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A Novel Approach for Allocation of Optimal Capacitor and Distributed Generation on Radial Distribution System

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Abstract: **Distributed generation (DG) units, based on their interfacing technology are divided into synchronous generator interfaced DGs, asynchronous generator interfaced DGs and inverter interfaced DGs. This paper presents two algorithms for allocation of optimal capacitor and distributed generation on radial distribution system. These algorithms predict requirement of reactive vars and real power and supplied via capacitor banks and distributed generation. This arrangement reduces transmission losses and voltage stability problem. Developed algorithm has been implemented on two IEEE 69 nodes and 52 nodes systems.**

Keywords: **Load flow, distributed generation, capacitor banks, voltage stability, and distribution system.**

1. INTRODUCTION

Usually, electric power is produced at central station power plants and delivered to consumers using transmission and distribution networks. For economic, technical and environmental reasons, there is today a trend toward the use of distributed generation (DG) units in addition to the large generators connected to the transmission system [1]. Thus, it is expected that DGs will have a significant contribution in electrical power systems in the near future. DG units are mainly connected to the distribution networks. Therefore, the implementation of these units influences the technical aspects of the distribution networks [2–6]. Generally, a few small-size DG units, compared to the large centralized power stations, will not influence the operation of the transmission system and hence their impacts can be ignored. Therefore, in power system voltage stability studies, they are normally considered as negative loads and their intrinsic dynamics and their controllers, if present, are not taken into account. However, when networks begin to contain large numbers of DG units with higher capacities, their impacts are no longer restricted to the distribution network but begin to influence the whole system and the overall dynamics of power systems are significantly impacted. Among the numerous issues related to power systems containing DG units which need investigation, voltage stability analysis is of major interest [7,8]. Modern power systems are mostly operating close to their stability limits for economical reasons. This situation demands accurate modeling of power systems, taking into consideration the different penetration levels of DG units, to adequately evaluate their impacts on the voltage stability of power systems. DG units, based on their interfacing technology are divided into synchronous generator interfaced DGs, asynchronous generator interfaced DGs and inverter interfaced DGs. Load flow solution is a solution of the network under steady state condition subject certain inequality constraints under which the system operates. These constraints can be in the form of the load nodal voltages, reactive power generation of generators, the tap settings of a tap changing under load transformer etc. The load flow of a power system gives the unfaltering state result through which different parameters of investment like currents, voltages, losses and so on can be figured. The load flow will be imperative for the investigation of transmission networks, to research the issues identified with planning, outline and the operation and control. The effectiveness of the optimization problem of transmission networks relies upon the load flow algorithm on the grounds that load flow result need to run for ordinarily. A technique which can discover the load flow result of radial distribution networks specifically by utilizing topological normal for distribution system [9-15] is utilized. In this strategy, the plan of tedious Jacobian matrix or admittance matrix, which are needed in customary techniques, is stayed away from. In this paper, the installation of two DG units will be assessed, meaning that a first

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generator will be installed, and then, the other one. In the first stage of the algorithm, one DG group will be installed following the losses allocation criteria which has as a main goal to maximize the first DG group avoided losses. In the second stage, considering that the first DG group is already installed, the second DG group will be installed using the same criteria and simultaneously inject reactive vars from capacitor banks. This arrangement reduce the transmission losses and improve voltage stability of the system [16-19].It is assumed that each DG units group installed on the network will intend to maximize the allocated avoided losses, and not the total losses.

2. LOAD FLOW OF RADIAL DISTRIBUTION NETWORK

A feeder brings power from substation to load points/nodes in radial distribution networks (RDN). Single or multiple radial feeders are used in this planning approach. Basically, the RDN total power losses can be minimized by minimizing the branch power flow or transported electrical power from transmission networks (i.e. some percentage of load are locally meeting by local DG). To determine the total power loss of the network on each feeder branch and the maximum voltage deviation are determined by performing load flow on the system. The Forward/Backward Sweep Load Flow technique is used in this case. The impedance of a feeder branch is computed by the specified resistance and reactance of the conductors used in the branch construction. The Forward/Backward Sweep Load Flow method consist two steps (i) backward sweep and (ii) forward sweep.

