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Optimal Allocation and Sizing of Renewable Energy Distributed Generation Using Particle Swarm Optimization Method for Power Loss Reduction in the Nigeria Power System

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***Abstract*—** *Selecting the most appropriate location for installation of DGs combined with the optimal size of the DG unit is of the greatest priority in a power system network. 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 the Particle Swarm Optimization (PSO) algorithm in MATPOWER 5.1 toolbox. The ETAP software environment was used to perform the baseline load flow calculation, and the RVSI technique produced the maximum voltage indices of 0.0261 and 0.0625 at the Ezeiweka bus and GCM bus, respectively. DG placed at these locations showed that at 80% of load size insertion, the least active and reactive power losses of 3.9176MW and 3.6283 MVar respectively were achieved. For the conventional PSO method, the minimum value of fitness losses of 0.0406 which represents the minimum amount of power loss was recorded at PP1-bus with a corresponding DG unit size of 5.6722 MW. When this optimal unit size of 5.6722MW was placed at PP1-bus, the power losses were reduced appreciably to 2.860MW, and 3.330 MVAr respectively. This shows that the PSO algorithm has a better performance than the RSVI method in terms of voltage stability and power loss reduction for DG sizing and location in a distribution network.*

***Keywords*—** *Load, Optimal, Particle, Power, Reduction, Renewable, Swarm*

I. Introduction

Installing a DG at a non-optimal location can instead have the opposite effect on the system by considering the cost efficiency, such as increasing system losses followed by an increase in cost. With all that in consideration, selecting the most appropriate location for installation combined with the optimal size of a DG unit is of the greatest priority in a power system network. However, it is the highest concern to choose the most suitable position for installation paired with the optimum size of a DG in a power system [1]. The most powerful and fundamental way to solve the problems of power system operation and planning is load flow analysis. Load flow analysis recognizes the consistent operation state with node voltages and branch power flow in the system. In optimization, numerous techniques are used in the power system to deal with the problem. The placement of DG sites must be optimized in order to create the most cost-effective, efficient, and technically sound distribution network [2] when addressing the issue of distributed generation (DG) allocation.

Optimal placement of DGs is basically a complex combinatorial optimization issue which requires concurrent optimization of multiple objectives, for instance minimizations of real and reactive power losses, node voltage deviation, carbon emanation, line loading, and short circuit capacity and maximization of network reliability etc. The objective is to find the best placement for DG devices in a distribution network. The optimization is performed within the bounds of voltage limit of the nodes, thermal limit of network branches, and maximum DG sizes [3]. In most of the planning models, the optimal distribution network is determined based on a deterministic load demand which is usually obtained from a load forecast. Also the placement of the DG units mainly the renewable energy sources placement, is affected by several factors such as wind speed, solar irradiation, environmental factors, geographical topography, political factors, etc [4]. The most essential uncertainty to account for the time-varying characteristics of both generation and demand of power are the increasing penetrations of different distributed generators at present load growth. This paper dwells on implementing an evolutionary technique Particle Swarm Optimization (PSO) method for finding the optimal size and location of DG in the Onitsha distribution network.

II. Materials and Methods

To determine the weak buses or critical lines that are most unstable, the Revamp Voltage Stability Indicator was deployed. The index gives low value under normal system condition and the stability index value is high when the system is subjected to instability. Thus, the buses or lines with high index are identified to be candidate location for the integration of PV [5]. The RVSI is used to identify the weak zones or critical lines that are on the brink of instability. The weakest of the buses will serve as the location for PV integration. This helps to reduce the computational time required in performance assessment of PV at all bus locations within the network. The RVSI employs factors such as reactive power flow, voltage angle, load demand, power flow and network topology to determine the margin of stability in the system.

