The results showed that an optimal DG unit size of 5.5103MW when placed in Market-bus in the Onitsha distribution system reduced the power losses significantly from 3.9176MW to 2.444MW, the voltage profile improved from 0.8825p.u to 1.0155p.u with a faster convergence at the 15th iteration. Thus, installing DG unit using the proposed MPSO method assures better system characteristics when compared to other methods.

Keywords: Optimal, Sizing, Algorithm, Convergence, Distribution, Network

1. Introduction

In power system optimization, numerous techniques have been used to deal with the problem of distributed generation sizing and positioning. This problem is solved in such a way that it provides most economical, efficient, technically sound distribution system (Thong and Belmans, 2016). In Engin et al. (2015) the threshold penetration level of distributed generation was studied. As a case study, the penetration level was assumed to be 4% and 2% of IEEE-30 and IEEE-57 bus systems, respectively. For IEEE 30 system, bus 26 was the most problematic bus in terms of voltage profile, while, bus 57 was found to be the most problematic bus for IEEE-57. For this reason, some measures were suggested for these buses in order to increase DG penetration. In addition, multiple-DG penetration was assumed to be better than the single-DG penetration for voltage profile because of the fact that the penetration level can be increased up to 4.4% without any measure.

Ben, Medani and Sayah (2016) applied a PSO-Thyristor Controlled Series Capacitor (PSO-TVAC) algorithm to solve the ORPD. The ORPD problem was formulated as a nonlinear, non-convex constrained optimization problem considering both continuous and discrete control variables. It also had both equality constraints and inequality constraints. The acceleration coefficients in the PSO algorithm were varied adaptively during iterations to improve the solution quality of the original PSO and avoided premature convergence. The proposed algorithm was tested on 12-bus, 30-bus, 33-bus and 69-bus radial distribution test systems. In Prakash and Lakshminarayana, (2016) particle optimization method was used for multi DG placement for losses reduction and voltage profile improvement. The proposed method was tested on IEEE-33 bus system and IEEE-69 bus. Maximum penetration of DG was considered as 100%, while, the maximum number of DG's was considered to be three. MATLAB environment was used to run load flow and to calculate power losses so as to find optimal location and optimal size of DG units. Jamil and Sharique, (2016) used an analytical approach to find the optimal size and location of solar photovoltaic in a primary distribution network based on multiple locations. This was tested on IEEE 33 and IEEE 69 bus system and the result showed that the placement of multiple DG is more significant and economical as compared to single DG placement. However, this approach was cumbersome as the author had to place the DG on each of all the buses to ascertain the optimal location; also this was not tested on a real case system. Kumar and Goyal (2015) presented a PSO based approach for solving the ORPD problem for minimizing power losses without violating the inequality constraints and satisfying the equality constraints. The control variables are bus voltage magnitudes (continuous type), transformer tap settings (discrete type) and reactive power generation of capacitor banks (discrete type).

The knowledge gap in literature hinges on the need to develop an improved PSO technique that speeds up the convergence such that the search algorithm does not get trapped in local optima thereby reducing the computational time. This paper bridged this gap by developing a non-linear strategy which reduces the time needed to get the optimum solution by spreading all the particles all over the search space quickly so as to determine the approximate range of global extremes. This was also tested on the Onitsha distribution network in the Nigeria power system.

2.0 Materials and methods

In this paper, the optimal size and location of distributed generation in the Onitsha distribution network in the Nigeria power system was solved by implementing a modified Particle Swarm Optimization (PSO) algorithm in MATPOWER 5.1 toolbox.

2.1 The Test-bed Network Data Presentation

Onitsha is a city on the eastern bank of the Niger River. It is the major commercial town in Anambra state Nigeria with a population of about 2million people. It has a coordinate of 6˚10’N, 6˚47’E. The network under study is the Onitsha distribution network which has twenty nine (29) load centers that are fed from two injection substations namely the Awada and GCM substations. Figure 2.1 shows the one line diagram of Onitsha distribution network system in ETAP environment.