Backward sweep: In this step, the load current of each node of a transmission network having

N number of nodes is determined as:

$$\overline{I_L}(\mathrm{m}) = \frac{P_L(m) - jQ_L(m)}{\overline{V^*}(m)} \qquad (\mathrm{m}=1,2,3.........\mathrm{N}) \qquad (1)$$

where, $P_L(m)$ and $Q_L(\mathrm{m})$ represent the active and reactive power demand at node *m* and the over bar notation$(\bar{x})$ indicates the phasor quantities, such as $\overline{I_L}$ *and* $\overline{V^*}$. Then, the current in each branch of the network is computed as:

$$\bar{I}(\mathrm{mn}) = \overline{I_L}(\mathrm{n}) + \sum_m \overline{I_L}(m) \qquad (2)$$

***Forward sweep*:** This step is used after the backward sweep so as to determine the voltage at

each node of a distribution network as follows:

$$\bar{V}(\mathrm{n}) = \bar{V}(\mathrm{m}) - \bar{I}(mn)Z(mn) \qquad (3)$$

where, nodes *n* and *m* represent the receiving and sending end nodes, respectively for the branch *mn* and Z(mn) is the impedance of the branch.

In this work the estimation method used within the forward/backward load flow is based on (i) equivalent current injections (ECI), (ii) the node-injection to branch current matrix (BIBC) and (ii) the branch-current to node-voltage matrix (BCBV). In this area, the advanced method will be depicted with suitable element. Load flow for transmission networks under balanced operating condition with constant power load model can be under remained through the accompanying focuses.

3. SOLUTION METHODOLOGY

BIBC and BCBV matrices investigate the topological structure of distribution networks. Basically the BIBC matrix is making an easy relation between the node current injections and branch currents. These relation give a simple solution for branch currents variation, which is occurs due to the variation at the current injection nodes, these can be obtained directly by using BIBC matrix. The BCBV matrix build an effective relations between the branch currents and node voltages. The concern variation of the node voltages is produced by the variant of the branch currents. These could be discovered specifically by utilizing the BCBV matrix. Joining the relations between the node current injections and node voltages could be communicated as:

$$[\Delta V] = [BCBV].[BIBC].[I] \qquad (4)$$

Now

$$[BCBV] = [BIBC]^T\,[ZD] \qquad (5)$$

So

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$[\Delta V] = [BIBC]^T [ZD].[BCBV].[I]$ (6)

Also

$[DLF] = [BIBC][BCBV]$ (7)

Therefore

$[\Delta V] = [DLF].[I]$ (8)

The iterative solution for the distribution system load flow can be obtained by

$I_i^k = (\frac{P_i - jQ_i}{V_i^k})^*$ (9)

$[\Delta V^{k+1}] = [DLF].[I^k]$ (10)

$[V^{k+1}] = [V^0] + [\Delta V^{k+1}]$ (11)

The new definition as illustrated uses just the DLF matrix to take care of load flow problem. Subsequently this strategy is extremely time efficient, which is suitable for online operation and optimization problem of distribution networks.

4. ALGORITHMS FOR TRANSMISSION NETWORKS IN LOAD FLOW ANALYSIS

The algorithm steps for load flow solution of transmission networks is given below:

Step 1: Read the transmission networks line data and bus data.

Step 2: Calculate the each node current or node current injection matrix. The relationship can be expressed as –

$[I] = \left[\frac{S}{V}\right]^* = \left[\frac{P - jQ}{V^*}\right]$ (12)

Step 3: Calculate the BIBC matrix by using steps given in section 3.

Step 4: Evaluate the branch current by using BIBC matrix and current injection matrix (ECI). The relationship can be expressed as –

$[IB] = [BIBC].[I]$ (13)

Step 5: Form the BCBV matrix by using steps given in section 3. The relationship therefore can be expressed as –

$[\Delta V] = [BCBV].[IB]$ (14)

Step 6: Calculate the DLF matrix by using the eq. (8). The relationship will be –

$[DLF] = [BCBV].[BIBC]$ (15)

$[\Delta V] = [DLF].[I]$ (16)

Step 7: Set Iteration k = 0.

Step 8: Iteration k = k + 1.

Step 9: Update voltages by using eq. (10-12), as –

$I_i^k = \left[\frac{P_i + jQ_i}{V_i^k}\right]^*$

$[\Delta V^{k+1}] = [DLF].[I^k]$

$[V^{k+1}] = [V^0] + [\Delta V^{k+1}]$

Step 10: If max $((|V(k+1)| - |V(k)|) › tolerance)$ go to step 6.

Step 11: Calculate branch currents, and losses from final node voltages.

Step 12: Display the node voltage magnitudes and angle, branch currents and losses.

