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Optimal Placement of Distributed Generation in Power System Using Particle Swarm optimization

Engr. Chizindu Stanley Esobinenwu[1] and Engr. Dr. J.P.ILoh [2]
[1] Department of Electrical/Electronic Engineering, University of Port Harcourt, Rivers State, Nigeria.
[2] Department of Electrical/Electronic Engineering, Chukwuemeka Odumegwu Ojukwu University Uli, Anambra State.

Email: chizindu.esobinenwu@uniport.edu.ng

Abstract
In electric power system, most of the electrical energy losses occur in the distribution system. Power loss in a distribution system is high because of low voltage and hence high current. The overall efficiency of the distribution system can be improved by integrating distributed generation (DG). However, the placement of DG unit at non optimal places can have a negative impact on the distribution system. This paper proposed the use of particle swarm optimization (PSO) for the optimal placement of Distributed Generation (DG) with the aim of reducing system losses and improving voltage profile. Etap 12.6 software was used to model the 73-bus system and the search space was reduced to 35 candidate buses using Newton-Raphson power flow method. The load flow result is further passed to PSO which determines the optimal DG placement**.** Distributed generation (DG) units of 25 MW gas turbine power plants were implemented on the test system The result obtained shows that 10 buses [Bus17, Bus21, Bus31, Bus37, Bus42, Bus54, Bus57, Bus59, Bus67, and Bus68] indicates the optimal location for DG placement. It was reviewed that the maximum reduction in line losses was achieved and the overall power losses reduced from [37.817MW, 239.832MVar] to [17.543MW,119.842MVar] using particle swarm optimization method. With DG integration at optimal location, the power demand required from the grid could be reduced thus cutting the need to strengthen the feeders connecting the network to the grid.

1.0 Introduction
Electricity is the basic requirement for the socio-economic and technological development of any society (Gupta, 2005). In developing countries, the energy need of the consumers is far above what is supplied. In recent time, due to depletion in conventional energy resources, increasing cost of power system infrastructures, and technological advancements has indeed necessitated the search for alternative sources of energy Bindumol and Babu (2016). Distributed generation is a power generation system with small grid connected energy resources located close to the load

centres. Unlike the conventional power generation system that are centralized, DGs are decentralized, modular, with more flexible technologies. Integration of DGs can impact negatively on the distribution system if placed at a non-optimal location. Therefore, it is important for planning engineers to adopt a proficient optimization method in solving problems related to DG placement and sizing. Growing interest in the application of artificial intelligence (AI) techniques to power system engineering has introduced the potential of using this state of the art technology. Some of the advantages of AI techniques over analytical and classical methods are the ability to adapt to nonlinearities and discontinuities commonly found in power systems. Secondly, they perform better in terms of accuracy and convergence for complex network. Thirdly, they are versatile for handling various qualitative constraints which enables them to compute multiple optimal solutions in a single simulation. Therefore, are quite suitable in solving multi-objective optimization problems. Particle swarm optimization (PSO) is a population-based optimization technique inspired by social behavior of bird flocking or fish schooling. The technique offers a powerful approach in finding the global solution for optimization problems. The PSO algorithm starts with a population of particles with random positions in the search space. Each particle is a solution of the problem and has a fitness value or objective function. A velocity is defined which directs each particle's position and gets updated in each iteration. Particles gradually moves toward the optima position due to their personal best experience and the global best experience the entire swarm.

2.0 Literature Review

Several literature reviews on the success made in using PSO for optimal placement of DG and its impact in power distribution system formed a key basis in choosing PSO as the most effective optimization method. Mounika et al. (2017) proposed the work on particle swarm optimization application for optimal location of multiple distributed generators in power distribution network. The proposed technique effectively solved multiple DGs optimal location problem.

Shaik et al. (2017) presented loss minimization and voltage profile improvement using autonomous group particle swarm optimization in a distributed power system. The results show that AGPSO has merit compared to other algorithms in terms of convergence speed, particularly for problems of higher dimensionality. Noradin (2013) proposed a method for placement of distributed generation (DG) units using particle swarm optimization. The result showed that DG placement affects the active power loss, reactive power losses and voltage profile.

Ali et al. (2012) proposed PSO based multi objective approach for optimal sizing and placement of distributed generation. The obtained results showed that any change in the weight of each parameter in the destination function of PSO algorithm and in the matrix of coefficients leads to a meaningful change in the location and capacity of the prospective DG.