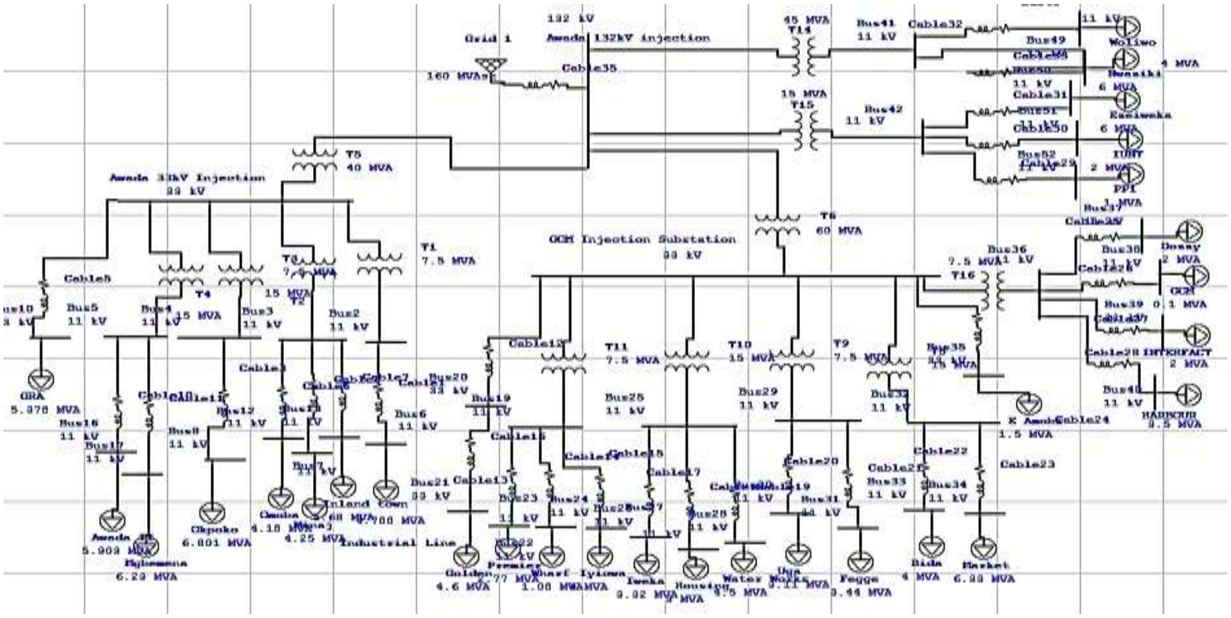


Figure 2.1: Onitsha distribution network system in ETAP

The Onitsha 132kV transmission line supplies the Awada 132kV injection substation which has four 132kV/33kV/11kV transformers feeding Onitsha distribution network namely; MOB 40MVA feeding Awada 33kV injection substation, MOB 45MVA feeding Woliwo and Nwaziki 11kV feeders, TR12 15MVA feeding Ezeiweka 11kV feeder, and TR13 60MVA feeding GCM 33kV injection substation.

2.2 The Revamp Voltage Stability Index

The Revamp Voltage Stability Indicator (RVSI) was utilized to identify weak buses or critical lines within the network that are most prone to instability. Under normal operating conditions, the RVSI yields low values, whereas higher values indicate proximity to voltage instability. Therefore, buses or lines with elevated index values are considered potential sites for PV integration (Rath et al., 2015). The RVSI specifically pinpoints vulnerable zones or lines nearing instability, with the weakest bus selected for PV placement. This targeted approach helps minimize the computational effort required to evaluate PV performance across all network buses (Nwokporo, Anazia, Ezendiokwelu and Ogboke 2025). RVSI takes into account parameters such as reactive power flow, voltage angle, load demand, power flow, and network configuration to assess the system's stability margin.

Using MATLAB software, the sending and receiving angle values for the buses were determined. Let the sending bus and receiving bus be V_k and V_{k+1} respectively, and current flowing through the sending and receiving bus I_{k+1}.

Therefore,

$$I_{k+1} = \frac{V_{k<\delta_k} - V_{k+1<\delta_{k+1}}}{R+jX} \tag{2.1}$$

Also,

$$I_{k+1} = \frac{P+jX}{V_{k+1<-\delta_{k+1}}} \tag{2.2}$$

Solving Equations (3.1) and (3.2), the equation for V_{k+1} becomes

$$V_{k+1}^2 - \left(\frac{R}{X}\sin\delta + \cos\delta\right) V_{k+1} V_k + \left(X + \frac{R^2}{X}\right) Q_{k+1} = 0 \tag{2.3}$$

Where,

$\delta = \delta_k - \delta_{k+1}$

For the solution the real part of the equation, equation determinant should be greater than zero.

$$\left(\frac{\mathrm{R}}{\mathrm{X}}\cos\delta + X\sin\delta\right)^2 - 4\left(\mathrm{X} + \frac{\mathrm{R}}{\mathrm{X}^2}\right) \geq 0 \tag{2.4}$$

Therefore,

$$\frac{4Z_{k,k+1}^2 Q_r X_{k,k+1}}{V_s^2 (R_{sin\delta} + X_{cos\delta})^2} \leq 1 \tag{2.5}$$

The equation for the Revamp Voltage Stability Indicator becomes

$$RVSI = \frac{4Z_{ij}^2 Q_r X_{ij}}{V_s^2 (R_{sin\delta} + X_{cos\delta})^2} \tag{2.6}$$

Where,

Z=line impedance, X=line reactance, Q_r=receiving end VAR, V_s= voltage at the sending end, R = line resistance, δ= power angle.

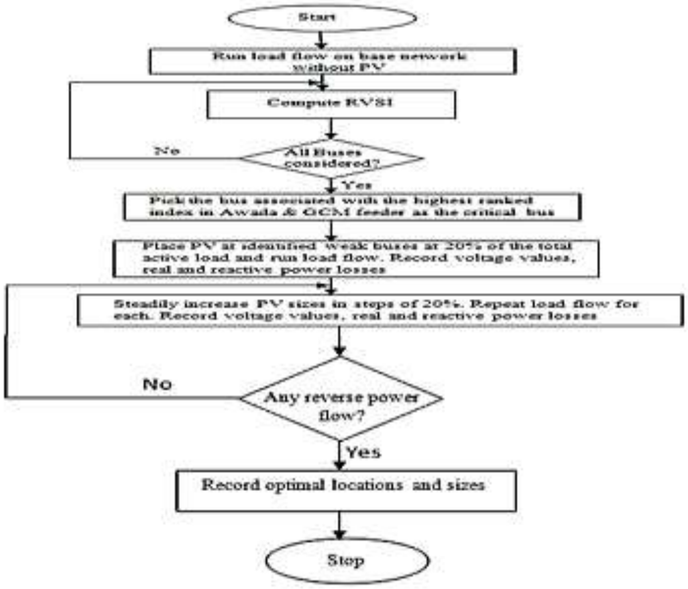
2.3 Determination of Injected PV Optimal Size

The hosting capacity of a network refers to the maximum percentage of PV integration that can occur without causing increased power losses or reverse power flow.