Step 13: Stop

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4.1 Allocation of Dg into Load Flow:

Assume that a single-source radial distribution networks with *NL* branches and a DG is to be placed at node *i* and α be a set of branches connected between the source and node *i*. It is known that, the DG supplies active power (P_{Gi}^{DG}) to the systems, but in case of reactive power (Q_{Gi}^{DG}) it is depend upon the source of DG, either it is supplies to the systems or consume from the systems. Due to this active and reactive power an active current (I_{PGi}^{r}) and reactive current (I_{DGi}^{i}) flows through the system, and it changes the active and reactive component of current of branch set α. The current of other branches (∉=α) are unaffected by the DG. Total Apparent Power at i^{th} node:

$$S = S_{D\_i} = \sum P_{D\_i} + jQ_{D\_i} \qquad i=1,2......N_B \qquad (17)$$

Current at i^{th} node is-

$$I_D = I_{D\_i}^{without\_DG} = \left(\frac{S_{D\_i}}{V_i}\right)^* \qquad (18)$$

DG power at i^{th} node:

$$S_{DG\_i} = \sum P_{G\_i}^{DG} \pm jQ_{G\_i}^{DG} \qquad i = 1,2....N_B \qquad (19)$$

Total apparent power at i^{th} node:

$$S = S_{D\_i} - S_{DG\_i} \qquad (20)$$

Now the updated network power can be expressed in matrix form

$$[S] = [S_{Di}] - [S_{DGi}] \qquad (21)$$

4.2 Incorporation of Capacitor Bank into Load Flow:

Assume that a single-source radial distribution networks with *NB* branches and a capacitor bank is to be placed at node *i*. The capacitor bank produces reactive power (Q_{Gi}^{CB}) due to this a reactive current (I_{CBi}^{i}) flow through the radial network branches which changes the reactive component of current of branch. To incorporate the capacitor bank model, the reactive power demand at i^{th} node at which a capacitor bank unit is placed, is modified by:

$$Q_{D\_i}^{with\_CB} = Q_{D\_i}^{without\_CB} - Q_{G\_i}^{CB} \qquad (22)$$

$$[S] = [S_{Di}] - [S_{CBi}] \qquad (23)$$

4.3 Algorithm for Distribution Networks with Dg in Load Flow:

The algorithm steps for load flow solution of distribution networks is given below:

Step 1: Read the distribution networks line data and bus data.

Step 2: Calculate DG power and capacitor bank power for each nodes and update the system bus data.

Step 3: Calculate the total power demand with DG or capacitor bank or with both by the help of eq. (23) (25). The relationship can be expressed as –

$$[S] = [S_{Di}] - [S_{CBi}]$$

Step 4: Calculate the each node current or node current injection matrix. The relationship can be expressed as –

$$[I] = \left[\frac{S}{V}\right]^* = \left[\frac{P - jQ}{V^*}\right]$$

Step 5: Calculate the modified impedance matrix and modified current injection matrix for tap changer by the help of eq. (3.42) (3.43).

Step 6: Calculate the BIBC matrix by using steps given in section 3.

Step 7: Evaluate the branch current by using BIBC matrix and current injection matrix (ECI). The relationship can be expressed as –

[IB] = [BCBI] [I]

Step 8: Form the BCBV matrix by using steps given in section 3. The relationship therefore can be expressed as –

$[\Delta V] = [BCBV]\ [IB]$

Step 9: Calculate the DLF matrix by using the eq. (8). The relationship will be –

$[DLF] = [BCBV][BIBC]$

$[\Delta V] = [DLF][I]$

Step 10: Set Iteration k = 0.

Step 11: Iteration k = k + 1.

Step 12: Update voltages by using eqs. (10-12), as –

$I_i^k = (\frac{P_i - jQ_i}{V_i^k})^*$

$[\Delta V^{k+1}] = [DLF].[I^k]$

$[V^{k+1}] = [V^0] + [\Delta V^{k+1}]$

Step 13: If max ((|V(k + 1)| − |V(k)|) > tolerance) go to step 6.

Step 14: Calculate branch currents, and losses from final node voltages.

Step 15: Display the node voltage magnitudes and angle, branch currents and losses.

Step 16: Stop

5. RESULTS AND DISCUSSIONS

The proposed technique is applied to the two standard test systems:

System 1: Standard IEEE 69-node Reliability Test System (RTS) [16] [18]. It have a single substation system with voltage magnitude of 1 p.u. and all other nodes are load node. From the system data it had been found that the load is varying highly (active power is varying from 0 to 1244kW, and reactive power is varying from 0 to 888kVAR). The system base MVA and base kVA are 10MVA and 11kV respectively with one slack node.