Deepak et al. (2014) has presented optimal placement and sizing of distributed generation(DG) to minimize active power loss using particle swarm optimization (PSO). The results showed the overall losses of the system are reduced by optimal placement of the DG.

Riccardo et al. (2007) presented an overview of particle swarm optimization. The paper comprises a snapshot of particle swarm from authors' perspective, including variations in the algorithm, current and ongoing research, applications and open problems.

Prakash et al. (2016) presented multiple DG placements in distribution system for power loss reduction using PSO algorithm. The proposed method was effective for loss reduction and voltage profile improvement. It also improves the voltages at tail end nodes.

Musa et al. (2015) carried out a review of particle swarm optimization (PSO) algorithms for optimal distributed generation placement. The review has shown that PSO algorithms are very effective in handling the DG placement and sizing problem.
Krischonme et al. (2013) presents a new methodology using particle swarm optimization (PSO) for the placement of distributed generation (DG) in the radial distribution systems to reduce the power loss. The simulation results show that PSO can obtain the maximum power loss reductions.
Alrashidi (2006) presents a survey of particle swarm optimization applications in electric power systems. It highlights the PSO key features and advantages over various optimizations.

3.0 PSO Model for Optimal DG Location

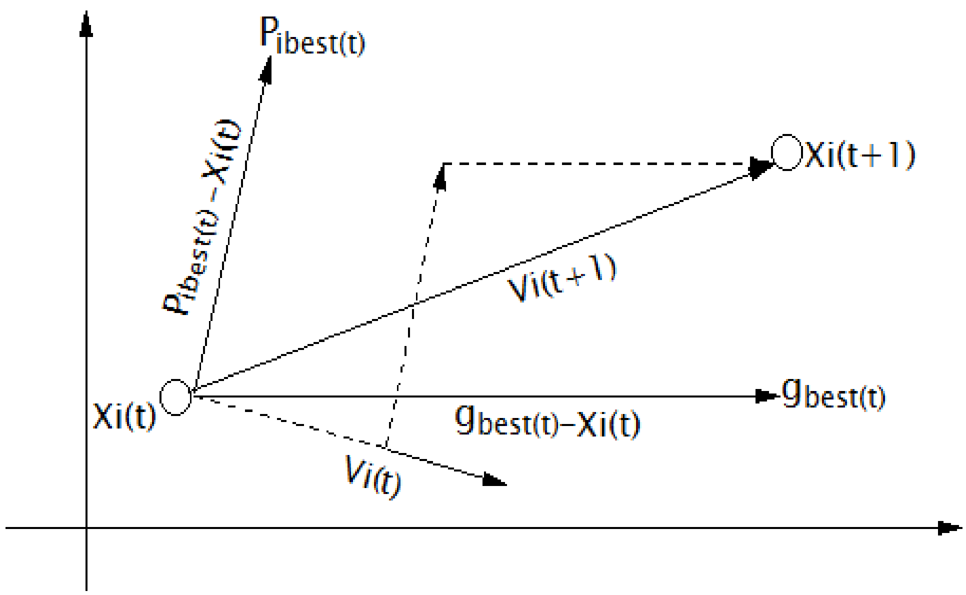

Figure 1: Velocity updating in PSO

$$V_i^{t+1} = w * V_i^t + c_1 * r_1(p_{best\ i(t)} - X_i^t) + c_2 * r_2(g_{best\ (t)} - X_i^t) \quad (1)$$

$$X_i^{t+1} = X_i^t + V_i^{t+1} \quad (2)$$

Where
X_i^t= initial position of particles
V_i^t= initial velocity of particles
X_i^{t+1}= particle new position
V_i^{t+1} = particle new velocity
$p_{best\ i(t)}$= personal best experience of particles
$g_{best\ (t)}$=global best experience of entire particle in the swarm

c_1, c_2 = acceleration coefficient
r_1, r_2 =random numbers[0,1]
w = inertial coefficient
$c_1 r_1 \left(p_{best\ i(t)} - X_i^t\right)$ = cognitive component
$c_2 r_2 \left(g_{best\ (t)} - X_i^t\right)$ = social component