Using MATLAB software, the sending and receiving angle values for the buses were determined. Let the sending bus and receiving bus be and respectively, and current flowing through the sending and receiving bus.
Therefore,

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

Also,

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

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

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

Where,

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

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

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

Therefore,

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

The equation for the Revamp Voltage Stability Indicator becomes

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

Where,

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

2.1 Bus Voltage Magnitude Constraints

In a radial distribution network, the voltage magnitude at each bus is considered unsatisfactory if the voltage is less than the 0.95 p.u minimal threshold value. One of the most practical solution to improve and support these low voltage magnitude is the integration distributed generation [7],[8]. However, if the amount integrated exceeds the maximum allowable limit, it may cause overvoltage problems. The lowest and maximum values to be maintained at all nodes and buses should be within limits.

$$(|V_{kmin}| \leq |V_k| \leq |V_{kmax}|) \equiv (0.95 \leq V_k \leq 1.05) \quad (3.7)$$

2.2 Power Flow Constraints

The sum of active power supplied ($P_{ksupplied}$) must be equivalent to the sum of the active bus loads (P_{TLoads}) and sum of the active power losses in the line ($P_{T\ Loss}$).

$$\sum P_{k\ supplied} = P_{T\ Loads} + P_{T\ Loss}$$

2.3 Determination of Injected PV Optimal Size

The optimal size or hosting capacity of the injected PV systems at various buses was determined by increasingly integrating the PVs at 20% of load demand into the indentified weak buses. As PV injects active power at unity power factor, the active power which is equivalent to the considered percentage values of active power at the identified critical buses were injected. The optimal value is reached when there is further increase in system losses. At this level, reversed power flow is bound to occur in the network. Reverse power flow occurs when the amount of power generated by distributed energy resources (DERs), such as photovoltaic (PV) systems exceeds the local demand. This situation is often referred to as "surplus generation". When the PV hosting capacity is exceeded, the excess power flow causes instability in the system [8],[9].

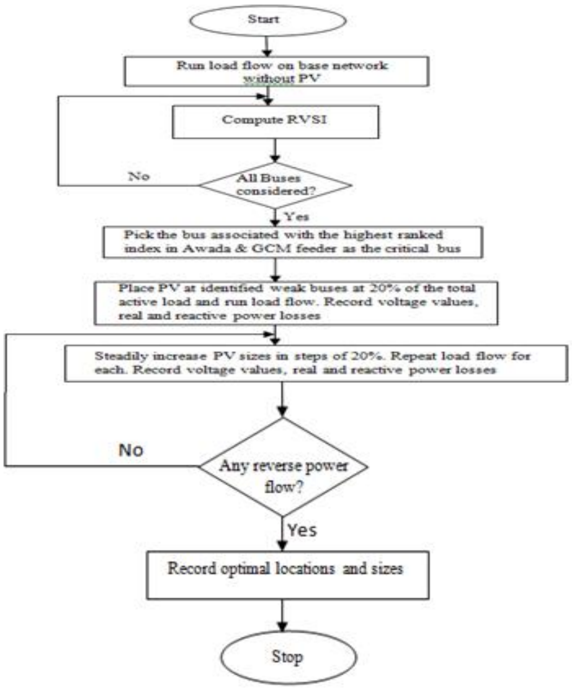

Fig. 2.1. Flow chart for determining the optimal location and size of PV using RVSI

The optimal percentage level at which the PV is integrated into the network without causing increase in losses and reverse flow of power marks the hosting capacity of the network. In this paper, the PV system were increasingly injected at various percentage levels starting from 20% of the load demand, then increasing in steps of twenties (20s) of the active power demand at the indentified weakest buses. The load demand of the Awada feeder is 63.18 MW, while that of GCM feeder is 56.74 MW and the percentage injection increase values are shown in Table 2.1.