System 2: An 11kV Practical Distribution Network from southern India grid. It have total 52 nodes with 3 main feeders [19] and one main substation with a voltage magnitude of 1 p.u. The system base MVA and base kVA are 1MVA and 11kV respectively with one slack node.

Load Flow Solution for Base Cases:

System 1: The total load of the networks is 4.660MW (3802.19 kW active power and 2694.6kVAR reactive power) and the slack node is delivering 4.902MW power. The distribution loss in the networks is 0.247 MW. The power loss due to active component of current is 224.995 kW and power loss due to reactive component of the current is 102.198 kVAR. All node voltages are within 0.90919 - 1p.u. Also the minimum voltage is 0.90919 p.u. is bearing the 65th number node of the system and the maximum branch current 0.49031p.u is bearing by the branch 1.The MATLAB® simulation result are shown in Figure 1 and Figure 2. The load flow study is carried out with an accuracy level of 10^{-9}, and maximum iteration of 300. The convergence of load flow with the accuracy level occur at 9 iteration. The Table-1 contains the node voltage magnitudes, branch current magnitudes, and the angle in radian of the converged load flow solutions. The results shows that, at the peak load condition system performance is not so poor. The system have a poor voltage profile at node 57 to node 65 due to the system hugely loaded at 61 node. While some of the node have no load.

System 2: The total load of the networks is 4.648 MW (4184 kW active power and 2025 kVAR reactive power) and the slack node is delivering 5.613 MW power. The distribution loss in the networks is 0.9658 MW. The power loss due to active component of current is 887.181 kW and power loss due to reactive component of the current is 381.694 kVAR. All node voltages are within 0.68442 - 1p.u. also the minimum voltage of 0.68442 p.u. occurs at the 50th node and the maximum branch current of 2.4382 p.u flows through the 31th branch. The MATLAB simulation results are shown in Figure 3 and Figure 4. In this case also the load flow study is carried out with an accuracy level of 10^{-9}, and maximum iteration of 300. The convergence of load flow with the accuracy level also occur at 9 iteration. The Table 2 contains the node voltage magnitudes, branch current magnitudes, and the angle in radian of the converged load flow solutions. The results shows that, at the peak load condition system performance is very poor. The system have a poor voltage profile at most of the nodes, basically at 5 to 19 and 32 to 52 nodes.

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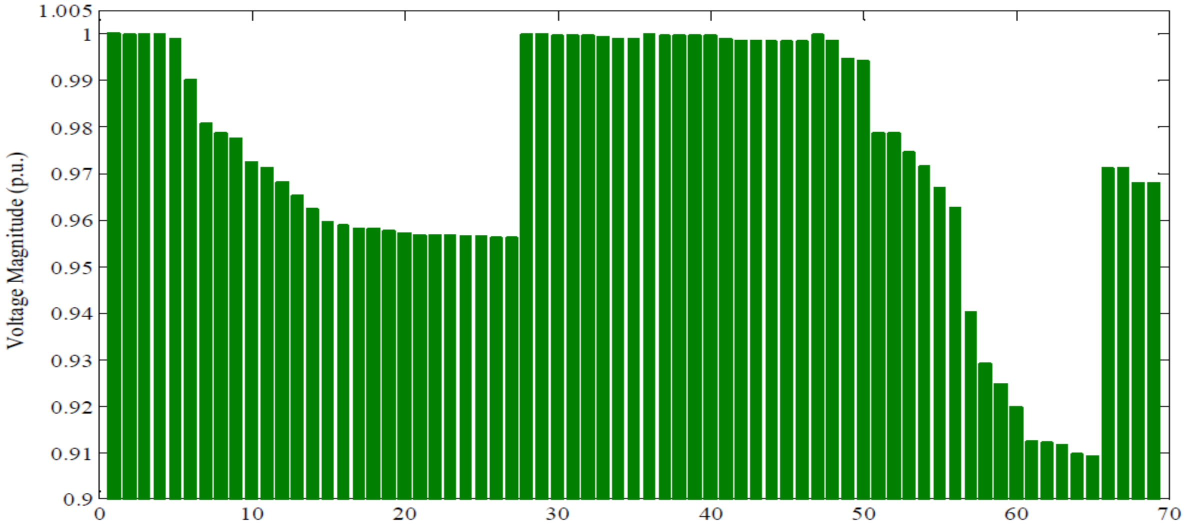