Table 2.1: Percentage injected PV capacities

Percentage Increase	Awada Feeder (MW)	GCM Feeder (MW)
20%	12.63	11.34
40%	25.27	22.69
60%	37.90	34.04
80%	50.54	45.39
100%	63.18	56.74

In this study, PV systems were incrementally integrated into the network, starting at 20% of the total load demand and increasing in steps of 20% of the active power demand at the identified weakest buses. The load demand for the Awada feeder is 63.18 MW, while the GCM feeder has a load demand of 56.74 MW. The corresponding percentage injection levels are detailed in Table 2.1.



2.2: Flow chart for determining the optimal location and size of PV using RVSI

Figure 2.3 and 2.4 show the stability index results for Awada injection feeder and GCM injection feeder respectively. Ezeiweka bus recorded the highest index value in Awada feeder, thus, the bus is taken to be the weakest bus for PV integration. On the GCM injection feeder, the highest index value was recorded at the Market bus, hence, the weakest bus for PV integration in the GCM feeder.

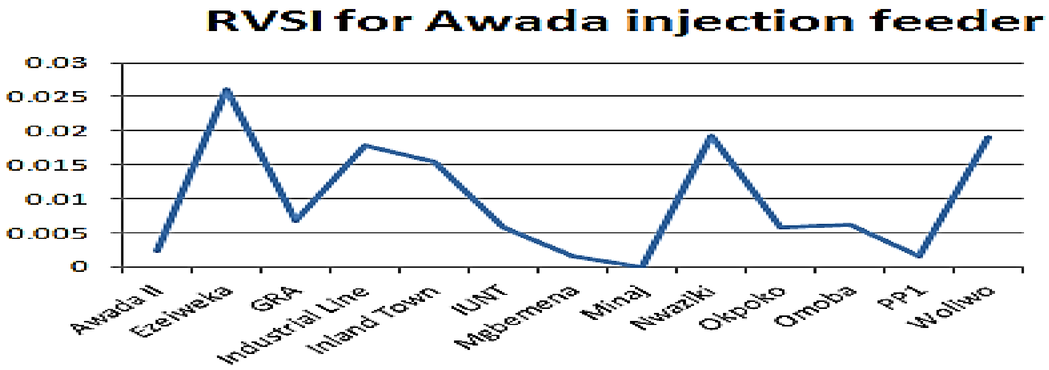


Fig 2.3: RVSI for Awada Injection Substation feeder

Fig 2.4: RVSI for GCM injection Substation feeder

2.3 Optimal Placement and Sizing of DG Using Conventional PSO Method

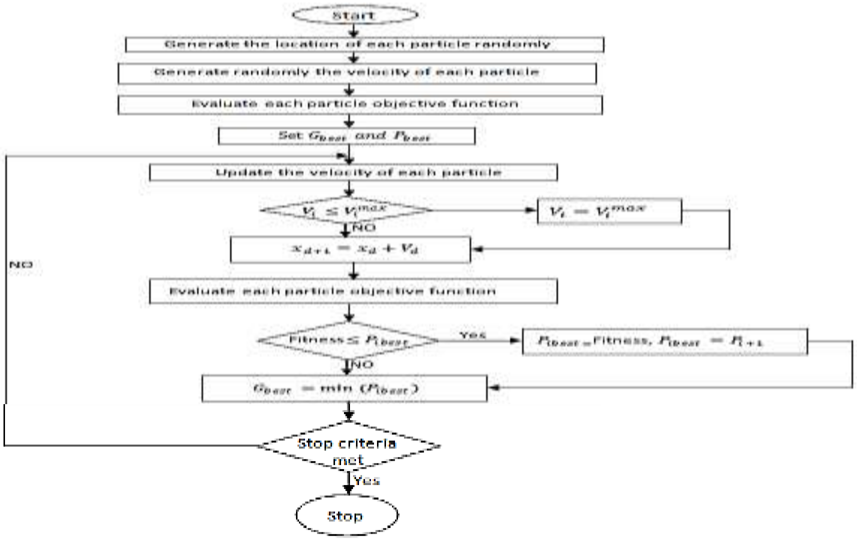


Fig. 2.5: Conventional PSO flow chart for optimal DG location

2.4 The Proposed Modified PSO Technique

The main aim of this paper is to obtain a better performing algorithm that combines the advantages of individual algorithms which is what the Modified-PSO (MPSO) technique offers. Hybrid algorithms benefit from synergy by choosing an adequate combination of component algorithms to achieve a better overall performance in a particular situation or problem is important. This paper tends to hybridize the PSO to form a tool that can out-perform the algorithms when individually applied in power system for optimal DG location. In the optimization process, a global exploration of the search space is required to probe a wider region for the perspective solution and later on search for a better solution in the vicinity of a given starting solution within a more promising region. Inertia weigh ω plays a key role in the process of providing balance between exploration and exploitation process. Also, it determines the contribution of the previous velocity of each particle with the current velocity. Following that the concept of inertia weight was introduced as constant value by Shi and Eberhart (2002), in which state that a large inertia weight facilities a global search while small inertia weight facilities a local search (Liang and Kang, 2016). It also has a great influence optimization performance. High value of ω is useful to improve the convergence speed of the algorithm, while the low ω improves the convergence precision of the algorithm. In order to improve PSO a time variant inertia weight has been introduced by many researchers which helps to come out quickly from a region where the velocity becomes stagnant (Ojha and Das, 2012).

There are many different strategies that have been proposed to change inertia weight, which can be divided into two categories, linear strategy and nonlinear strategy. The linear strategy suggests that inertia weight with the number of iterations increased can be decrease linearly as in equation (2.9), which can ensure early larger ω value so as to accelerate convergence and smaller value ω so as to avoid falling into local optimum. By comparing with linear strategy, nonlinear strategy not only suggests ω in the initial stage in a better way, but it also reduces time needed to get the optimum solution. Moreover, with nonlinear inertia strategy, all particles can be quickly spread all over the search space so as to determine the approximate range of global extremes. Therefore, nonlinear strategy can obtain better performance than linear strategy (Liang and Kang, 2016).

In this paper, linear strategies will be used in conventional PSO algorithm. Meanwhile, an improved version of PSO which offers improvement in quality solution and computational time is proposed by controlling the inertia weight ω by using exponentially time varying weight. The linear equation of inertia weight used in conventional PSO algorithm can be described as below (Jamil, Sharique and Ahmed 2016).

$$\omega = \omega_{max} - \left((\omega_{max} - \omega_{min}) \text{ x } \left(\frac{iter}{\text{maxiter}}\right)\right) \qquad (2.9)$$

where:
ω_{max} = the maximum weight.
ω_{min} = the minimum weight.
Iter = the current iteration number.
Maxiter = maximum number of iterations.
ω = the constant weight suggested value is 0.9.

The equations (2.9) and (2.10) offer a linear decreasing inertia weight. This inertia weight linearly decreases with respect to time. Generally for initial stages of the search process, large inertia weight is recommended to enhance the global exploration (searching new area). Meanwhile, for last stages, the inertia weight is reduced for local exploration (fine tuning of the current search area). As an addition to linear strategies, equation (2.10) can be used as a time varying inertia weight which decreases exponentially with time. By starting from maximum toward minimum weight, the exponential inertia weight reduces computational time in PSO and improves convergence.

$$\omega = \omega_{max} \text{ x } e^{\left(\left(\frac{(maxiter-iter)}{maxiter}\right)-1\right)} - \omega_{min} \qquad (2.11)$$

In this paper, equation (2.11) was used in the PSO algorithm so as to provide an improved version of PSO method.

