Optimum Simultaneous DG and Capacitor Placement on the Basis of Minimization of Power Losses

M. M. Aman, G. B. Jasmon, K. H. Solangi, A. H. A. Bakar, and H. Mokhlis

Abstract—Optimum Distributed Generation (DG) placement and sizing is one of the current topics in new restructured power system. Most of the authors have worked out either DG unit placement or shunt capacitor placement as criteria for minimization of power system losses. However in the present paper, both approaches have been combined together to achieve overall minimum power losses and better voltage regulation. Particle Swarm Optimization (PSO) algorithm will be used for simultaneous finding of optimum DG and shunt capacitor bank location and size. The proposed algorithm will be tested on 12-bus, 30-bus, 33-bus and 69-bus radial distribution networks and the results will also be discussed in detail.

Index Terms—DG unit placement, shunt capacitor, particle swarm optimization (PSO), distribution system, power losses.

I. INTRODUCTION

With the advent of restructuring in power system, many power companies are investing in small scale distributed power generation. Distributed Generation (DG) have many different types ranging from conventional fossil fuel based combustion engines to the renewable energy including wind, photo-voltaic cells, micro-turbines, small hydro turbines, CHP or hybrid. Different authors have given different definitions of DG, in different perspective. For the purpose of this paper, the “distributed generation is an electric power source connected directly to the distribution network or on the consumer side of the meter” [1].

The word distributed generation is also subjective and changes with respect to the region. For example, ‘embedded generation’ term is used in Anglo-American countries, ‘dispersed generation’ is used in North American countries, and ‘decentralized generation’ term is used in Europe and parts of Asia [1].

Distributed Generation (DG) has many advantages over centralized power generation. The optimum DG placement and sizing at planning stage of distribution system is necessary to achieve the maximum benefits. The non-optimum DG placement and sizing could result in increase power losses, thus making the voltage profile lower than the allowable voltage limit [2].

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The increment in active power loss represents loss in savings to the utility as well as a reduction in feeder utilization. Studies have shown that 70% of power losses are due to distribution system [3] and the losses resulting from Joule effect only account for 13% of the generated energy [4]. This non-negligible amount of losses has a direct impact on the financial results and the overall efficiency of the system. The unbundling of utility has forced the distribution companies to reduce the losses and operate at the highest efficiency for their own economic benefits. Since utilities are already facing technical and non-technical issues, they cannot tolerate such additional issues. Hence an optimum placement of DG is needed in order to minimize overall system losses and therefore improve voltage profiles [5]- [7].

DG is mainly considered as an active source of energy (kWh) to get the maximum benefit. Companies are investing in distribution system to meet the active power demand and to get the maximum profit. However, drawing maximum active power can result into deficiency in fulfilling the kVar of reactive load requirement. This situation can become worst and voltage collapse condition can occur. Thus it is necessary to optimally place the shunt capacitors for reactive power support in the distribution system. Optimal capacitor placement and sizing also helps in reduction of losses and increases power transfer capability on congested transmission system. The recent power blackouts, due to insufficient reactive power, have also increased the importance of meeting reactive power demand of the system locally. The stability of voltage can be maintained by providing reactive power support to the distribution system at optimum locations locally [8], [9].

In this paper, the above problem is solved by simultaneous DG and capacitor bank placement in distribution system, considering minimization of power losses as fitness function. Voltage limits (V_{min} and V_{max}) is considered as one of the system constraints.

This paper is organized as follows: In section 2, problem formulation will be presented. Section 3, will briefly discuss about the Particle Swarm Optimization (PSO) algorithm. In section 4, the proposed algorithm will be tested on four different radial distribution test systems.

II. PROBLEM FORMULATION

In the proposed algorithm of simultaneous DG and capacitor placement, the fitness function considered is minimization of total active power losses (P_L), given by Eqn. (1).

$$f = \text{Min} \left\{ P_L = \sum_{i=1}^n |I_i|^2 R_i \right\} \quad (1)$$

where,

I is the line current in branch i .

R is the resistance of branch i .

N is total number of branches.