Fig 1: For System 1 Base Case Node Voltage Magnitude

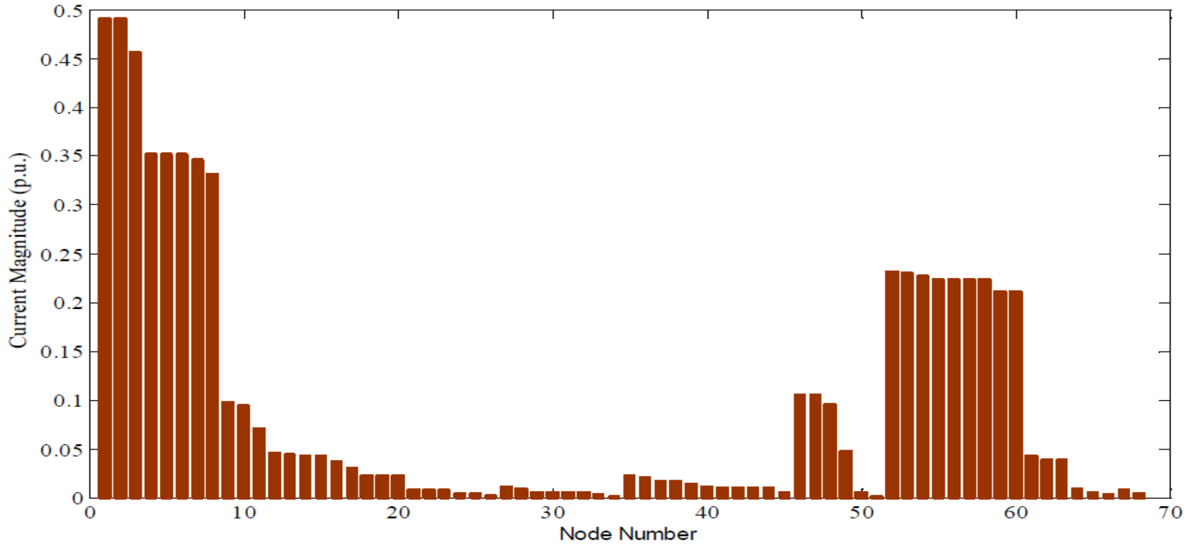

Fig 2: For System 1 Base Case Current Magnitude

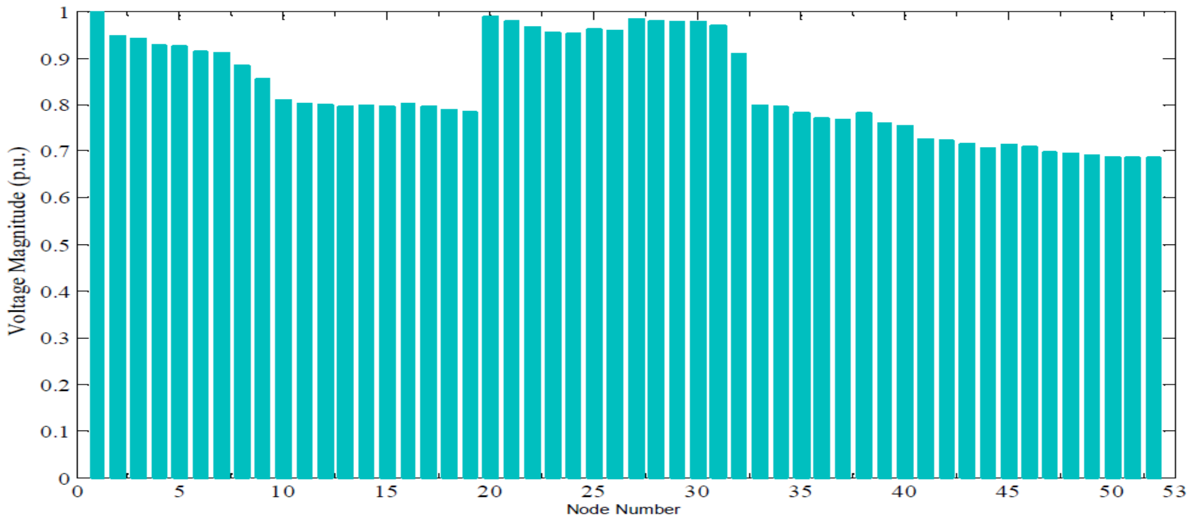

Fig 3: For System 2 Base Case Node Voltage Magnitude

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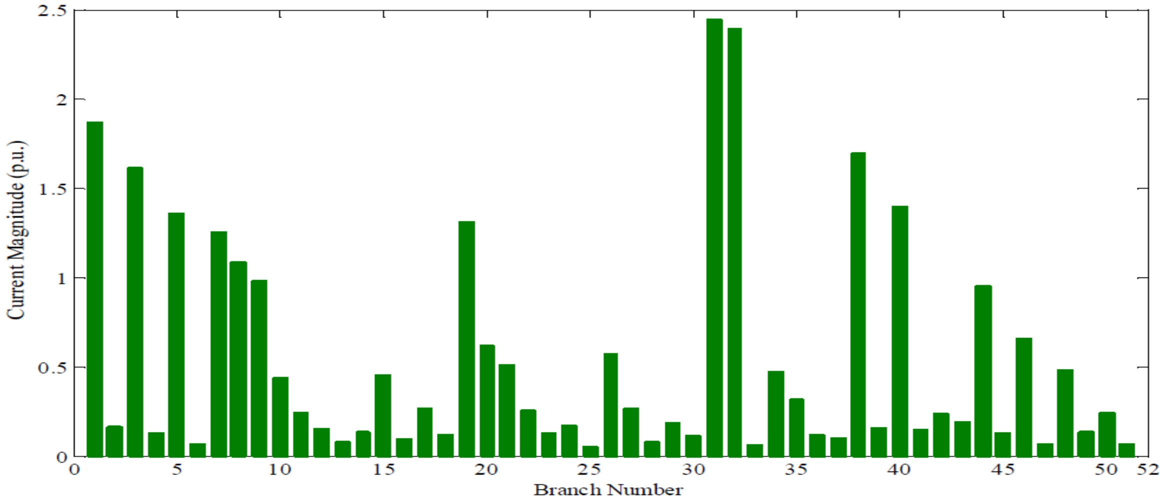

Fig 4: For System 2 Base Case Branch Current Magnitude

Table.1: Base Case Converged Flow Solution for System 1.

Node/ Branch	Voltage (p.u)	Angle (radian)	Current (p.u)	Node/ Branch	Voltage (p.u)	Angle (radian)	Current (p.u)
1	1	0	0.49031029	36	0.999919	-5.18E-05	0.019432
2	0.9999665	-2.14E-05	0.49031029	37	0.999747	-0.00016	0.016238
3	0.9999330	-4.29E-05	0.45644465	38	0.999589	-0.00021	0.016238
4	0.9998395	-0.000103	0.35169363	39	0.999543	-0.00022	0.013296
5	0.9990203	-0.000323	0.35169363	40	0.999541	-0.00022	0.010354
6	0.9900848	0.0008609	0.35135134	41	0.998843	-0.00041	0.010198
7	0.9807910	0.0021143	0.34622390	42	0.998551	-0.00049	0.010198
8	0.9785749	0.0024147	0.33127331	43	0.998512	-0.0005	0.009459
9	0.9774414	0.0025687	0.09670386	44	0.998504	-0.0005	0.009459
10	0.9724411	0.0040490	0.09322422	45	0.998405	-0.00054	0.00473
11	0.9713158	0.0043418	0.07028809	46	0.998405	-0.00054	0.104769
12	0.9681542	0.0052642	0.04476029	47	0.999789	-0.00013	0.104769
13	0.9652284	0.0060756	0.04375473	48	0.998543	-0.00092	0.095048