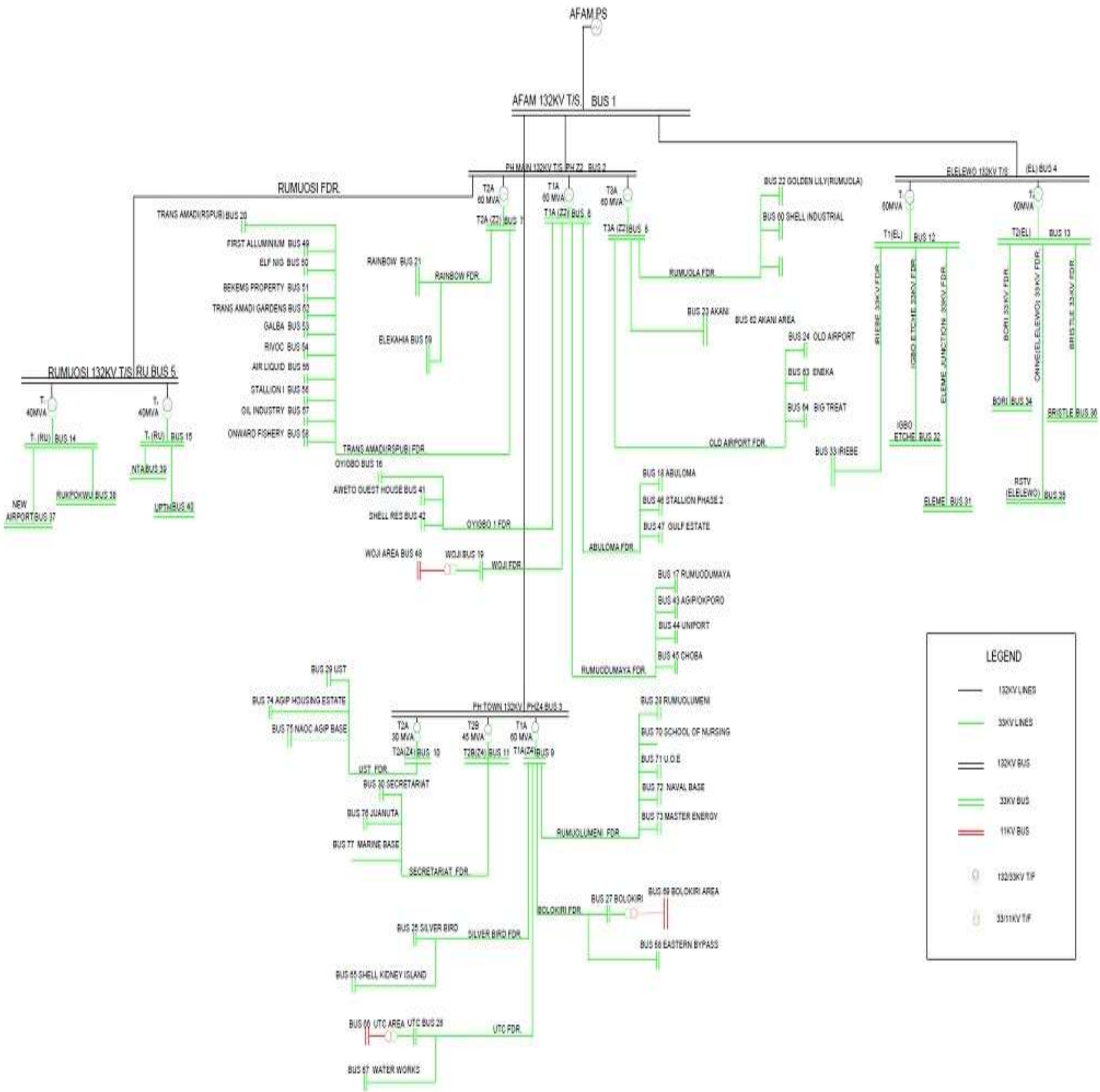

Figure2: Single Line Diagram of 73 Bus Port Harcourt 33kv Power Distribution System

4.0 Result and Discussion

Table 1: Bus Voltage Profile (PSO Method)

