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DYNAMIC LOAD FLOW SOLUTION IN RADIAL DISTRIBUTION NETWORK

Prakash Kumar
ITM University Gwalior,
Department of Electrical Engineering.

Dr. Ramswaroop
NIMS University
HOD, Mathematics

Abstract – This paper aims at developing a new method of load flow involving distributed generator for the improvement of voltage profile. The involvement of distributed generator results in improved voltage regulation due to increase in the magnitude of the voltage. Whereas the load flow solution gives the solution in lesser time due to lower iteration and thus lower computational time during fault. The node at which distributed generator is connected is independent of node and branch number. In the method proposed here, simple equations have been used to calculate the magnitude of the voltage and in case of high load condition; the voltage profile can easily be improved by implementing distributed generation connected with self converting station arrangement. This method deals with the total voltage profile to specified area of load and involves nodes of the the connected distribution substation, laterals and sub laterals. During faulty condition, the distributed generator compares the voltage ratio (obtained by dividing the voltage after the fault with the voltage just after the fault) and compensated the voltage difference, as required, to maintain the system healthy.

Keywords – Load flow, voltage sag, voltage profile, feeders, Distributed Generation.

1. Introduction

Improvement of power quality has always been a matter of concern for electrical engineers. The users, being most untrustful part of the power system, need to be mitigated and studied carefully for obtaining fault free power system. Electrical distribution system being most important part of power system economics, as the main source of revenue, need to be compensated carefully to keep high R/X ratio. A radial distributed is generally radial in nature and has high R/X ratio, whereas the transmission system is generally ring system/mesh in nature and has high X/R ratio [1].

In this quest, many researchers have made remarkable work to improve quality factor by improving power factor, reducing voltage sag, reducing harmonic components, etc. it is challenging to work with distributed system, as it is most uncertain and contains highest disturbance. A number of new sophisticated methods proved efficient for the solution of problems associated with transmission system; but the theory gets limited in case of distribution system. The efficient methods like Gauss-Seidel and Newton Rapson methods has also not proven efficient enough in case of solving problems associated with distribution system.

The distributed generator basically includes reciprocating engines, solar cells, fuel cells, combustion gas turbine, micro turbines and wind turbines; i.e. alternate energy sources as compared to conventional fossil fuel based energy sources. It causes low emission, low pollution, high efficiency and uninterrupted supply to loads where interruption in power is not a choice e.g. hospital, mines, relevant industries, etc.; however implementation of distributed generator in electrical distribution system increases its complexity. Distributed generators can work not only in upstream for improvement of voltage during the dip but also in downstream to regulate the voltage or remain standstill when no any action is required i.e. as reserved alternate solution for power failure.

2. Review of literature

Many researchers have made significant effort in the field of DG installation and allocation. In [2] operation and control model of DG has been explained to improve voltage efficiency. In [3], the effect of DG on electrical power loss, impact on voltage profile and consecutive cases were discussed. In this case the author aimed at optimizing DG location, minimising losses and improve power quality. In [4], the effect of DG on power system has been discussed with reference to losses, voltage regulation, voltage fluctuations, short circuit condition, islanding operation and harmonics. In [5], simulation technique has been used to obtain voltage regulation to optimize power support by DG in the distribution system. In [6], tap changing transformer method has been proposed for voltage regulation in under voltage and over voltage conditions.

3. Notations used

Abb.	**Full form**
DG	Distributed Generator
$\|V\|\angle\alpha$	System voltage & angle
$\|I\|\angle\beta$	System current & angle
S	Apparent Power
Subscript pq	Over the bus p to q
a	Phase a
L_F	Load Factor
P	Real Power
Q	Reactive Power
Y	Admittance
Superscript *	Conjugate
N_F	Nodes of feeder
N_L	Nodes of Lateral
N_{SL}	Nodes of Sub-Lateral
B_F	Branch of feeder
B_L	Branch of Lateral
B_{SL}	Branch of Sub-Lateral
x,y	Node x,y
Pml	Pointer memory location
F_{TS}	F,L&SL total sum
F,L&SL	Feeder, Lateral & Sub-Lateral
LLF	Line Loss Factor
VCF	voltage compensation factor

4. Losses in distribution system

If the phasor expression for voltage and current are known, then the calculation of real and reactive power can be done easily. If the voltage across and current into a certain load or part of circuit is $|V|\angle\alpha$ and $|I|\angle\beta$, respectively, apperent power is given by[7]

