

Power Flow Analysis of Three Phase Unbalanced Radial Distribution Networks with Multiple DGs

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Abstract: As the installations of distributed generators (DGs) within distribution systems increasing, power flow analysis of unbalanced distribution networks needs special algorithms to handle multiple sources. In this paper, the development of an unbalanced three phase power flow algorithm which can handle multiple sources is described. According to the control and characteristics of output power, DGs can be specified as constant power factor model and constant voltage model or variable reactive power model. In this paper, these two models are all derived and integrated into the proposed load flow method. This load flow is capable of switching the DG mode of operation from constant voltage to constant power factor in the presence of multiple DGs. This algorithm requires dynamic data structure (DDS) to store the details of the branches. The algorithm uses basic principles of circuit theory and can be easily understood. This algorithm has been tested with IEEE 8 bus and IEEE 25 bus unbalanced radial distribution networks and the results are quite promising and are in agreements with the literature.

Index Terms: unbalance radial distribution networks, power flow, distributed generation.

I. INTRODUCTION

Distribution automation & optimization needs fast and efficient power flow which needs to be run repeatedly. The distribution network is inherently an unbalanced network due to a large number of unequal single-phase loads and the unsymmetrical spacing between the conductors. Due to these factors, conventional power flow algorithms used for transmission system studies do not show good convergence properties for distribution systems. Since dispersed generators are becoming prevalent in distribution systems, integrating multiple DGs in to distribution power flow algorithm has become an important task. Depending on the characteristics and control status of a generator, it may be operated in one of the following modes:

1. To output power at fixed real and reactive power.
2. To output power at a specified power factor.
3. To output power at a specified terminal voltage (or) variable reactive power.

The generator operating in first two modes can be equivalently represented as PQ node model, which require a little treatment in the power flow algorithm and the third mode of operation is well represented as PV node model. This model needs some special procedure in the load flow algorithm for maintaining its voltage magnitude and to monitor its reactive power flow capability.

A lot of work has been done for power flow solution of balanced and unbalanced radial distribution networks. Cheng and Shirmohammadi [11] proposed a load flow solution for real-time distribution system and it gives some initial discussions on a PV node concept in unbalanced power flow.

In this paper we developed an unbalanced distribution power flow algorithm using Dynamic Data Structure (DDS) and PV node sensitivity matrix. This algorithm can handle multiple DGs for their both modes of operation (PV and PQ). This algorithm is tested for the impact of DGs on the two unbalanced radial test systems by considering all the loads as constant power loads and the results are presented. However, this algorithm can also handle composite load modeling.

II. UNBALANCED POWER FLOW

The proposed unbalanced power flow algorithm uses Dynamic Data Structure (DDS) to store the details of the branches.

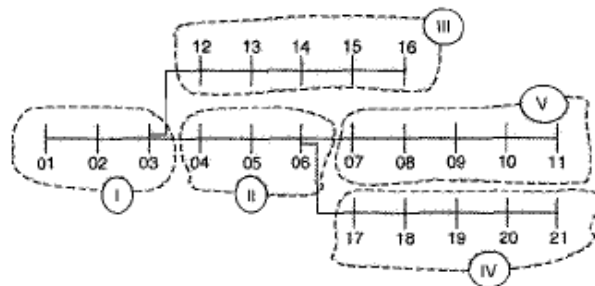


Fig. 1 a simple radial network with several laterals

The dynamic data structure is created by using the pseudocode presented in[2].With the help of this pseudocode, the first branch labeled I as shown in Fig.1 is formed by Starting at the main substation bus and sequentially considering buses until it finds one that has several branches leaving from it. It builds the first branch from bus number 1 up to bus number 3 where two branches leaves. Thus the branch I consists of three buses. From the bus 3 two branches emanates naming II and III. This structure stores pointers that point towards the structures storing details of branches II and III. This process proceeds until data structures for all the branches are built. The data structure storing details of branch II is shown in Table. I.

TABLE I
Details stored in branch II

Branch II	
No. of busses (03)	No. of branch emanates (02)
04	07
05	17
06	

After the DDS is formed for the system, the load flow is started at the end node of newly created branch V, with reference to Fig.1. Once the load flow has started from the “Start Bus” (an end bus), it can continue to solve the currents in branches upwards (towards the substation) until the head bus of that particular branch has been reached. This is explained by taking sample three buses in the system as shown in Fig. 2.