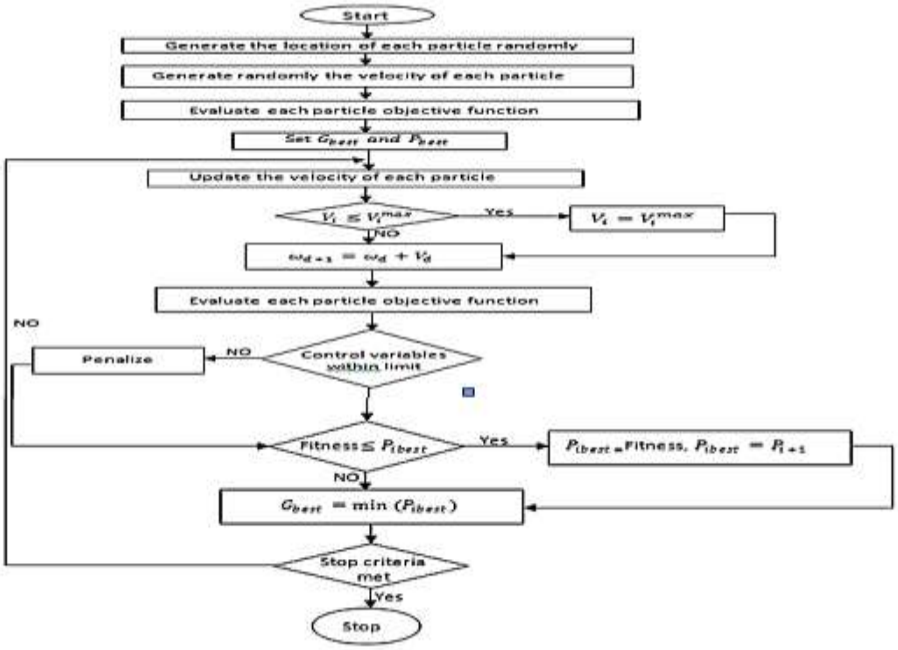


Fig. 2.6: Modified PSO flowchart for optimal DG location

3.0 Results and Discussions

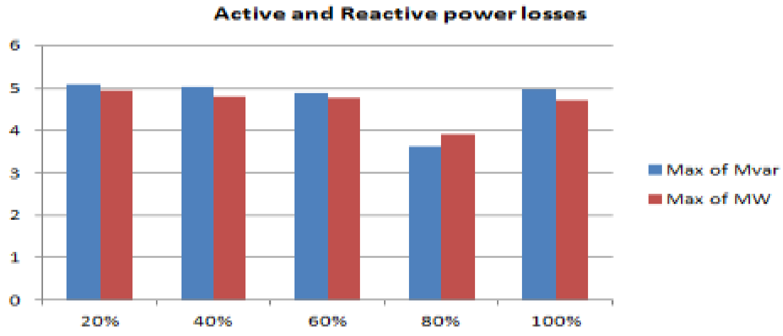


Fig 2.7: Active and reactive power losses at incremental PV integration

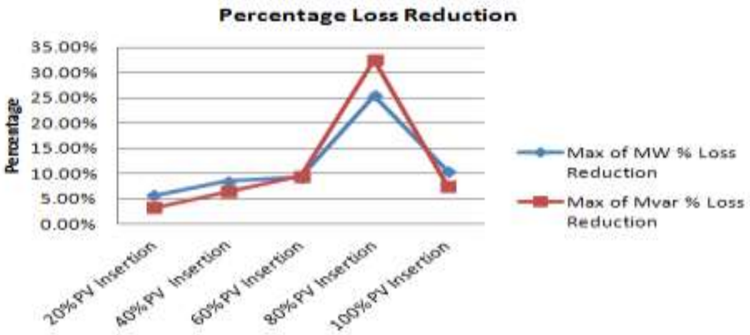


Fig 2.: Percentage Loss Reduction at Incremental PV Insertion

Following the simulation for percentage incremental PV integration, at 20% integration the active and reactive power losses on the Onitsha distribution network was reduced from 5.2542 MW and 5.3803MVar to 4.9551 MW and 5.0795 MVar respectively. This accounts for a 5.69% and 3.24% reduction on power losses on the base network active and reactive power losses respectively. For 40% integration, the active and reactive losses were reduced from base value 5.2542MW and 5.3803MVar to 4.808MW and 5.0337MVar respectively. This accounts for 8.49% and 6.44% reduction on power losses. When the PV integration was increased to 60%, the active and reactive power losses were reduced to 4.7684MW and 4.8720MVar accounting to 9.24% and 9.44% reduction respectively. Also for 80% integration, the power losses were reduced from the base values to 3.9176MW and 3.6283MVar which represents 25.43% and 32.56%. When the PV integration was increased to 100%, the active and reactive power losses were reduced from the base values to 4.7038MW and 4.9765Mvar which account for 10.47% and 7.50% reduction respectively. Thus, it can be stated that using ETAP which is based on Netwon Raphson method, the Ezeiweka bus and Market bus are the optimal locations for PV in the Onitsha distribution network, while the optimal sizing of PV is at 80% integration.

3.1 Simulation Results for the Optimal Placement and Sizing of DG Using Conventional PSO Technique