$S=VI^*=|V|e^{j\alpha}.|I|e^{-j\beta}=|V||I|e^{j(\alpha-\beta)}=|V||I|\angle(\alpha-\beta)$....(i)

The complex power injected from bus p to q is given by S_{pq} or from bus q to p is given as S_{qp} i.e.

$$\left.\begin{aligned} S_{pq} &= V_{pq} I_{pq}^* \\ \text{Or, } S_{qp} &= V_{qp} I_{qp}^* \end{aligned}\right\} \quad \text{.................................(ii)}$$

Where, I* represents the conjugate of the current.

Voltage at phase 'a' of pth bus is given as:

$$\left.\begin{aligned} |V_P^a| &= f_p^a\,(V, L_F) \text{ and angle} \\ \alpha_P^a &= f_\alpha^a\,(V, L_F) \end{aligned}\right\} \quad \text{................(iii)}$$

The current form p to q bus for phase R is given as:

$$|I_{Pq}^a| = f_{|p|}^a\,(V,\ L_F) = \left|\sum_a Y_{Pq}^a\ (V_P^a - V_q^a)\right| \quad \text{.....(iv)}$$

Where V_P^a is the bus voltage at bus p over phase a and Y_{Pq}^a is element of branch admittance matrix.

Real and reactive power flow measurement from bus p to bus k over phase a is given as:

$$S_{pq}^p = f_P^a(V,\ L_F) + j f_Q^a(V,\ L_F) = V_q^a (I_{pq}^a)^* \quad \text{..........(v)}$$

Power supplied at bus q for phase a can be measured as:

$$S_{pq,supplied}^p = f_{P,supplied}^a\,(V,\ L_F) + j f_{Q,supplied}^a\,(V,\ L_F)$$

$$= V_q^a \left(\sum_p \sum_a Y_{Pq}^a\,(V_q^a - V_p^a)\right)^* \quad \text{.............(vi)}$$

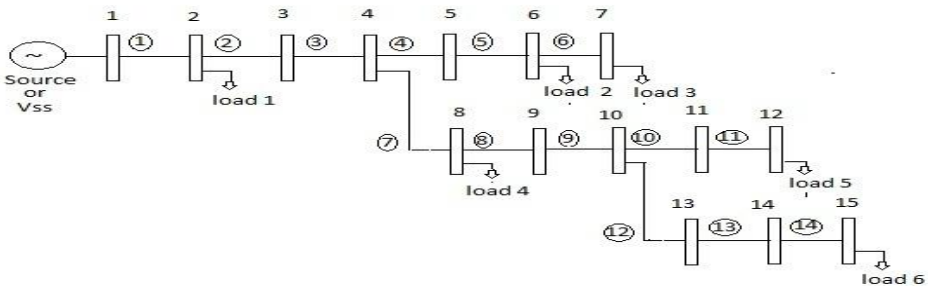

Figure4.1: A 15 node test system with regular and symmetric numbering of nodes and branches.

Considering a 15 node test system with regular and symmetric numbering of nodes and branches as illustrated in *Fig.4.1* and a 15 node test system with irregular and asymmetric numbering of nodes and branches as illustrated in *Fig.4.2*:

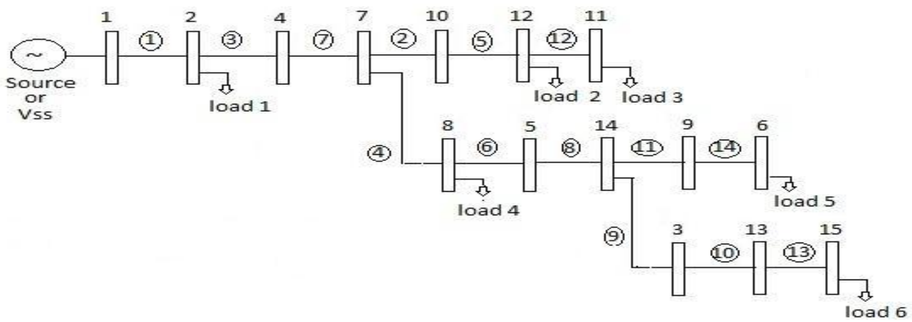

Figure 4.2: A 15 node test system with irregular and asymmetric numbering of nodes and branches

The *fig.4.1* represents a radial distribution system, the branches and nodes have been sub-divided into feeder, lateral and sub-lateral. For representing the feeders, laterals and sub-laterals in form of two dimensional arrays in which the first number represents the feeder (1), lateral (2) and sub-lateral (3); and the second number represents the order of node or branch, as applicable.