Subjected to the following generation constraints:

$$0 \leq P_{dg} \leq \sum P_{load} \quad (2)$$

$$0 \leq Q_{shunt} \leq \sum Q_{slack} \quad (3)$$

Other system constraints include bus voltages (V_{bus}):

$$1.05 \leq V_{bus}^n \leq 0.95 \quad (4)$$

where

V_{bus} is n^{th} bus voltage.

To find the optimum DG and capacitor placement and corresponding size, Particle Swarm Optimization (PSO) algorithm is used here. The brief introduction of PSO algorithm is presented in section 3.

III. PARTICLE SWARM OPTIMIZATION (PSO) ALGORITHM

Particle Swarm Optimization (PSO) is introduced by [10] to solve the optimization problem, based on social-psychological 'bird flock's behaviour. In this case, social sharing of information takes place and individuals can take profit from the findings and experience of all the other companions during the search for food. Each companion, called particle, in the population, which is called swarm, is assumed to 'fly' over the search space 'S' in order to find promising regions of the landscape.

The complete illustration of PSO algorithm is shown in Fig. 2. A particle i is represented as $x_i = (x_{i1}, x_{i2}, x_{i3}, x_{i4}, \dots, x_{id})$. The position associated with the best fitness $pbest_i = (pbest_{i1}, pbest_{i2}, pbest_{i3}, pbest_{i4}, \dots, pbest_{id})$ is considered as its current best position. Here d is a total number of initial particles. The overall best particle among all particles in the group is recorded as g_{best} .

The new particle position is based on the rate of the position of i^{th} particle, represented as $v_i = (v_{i1}, v_{i2}, v_{i3}, v_{i4}, \dots, v_{id})$. During the iteration procedure, the velocity and the position of i^{th} particles are updated according to the Eqns. (6-7):

Fig. 1. Magnetization as a function of applied field.

$$v_{id}^{(t+1)} = w \cdot v_{id}^{(t)} + c_1 \cdot r_1 \cdot (pbest_{id} - x_{id}) + c_2 \cdot r_2 \cdot (gbest - x_{id}) \quad (5)$$

$$x_{id}^{(t+1)} = x_{id}^{(t)} + v_{id}^{(t+1)} \quad (6)$$

where,

t is number of iterations, c_1 and c_2 are acceleration constants (usually taken as 0.7), r_1 and r_2 are random numbers, w is inertia weight given by Eqn. (8).

$$w = w_{max} + \frac{w_{max} - w_{min}}{iter_{max}} \times t \quad (7)$$

where,

w_{max} and w_{min} is 0.9 and 0.4 respectively, c_1 and c_2 are constants (0.7).

In the present case of DG placement and sizing, the i^{th} particle (x_i) is a four dimension vector (P_{DG} , P_{DG} , Q_{Shunt} , Q_{Shunt}), representing random DG and shunt capacitor positions (P_{DG} , Q_{Shunt}) and DG and shunt capacitor sizes (P_{DG} , Q_{Shunt}).

IV. PROPOSED ALGORITHM

Table I shows the complete steps of the proposed algorithm for optimum DG and shunt capacitor placement and sizing. Thukaram load flow is used to carry out the load flow analysis.

TABLE I: PROPOSED ALGORITHM FOR SIMULTANEOUS OPTIMUM DG AND CAPACITOR PLACEMENT

Steps	Discussion
Initialization	<ul style="list-style-type: none"> Initialize PSO parameters A particle i among initial populations (d) is a six dimension position vector x_i representing DG positions (P_{DG}), Shunt Capacitor positions (Q_{Shunt}), DG sizes (P_{DG}) and Shunt Capacitor size (Q_{Shunt}) $x_i = [P_{DG}, P_{DG}, Q_{Shunt}, Q_{Shunt}]$
Generate Initial Solutions	Calculate the best fitness function (Eqn. (1)) among initial solution of x_i , considering the constraints given in Eqns. (2)-(4).
Update Initial pbest and gbest	For Iteration=1, find initial pbest and gbest.
Generate new set of positions	<ul style="list-style-type: none"> Update velocity and position vectors using Eqns. (5-6) Check the feasibility of the new generated particles x_i, given in Eqns. (2)-(4).
Update Initial pbest and gbest	<ul style="list-style-type: none"> Calculate new fitness function of updated particles. Update pbest and gbest.
Stopping Criteria	Update Iteration If Iteration = Iteration _(max) End

V. RESULTS AND DISCUSSION

The proposed algorithm is tested on 12-bus [11], 30-bus [12], 33-bus [13] and 69-bus [14] radial distribution systems.