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

2.4 Load Flow Simulation Result of the Onitsha Distribution Network without DG

The result obtained from the load flow study of the network which include the active power loss, reactive power loss, voltage magnitude and voltage angles are shown in Table 2.2

TABLE 2.2. Result of Load Flow Study of the Onitsha Distribution Network using ETAP

Bus No.	Bus Name	From Bus	To Bus	Line No	Line losses		Voltage Magnitude (p.u)	Angle (Deg.)
					MW	MVar		
1	Slack Bus	1			0.000	0.000	1	0
2	Awada II	1	2	1	0.1336	0.1480	0.9913	-0.0025
3	Mgbemena	2	3	2	0.0440	0.0488	0.9913	-0.0027
4	Okpoko	3	4	3	0.0015	0.0117	0.9906	-0.0034
5	Omoba	4	5	4	0.1903	0.2107	0.9984	-0.0053
6	Minaj	5	6	5	0.0108	0.0120	0.9965	-0.0071
7	Inland Town	4	7	6	0.0165	0.0155	0.9765	-0.0097
8	Industrial Line	7	8	7	0.2082	0.2306	0.9608	-0.0115
9	GRA	8	9	8	0.0330	0.3660	0.9586	-0.0125
10	PP1	8	10	9	0.0319	0.0353	0.9581	-0.0127
11	IUNT	10	11	10	0.0335	0.0310	0.9655	-0.0103
12	Ezeiweka	11	12	11	0.8213	0.8033	0.9634	-0.0110
13	Nwaziki	12	13	12	0.7015	0.7024	0.8825	-0.0113
14	Woliwo	12	14	13	0.0314	0.0492	0.8816	-0.0116
15	Premier	14	15	14	0.0011	0.0017	0.9614	-0.0644
16	Wharf	15	16	15	0.1635	0.2565	0.9209	-0.0707
17	Iyiowa	12	17	16	0.0023	0.0036	0.9182	-0.0791
18	Iweka	17	18	17	0.0173	0.0271	0.9148	-0.0921
19	Housing	18	19	18	0.0013	0.0020	0.9097	-0.0921
20	Water works	19	20	19	0.0041	0.0052	0.9036	-0.1088
21	Uga	20	21	20	0.1170	0.1282	0.8980	-0.1254
22	Fegge	1	22	21	0.7608	0.3420	0.8930	-0.1419
23	Bida	22	23	22	0.0004	0.0006	0.8955	-0.1698
24	Market	23	24	23	0.7808	0.7836	0.8994	-0.1699
25	Harbour	24	25	24	0.6965	0.6578	0.9018	-0.1975
26	Interfact	25	26	25	0.0340	0.0488	0.9103	-0.2814
27	GCM II	26	27	26	0.1934	0.2140	0.9218	-0.2846
28	Dozzy	27	28	27	0.0203	0.0215	0.9334	-0.3080
29	E. Amobi	28	29	28	0.1905	0.2117	0.9590	-0.3383
30	Golden	29	30	29	0.0134	0.0115	0.9711	-0.3782
				Total	5.2542	5.3803		

In Table 2.2, Bus 1 represents the slack bus, with a reference voltage of 1 per unit and an angle of 0 degrees. Other buses have varying voltage magnitude and angles, which reflect the voltage levels and phase angles at these points in the network relative to the slack bus. The allowable voltage drop is ±5%.

TABLE 2.3. Result of voltage stability index (RSVI) for the two feeders

Bus No.	Name of Substation	From Bus	To Bus	RSVI
1	Slack	1		
2	Awada II	1	2	0.0023
3	Mgbemena	2	3	0.0015
4	Okpoko	3	4	0.0058
5	Omoba	4	5	0.0061
6	Minaj	5	6	0.0000
7	Inland Town	4	7	0.0154
8	Industrial Line	7	8	0.0179
9	GRA	8	9	0.0067
10	PP1	8	10	0.0015
11	IUNT	10	11	0.0057
12	Ezeiweka	11	12	0.0261
13	Nwaziki	12	13	0.0193
14	Woliwo	12	14	0.0190
15	Premier	14	15	0.0130
16	Wharf	15	16	0.0113
17	Iyiowa	12	17	0.0012
18	Iweka	17	18	0.0041
19	Housing	18	19	0.0011
20	Water works	19	20	0.0071
21	Uga	20	21	0.0051
22	Fegge	1	22	0.0241
23	Bida	22	23	0.0492
24	Market	23	24	0.1884
25	Harbour	24	25	0.0485
26	Interfact	25	26	0.0504
27	GCM II	26	27	0.0625
28	Dozzy	27	28	0.0524
29	E. Amobi	28	29	0.0180
30	Golden	29	30	0.0531