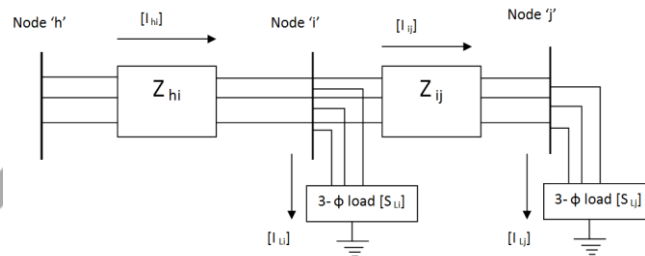


Fig. 2 The sample three buses in the system

The load current at node ‘j’ is find using equation (1) and which will be equal to the current in branch ‘ij’. The load current is written by assuming that the load draw constant complex power ($S = P + jQ$). It is further assumed that all three-phase loads are star connected and all double- and single-phase loads are connected between line and neutral. The double-phase and single-phase loads are modeled by setting the complex power of the non-existing phases to zero.

$$\begin{bmatrix} I_{ij}^a \\ I_{ij}^b \\ I_{ij}^c \end{bmatrix} = \begin{bmatrix} I_{ij}^a \\ I_{ij}^b \\ I_{ij}^c \end{bmatrix} = \begin{bmatrix} (S_{ij}^a/V_j^a)^* \\ (S_{ij}^b/V_j^b)^* \\ (S_{ij}^c/V_j^c)^* \end{bmatrix} \tag{1}$$

For the better starting of the power flow algorithm, the voltages at all nodes are taken equal to the substation voltage. And then the current in branch ‘hi’ can find applying KCL at node ‘i’ and is given below.

$$\begin{bmatrix} I_{hi}^a \\ I_{hi}^b \\ I_{hi}^c \end{bmatrix} = \begin{bmatrix} I_i^a \\ I_i^b \\ I_i^c \end{bmatrix} + \begin{bmatrix} I_{ij}^a \\ I_{ij}^b \\ I_{ij}^c \end{bmatrix} \tag{2}$$

Like this the currents in the branches towards the head bus are calculated. When the branch head bus has been reached, the load flow program must look at the branch parent bus and see if the branch currents have been done for all of the buses below that parent bus. Then continue to solve the node voltages using equation (3) downwards (from the substation).

$$\begin{bmatrix} V_i^a \\ V_i^b \\ V_i^c \end{bmatrix} = \begin{bmatrix} V_h^a \\ V_h^b \\ V_h^c \end{bmatrix} - \begin{bmatrix} Z_{hi}^{aa} & Z_{hi}^{ab} & Z_{hi}^{ac} \\ Z_{hi}^{ba} & Z_{hi}^{bb} & Z_{hi}^{bc} \\ Z_{hi}^{ca} & Z_{hi}^{cb} & Z_{hi}^{cc} \end{bmatrix} \begin{bmatrix} I_{hi}^a \\ I_{hi}^b \\ I_{hi}^c \end{bmatrix} \tag{3}$$

In the above equation (3) the phase impedance matrix (3x3) for each branch is obtained from the line data, spacing configuration and phasing information is explained in [9]. For the double-phase and single-phase line sections the phase impedance matrix will have entries zeros in place of missing phases [5]. Once the voltages are calculated at all nodes at the end of first iteration, these voltages can be used to find the node currents for the back word sweep for the next iteration. The algorithm stops if the changes in the computed bus voltage magnitudes are the same in two successive iterations.

III. POWER FLOW ALGORITHM WITH DISTRIBUTED GENERATION

According to the characteristics and control on the output power, the DGs can be modeled as constant power factor model for small DGs and constant voltage or variable reactive power model for large DGs. The constant power factor model can be taken as PQ node model in the power flow algorithm, and constant voltage model or variable reactive power model is taken as PV node model in the power flow algorithm.

The methodology for modeling PV node in the power flow algorithm is explained as follows. After the power flow explained in section II is converged, suppose the voltage magnitudes at PV nodes is not equal to the scheduled values, In order to obtain the scheduled voltage magnitude at the PV node, we need to determine the correct amount of reactive power generated by the unit. The reactive power generation can be found from reactive current injection. Therefore, the PV node voltage magnitude can be compensated by finding the reactive current injection at each PV node. Since the relation between reactive current injection and magnitude V is nonlinear, reactive current can only be determined iteratively.

The methodology followed for modeling PQ node is model it as negative load and inject the specified active and reactive powers in to the node.

Since the terminal voltages may be unbalanced, the injected currents may also be unbalanced. If there is a large imbalance in the injected currents the machine may be shut down by its protection system.