In case of Nodes:

$N_F(1,1)=1$, $N_F(1,2)=2$, $N_F(1,3)=3$, $N_F(1,4)=4$, $N_F(1,5)=5$, $N_F(1,6)=6$, $N_F(1,7)=7$, for feeders.

$N_F(2,1)=4$, $N_F(2,2)=8$, $N_F(2,3)=9$, $N_F(2,4)=10$, $N_F(2,5)=11$, $N_F(2,6)=12$ for laterals.

$N_F(3,1)=10$, $N_F(3,2)=13$,$N_F(3,3)=14$, $N_F(3,4)=15$ for sub-laterals.

In case of Branches:

$B_F(1,1)=1$, $B_F(1,2)=2$, $B_F(1,3)=3$, $B_F(1,4)=4$, $B_F(1,5)=5$, $B_F(1,6)=6$ for feeders.

$B_F(2,1)=7$, $B_F(2,2)=8$, $B_F(2,3)=9$, $B_F(2,4)=10$, $B_F(2,5)=11$ for lateral.

$B_F(3,1)=12$, $B_F(3,2)=13$, $B_F(3,3)=14$ for sub-lateral.

In either case, the sequences are independent of nodes or branches.

In this quest:

Let $\gamma= B_F(x,y)$; $\xi_1= N_F(x,y)$ and $\xi_2= N_F(x,y+1)$

So, $V_{(\xi 2)}= V_{(\xi 1)}-I_\gamma Z_\gamma$

Where,

$V_{(\xi 2)}= | V_{(\xi 2)}|\angle\alpha_2$

$V_{(\xi 1)}= | V_{(\xi 1)}|\angle\alpha_1$

$I_\gamma = | I_\gamma|\angle-\beta$

$Z_\gamma= | Z_\gamma |\angle\Phi= R_\gamma+jX_\gamma$

Voltage at node 2 is given as

$|V_{(\xi 2)}|= |V_{(\xi 1)}|- [\{(P_\gamma^2+Q_\gamma^2)^{1/2}\}.|Z_\gamma|]/|V_{(\xi 1)}|$ ......(vii)

Where, $(P_\gamma^2+Q_\gamma^2)^{1/2}=| S_\gamma |=| V_{(\xi 1)}| \, | I_\gamma|$

P_γ &Q_γ are the real & reactive power at output port of node ξ_1.

And, $I_\gamma=[(P_{\gamma P}^2+Q_{\gamma p}^2)^{1/2}]/ | V_{(\xi 2)}|$; with reference to primary side i.e. entering port of node (x,y) node.

And, $I_\gamma=[(P_{\gamma S}^2+Q_{\gamma S}^2)^{1/2}]/ | V_{(\xi 1)}|_{\,)}|$; with reference to secondary side i.e. output port of node (x,y) node.

The current $|I_\gamma|=[| V_{(\xi 1)} |-| V_{(\xi 2)}|]/| Z_\gamma |$ ....(viii)

Real & reactive power loss can be given as

$$\left.\begin{aligned} P_L&=|I_\gamma^2|R_\gamma \\ Q_L&=|I_\gamma^2|X_\gamma \end{aligned}\right\} \text{ ....(ix)}$$

The power can be given for branches as

For feeder branches:

$P_S[B_F(1,6)]=T_L[N_F(1,7)]+P_L[N_F(1,6)]$

$P_S[B_F(1,5)]=T_L[N_F(1,6)]+P_L[N_F(1,5)]+P_S[B_F(1,6)]$

$P_S[B_F(1,4)]=T_L[N_F(1,5)]+P_L[N_F(1,4)]+P_S[B_F(1,5)]$

$P_S[B_F(1,3)]=T_L[N_F(1,4)]+P_L[N_F(1,3)]+P_S[B_F(1,4)]$

$P_S[B_F(1,2)]=T_L[N_F(1,3)]+P_L[N_F(1,2)]+P_S[B_F(1,3)]$

$P_S[B_F(1,1)]=T_L[N_F(1,2)]+P_L[N_F(1,1)]+P_S[B_F(1,2)]$

For lateral branches:

$P_S[B_F(2,5)]=T_L[N_F(2,6)]+P_L[N_F(2,5)]$

$P_S[B_F(2,4)]=T_L[N_F(2,5)]+P_L[N_F(2,4)]+P_S[B_F(2,5)]$

$P_S[B_F(2,3)]=T_L[N_F(2,4)]+P_L[N_F(2,3)]+P_S[B_F(2,4)]$

$P_S[B_F(2,2)]=T_L[N_F(2,3)]+P_L[N_F(2,2)]+P_S[B_F(2,3)]$

$P_S[B_F(2,1)]=T_L[N_F(2,2)]+P_L[N_F(2,1)]+P_S[B_F(2,2)]$

For sub-lateral branches:

$P_S[B_F(3,3)]=T_L[N_F(3,4)]+P_L[N_F(3,3)]$

$P_S[B_F(3,2)]=T_L[N_F(3,3)]+P_L[N_F(3,2)]+P_S[B_F(3,3)]$

$P_S[B_F(3,1)]=T_L[N_F(3,2)]+P_L[N_F(3,1)]+P_S[B_F(3,2)]$

Thus from the above cases of feeder, lateral and sub-lateral branches, we conclude:

For dead end branches

$P_S[B_F(x,y)]=T_L[N_F(x,y+1)]+P_L[N_F(x,y)]$ ....(x)

And for other mid branches

$P_S[B_F(x,y)]=T_L[N_F(x,y+1)]+P_L[N_F(x,y)]+P_S[N_F(x,y+1)]$ ....(xi)

The equation (x) & (xi) are valid for all branches of feeder, lateral and sub-lateral network.

Similarly, reactive power losses are given as:

For dead end branches

$Q_S[B_F(x,y)]=T_{QL}[N_F(x,y+1)]+Q_L[N_F(x,y)]$ ....(xii)

And for other mid branches

$Q_S[B_F(x,y)] = T_{QL}[N_F(x,y+1)] +Q_L[N_F(x,y)] + Q_S[N_F(x,y+1)]$ ....(xiii)

For sub-lateral and lateral network connected to $N_F(2,3)$, the total power flowing through branch $B_F(2,1)$ is given as

$P_S[B_F(2,1)] = P_L[B_F(2,1) + T_L[N_F(2,3)] + P_S[B_F(2,3)] + P_S[B_F(3,1)]$ ....(xiii)

And $Q_S[B_F(2,1)] = P_{QL}[B_F(2,1) + T_{QL}[N_F(2,3)] + Q_S[B_F(2,3)] + Q_S[B_F(3,1)]$ ....(xiv)

Thus we find that the common nodes of sub-lateral & lateral, feeder & lateral should be pointed first. If $N_F(x,y)$ is the node from which other lateral and sub-lateral have emerged, then the feeder branch B_F is stored as $B_F(x,y-1)$.

In the methodology suggested in this paper checks the node from which lateral and sub-lateral have emerge and store the branch number irrespective of the actual numbering of the node as depicted in *fig 4.2*; i.e. if the feeder node is $N_F(x,y)$, lateral node is $N_F(x+1, y)$ and sub-lateral node as $N_F(x+2)$, then $N_F(x,y)$ of feeder & $N_F(x+1,1)$ and $N_F(x+1,y)$ & N_F $(x+2,1)$ are same; and the branch $B_F(x,y-1)$ is stored in the pointer memory location pml(F_{TS}-1)(say). Here (F_{TS}-1) refers to the pointer memory address storage size. In this way, the common nodes of Feeders & laterals, laterals & sub-laterals can be identified easily. The lateral node in case of Feeder & lateral common node or lateral & sub-lateral common node; the lateral and sub-lateral node respectively can be shown to be stored in pointer pml'(F_{TS}-1) for simplicity.

Thus the following results are obtained:

$P_S(B_F(x,y) = T_L[N_F(x,y+1)] + P_L[B_F(x,y)] + P_S[B_F(x,y+1)+P_S[B_F(F_{TS},1)$ ....(xv)

And Q_S $(B_F(x,y) = T_{QL}[N_F(x,y+1)] + Q_L[B_F(x,y)] + Q_S[B_F(x,y+1)+Q_S[B_F(pml',1)$.................(xvi)

Thus from the above results, it is obtained that the suggested method does not depend on the node or branch numbering of F,L& SL. This makes this method more reliable and fast as the calculation of P_S and Q_S is independent of the node & branch complex nomenclature.