14	0.9623291	0.0068821	0.04274612	49	0.994699	-0.00334	0.047537
15	0.9594589	0.0076840	0.04274612	50	0.994154	-0.00369	0.005509
16	0.9589256	0.0078334	0.03706268	51	0.978539	0.002420	0.000460
17	0.9580450	0.0080804	0.02982539	52	0.978530	0.002423	0.230766
18	0.9580360	0.0080829	0.02259646	53	0.974655	0.002951	0.230194
19	0.9575710	0.0082318	0.02259646	54	0.971412	0.003398	0.226847
20	0.9572720	0.0083276	0.02247500	55	0.966939	0.004019	0.223794
21	0.9567898	0.0084825	0.00785879	56	0.962570	0.004630	0.223794
22	0.9567829	0.0084847	0.00719537	57	0.940096	0.011551	0.223794
23	0.9567110	0.0085080	0.00719537	58	0.929036	0.015086	0.223794
24	0.9565546	0.0085588	0.00359816	59	0.924759	0.016500	0.210469
25	0.9563820	0.0086085	0.00359816	60	0.919734	0.018324	0.210469
26	0.9563123	0.0086311	0.00179910	61	0.912337	0.019529	0.042940
27	0.9562927	0.0086375	0.01124029	62	0.912047	0.019576	0.038620
28	0.9999261	-4.72E-05	0.00804325	63	0.911660	0.019640	0.038620
29	0.9998544	-9.26E-05	0.00484600	64	0.909759	0.019952	0.007966
30	0.9997333	-5.55E-05	0.00484600	65	0.909185	0.020045	0.004572
31	0.9997119	-4.90E-05	0.00484600	66	0.971259	0.004362	0.002286
32	0.9996050	-1.62E-05	0.00484600	67	0.971258	0.004362	0.007111
33	0.9993488	6.10E-05	0.00312443	68	0.967824	0.005370	0.003555
34	0.9990133	0.0001632	0.00072187	69	0.967823	0.005370	
35	0.9989459	0.0001818	0.02262620				