The detailed iterative procedure for power algorithm with the DGs is explained as follows,

1. Run the unbalanced radial distribution power flow as explained in section II.
2. After the load flow is converged, for the outside k^{th} iteration, check the type of DGs available.
3. If the DGs available are output power at constant power factor then model that nodes as PQ node and inject complex powers specified by the generator in to each phase S_{gi}^a , S_{gi}^b & S_{gi}^c at that node by taking them as negative load.

Where,

$$\begin{bmatrix} S_{gi}^a \\ S_{gi}^b \\ S_{gi}^c \end{bmatrix} = \begin{bmatrix} P_{gi}^a \\ P_{gi}^b \\ P_{gi}^c \end{bmatrix} + j^* \begin{bmatrix} Q_{gi}^a \\ Q_{gi}^b \\ Q_{gi}^c \end{bmatrix} \quad (4)$$

The power injections in to each phase are found by dividing the total specified power by three.

4. If the DGs available are output power at constant voltage or variable reactive power the model that node as PV node. And calculate the voltage mismatches at all the PV nodes as,

$$\Delta V_i^k = |V_i^{\text{sp}}| - |V_i^{\text{cal}}(k)| \quad \text{for all the PV nodes 'i'} \quad (5)$$

5. If any of the ΔV_i^k is not less than the specified tolerance, then reactive current injection at the PV node in order to maintain the specified voltage needs to be calculated for the k^{th} iteration. Reactive current injection is calculated using equation (6).

$$[\Delta I_q]^k = [Z_{pv}]^{-1} [\Delta V]^k \quad (6)$$

Where, the size of $[\Delta V]^k$ & $[\Delta I_q]^k$ is $3*n \times 1$. ('n' indicates the number of PV busses). And $[Z_{pv}]$ is the PV node sensitivity matrix. The procedure to form $[Z_{pv}]$ is explained in next step.

6. The $[Z_{pv}]$ can be formed by observing the following numerical properties of its entries. The diagonal entry, Z_{ii} in $[Z_{pv}]$ is equal to the modulus of the sum positive sequence impedance of all line sections between PV nodes 'i' and the root node (substation bus). Since all the lines are three phase line sections, the size of Z_{ii} is 3×3 . If from the root node any two PV nodes, i and j, have different paths, then the off diagonal entry Z_{ij} (size 3×3), is zero. If 'i' and 'j' share a piece of common path to the root node, then Z_{ij} is equal to the modulus of the sum positive sequence impedance of all line sections on this common path. Based on these, $[Z_{pv}]$ can be formed by identifying the path between PV nodes and the root node. The dimension of $[Z_{pv}]$ is equal to three times the number of PV nodes since it consists of 3×3 block sub matrices.

7. If the reactive power generations (Q without limits) were unlimited at the PV node, we would inject the reactive currents at 90 degrees leading the corresponding node voltages V_i^a , V_i^b & V_i^c at each PV node. The reactive current to be injected at the i^{th} PV node is given in equation (7).

$$\begin{bmatrix} I_{qi}^a \\ I_{qi}^b \\ I_{qi}^c \end{bmatrix} = \begin{bmatrix} |\Delta I_{qi}^a|^k (\cos(90^\circ + \delta_{vi}^a) + j^* \sin(90^\circ + \delta_{vi}^a)) \\ |\Delta I_{qi}^b|^k (\cos(90^\circ + \delta_{vi}^b) + j^* \sin(90^\circ + \delta_{vi}^b)) \\ |\Delta I_{qi}^c|^k (\cos(90^\circ + \delta_{vi}^c) + j^* \sin(90^\circ + \delta_{vi}^c)) \end{bmatrix} \quad (7)$$

Where δ_{vi}^a , δ_{vi}^b & δ_{vi}^c are the voltage angles of the three phases at the i^{th} PV node.

8. Now, to find the reactive power injection needed to eliminate the voltage mismatch at k^{th} iteration is obtained by applying the KCL at node ‘i’ at k^{th} iteration for the Fig.3.