The conventional Particle swarm optimization (PSO) code was implemented to place the DG in an appropriate location in order to minimize system active and reactive power losses. This was implemented by randomly initializing the DG sizes for each location. PSO being an exhaustive search is expected to come up with capable solutions that are optimal DG size for each location. The best position combines the ideal (optimal) DG sizes and positions (location) with the appropriate fitness value, which represents the minimum amount of power loss. Table 3.2 shows the fitness losses, DG size and bus number for the iterations counts. It shows that a DG unit with a size of 5.6722 MW can be installed at bus number 10 (PP1-bus) which makes the voltage magnitude 1.0055 pu. The minimum value of fitness losses is 0.0406.

Table 3.2: Simulation Result for the Conventional PSO method

Iteration Number	DG Capacity (MW)	DG voltage (pu)	DG Location (number of bus)	Fitness Losses
1	1.4165	0.989	21	0.0498
2	1.8918	1.0152	7	0.1663
3	1.3156	1.0076	28	0.0645
4	3.344	1.0179	21	0.0664
5	1.9281	1.0127	28	0.041
6	2.9079	1.0113	3	0.1163
7.	1.4609	1.0033	19	0.0801
8	5.9967	1.0076	3	0.1343
9	1.6618	1.0113	18	0.1431
10	1.4685	1.0027	4	0.1263
11	1.7772	0.9819	16	0.1169
12	2.8279	0.9816	27	0.1247
13	1.6402	1.0127	27	0.0984
14	1.472	0.9815	3	0.0721
15	3.751	0.9959	11	0.1136
16	1.338	0.995	5	0.1302
17	2.375	1.0048	22	0.0684
18	1.2432	0.9907	24	0.1166
19	1.6481	1.0199	13	0.1025
20	1.7583	0.9801	16	0.1144
21	3.8081	0.9801	24	0.1149
22	1.9567	0.9915	15	0.1360
23	1.5271	0.9997	6	0.1247
24	2.9477	0.9883	21	0.1092
25	1.9894	1.0107	11	0.1066
26	1.5073	0.9808	32	0.1121
27	3.5251	1.0076	14	0.0626
28	1.4467	1.0077	27	0.0697
29	3.3607	0.9954	8	0.1117
30	1.9343	0.9808	11	0.1102
31	1.8768	0.9815	24	0.1058
32	5.3653	1.0054	11	0.1135
33	1.2973	1.0033	13	0.1127
34	1.8637	0.9848	21	0.1087
35	4.8891	0.9929	7	0.0905
36	1.3801	1.0046	26	0.0551
37	1.5144	0.9859	4	0.1041
38	1.5378	1.0098	18	0.0730
39	1.8128	0.9827	21	0.0648
40	5.9418	0.9854	25	0.1086
41	1.9973	0.9811	6	0.216
42	3.2275	1.0062	28	0.1066
43	1.5495	0.9887	4	1.5188
44	1.5188	0.9923	27	0.1065
45	1.5526	1.0138	3	0.0998
46	4.8759	1.0018	25	0.1171
47	1.468	0.993	11	0.0573
48	1.6484	1.0015	22	0.0607
49	1.3791	1.0194	23	0.0798
50	3.8936	0.9838	26	0.1128
51	1.2808	1.0047	7	0.1302
52	1.9999	0.9865	24	0.1111