A. Results

Using the proposed method following optimum DG and shunt capacitor locations and their corresponding sizes have been calculated. The results are tabulated in Table II.

TABLE II: APPLICATION OF PROPOSED ALGORITHM FOR SIMULTANEOUS DG AND CAPACITOR PLACEMENT AND SIZING

Test System	Proposed Method			
	DG Position	DG Size(MW)	Shunt Capacitor Position	Shunt Capacitor Size(MW)
12-Bus	9	0.2339	9	0.2107
30-Bus	21	5.7553	21	3.4378
33-Bus	6	2.5106	30	1.4571
69-Bus	61	1.5660	61	1.4013

B. Discussion

The effect of DG and shunt capacitor placement is also measured by calculating the power system losses and system loading factor. Table III shows the effect of DG placement on system performance.

TABLE III: Effect of Proposed Algorithm for Simultaneous DG and Capacitor Placement and Sizing

Test System	Without DG		Proposed Method	
	System Loadability	System Losses (MW)	System Loadability	System Losses (MW)
12-Bus	5.33	0.0207	6.33	0.0032
30-Bus	2.78	0.8819	3.58	0.1754
33-Bus	3.40	0.2110	3.93	0.0597
69-Bus	3.20	0.2250	4.18	0.0259

From Table III, it can be seen that the system losses have been considerably reduced and system loading capability has significantly improved. These results are also shown in Fig. 2 and Fig. 3.

Fig. 2. System Loading Improvement due to DG Placement

Fig. 3. System Loading Improvement due to DG and Capacitor Placement

Fig. 4(a-d) shows the voltage profile improvement for all test systems.

(a) 12-Bus System

(b) 30-Bus System

(c) 33-Bus System

(d) 69-Bus System

Fig. 4. Voltage Profile Improvement due to DG and Capacitor Placement

From Fig. 4, it can be seen that the overall voltage profile has been significantly improved. Further the voltage levels are in allowable maximum and minimum levels.

VI. CONCLUSION

This paper has presented a new approach for optimum DG and shunt capacitor placement simultaneously. The proposed method is tested on several radial distribution networks. The result shows that the proposed methods has significantly reduced the power system losses as well as improve the overall loading factor. The system voltage profile has also been significantly improved and all busses found operating in allowable operating limit.

APPENDIX

Radial distribution test systems 12-bus [11], 30-bus [12], 33-bus [13] and 69-bus [14] data.

TABLE A-I: 12 BUS-SYSTEM DATA

Line No.	From	To	R(pu)	X(pu)	P _L (kW)	Q _L (kW)
1	1	2	0.00009	0.000038	0.06	0.06
2	2	3	0.000098	0.000041	0.04	0.03
3	3	4	0.000173	0.000072	0.055	0.055
4	4	5	0.000263	0.00011	0.03	0.03
5	5	6	0.00009	0.000038	0.02	0.015
6	6	7	0.000083	0.000034	0.055	0.055
7	7	8	0.000364	0.0001	0.045	0.045
8	8	9	0.000466	0.000132	0.04	0.04
9	9	10	0.000239	0.000068	0.035	0.03
10	10	11	0.000125	0.000035	0.04	0.03
11	11	12	0.000102	0.000029	0.015	0.015