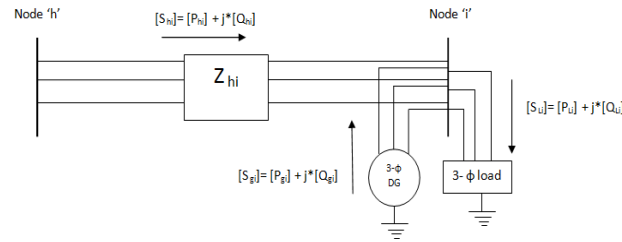


Fig. 3 a sample two nodes in the system with DG placed at node ‘i’

$$\begin{bmatrix} \Delta Q_{gi}^a \\ \Delta Q_{gi}^b \\ \Delta Q_{gi}^c \end{bmatrix}^k = \begin{bmatrix} Q_{Li}^a \\ Q_{Li}^b \\ Q_{Li}^c \end{bmatrix} - \begin{bmatrix} Q_{hi}^a \\ Q_{hi}^b \\ Q_{hi}^c \end{bmatrix}^k \tag{8}$$

Where, $[Q_{hi}]^k$ is the reactive power flowing in the line ‘hi’ for the k^{th} iteration. It can find from equation (9)

$$[Q_{hi}]^k = \begin{bmatrix} V_i^a * ((I_{hi}^a)^k)^* \\ V_i^b * ((I_{hi}^b)^k)^* \\ V_i^c * ((I_{hi}^c)^k)^* \end{bmatrix} \tag{9}$$

The branch currents in equation (9) at the k^{th} iteration are calculated as,

$$\begin{bmatrix} I_{hi}^a \\ I_{hi}^b \\ I_{hi}^c \end{bmatrix}^k = \begin{bmatrix} I_{Li}^a \\ I_{Li}^b \\ I_{Li}^c \end{bmatrix} - \begin{bmatrix} I_{qi}^a \\ I_{qi}^b \\ I_{qi}^c \end{bmatrix}^k \tag{10}$$

The reactive power generation needed at i^{th} PV node for k^{th} iteration is,

$$\begin{bmatrix} Q_{gi}^a \\ Q_{gi}^b \\ Q_{gi}^c \end{bmatrix}^k = \begin{bmatrix} Q_{gi}^a \\ Q_{gi}^b \\ Q_{gi}^c \end{bmatrix}^{k-1} + \begin{bmatrix} \Delta Q_{gi}^a \\ \Delta Q_{gi}^b \\ \Delta Q_{gi}^c \end{bmatrix}^k \tag{11}$$

9. Then inject complex power generations at the PV nodes for the k^{th} iteration as,

$$\begin{bmatrix} S_{gi}^a \\ S_{gi}^b \\ S_{gi}^c \end{bmatrix}^k = \begin{bmatrix} P_{gi}^a \\ P_{gi}^b \\ P_{gi}^c \end{bmatrix} + j * \begin{bmatrix} Q_{gi}^a \\ Q_{gi}^b \\ Q_{gi}^c \end{bmatrix}^k \tag{12}$$

Where, P_{gi} is the specified real power generation at the i^{th} PV node.

10. If the reactive power generations (Q with limits) were limited at the PV node, then reactive power limits must be checked first. The total 3- ϕ reactive power needed at i^{th} PV node is the sum of reactive power generations of three phases.

$$(Q_{gi}^\gamma)^k = (Q_{gi}^a)^k + (Q_{gi}^b)^k + (Q_{gi}^c)^k \tag{13}$$

11. The $(Q_{gi}^\gamma)^k$ is compared with the reactive power generation limits, if the Q_{gi}^γ is within the limits, i.e.,

$$Q_{gi, \max} \leq (Q_{gi}^\gamma)^k \leq Q_{gi, \min}$$

Then inject the complex power as given equation (12).

12. Otherwise, if (Q_{gi}^γ) violates any reactive power generation limits, it will be set to that limit, divided by three for three phases. i.e.,

$$\begin{aligned} \text{If } Q_{gi}^\gamma \leq Q_{gi, \min} \text{ then set } Q_{gi}^\gamma &= Q_{gi, \min} & \text{and } (Q_{gi}^a)^k &= (Q_{gi}^b)^k = (Q_{gi}^c)^k = Q_{gi, \min} / 3 \\ \text{If } Q_{gi}^\gamma \geq Q_{gi, \max} \text{ then set } Q_{gi}^\gamma &= Q_{gi, \max} & \text{and } (Q_{gi}^a)^k &= (Q_{gi}^b)^k = (Q_{gi}^c)^k = Q_{gi, \max} / 3 \end{aligned}$$

These reactive power generations are combined with the active power generations at that node and inject into the node.

13. Now set $k=k+1$ and run the load flow with the complex power injections at the PV nodes and PQ nodes.

14. Stop the iterations when the voltage mismatches at all the PV nodes is less than the threshold values or the changes in the bus voltage magnitudes in two successive iterations at all nodes are less than the threshold values.

The flow chart for the above algorithm is given in Fig. 6.

IV. RESULTS

The impact of the DGs on the distribution network is examined on two unbalanced distribution networks with the algorithm presented in this paper.