The voltage stability index simulation results are as shown in Table 2.3. Figure 2.2 and 2.3 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.

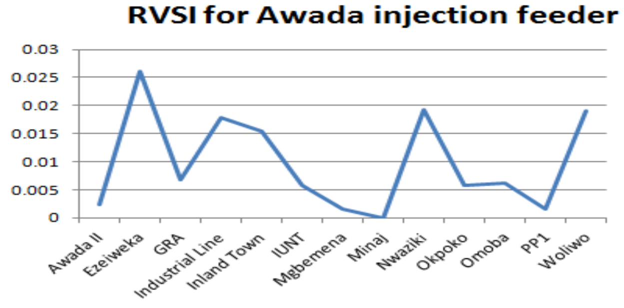

Fig. 2.2. RVSI for Awada Injection Substation feeder

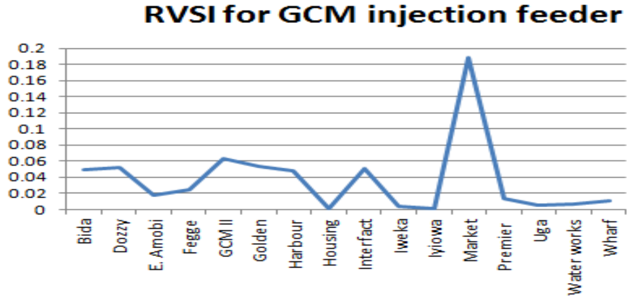

Fig 2.3. RVSI for GCM injection Substation feeder

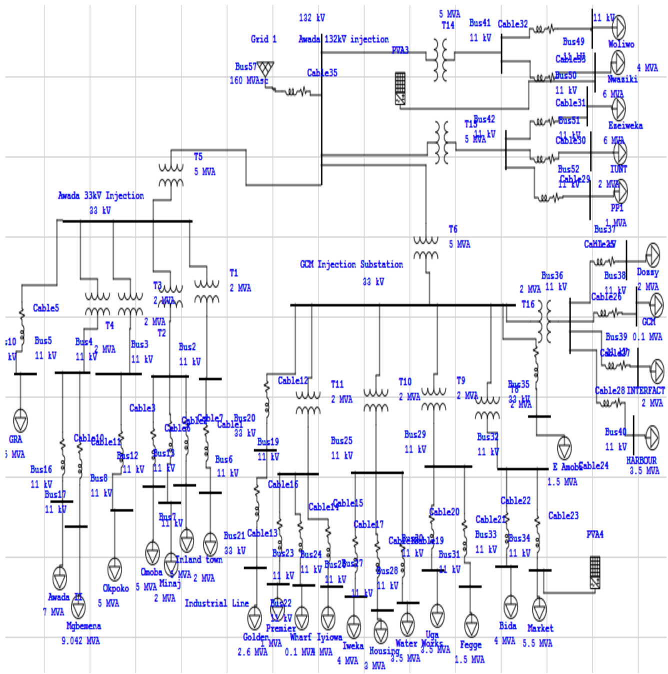

Fig. 2.4. Onitsha Distribution Network with PV location in ETAP environment

Figure 2.4 shows the Onitsha distribution network with PV located at the Nwaziki bus and Market bus following the results obtained from the RVSI study. The PV located at these weak buses would be simulated in incremental steps of 20% of the load demand so as to ascertain the optimal size.