Fig. A-1. 12-Bus radial distribution system

TABLE A-II: 30 BUS-SYSTEM DATA

Line No.	From	To	R(pu)	X(pu)	P _L (kW)	Q _L (kW)
1	1	2	0.0967	0.0397	0.4182	0.2591
2	2	3	0.0886	0.0364	0	0
3	3	4	0.1359	0.0377	0.4182	0.2591
4	4	5	0.1236	0.0343	0.4182	0.2591
5	5	6	0.1236	0.0343	0	0
6	6	7	0.2598	0.0446	0	0
7	7	8	0.1732	0.0298	0.4182	0.2591
8	8	9	0.2598	0.0446	0.4182	0.2591
9	9	10	0.1732	0.0298	0.4071	0.2464
10	10	11	0.1083	0.0186	0.4182	0.2591
11	11	12	0.0866	0.0149	0.2491	0.1527
12	3	13	0.1299	0.0223	0.1143	0.0714
13	13	14	0.1732	0.0298	0.1143	0.0714
14	14	15	0.0866	0.0149	0.1143	0.0714
15	15	16	0.0433	0.0074	0.0214	0.0119
16	6	17	0.1483	0.0412	0.4423	0.274
17	17	18	0.1359	0.0377	0.4423	0.274
18	18	19	0.1718	0.0391	0.4423	0.274
19	19	20	0.1562	0.0355	0.4423	0.274
20	20	21	0.1562	0.0355	0.4423	0.274
21	21	22	0.2165	0.0372	0.4423	0.274
22	22	23	0.2165	0.0372	0.4423	0.274
23	23	24	0.2598	0.0446	0.4423	0.274
24	24	25	0.1732	0.0298	0.4423	0.274
25	25	26	0.1083	0.0186	0.4423	0.274
26	26	27	0.0866	0.0149	0.2635	0.1635
27	7	28	0.1299	0.0223	0.1667	0.1067
28	28	29	0.1299	0.0223	0.1667	0.1067
29	29	30	0.1299	0.0223	0.1667	0.1067

Fig. A-2. 30-Bus radial distribution system

TABLE A-III: 33 BUS-SYSTEM DATA

Line No.	From	To	R(pu)	X(pu)	P _L (kW)	Q _L (kW)
1	1	2	0.0575	0.0293	0.1	0.06
2	2	3	0.3076	0.1566	0.09	0.04
3	3	4	0.2284	0.1163	0.12	0.08
4	4	5	0.2378	0.1211	0.06	0.03
5	5	6	0.511	0.4411	0.06	0.02
6	6	7	0.1168	0.3861	0.2	0.1
7	7	8	1.068	0.771	0.2	0.1
8	8	9	0.6426	0.4617	0.06	0.02
9	9	10	0.6514	0.4617	0.06	0.02
10	10	11	0.1227	0.0406	0.045	0.03
11	11	12	0.2336	0.0772	0.06	0.035
12	12	13	0.9159	0.7206	0.06	0.035
13	13	14	0.3379	0.4448	0.12	0.08
14	14	15	0.3687	0.3282	0.06	0.01
15	15	16	0.4656	0.34	0.06	0.02
16	16	17	0.8042	1.0738	0.06	0.02
17	17	18	0.4567	0.3581	0.09	0.04
18	2	19	0.1023	0.0976	0.09	0.04
19	19	20	0.9385	0.8457	0.09	0.04
20	20	21	0.2555	0.2985	0.09	0.04
21	21	22	0.4423	0.5848	0.09	0.04
22	3	23	0.2815	0.1924	0.09	0.05
23	23	24	0.5603	0.4424	0.42	0.2
24	24	25	0.559	0.4374	0.42	0.2
25	6	26	0.1267	0.0645	0.06	0.025
26	26	27	0.1773	0.0903	0.06	0.025
27	27	28	0.6607	0.5826	0.06	0.02
28	28	29	0.5018	0.4371	0.12	0.07
29	29	30	0.3166	0.1613	0.2	0.6
30	30	31	0.608	0.6008	0.15	0.07
31	31	32	0.1937	0.2258	0.21	0.1
32	32	33	0.2128	0.3308	0.06	0.04

Fig. A-3. 33-Bus radial distribution system

TABLE A-IV: 69 BUS-SYSTEM DATA

Line No.	From	To	R(pu)	X(pu)	P _L (kW)	Q _L (kW)
1	1	2	0.0003	0.0007	0	0
2	2	3	0.0003	0.0007	0	0
3	3	4	0.0009	0.0022	0	0
4	4	5	0.0157	0.0183	0	0
5	5	6	0.2284	0.1163	0.0026	0.0022
6	6	7	0.2378	0.1211	0.0404	0.03
7	7	8	0.0575	0.0293	0.075	0.054
8	8	9	0.0308	0.0157	0.03	0.022
9	9	10	0.511	0.1689	0.028	0.019
10	10	11	0.1168	0.0386	0.145	0.104
11	11	12	0.4438	0.1467	0.145	0.104
12	12	13	0.6426	0.2121	0.008	0.0055
13	13	14	0.6514	0.2152	0.008	0.0055