A. Example 1

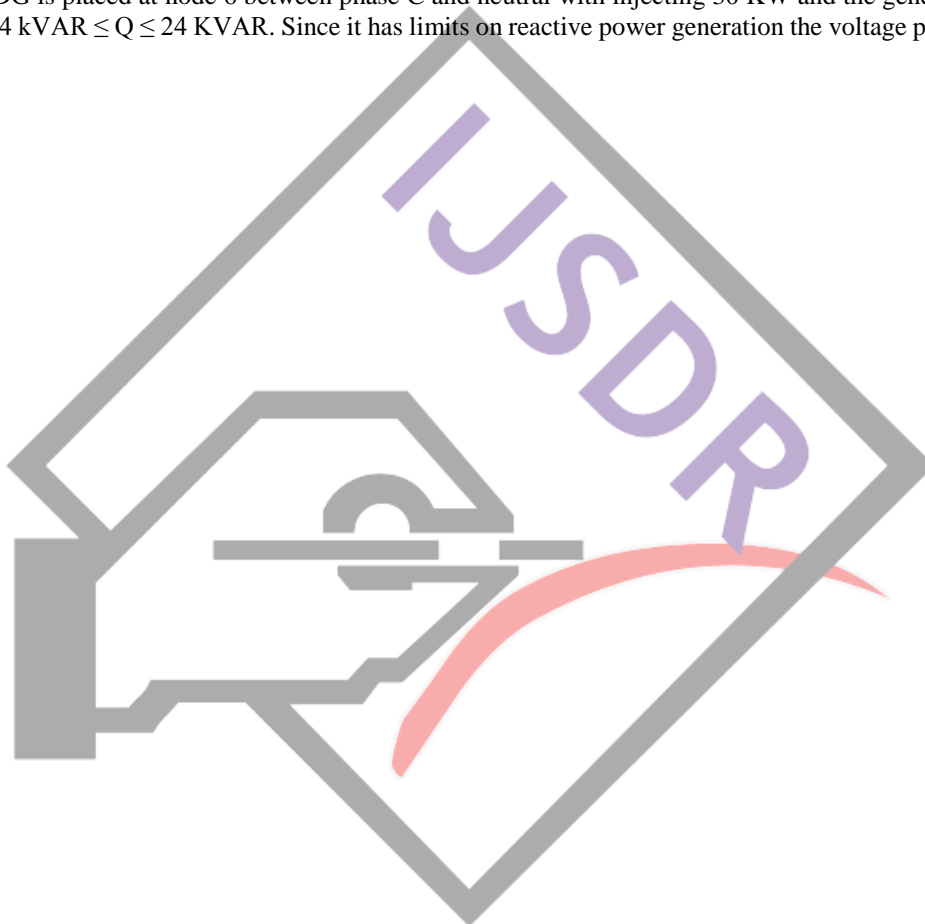
A sample system 14.4 kV of 8 buses shown in Fig. 4 has been taken from the Taiwan Power Corporation [12]. It is assumed that the transformer at the substation is balanced, voltage regulators and capacitors at various buses is neglected. The base values of the system are chosen 14.4 kV and 300 kVA. The convergence tolerance specified for the load flow analysis is 0.00001 p.u. and the convergence tolerance for voltage mismatches at PV nodes is taken as 0.0001 p.u. The load flow solution without DGs and impacts of DGs on the system with the following cases is presented in the Table II.

Without DGs: The first two columns in the Table II is the power flow solution of the system without injecting DGs into it.

Case-I: From the Table-II, the case- I is the power flow solution of the system when a 1- ϕ DG is connected at node 6 between the phase C and neutral with injecting 30 kVA at constant power factor 0.8. This node is modeled as PQ node for the power flow analysis. It is found that voltage profile is improved at all busses when compared with without DGs.

Case-II: A 1- ϕ DG is placed at node 6 between phase C and neutral with injecting 30 KW and it has no limits on reactive power generation. At the end of the convergence to get the voltage profile as in Table-II the generator is required to generate reactive power 73.726 kVAR. It is found that phase voltage at bus 6 is 1 p.u.

Case - III: The 1- ϕ DG is placed at node 6 between phase C and neutral with injecting 30 KW and the generator has the limits on the reactive power $-24 \text{ kVAR} \leq Q \leq 24 \text{ KVAR}$. Since it has limits on reactive power generation the voltage profile is less than case-II.