2.5 Simulation results for the integration of PV at incremental steps of 20% of load demand

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The integration of photovoltaic (PV) system into the power distribution network has profound implication for the power losses. The load demand of the Nwaziki bus is 7.1 MW, while that of Market bus is 6.4 MW and the percentage injection increase values are shown in Table 2.5.

TABLE 2.4. Percentage injected PV capacities

Percentage Increase	Nwaziki Bus (MW)	Market Bus (MW)
20%	1.42	1.28
40%	2.84	2.56
60%	4.26	3.84
80%	5.68	4.88
100%	7.1	6.4

The results in Table 2.5 show power losses for the incremental step integration of PV on Nwaziki bus and Market bus. It is evident that the PV integration in the identified buses have significant effect in improving the performance of the distribution network.

TABLE 2.5a. Results for Active and Reactive Power losses at Percentage Incremental PV integration

Bus No.	From Bus	To Bus	Line No	Line losses					
				PV at 20%		PV at 40%		PV at 60%	
				MW	MVar	MW	MVar	MW	MVar
1	1			0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2	1	2	1	0.1331	0.1480	0.1321	0.1470	0.1215	0.1350
3	2	3	2	0.0440	0.0488	0.0431	0.0475	0.0421	0.0473
4	3	4	3	0.0014	0.0107	0.0012	0.0105	0.0010	0.0105
5	4	5	4	0.1900	0.2107	0.1850	0.2005	0.1840	0.2005
6	5	6	5	0.0107	0.0110	0.0105	0.0105	0.0105	0.0105
7	4	7	6	0.0155	0.0150	0.0125	0.0145	0.0115	0.0133
8	7	8	7	0.2070	0.2300	0.2050	0.2225	0.2045	0.2211
9	8	9	8	0.0325	0.3550	0.0312	0.3525	0.0311	0.3512
10	8	10	9	0.0310	0.0350	0.0210	0.0250	0.0203	0.0245
11	10	11	10	0.0322	0.0300	0.0252	0.0250	0.0251	0.0245
12	11	12	11	0.8202	0.8030	0.7552	0.7530	0.7549	0.7416
13	12	13	12	0.7010	0.7020	0.7010	0.7020	0.7008	0.7025
14	12	14	13	0.0300	0.0480	0.0250	0.0475	0.0246	0.0463
15	14	15	14	0.0011	0.0017	0.0101	0.0115	0.0067	0.0111
16	15	16	15	0.1630	0.2550	0.1525	0.2432	0.1417	0.2421
17	12	17	16	0.0023	0.0036	0.0023	0.0036	0.0021	0.0035
18	17	18	17	0.0173	0.0271	0.0173	0.0271	0.0173	0.0271
19	18	19	18	0.0013	0.0020	0.0013	0.0020	0.0012	0.0020
20	19	20	19	0.0040	0.0042	0.0040	0.0042	0.0035	0.0041
21	20	21	20	0.1170	0.1282	0.1170	0.1282	0.1163	0.1271
22	1	22	21	0.6401	0.2010	0.6325	0.2120	0.6316	0.2112
23	22	23	22	0.0004	0.0006	0.0004	0.0006	0.0002	0.0004
24	23	24	23	0.6708	0.6830	0.6645	0.6526	0.6621	0.6415
25	24	25	24	0.6615	0.6340	0.6512	0.6234	0.6511	0.6223
26	25	26	25	0.0320	0.0452	0.0315	0.0342	0.0310	0.0332
27	26	27	26	0.1816	0.2132	0.1712	0.2111	0.1711	0.2106
28	27	28	27	0.0203	0.0215	0.0203	0.0215	0.0202	0.0214
29	28	29	28	0.1805	0.2005	0.1714	0.1865	0.1682	0.1743
30	29	30	29	0.0134	0.0115	0.0125	0.0114	0.0122	0.0113
			Total	**4.9551**	**5.0795**	**4.808**	**5.0337**	**4.7684**	**4.8720**

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.