Now after calculating power at respective nodes, the convergence is checked for the voltages at the respective nodes. In case of non-converging system, the DG is placed at the common nodes and convergence is obtained. Now we determine voltage compensation factor (VCF) by following formula.

$$VCF=\frac{\text{Improved voltaage profile with DG}}{\text{Voltage profile with out DG}}$$

Where, voltage profile depends on the magnitude of voltage at which the DG is placed and the load connected to that branch or node. While considering the factor VCF, one more factor should be considered very keenly, i.e. load loss factor due to DG installation. The installation of DG not only reduces line losses but can also result in increased line loss as depicted in *fig.4.3* below. This is observed in the distributed systems where sufficiently high capacity DG is installed in the network. The at most size of DG should be such that the generated power should easily be consumed within the coned common points of F, L & SL. Any attempt to install high capacity DG with the purpose of exporting power beyond the substation (reverse flow of power though distribution substation), will lead to very high losses. So, the size of distribution system in term of load (MW) will play important role is selecting the size of DG. So we always try to keep low line loss factor (LLF) given as

$$LLF=\frac{\text{Reduction of line lossess by using DG}}{\text{Reduction of line losses without using DG}}$$

The factor LLF should always be less than 1 otherwise the loss with DG will become more as compared to losses without DG. In case LLF≥1, either the size of DG is reduced or the location of DG is changed to give the value of LLF lower than 1. The factors affecting the losses by using DG includes line length, line resistance, load distribution etc. In case of the losses without DG, the load is assumed to be distributed uniformly throughout the nodes of the Feeders.

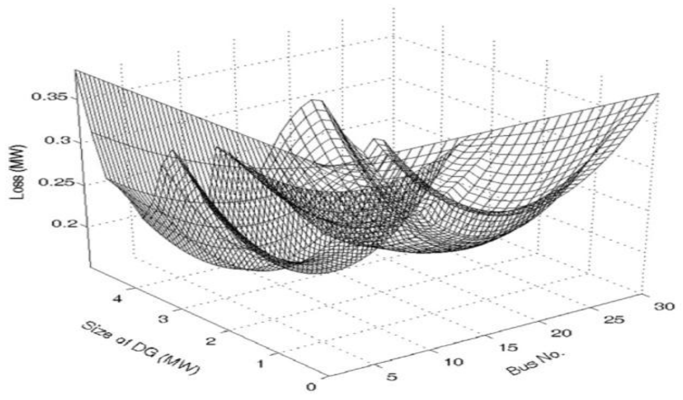

Figure 4.3: Effect of size and location of DG on system loss

5. Proposed Algorithm

Step 1: Obtain the number of F, L & SL.

Step 2: let number of $N_F(x,y)$= P, number of $N_F(x+1,y)$=Q, number of $N_F(x+2,y)$=R

Step 3: F_{TS}=P+Q+R.

Step 4: If the numbering of the nodes are sequential, read the first node for F, L, SL i.e. $N_F(x,1)$, $N_F(x+1,1)$ & $N_F(x+2,1)$. Proceed to step 7.

Step 5: If the numbering of the nodes is not sequential, call the pointer and store the value of numbered node under different F, L & SL as $N_F(x,y)$, $N_F(x+1,y)$ & $N_F(x+2,y)$ irrespective of actual node numbering.

Step 6: Call the value of first node for F, L, SL i.e. $N_F(x,1)$, $N_F(x+1,1)$ & $N_F(x+2,1)$. Proceed to step 7.

Step 7: Obtain common nodes for lateral & feeder and sub-lateral & lateral, as emerging point for lateral and sub-lateral nodes.

Step 8: for common nodes of lateral & sub-lateral i.e. $N_F(x+1,y)$ & $N_F(x+2,1)$ for $x=F_{TS}$ to $F_{TS}-R+1$ and $y=1,2,\ldots\ldots,F_{TS}$. Call the pointer & store branch of lateral $B_F(x,y-1)$ for corresponding node $N_F(x,y)$ in pml'(z) for z=1,2,.....,R.