Bus ID	Nominal kV	Voltage(kV)	Voltage (p.u)
BUS 1	132	135.96	1.03
BUS 2	132	133.007	1.01
BUS 3	132	133.951	1.01
BUS 4	132	134.566	1.02
BUS 5	132	132.652	1.00
BUS 6	33	33.362	1.01
BUS 7	33	33.867	1.03
BUS 8	33	33.17	1.01
BUS 9	33	32.866	1.00
BUS 10	33	32.319	0.98
BUS 11	33	33.011	1.00
BUS 12	33	32.979	1.00
BUS 13	33	32.626	0.99
BUS 14	33	32.887	1.00
BUS 15	33	31.86	0.97
BUS 16	33	32.707	0.99
BUS 17	33	33	1.00
BUS 18	33	32.752	0.99
BUS 19	33	32.712	0.99
BUS 20	33	32.561	0.99
BUS 21	33	33	1.00
BUS 22	33	32.304	0.98
BUS 23	33	32.87	1.00
BUS 24	33	31.786	0.96
BUS 25	33	32.369	0.98
BUS 26	33	32.682	0.99
BUS 27	33	32.499	0.98
BUS 28	33	32.76	0.99
BUS 29	33	31.797	0.96
BUS 30	33	32.352	0.98
BUS 31	33	33	1.00
BUS 32	33	32.636	0.99
BUS 33	33	32.852	1.00
BUS 34	33	32.407	0.98
BUS 35	33	32.097	0.97
BUS 36	33	32.349	0.98
BUS 37	33	33	1.00
BUS 38	33	32.73	0.99
BUS 39	33	31.39	0.95
BUS 40	33	31.749	0.96
BUS 41	33	32.341	0.98
BUS 42	33	33	1.00
BUS 43	33	32.754	0.99

BUS 44	33	32.778	0.99
BUS 45	33	32.876	1.00
BUS 46	33	32.601	0.99
BUS 47	33	32.694	0.99
BUS 48	33	32.512	0.99
BUS 49	33	32.59	0.99
BUS 50	33	32.58	0.99
BUS 51	33	32.587	0.99
BUS 52	33	32.591	0.99
BUS 53	33	32.431	0.98
BUS 54	33	33	1.00
BUS 55	33	32.58	0.99
BUS 56	33	32.518	0.99
BUS 57	33	33	1.00
BUS 58	33	32.79	0.99
BUS 59	33	33	1.00
BUS 60	33	32.089	0.97
BUS 61	33	31.573	0.96
BUS 62	33	31.489	0.95
BUS 63	33	32.411	0.98
BUS 64	33	32.672	0.99
BUS 65	33	32.241	0.98
BUS 66	33	32.742	0.99
BUS 67	33	33	1.00
BUS 68	33	33	1.00
BUS 69	33	32.691	0.99
BUS 70	33	31.713	0.96
BUS 71	33	31.698	0.96
BUS 72	33	32.274	0.98
BUS 73	33	32.242	0.98

Table 2: Line Flow And Losses (PSO Method)

ID	MW Flow	Mvar Flow	kW Losses	kvar Losses
Line1	318.416	227.289	3652	9419
Line2	130.417	92.29	1016	2395
Line3	75.213	53.284	406	740
Line4	42.134	24.725	59.591	-0.646
Line5	83.397	62.27	37.811	77.165
Line6	115.267	73.7	65.332	149
Line7	73.965	57.176	30.507	58.005
Line8	64.696	39.407	14.106	21.045
Line9	29.591	23.743	3.538	-6.677
Line10	35.111	26.752	4.79	-3.393
Line11	35.465	23.493	4.408	-4.542
Line12	39.342	29.051	5.826	-0.822
Line13	12.879	2.648	0.433	-14.517
Line14	29.192	22.099	3.36	-6.836
Line15	11.998	7.442	13.881	15.079