53	2.7768	0.9944	15	0.0628
54	1.717	1.0175	8	0.1322
55	1.2466	0.9943	22	0.1103
56	3.2032	0.9873	19	0.0565
57	1.3759	0.9869	10	0.0447
58	5.7236	0.9910	11	0.0805
59	1.4358	1.0072	10	0.1319
60	1.5348	1.0091	26	0.0679
61	4.9191	0.9822	23	0.1095
62	1.3079	0.9801	21	0.0495
63	1.2814	1.0116	27	0.0506
64	1.3493	0.986	27	0.063
65	2.543	0.9987	3	0.0738
66	1.9672	0.9839	7	0.07
67	1.9619	1.0147	24	0.0996
68	3.8082	1.0051	21	0.0701
69	1.8209	0.9822	20	0.1213
70	1.9628	0.9815	19	0.1246
71	3.2988	0.999	22	0.1099
72	1.3773	1.0019	28	0.079
73	1.3185	0.9905	14	0.1116
74	1.599	1.0014	29	0.0956
75	1.5696	0.9922	24	0.0503
76	5.6722	1.0055	10	0.0406
77	1.769	0.9807	25	0.0564
78	2.9375	0.9837	24	0.1057
79	1.3305	1.0154	3	0.0776
80	1.5414	1.0052	23	0.0745
81	5.8384	0.9954	18	0.1209
82	1.9327	1.0028	17	0.1839
83	1.2197	1.0024	29	0.0693
84	3.2149	0.9941	17	0.1178
85	1.2092	0.9857	8	0.1078
86	1.6991	1.0071	26	0.0423
87	2.6308	0.9892	24	0.113
88	1.4318	1.0093	23	0.067
89	1.8131	1.0182	27	0.1184
90	2.7299	1.0064	24	0.0747
91	1.4127	1.0103	27	0.0761
92	3.4282	0.9896	17	0.115
93	1.6488	0.9812	26	0.1278
94	1.5179	1.0063	25	0.0706
95	1.2917	1.0125	22	0.0481
96	2.5318	1.0129	7	0.0642
97	1.9949	1.011	12	0.0686
98	4.9076	1.0096	26	0.0689
99	1.6535	0.9904	2	0.0633
100	1.404	1.0136	10	0.128

After getting the optimum results from conventional PSO optimization method, a power flow analysis study is conducted again for the network considering the newly installed DG unit. As a result of installing the newly optimized DG unit in the power system, the total power losses reduced appreciably to 2.860MW, and 3.330 MVAr .

Table 3.3: Comparison between network status before and after DG installation for the Conventional PSO method

	Before DG installation	**After Optimal DG installation**
Total active power losses (MW)	5.2542	2.880
Total reactive power losses(MVar)	5.3803	3.330
Bus voltage pu	0.9290 – 1.000	0.9801-1.0055

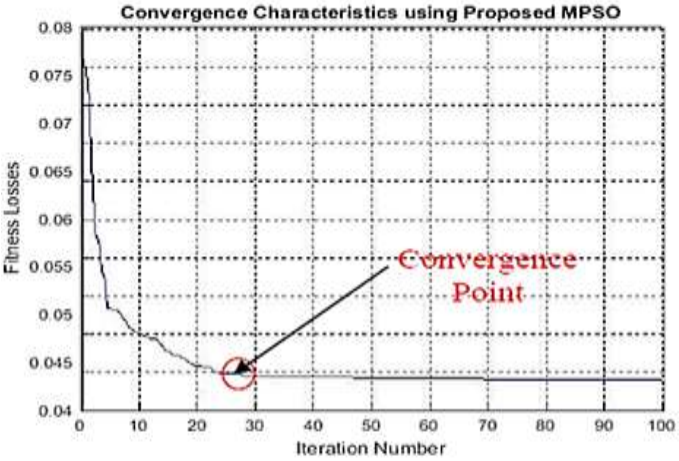


Fig. 3.1: Average convergence curve with the conventional PSO method

Figure 3.1 shows the average convergence curve of the conventional PSO technique for the Onitsha distribution network. The figure shows that the PSO starts converging at about the 28th iteration.