Step 9: obtain common nodes of lateral & feeder i.e. $N_F(x,y)$ & $N_F(x,1)$ for $x=F_{TS}-R$ to $F_{TS}-R-Q+1$ from $N_F(1,y)$ for $y=1,2,\ldots.,F_{TS}$. Store pml'(x) for x=R+1,....,R+Q and BF(x,y-1) corresponding to $N_F(x,y)$ in pml'(x) for x=R+1,...,R+Q

Step 10: Calculate $P_S[B_F(x,y)]$ and $Q_S[B_F(x,y)]$ for $x=F_{TS}$ to $F_{TS}-R+1$ and y=N(x)-1,....,2,1 using equation

Step 11: Calculate $P_S[B_F(x,y)]$ and $Q_S[B_F(x,y)]$ for $x=F_{TS}-R$ to $F_{TS}-R-Q+1$ using equation.

Step 12: Calculate total P_S and Q_S for the F, L & SL. Total power loss thus obtained is $S_L=P_S+QS$.

Step 13: Calculate the F, L & SL voltage and check if the terminal voltage converges with the obtained voltage within permissible limit i.e. $V_{loss}=V_S-V_0= \pm 5\%$ of V_S, where $V_0=S_L$/Feeder node current. If the voltage is within permissible limit go to step 16 or go to step 14.

Step 14: Start DG placed near common node of feeder & lateral i.e. $N_F(x,y)$ & $N_F(x+1,1)$ or lateral & sub-lateral i.e. $N_F(x+1,y)$ & $N_F(x+2,1)$. Check for convergence. If the voltage converges with requisite voltage, calculate voltage compensation factor (VCF) and line loss factor (LLF). If LLF<1, go to step 16 or go to step 15.

Step 15: change DG location and place it to another location near common node of feeder & lateral i.e. $N_F(x,y)$ & $N_F(x+1,1)$ or lateral & sub-lateral i.e. $N_F(x+1,y)$ & $N_F(x+2,1)$ and go to step 14.

Step 16: verify results for $B_F(x,y)$ for y=N(x)-1,...,2,1 and $x=F_{TS}-R$ to $F_{TS}-R-Q+1$ with pml'(z) for z=1,2,..,R.

Step 17: Calculate $P_S[B_F(1,y)]$ &$Q_S[B_F(1,y)]$ for y=N(x)-1,....,2,1 using equation

Step 18: check the results for feeder branch $B_F(1,y)$ for y=N(x)-1,...,2,1 with pml'(z) for z=R+1,...,R+Q.

Step 19: If the result converges, go to step 20 or go to step 16.

Step 20: Stop.

6. Result and Conclusion

In distribution system, it is common to consider a radial system. In the table 6.1, the load at different nodes has been considered. These loads have been considered irrespective of the actual node numbering rather the position of the F, L & SL. In table 6.2, the loss has been considered uniformly throughout the distribution system and the relative minimum voltage in the system in p.u. system. The disturbance has been considered to be maximum i.e. 5%. In table 6.3, the loss has been considered random throughout the distribution system and the relative voltage in the system in p.u. system. The disturbance has been considered to be within ±5%.

Table 6.1. Load on three phase system

Node No.	Phase A		Phase B		Phase C		Total Load	
	P (kW)	Q (kVAr)	P (kW)	Q (kVAr)	P (kW)	Q (kVAr)	P (kW)	Q (kVAr)
$N_F(1,2)$	56.26	12.32	56.26	12.32	56.26	12.32	168.78	36.96
$N_F(1,4)$	245.56	20.58	245.56	20.58	245.56	20.58	736.68	61.74
$N_F(1,6)$	62.15	12.35	62.14	12.36	62.19	12.22	186.48	36.93
$N_F(1,7)$	33.59	11.21	36.25	25.24	58.56	21.24	128.4	57.69
$N_F(2,2)$	85.55	35.25	85.55	35.25	85.55	35.25	256.65	105.75
$N_F(2,4)$	140.54	56.65	140.54	56.65	140.54	56.65	421.62	169.95
$N_F(2,6)$	34.25	12.25	34.25	12.25	34.25	12.25	102.75	36.75
$N_F(3,4)$	19.47	-71.32	19.47	-71.32	19.47	-71.32	58.41	-213.96