Line16	4	-8.677	6.263	6.086
Line17	9.564	5.931	8.799	9.091
Line18	10.781	6.755	169	178
Line19	28.801	17.893	80.439	93.481
Line20	2.7	4.5	1.889	0.935
Line21	17.471	10.843	30.136	34.255
Line22	14.89	9.282	108	121
Line23	20.268	12.583	41.861	48.103
Line24	15.418	9.567	23.385	26.299
Line25	10.604	6.576	10.861	11.525
Line26	9.513	5.899	8.842	9.161
Line27	13.618	8.448	17.817	19.711
Line28	11.898	7.381	14.441	15.809
Line29	15.594	9.677	23.947	26.963
Line30	0.301	-1.822	1.167	-5.075
Line31	26.235	16.377	219	254
Line32	8.848	5.494	27.323	27.473
Line33	11.053	6.877	59.481	63.792
Line34	17.732	11.109	231	262
Line35	10.449	6.507	70.92	75.191
Line36	0.9	-5.323	18.7	10.02
Line37	11.948	7.426	45.57	49.421
Line38	16.481	10.314	195	221
Line39	12.623	7.84	35.213	38.877
Line40	9.799	6.115	99.154	103
Line41	7.6	1.458	47.945	41.524
Line42	11.096	6.905	62.551	66.843
Line43	9.916	6.167	49.945	51.991
Line44	6.468	4.013	17.245	14.742
Line45	8.727	5.424	40.355	40.562
Line46	7.281	4.517	17.006	15.795
Line47	10.33	6.42	41.41	43.737
Line48	11.728	7.28	24.445	26.477
Line49	10.259	6.368	23.804	25.092
Line50	11.141	6.915	24.062	25.816
Line51	10.654	6.612	22.003	23.391
Line52	11.951	7.44	71.66	77.912
Line53	14.5	20.913	163	187
Line54	13.092	8.128	30.463	33.566
Line55	11.892	7.391	45.731	49.665
Line56	6.2	18.33	133	150
Line57	14.681	9.132	68.433	76.328
Line58	6.2	8.266	127	128
Line59	10.189	6.346	71.916	76.084
Line60	7.285	4.533	54.197	51.908
Line61	7.998	4.985	76.274	75.959
Line62	5.019	3.11	2.476	1.671
Line63	3.73	2.31	4.702	1.103
Line64	11.154	6.949	81.267	87.427
Line65	3.649	2.258	6.393	1.162

Line66	6.8	15.204	63.443	70.445
Line67	9.9	6.577	45.234	47.288
Line68	7.776	4.827	23.252	22.301
Line69	8.154	5.064	27.153	27.193
Line70	9.075	5.638	33.641	34.837
Line71	10.558	6.559	36.619	38.997
Line72	8.34	5.182	35.429	35.328
Line73	14.473	12.397	228	256
Line74	102.305	38.908	2861	3365
Line75	22.004	9.528	416	477
Line77	29.474	18.486	346	403
Line78	35	22.011	508	593
Line79	31.778	8.751	292	338
Line80	25.928	16.285	357	413
Line81	12.236	4.902	253	268
Line82	36.711	23.456	1160	1355
Line83	20.656	12.929	219	251
Line84	14.383	8.942	49.597	55.229
Line85	20.834	13.041	167	192
Line86	8.576	-6.002	126	127

The result obtained using PSO method for optimal DG placement in a distribution network is shown in table 1 and 2 respectively. Ten (10) buses [Bus17, Bus21, Bus31, Bus37, Bus42, Bus54, Bus57, Bus59, Bus67, and Bus68] indicates the optimal location for DG placement. Table1 shows the voltage profile of the distribution network using PSO method. A quick look at the voltage profile shows that there was no violation of bus voltage statutory limit (0. 95p.u – 1. 05p.u) that is 31.35KV- 34.65KV. Table 2 shows the line real and reactive power losses in the distribution system using PSO method. From table 2, it was reviewed that the maximum reduction in line losses was achieved and the overall power losses reduced from [37.817MW, 239.832MVar] to [17.543MW,119.842MVar]. With this, the power demand required from the grid could be reduced thus cutting the need to strengthen the feeders connecting the network to the grid.

5.0 Conclusion

The solution of DG placement in distribution system is of great importance and useful for the system planning engineers. Placing DG unit at non optimum location can impact negatively on the system. For this reason, this paper proposes PSO method for DG location and sizing. The proposed method outweighs analytical method in terms of fast computational speed, time and memory. Based on the findings, it is hereby concluded that DG integration can improved the overall efficiency of the distribution system in terms of voltage profile improvement and loss reduction. Thus, reducing the power demand from the grid and mitigating the need for feeder reinforcement connecting the network to the grid. In PSO method, there is only one population in each iteration that moves towards the global optimal point. This makes PSO computationally faster and the convergence abilities of this method are better than the other evolutionary techniques. The search process for PSO does not involve use of derivative function; instead it uses the fitness function value as a guide for finding optimal solution in problem space. This concept of PSO helps in eliminating the approximations and assumptions usually adapted on objective functions and constraints as in conventional optimization methods. For this reason, PSO is considered as a stochastic optimization method and found to be very efficient in handling problems that their objective functions are time varying or stochastic in nature.

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