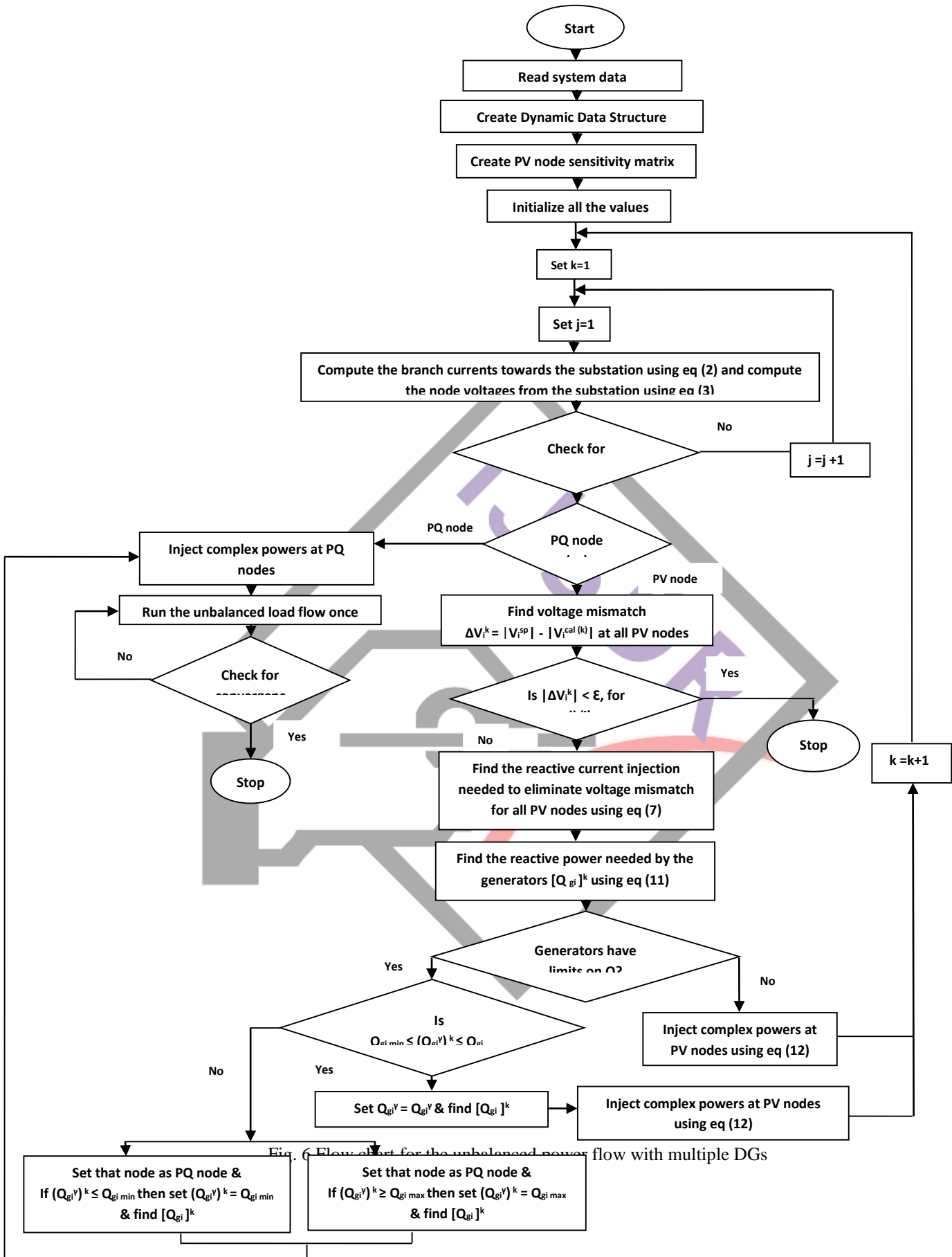


Fig. 6 Flow chart for the unbalanced power flow with multiple DGs

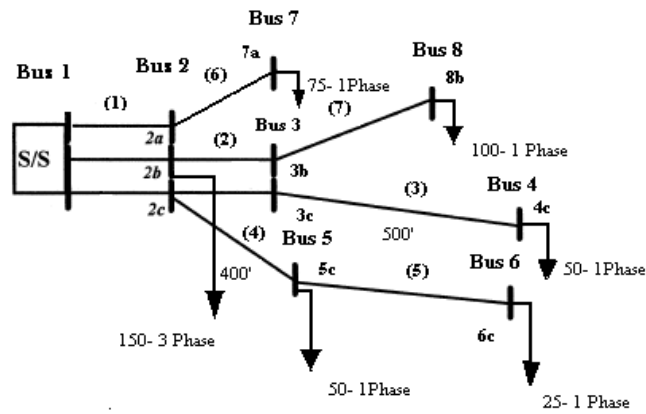


Fig. 4 IEEE-8 bus unbalanced radial distribution network

TABLE II
Power flow solution of IEEE-8 bus system

Node no.	Without DGs		Case -I		Case -II		Case -III	
	$ V $ in P.U	$\angle v$ in (rad)	$ V $ in P.U	$\angle v$ in (rad)	$ V $ in P.U	$\angle v$ in (rad)	$ V $ in P.U	$\angle v$ in (rad)
2a	0.9975	-0.0009	0.9972	-0.0008	0.9970	-0.0002	0.9974	-0.0006
2b	0.9969	-2.095	0.9969	-2.0959	0.9965	-2.0965	0.9967	-2.0958
2c	0.9961	2.0918	0.9971	2.0924	0.9990	2.0918	0.9969	2.0915
3b	0.9944	-2.095	0.9944	-2.096	0.9940	-2.0965	0.9942	-2.0958
3c	0.9955	2.0913	0.9964	2.0919	0.9984	2.0913	0.9963	2.091
4c	0.9932	2.0913	0.9941	2.0918	0.9960	2.0913	0.994	2.091
5c	0.9934	2.0918	0.9954	2.0924	0.9988	2.0903	0.9947	2.0908
6c	0.9924	2.0918	0.9956	2.0924	1.000	2.0888	0.9943	2.0901
7a	0.9940	-0.0009	0.9937	-0.0008	0.9935	-0.0002	0.9940	-0.0007
8b	0.9897	-2.095	0.9898	-2.096	0.9893	-2.0966	0.9895	-2.0958

B. Example 2

A 4.16 kV IEEE 25 has taken from [7]. It is assumed that the transformer at the substation is balanced, voltage regulators and capacitors at various buses is neglected. For the load flow, base voltage and base MVA are chosen as 4.16 kV and 1000 kVA respectively.

Without DGs: Table-III is the power flow solution of the system without injecting DGs into it.