14	14	15	0.6601	0.2181	0	0	43	43	44	0.0057	0.0072	0	0
15	15	16	0.1227	0.0406	0.0455	0.03	44	44	45	0.0679	0.0857	0.0392	0.0263
16	16	17	0.2336	0.0772	0.06	0.035	45	45	46	0.0006	0.0007	0.0392	0.0263
17	17	18	0.0029	0.001	0.06	0.035	46	4	47	0.0021	0.0052	0	0
18	18	19	0.2044	0.0676	0	0	47	47	48	0.0531	0.13	0.079	0.0564
19	19	20	0.1314	0.0434	0.001	0.0006	48	48	49	0.1808	0.4424	0.3847	0.2745
20	20	21	0.2131	0.0704	0.114	0.081	49	49	50	0.0513	0.1255	0.3847	0.2745
21	21	22	0.0087	0.0029	0.0053	0.0035	50	8	51	0.0579	0.0295	0.0405	0.0283
22	22	23	0.0993	0.0328	0	0	51	51	52	0.2071	0.0695	0.0036	0.0027
23	23	24	0.2161	0.0714	0.028	0.02	52	9	53	0.1086	0.0553	0.0043	0.0035
24	24	25	0.4672	0.1544	0	0	53	53	54	0.1267	0.0645	0.0264	0.019
25	25	26	0.1927	0.0637	0.014	0.01	54	54	55	0.1773	0.0903	0.024	0.0172
26	26	27	0.1081	0.0357	0.014	0.01	55	55	56	0.1755	0.0894	0	0
27	3	28	0.0027	0.0067	0.026	0.0185	56	56	57	0.992	0.333	0	0
28	28	29	0.0399	0.0976	0.026	0.0185	57	57	58	0.489	0.1641	0	0
29	29	30	0.2482	0.082	0	0	58	58	59	0.1898	0.0628	0.1	0.072
30	30	31	0.0438	0.0145	0	0	59	59	60	0.2409	0.0731	0	0
31	31	32	0.219	0.0724	0	0	60	60	61	0.3166	0.1613	1.244	0.888
32	32	33	0.5235	0.1757	0.014	0.01	61	61	62	0.0608	0.0309	0.032	0.023
33	33	34	1.0656	0.3523	0.0195	0.014	62	62	63	0.0905	0.046	0	0
34	34	35	0.9196	0.304	0.006	0.004	63	63	64	0.4433	0.2258	0.227	0.162
35	3	36	0.0027	0.0067	0.026	0.0186	64	64	65	0.6495	0.3308	0.059	0.042
36	36	37	0.0399	0.0976	0.026	0.0186	65	11	66	0.1255	0.0381	0.018	0.013
37	37	38	0.0657	0.0767	0	0	66	66	67	0.0029	0.0009	0.018	0.013
38	38	39	0.019	0.0221	0.024	0.017	67	12	68	0.4613	0.1525	0.028	0.02
39	39	40	0.0011	0.0013	0.024	0.017	68	68	69	0.0029	0.001	0.028	0.02
40	40	41	0.4544	0.5309	0.0012	0.001	*P _L and Q _L represent receiving end bus power.						
41	41	42	0.1934	0.226	0	0							
42	42	43	0.0256	0.0298	0.006	0.0043

Fig. A-4. 69-Bus radial distribution system

Without DG and shunt capacitor placement, load flow analysis results are as follows:

TABLE A-V: 12 BUS-SYSTEM DATA

Bus No.	V (pu)	From	To	Line Losses	
				P	Q
1	1	1	2	0.003404	0.001437
2	0.994331	2	3	0.002751	0.001151
3	0.989017	3	4	0.003977	0.001655
4	0.980574	4	5	0.004213	0.001762
5	0.969829	5	6	0.001144	0.000483
6	0.966542	6	7	0.000908	0.000372
7	0.963761	7	8	0.002278	0.000626
8	0.955326	8	9	0.001572	0.000445
9	0.947297	9	10	0.000368	0.000105
10	0.944477	10	11	7.09E-05	1.99E-05
11	0.943581	11	12	5.16E-06	1.47E-06
12	0.943373	Total		0.0207	0.0081