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Table.2: Base Case Converged Flow Solution for System 2

Node/ Branch	Voltage (p.u)	Angle (radian)	Current (p.u)	Node/ Branch	Voltage (p.u)	Angle (radian)	Current (p.u)
1	1	0	1.866065	27	0.982427	0.000785	0.261515
2	0.947626	0.002020	0.159368	28	0.978758	0.000960	0.077368
3	0.940172	0.002354	1.611831	29	0.976950	0.001044	0.186260
4	0.925007	0.002949	0.129840	30	0.975459	0.001104	0.108774
5	0.923185	0.003033	1.352408	31	0.970372	0.001337	2.437959
6	0.912355	0.003480	0.065779	32	0.908758	0.003349	2.387765
7	0.911124	0.003537	1.253784	33	0.797069	0.008460	0.057384
8	0.883032	0.004758	1.084104	34	0.794923	0.008588	0.468122
9	0.852608	0.006163	0.978664	35	0.781747	0.009387	0.312865
10	0.806836	0.008465	0.432591	36	0.770045	0.010133	0.117731
11	0.800766	0.008777	0.244147	37	0.767294	0.010321	0.096907
12	0.798482	0.008895	0.151022	38	0.779935	0.009492	1.693390
13	0.793703	0.009152	0.075291	39	0.757467	0.010512	0.158861
14	0.796017	0.009026	0.131326	40	0.754495	0.010679	1.395190
15	0.793568	0.009142	0.454050	41	0.724840	0.012352	0.146440
16	0.800466	0.008826	0.093921	42	0.720731	0.012605	0.233840
17	0.795197	0.009164	0.266830	43	0.714998	0.012941	0.191932
18	0.787986	0.009486	0.114713	44	0.706022	0.013496	0.951980
19	0.783694	0.009717	1.309082	45	0.711483	0.013142	0.127090
20	0.987756	0.000542	0.617945	46	0.707323	0.013390	0.656427
21	0.979087	0.000932	0.511059	47	0.696134	0.014092	0.065612
22	0.964746	0.001579	0.251957	48	0.695214	0.014155	0.482247
23	0.952963	0.002097	0.126174	49	0.689368	0.014516	0.131335
24	0.950012	0.002229	0.165920	50	0.684454	0.014819	0.241278
25	0.960092	0.001816	0.047602	51	0.685983	0.014732	0.066555
26	0.958311	0.001904	0.569785	52	0.685361	0.014775	

6. CONCLUSIONS

In this paper, the impacts of Distribution generation and capacitor banks on power system voltage stability were investigated separately. Insertion of DG units is a process, which is actually growing in the operation of distribution networks, mainly due to both the technological changes and, permissible regulatory changes. This paper’s main contribution is that it establishes how the Regulator’s incentives, to reduce the losses, may affect the level of DG units penetration, both in sizing and location of the DG units in the network. Firstly, to include the time variability of DG units capacity. Second, to incorporate the changes in network configuration or topology that may occur during the evaluation period. In this paper, only two DG units were located, however the algorithm may be repeated to include a third or more units if necessary. It was considered that with two DG units, the generality is not lost, and it can be observed how the allocation of losses from the first DG group is affected by the entrance of the second DG group to the network. Another developed algorithm that provide optimal vars injection in to the system as and when required by the system to maintain the stability of the system. The algorithm responded well to the objective sought which was reflected in that, for all the cases studied, and for the different sensibilities, the algorithm responded correctly.