TABLE 2.5b. Results for Active and Reactive Power losses at Percentage Incremental PV integration

Bus No.	From Bus	To Bus	Line No	Line losses			
				PV at 80%		PV at 100%	
				MW	MVar	MW	MVar
1	1			0.0000	0.0000	0.0000	0.0000
2	1	2	1	0.1110	0.1257	0.1165	0.1240
3	2	3	2	0.0241	0.0250	0.0322	0.0335
4	3	4	3	0.0000	0.0005	0.0015	0.0115
5	4	5	4	0.1240	0.1155	0.1845	0.2125
6	5	6	5	0.0105	0.0005	0.0125	0.0135
7	4	7	6	0.0113	0.0110	0.0215	0.0175
8	7	8	7	0.1025	0.1201	0.2038	0.2231
9	8	9	8	0.0215	0.2510	0.0315	0.3507
10	8	10	9	0.0115	0.0125	0.0223	0.0226
11	10	11	10	0.0141	0.0123	0.0228	0.0239
12	11	12	11	0.6345	0.6415	0.7516	0.7400
13	12	13	12	0.6252	0.6501	0.7005	0.7021
14	12	14	13	0.0176	0.0352	0.0235	0.0446
15	14	15	14	0.0056	0.0005	0.0055	0.0104
16	15	16	15	0.1305	0.1311	0.1402	0.2415
17	12	17	16	0.0015	0.0010	0.0012	0.0034
18	17	18	17	0.0152	0.0171	0.0163	0.0278
19	18	19	18	0.0002	0.0015	0.0012	0.0020
20	19	20	19	0.0035	0.0041	0.0035	0.0041
21	20	21	20	0.1163	0.1271	0.1163	0.1271
22	1	22	21	0.6316	0.2112	0.6218	0.2106
23	22	23	22	0.0002	0.0004	0.0005	0.0008
24	23	24	23	0.5510	0.5421	0.6618	0.6413
25	24	25	24	0.5361	0.5153	0.6502	0.6220
26	25	26	25	0.0070	0.0031	0.0220	0.1435
27	26	27	26	0.1581	0.0112	0.1685	0.2154
28	27	28	27	0.0008	0.0017	0.0232	0.0245
29	28	29	28	0.0465	0.0521	0.1658	0.1726
30	29	30	29	0.0057	0.0043	0.0111	0.0100
			Total	**3.9176**	**3.6283**	**4.7038**	**4.9765**

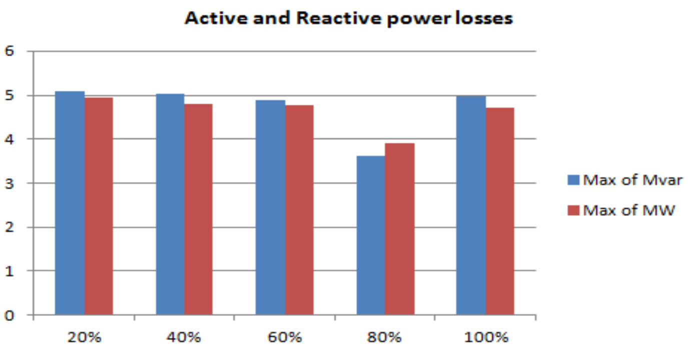

Fig. 2.5. Active and reactive power losses at incremental PV integration

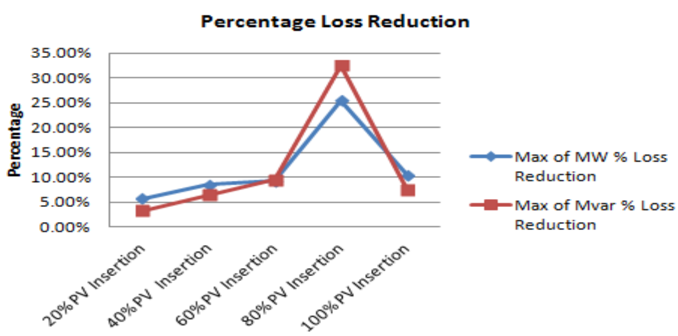

Fig. 2.6. Percentage Loss Reduction at Incremental PV Insertion

Thus, it can be stated that using ETAP which is based on Netwon Raphson method, the Nwaziki bus and Market bus are