TABLE A-VI: 30-BUS SYSTEM DATA

Bus No.	V (pu)	From	To	Line Losses	
				P	Q
1	1	1	2	0.12008	0.049299
2	0.988472	2	3	0.100415	0.041254
3	0.978381	3	4	0.141594	0.03928

4	0.964491	4	5	0.116232	0.032255
5	0.952497	5	6	0.104182	0.028911
6	0.94115	6	7	0.024389	0.004187
7	0.933652	7	8	0.010204	0.001756
8	0.929688	8	9	0.00936	0.001607
9	0.92504	9	10	0.003233	0.000556
10	0.922809	10	11	0.000784	0.000135
11	0.921941	11	12	8.70E-05	1.50E-05
12	0.921683	3	13	0.00025	4.29E-05
13	0.977846	13	14	0.000157	2.70E-05
14	0.977355	14	15	2.30E-05	3.96E-06
15	0.977222	15	16	2.72E-07	4.65E-08
16	0.977212	6	17	0.055492	0.015416
17	0.932078	17	18	0.041995	0.01165
18	0.924528	18	19	0.042884	0.00976
19	0.916174	19	20	0.030631	0.006961
20	0.909447	20	21	0.023228	0.005279
21	0.903591	21	22	0.023298	0.004003
22	0.896896	22	23	0.015787	0.002713
23	0.891389	23	24	0.01164	0.001998
24	0.886213	24	25	0.004052	0.000697
25	0.88372	25	26	0.000959	0.000165
26	0.882761	26	27	0.000107	1.84E-05
27	0.882475	7	28	0.000527	9.04E-05
28	0.932878	28	29	0.000234	4.02E-05
29	0.932363	29	30	5.86E-05	1.01E-05
30	0.932105	Total		0.8819	0.2581

TABLE A-VI: 33-BUS SYSTEM DATA

Bus No.	V (pu)	From	To	Line Losses	
				P	Q
1	1	1	2	0.012294	0.006265
2	0.997027	2	3	0.052073	0.026511
3	0.982896	3	4	0.020055	0.010212
4	0.975386	4	5	0.01885	0.009599
5	0.96796	5	6	0.038562	0.033287
6	0.949483	6	7	0.001946	0.006433
7	0.945958	7	8	0.011875	0.008572
8	0.932299	8	9	0.004265	0.003064
9	0.925967	9	10	0.003633	0.002575
10	0.920093	10	11	0.000565	0.000187
11	0.919224	11	12	0.000899	0.000297
12	0.917709	12	13	0.002721	0.002141
13	0.911534	13	14	0.000744	0.000979
14	0.909244	14	15	0.000364	0.000324
15	0.907817	15	16	0.000287	0.00021
16	0.906436	16	17	0.000257	0.000343
17	9.04E-01	17	18	5.42E-05	4.25E-05
18	0.903774	2	19	0.000161	0.000154
19	0.996499	19	20	0.000832	0.00075
20	0.992921	20	21	0.000101	0.000118
21	9.92E-01	21	22	4.36E-05	5.77E-05
22	0.991579	3	23	0.003182	0.002175
23	0.979311	23	24	0.005144	0.004062
24	0.972639	24	25	0.001287	0.001007
25	0.969314	6	26	0.002603	0.001325
26	0.947553	26	27	0.00333	0.001696
27	0.944989	27	28	0.011304	0.009968
28	0.933547	28	29	0.007836	0.006826
29	0.925328	29	30	0.003896	0.001985
30	0.92177	30	31	0.001594	0.001575
31	0.917608	31	32	0.000213	0.000249
32	9.17E-01	32	33	1.32E-05	2.05E-05
33	0.916409	Total		0.2110	0.1430