Case-I: two DGs are injected in the system. The first 3- ϕ DG is connected at bus number 15 is output 3000 KW and it has no limits on the reactive power generation hence it is modeled as PV node. The second 3- ϕ DG placed at bus 18 is output 300 kVA at 0.8 p.f, which is modeled as PQ node. At the end of the power flow algorithm to get the voltage profile as in Table-IV the generator is required to generate total reactive power 4252.1 kVAR. The Table-IV presents the power flow solution and the phase voltages at bus 15 are found to be 1 p.u.

Case-II: The 3- ϕ DG placed at bus 15 with injecting total power 1800 KW and the generator has the limits on the reactive power - 1350 kVAR $\leq Q \leq$ 1350 kVAR. The Table-V Presents the power flow solution.

TABLE III
Power flow solution of IEEE-25 bus system without DGs

Node no.	$ V_a $ in P.U	$\angle V_a$ in rad.	$ V_b $ in P.U	$\angle V_b$ in rad.	$ V_c $ in P.U	$\angle V_c$ in rad.
1	1	0	1	-2.094	1	2.094
2	0.9859	-0.0047	0.9878	-2.097	0.9887	2.089
3	0.9836	-0.0054	0.9849	-2.097	0.9863	2.088
4	0.9822	-0.0058	0.9833	-2.098	0.9856	2.087
5	0.9811	-0.0058	0.9823	-2.098	0.9847	2.087
6	0.9771	-0.0048	0.9816	-2.096	0.9821	2.089
7	0.9750	-0.0048	0.9796	-2.096	0.9803	2.089
8	0.9693	-0.0049	0.9764	-2.096	0.9765	2.089
9	0.9648	-0.0050	0.9748	-2.096	0.9768	2.089
10	0.9619	-0.0050	0.9729	-2.097	0.9771	2.089
11	0.9594	-0.0061	0.9724	-2.097	--	--
12	0.9582	-0.0061	--	--	--	--
13	--	--	0.9716	-2.097	--	--
14	0.9661	-0.0049	0.9729	-2.095	0.9706	2.089
15	0.9640	-0.0049	0.9708	-2.095	0.9687	2.089
16	--	--	--	--	0.9694	2.089
17	0.9693	-0.0049	0.9764	-2.096	0.9765	2.089
18	0.9816	-0.0054	0.9822	-2.097	0.9829	2.087
19	0.9805	-0.0052	0.9807	-2.097	0.9832	2.087
20	--	--	0.9783	-2.097	--	--
21	--	--	--	--	0.9789	2.087
22	--	--	--	--	0.9765	2.087
23	0.9809	-0.0057	0.9817	-2.098	0.9850	2.087
24	--	--	0.9791	-2.099	0.9843	2.087
25	--	--	0.9759	-2.099	--	--