3.2 Simulation Results for the Optimal Sizing and Location of DG in the Onitsha Distribution Network using the MPSO method

The modified PSO method is used to reduce the elapse time by using new proposed weight equation**.** The inertia weight decreases exponentially using the proposed non-linear equation (2.11). The best position combines the optimal DG sizes and positions (location) with the appropriate fitness value, which represents the minimum amount of power loss. Table 3.4 shows the fitness losses, DG size and bus number for the chosen number iterations. It shows that a DG unit with a size of 5.5103 MW can be installed at bus number 24 (Market-bus) which makes the voltage magnitude 1.0155pu. The minimum value of fitness losses is 0.0425.

Table 3.4: Simulation Result for the Modified PSO method

Iteration Number	DG Capacity (MW)	DG voltage (pu)	DG Location (number of bus)	Fitness Losses
1	1.9326	1.0029	4	0.0693
2	1.6661	0.9854	24	0.0706
3	2.6401	0.9935	6	0.072
4	1.6478	0.9918	25	0.0608
5	1.9822	1.014	25	0.0608
6	1.7122	0.9863	23	0.0682
7	1.549	0.9826	23	0.0724
8	1.8252	1.0032	24	0.061
9	3.417	1.0145	23	0.0503
10	1.6298	1.002	13	0.0621
11	3.6775	0.9984	14	0.0649
12	1.8085	1.0168	3	0.064
13	1.752	1.0141	9	0.0438
14	2.3028	1.018	7	0.0757
15	1.582	1.0032	7	0.0658
16	1.9278	1.0199	9	0.0683

17	4.7481	1.0154	29	0.052
18	1.2555	1.0166	12	0.0648
19	2.8214	0.999	10	0.0607
20	1.7482	0.9812	2	0.0706
21	1.6192	1.011	25	0.0707
22	3.2344	0.9972	24	0.0674
23	1.388	1.0006	11	0.07
24	1.7942	0.9864	23	0.0644
25	2.8039	1.011	10	0.0712
26	1.871	0.9973	6	0.0731
27	2.8453	1.0162	16	0.0683
28	5.6678	0.9902	24	0.0675
29	1.2181	1.0076	29	0.068
30	1.7393	1.0145	23	0.0678
31	4.8074	0.9987	23	0.0679
32	1.3681	1.0102	27	0.0659
33	3.4793	0.9834	22	0.069
34	1.3058	0.98	5	0.0609
35	2.3134	1.0064	9	0.0671
36	3.9016	0.9833	21	0.0698
37	1.3336	1.0143	6	0.0723
38	2.6476	0.9911	8	0.0731
39	1.811	1.0044	7	0.0626
40	1.5266	0.9836	10	0.0667
41	4.6016	0.9821	23	0.071
42	1.8322	0.9877	30	0.0721
43	1.4156	1.0075	16	0.0706
44	2.4201	0.9954	29	0.0752
45	1.4459	0.9855	8	0.0778
46	1.9533	0.9908	23	0.0626
47	3.2489	1.0021	16	0.065
48	1.5706	1.0022	27	0.0691
49	1.7299	1.0051	24	0.0664
50	3.915	0.9851	4	0.066
51	1.9879	0.9865	20	0.0659
52	1.2296	0.9885	5	0.065
53	2.8767	0.9861	21	0.0657
54	1.9008	0.9972	11	0.0697
55	1.4868	0.9855	28	0.0647
56	4.4425	1.0056	27	0.0737
57	1.579	1.0108	11	0.0714
58	1.8343	1.0087	14	0.0746
59	3.8677	0.9963	27	0.0774
60	1.6188	0.9824	10	0.0726
61	1.5457	0.9991	19	0.0798
62	3.4731	1.0078	13	0.0657
63	1.8003	1.0178	8	0.0575
64	1.6784	1.0122	13	0.07
65	1.2903	1.0098	15	0.0664
66	1.53	1.0049	25	0.0737
67	3.3506	1.0164	23	0.0546
68	1.958	0.9908	24	0.0658
69	1.6046	0.9821	22	0.0711
70	3.7752	0.9883	23	0.0696
71	1.9669	1.001	17	0.0682
72	2.4995	0.9816	12	0.0739

73	1.268	0.9809	23	0.0695
74	2.9677	0.9861	20	0.0663
75	1.8938	0.9885	13	0.0609
76	1.6041	1.0004	28	0.0627
77	2.561	0.9805	22	0.0733
78	1.9779	1.0101	18	0.0683
79	3.4609	1.0012	24	0.0763
80	1.943	0.9933	26	0.0665
81	5.5103	1.0155	24	0.0425
82	1.3764	1.0005	26	0.0735
83	4.4772	1.0188	27	0.0493
84	1.8339	0.9875	24	0.0703
85	4.7331	1.0195	26	0.0593
86	1.6218	0.983	21	0.0754
87	4.5527	0.9957	4	0.0691
88	1.4111	1.0067	30	0.0607
89	3.2167	0.9888	13	00735
90	1.6427	0.9859	23	0.0737
91	4.5576	1.0096	21	0.0749
92	3.342	0.9846	29	0.0665
93	4.271	0.9818	2	0.0682
94	1.6712	0.9886	18	0.0734
95	3.5319	0.9948	8	0.0662
96	2.4057	1.0143	23	0.0492
97	2.7874	0.9827	29	0.0697
98	1.2119	0.9942	14	0.0623
99	4.9192	1.0138	19	0.0661
100	1.8577	0.9915	20	0.0764

A power flow analysis study is conducted again for the network considering the optimized DG size and location using the MPSO method. The result shows that the total power losses reduced appreciably to 2.444MW and 3.48 MVAr.