TABLE A-VI: 69-BUS SYSTEM DATA

Bus No.	V (pu)	From	To	Line Losses	
				P	Q
1	1	1	2	7.21E-05	0.000168
2	0.999968	2	3	7.21E-05	0.000168
3	0.999937	3	4	0.000187	0.000458
4	0.999846	4	5	0.001942	0.002263
5	0.999026	5	6	0.028249	0.014384
6	0.99009	6	7	0.029354	0.014949
7	0.980796	7	8	0.006892	0.003512
8	0.978581	8	9	0.00338	0.001723
9	0.977446	9	10	0.004778	0.001579
10	0.972445	10	11	0.001015	0.000335
11	0.971344	11	12	0.002192	0.000725
12	0.968183	12	13	0.001287	0.000425
13	0.965257	13	14	0.001247	0.000412
14	0.962358	14	15	0.001206	0.000398
15	0.959488	15	16	0.000224	7.42E-05
16	0.958954	16	17	0.000321	0.000106
17	0.958074	17	18	2.58E-06	8.89E-07
18	0.958065	18	19	0.000104	3.45E-05
19	0.9576	19	20	6.71E-05	2.22E-05
20	0.957301	20	21	0.000108	3.56E-05
21	0.956819	21	22	5.37E-07	1.79E-07
22	0.956812	22	23	5.14E-06	1.70E-06
23	0.95674	23	24	1.12E-05	3.70E-06
24	0.956584	24	25	6.05E-06	2.00E-06
25	0.956415	25	26	2.49E-06	8.25E-07
26	0.956345	26	27	3.50E-07	1.16E-07
27	0.956325	3	28	3.40E-07	8.45E-07
28	0.99993	28	29	2.58E-06	6.30E-06
29	0.999858	29	30	5.83E-06	1.93E-06
30	0.999737	30	31	1.03E-06	3.41E-07
31	0.999716	31	32	5.14E-06	1.70E-06
32	0.999609	32	33	1.23E-05	4.13E-06
33	0.999353	33	34	1.04E-05	3.44E-06
34	0.999017	34	35	4.79E-07	1.58E-07
35	0.99895	3	36	1.38E-06	3.43E-06
36	0.999923	36	37	1.51E-05	3.69E-05
37	0.999751	37	38	1.73E-05	2.02E-05

Bus No.	V (pu)	From	To	Line Losses	
				P	Q
38	0.999593	38	39	5.01E-06	5.82E-06
39	0.999547	39	40	1.94E-07	2.30E-07
40	0.999545	40	41	4.87E-05	5.69E-05
41	0.998847	41	42	2.01E-05	2.35E-05
42	0.998555	42	43	2.66E-06	3.10E-06
43	0.998516	43	44	5.10E-07	6.44E-07
44	0.998508	44	45	6.07E-06	7.66E-06
45	0.99841	45	46	1.34E-08	1.56E-08
46	0.998409	4	47	2.31E-05	5.71E-05
47	0.999796	47	48	0.000583	0.001427
48	0.99855	48	49	0.001633	0.003997
49	0.994705	49	50	0.000116	0.000284
50	0.99416	8	51	1.76E-06	8.95E-07
51	0.978545	51	52	4.38E-08	1.47E-08
52	0.978536	9	53	0.005783	0.002945
53	0.974658	53	54	0.006714	0.003418
54	0.971415	54	55	0.009124	0.004647
55	0.966941	55	56	0.008789	0.004477
56	0.962573	56	57	0.049682	0.016677
57	0.9401	57	58	0.02449	0.008219
58	0.92904	58	59	0.009506	0.003145
59	0.924762	59	60	0.010671	0.003238
60	0.919737	60	61	0.014024	0.007145
61	0.912341	61	62	0.000112	5.70E-05
62	0.912051	62	63	0.000135	6.86E-05
63	0.911664	63	64	0.000661	0.000337
64	0.909763	64	65	4.12E-05	2.10E-05
65	0.909189	11	66	2.62E-06	7.96E-07
66	0.971287	66	67	1.52E-08	4.70E-09
67	0.971286	12	68	2.33E-05	7.71E-06
68	0.967853	68	69	3.67E-08	1.26E-08
69	0.967852	Total		0.2250	0.1021

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