TABLE IV
Case - I

Node no.	$ V_a $ in P.U	$\angle V_a$ in rad.	$ V_b $ in P.U	$\angle V_b$ in rad.	$ V_c $ in P.U	$\angle V_c$ in rad.
1	1	0	1	-2.094	1	2.094
2	0.9978	-0.009	0.9974	-2.102	0.9989	2.086
3	0.9966	-0.010	0.9955	-2.102	0.9974	2.085
4	0.9952	-0.010	0.994	-2.103	0.9966	2.085
5	0.9942	-0.010	0.993	-2.103	0.9957	2.085
6	0.9957	-0.017	0.9966	-2.108	0.9981	2.079
7	0.9936	-0.017	0.9946	-2.108	0.9963	2.079
8	0.9946	-0.0255	0.9968	-2.115	0.9983	2.073
9	0.9902	-0.025	0.9952	-2.115	0.9985	2.073
10	0.9874	-0.025	0.9934	-2.116	0.9988	2.073
11	--	--	0.9929	-2.116	0.9988	2.073
12	0.9838	-0.026	--	--	--	--
13	--	--	0.9921	-2.116	--	--
14	0.9980	-0.033	0.9987	-2.122	0.9983	2.066
15	0.9999	-0.038	0.9999	-2.126	0.9999	2.062
16	--	--	--	--	0.9971	2.066
17	0.9946	-0.025	0.9968	-2.115	0.9983	2.073
18	0.9967	-0.010	0.9949	-2.102	0.9958	2.085
19	0.9956	-0.009	0.9934	-2.102	0.9961	2.085
20	--	--	0.9910	-2.102	--	--
21	--	--	--	--	0.9919	2.085
22	--	--	--	--	0.9895	2.085
23	0.9939	-0.010	0.9923	-2.103	0.9960	2.085
24	0.9939	-0.010	--	--	0.9953	2.085
25	--	--	0.9866	-2.104	--	--

Table V
Case- II

Node no.	$ V_a $ in P.U	$\angle V_a$ in rad.	$ V_b $ in P.U	$\angle V_b$ in rad.	$ V_c $ in P.U	$\angle V_c$ in rad.
1	1	0	1	-2.094	1	2.094
2	0.9915	-0.002	0.9931	-2.096	0.9933	2.091
3	0.9891	-0.003	0.9901	-2.096	0.9909	2.090
4	0.9877	-0.004	0.9886	-2.097	0.9902	2.089
5	0.9867	-0.003	0.9876	-2.097	0.9892	2.089
6	0.9880	-0.003	0.9920	-2.095	0.9915	2.091
7	0.9859	-0.003	0.9900	-2.095	0.9896	2.091
8	0.9855	-0.003	0.9919	-2.095	0.9905	2.091
9	0.9810	-0.003	0.9903	-2.096	0.9908	2.092
10	0.9782	-0.003	0.9885	-2.096	0.9911	2.092
11	--	--	0.9880	-2.096	0.9911	2.092
12	0.9745	-0.004	--	--	--	--
13	--	--	0.9872	-2.096	--	--
14	0.9874	-0.003	0.9934	-2.095	0.9894	2.091
15	0.9884	-0.003	0.9944	-2.095	0.9903	2.091
16	--	--	--	--	0.9882	2.091
17	0.9855	-0.003	0.9919	-2.095	0.9905	2.091
18	0.9872	-0.003	0.9875	-2.096	0.9875	2.09
19	0.9861	-0.003	0.9860	-2.096	0.9877	2.09
20	--	--	0.9836	-2.096	--	--
21	--	--	--	--	0.9835	2.09
22	--	--	--	--	0.9811	2.09
23	0.9865	-0.003	0.9869	-2.097	0.9896	2.089
24	0.9865	-0.003	--	--	0.9889	2.089
25	--	--	0.9812	-2.098	--	--

V. CONCLUSION

In this paper a 3- ϕ unbalanced radial distribution power flow algorithm which can handle multiple DGs is presented. The impact of DGs on the system voltage profile has seen. It is basically a Forward Backward Sweep based method which requires dynamic data structure (DDS) to store the details of a branches of RDS and PV node sensitivity matrix to find the reactive current injections at the PV nodes. The proposed method has good convergence property for any practical distribution networks with practical R/X ratio.

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