Table 3.5: Comparison between network status before and after DG installation for the Modified PSO method

	Before DG installation	After Optimal DG installation
Total active power losses (MW)	5.2542	2.440
Total reactive power losses(MVar)	5.3803	3.380
Bus voltage pu	0.9290	1.0155

The average convergence curve for the optimal placement of a DG unit at bus 24 using the MPSO method. From the figure, it is observed that MPSO hybrid approach showed a good convergence characteristics and performance.

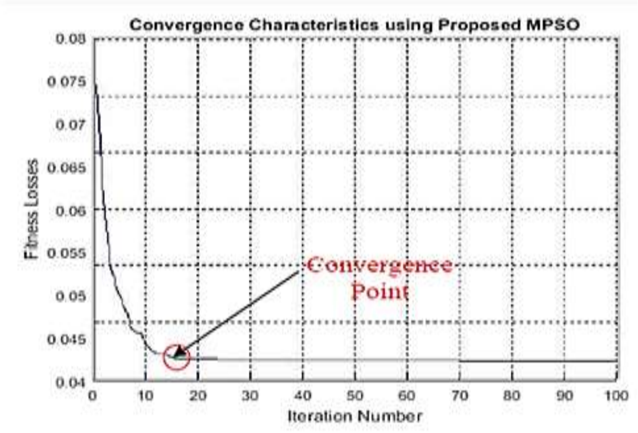


Fig. 3.2: Average convergence curve with the MPSO

Figure 3.2 shows the average convergence curve of the MPSO techniques for the Onitsha distribution network. It can be seen that the proposed MPSO approach showed better convergence characteristics than the conventional PSO method. While the conventional PSO in Fig. 3.1 starts converging at about the 28th iteration, the MPSO in Fig. 3.2 starts to converge at about the 15th iteration.

3.3 Comparison of the MPSO, with the Conventional PSO and ETAP

Comparison between conventional PSO and the modified PSO is presented in Table 3.6. The MPSO was used to reduce the elapse time by using new proposed weight equation. This equation has a non-linear pattern with the inertia weight decreasing exponentially using the proposed non-linear equation.

3.4 Comparison of the MPSO, with the Conventional PSO and ETAP

Comparison between conventional PSO and the modified PSO is presented in Table 4.10. The MPSO was used to reduce the elapse time by using new proposed weight equation. This equation has a non-linear pattern with the inertia weight decreasing exponentially using the proposed non-linear equation.

Table 4.10: Comparison of the MPSO, with the conventional PSO and ETAP

	Modified PSO	Conventional PSO	RSVI
DG Size (MW)	5.5103	5.6722	5.6800
DG Voltage	1.0155	1.0055	0.8825
DG Location	24	10	13
Fitness Value	0.0425	0.0406	-
Total active power losses (MW)	2.444	2.860	3.9176
Average convergence (iteration)	15th	28th	-

From table 4.10, it can be seen that the improvement in PSO algorithm performance was achieved by the new proposed equation as the lowest power losses and convergence time was achieved by using the proposed algorithm. If a comparison was conducted between the bus 24 (Market) that the proposed MPSO had chosen, a load flow analysis conducted by inserting 5.5103 MW distributed generation unit to the Market bus, and a DG of 5.6722 to the bus 10 (PP1) that the conventional PSO had chosen. Results showed that the total active power losses were 2.444 MW for MPSO and 2.860 MW for the conventional PSO. This reveals that the proposed MPSO has better performance to choose the optimum size and location for DG integration

4.0. Conclusion

In this paper, a modified particle swarm optimization method (MPSO) was used to find the optimum size and location of a distributed generation unit in Onitsha distribution network in the Nigeria Power system in order to improve the voltage profile and reduce the losses. A new equation of weight inertia was proposed so as to improve the performance of conventional PSO algorithm. This development was done by controlling the inertia weight affecting the updating velocity of the particles in the algorithm. By using non-linear equation of the inertia weight has a significant impact on the performance of the conventional PSO algorithm which is based on linear inertia weight equations. MATLAB codes were developed for the power system, the modified PSO algorithm and power flow analysis so as to conduct this paper. Results showed that the proposed Modified PSO algorithm successfully found the optimal size and location of the desired DG unit with an improved performance profile than the conventional PSO method. Thus installing DG unit at the optimum bus with optimum size using the MPSO assures reduced active power losses and improved the voltage profile better than other methods.

5.0 Recommendation

In this paper a significant contribution has been made to the science of optimum sizing and placement of DG units in the electrical power system. However consideration should be made to other factors in the power system such as network stability and total harmonic distortion.

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