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REFERENCES

[1] T. Ackermann, G. Andersson, and L. Sder, “Distributed generation: a definition,” Electric Power Systems Research, vol. 57, pp. 195–204, 2001.

[2] T. Ackerman and V. Knyazkin, " Interaction between distributed generation and the distribution network: operation aspects," IEEE PES Transmission and Distribution Conference and Exhibition, vol. 2 (2002), pp. 1357- 1362.

[3] P. S. Georgilakis and N. D. Hatziargyriou, “Optimal distributed generation placement in power distribution networks: models, methods, and future research,” IEEE Trans. Power Syst., 2013, 28, (3), pp. 3420–3428.

[4] J. A. Peças Lopes, N. Hatziargyriou, J. Mutale, P. Djapic, and N. Jenkins, “Integrating distributed generation into electric power systems: a review of drivers, challenges and opportunities,” Elect. Power Syst. Res., 2007, 77, (9), pp. 1189–1203.

[5] Mohd Zamri Che Wanik, Istvan Erlich, and Azah Mohamed, "Intelligent Management of Distributed Generators Reactive Power for Loss Minimization and Voltage Control," MELECON 2010 - 2010 15th IEEE Mediterranean Electro-technical Conference, pp. 685-690, 2010.

[6] A. Gopi, and P.A. Raj, “Distributed Generation for Line Loss Reduction in Radial Distribution System,” International Conference on Emerging Trends in Electrical Engineering and Energy Management (ICETEEEM-2012), pp. 29-32, 2012.

[7] A. Keane et al. “State-of-the-Art Techniques and Challenges Ahead for Distributed Generation Planning and Optimization,” IEEE Trans. Power Systems, vol. 28, no. 2, pp. 1493-1502, 2013.

[8] D.Q. Hung, N. Mithulananthan, R.C. Bansal, “Analytical expressions for DG allocation in primary distribution networks,” IEEE Transactions on Energy Conversion, vol. 25, no. 3, pp. 814-820, 2010.

[9] K. Vinoth kumar and M.P. Selvan, “Planning and Operation of Distributed Generations in Distribution Systems for Improved Voltage Profile,” IEEE PES Power Systems Conference and Exposition (PSCE 2009), March 15-18, 2009, Washington, USA.

[10] J. B. V. Subrahmanyam and C. Radhakrishna “Distributed Generator Placement and Sizing in Unbalanced Radial Distribution System,” International Journal of Electrical and Electronics Engineering, Vol.3, pp.746 – 753. 2009.

[11] D. Singh, D. Singh, K.S. Verma, “Multi-objective optimization for DG planning with load models,” IEEE Trans. power systems, vol. 24, no. 1, pp. 427–436, 2009.

[12] N.S. Rau and Y.H. Wan, “Optimum location of resources in distributed planning,” IEEE Trans. Power Systems, 1994, 9, (4), pp. 2014–2020.

[13] Satish Kansal, B.B.R. Sai, Barjeev Tyagi and Vishal Kumar, “Optimal placement of distributed generation in distribution networks,” International Journal of Engineering, Science and Technology, Vol. 3, No. 3, pp. 47-55, 2011.

[14] Zhipeng Liu, Fushuan Wen, and Gerard Ledwich, “Optimal Siting and Sizing of Distributed Generators in Distribution Systems Considering Uncertainties,” IEEE Transactions on Power Delivery, 26(2011) 2541-2551.

[15] Evangelopoulos, V.A. and Georgilakis, P.S. “Optimal distributed generation placement under uncertainties based on point estimate method embedded genetic algorithm,” IET Generation, Transmission & Distribution, 8 (2014), 389 – 400.

[16] Dharmasa, C. Radhakrishna, H.S. Jain, and S. Ravi, “Non-iterative Power Flow Method for Radial Distribution Networks with Parameter Uncertainties,” TENCON – IEEE Conference, 23rd-26th Jan. 2009, pp. 1-7, Singapore.

[17] J. H. Teng, “A Direct Approach for Distribution System Load Flow Solutions,” IEEE Transactions on Power Delivery, vol. 18, no. 3, pp. 882-887, 2003.

[18] B. Venkatesh and R. Ranjan, “Data Structure for Radial Distribution Load Flow Analysis,” IEE Proceedings in Generation, Transmission and Distribution, vol 150, num. 1, pp. 101-106, January 2003.

[19] A. Alsaadi, and B. Gholami, “An Effective Approach for Distribution System Power Flow Solution,” International Journal of Electrical and Electronics Engineering 3:12 2009.