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the optimal locations for PV in the Onitsha distribution network, while the optimal sizing of PV is at 80% integration.

2.6 Optimal Placement and Sizing of DG Using Conventional PSO Method

The conventional particle swarm optimization algorithm for optimum DG placement and sizing in the power system was implemented using MATLAB software in this work. The size and position of a three-dimensional DG unit are determined by generating 50 particles in the old PSO code. In the used PSO code constants are used to update the velocity of the algorithm such as inertia weight which has 0.9 and 0.4 as maximum and minimum value respectively as recommended by [10]. In addition, c1 and c2 are positive constant used in the algorithm whereas these constants are assumed to be equal to 2 as recommended by [11]. Some boundaries are achieved according to DG capacity, voltage and location of the DG unit. The capacity of the DG is assumed to be in the range of 1.2 - 10MW. According to the location of the generation load buses which are located between buses 2 and 29 are considered as a possible location for the DG unit. A constraint is considered for the bus voltage magnitude, they should be in the range from 0.9 up to 1.05 pu.

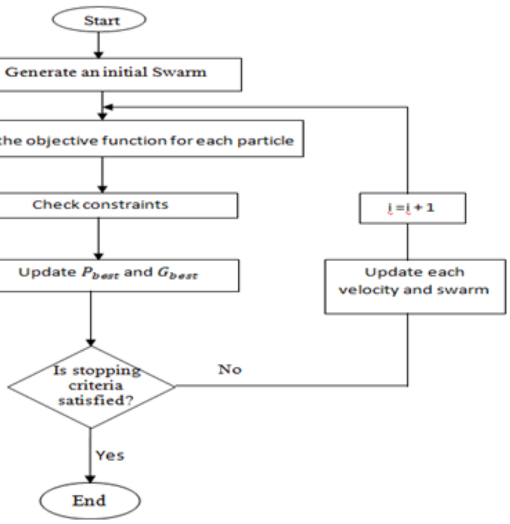

Fig. 3.3. PSO flowchart for optimal DG location

2.7 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. The DG sizes for each site are randomly initialized as part of this implementation. PSO being an exhaustive search is expected to come up with capable solutions that are optimal DG size for each location. The ideal posture maximizes the fitness value—which represents the minimum power loss—together with the best DG sizes and locations. Table 2.6 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 2.6. 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

A power flow analysis research is carried out for the network, taking the newly installed DG unit into consideration, following the best outcomes from the traditional PSO optimization approach. 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 2.7. Result for the 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

TABLE 2.8. Comparison of the Conventional PSO with the Base Case using RVSI

	Conventional PSO	RSVI
DG Size (MW)	5.6722	5.6800
DG Voltage	1.0055	0.8825
DG Location	10	13
Total active power losses (MW)	2.860	3.9176

III. Conclusion

For the base case using the RSVI method in determining the optimal size and location of DG in the Onitsha distribution network, 80% DG integration was found to have the least active and reactive power losses of 3.9176MW and 3.6283MVar respectively. However, it could be seen that implementing the PSO algorithm recorded a more substantial reduction in the active and reactive power losses to 2.880MW and 3.330 Mvar respectively when the DG was installed at bus 10. In addition, the PSO technique produced a better voltage profile. As a result, when it comes to DG sizing and placement in a distribution network, the PSO algorithm outperforms the RSVI technique in terms of voltage stability and power loss reduction.

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