Table 6.2. Results for uniform power loss without DG

Bus No.	Uniform Power Loss +5%				Total Load		Minimum Voltage (in p.u.)
	Loss (%)		Loss (kW, kVAr)				
	P	Q	P	Q	P	Q	
$N_F(1,2)$	5	5	8.439	1.848	168.78	36.96	0.95
$N_F(1,4)$	5	5	36.834	3.087	736.68	61.74	0.95
$N_F(1,6)$	5	5	9.324	1.8465	186.48	36.93	0.95
$N_F(1,7)$	5	5	6.42	2.8845	128.4	57.69	0.95
$N_F(2,2)$	5	5	12.8325	5.2875	256.65	105.75	0.95
$N_F(2,4)$	5	5	21.081	8.4975	421.62	169.95	0.95
$N_F(2,6)$	5	5	5.1375	1.8375	102.75	36.75	0.95
$N_F(3,4)$	5	5	2.9205	-10.698	58.41	-213.96	0.95

Table 6.3. Results for Random power loss without DG

Bus No.	Random power loss within ±5%				Total Load		Minimum Voltage (in p.u.)
	Loss (%)		Total Power Loss				
	P	Q	P	Q	P	Q	
$N_F(1,2)$	1.42	1.42	2.396676	0.524832	168.78	36.96	0.9858
$N_F(1,4)$	3.95	3.95	29.09886	2.43873	736.68	61.74	0.9605
$N_F(1,6)$	2.85	2.85	5.31468	1.052505	186.48	36.93	0.9715
$N_F(1,7)$	4.9	4.9	6.2916	2.82681	128.4	57.69	0.951
$N_F(2,2)$	3.56	3.56	9.13674	3.7647	256.65	105.75	0.9644
$N_F(2,4)$	-0.54	-0.54	-2.27675	-0.91773	421.62	169.95	1.0054
$N_F(2,6)$	1.13	1.13	1.161075	0.415275	102.75	36.75	0.9887
$N_6(3,4)$	5	5	2.9205	-10.698	58.41	-213.9	0.95

Now using DG at the common node of lateral and feeder i.e. $N_F(1,4)$, the net rective need of the system reduces due to injected power of the DG. Thus the net voltage regulation improves and the minimum voltage at different nodes of the distribution system is as obtained in in *figure 6.4 and 6.5*. The selection of node can vary for the variation of load at different nodes with the proposed algorithm which will depend on the F, L & SL rather the actual node.

Table 6.4. Results for uniform power loss with DG.

Bus No.	Uniform Power Loss +5%				Total Load		Minimum Voltage (in p.u.)
	Loss (%)		Loss (kW, kVAr)				
	P	Q	P	Q	P	Q	
$N_F(1,2)$	5	5	8.439	1.848	168.78	36.96	0.95
$N_F(1,4)$	5	5	36.834	3.087	736.68	61.74	0.99
$N_F(1,6)$	5	5	9.324	1.8465	186.48	36.93	0.99
$N_F(1,7)$	5	5	6.42	2.8845	128.4	57.69	0.99
$N_F(2,2)$	5	5	12.8325	5.2875	256.65	105.75	0.99
$N_F(2,4)$	5	5	21.081	8.4975	421.62	169.95	0.99
$N_F(2,6)$	5	5	5.1375	1.8375	102.75	36.75	0.99
$N_F(3,4)$	5	5	2.9205	-10.698	58.41	-213.96	0.99

Table 6.5. Results for Random power loss with DG.

Bus No.	Random power loss within ±5%				Total Load		Minimum Voltage (in p.u.)
	Loss (%)		Total Power Loss				
	P	Q	P	Q	P	Q	
$N_F(1,2)$	1.42	1.42	2.396676	0.524832	168.78	36.96	0.9858
$N_F(1,4)$	3.95	3.95	29.09886	2.43873	736.68	61.74	0.98
$N_F(1,6)$	2.85	2.85	5.31468	1.052505	186.48	36.93	0.99
$N_F(1,7)$	4.9	4.9	6.2916	2.82681	128.4	57.69	0.99
$N_F(2,2)$	3.56	3.56	9.13674	3.7647	256.65	105.75	0.98
$N_F(2,4)$	-0.54	-0.54	-2.27675	-0.91773	421.62	169.95	1
$N_F(2,6)$	1.13	1.13	1.161075	0.415275	102.75	36.75	0.99
$N_6(3,4)$	5	5	2.9205	-10.698	58.41	-213.9	0.99

In the above cases, by the properplacement of DG can give better voltage regulation and the placement of DG can easily be obtained by sing the dynamic algorithm proposed above. Since the algorithm is independent of actual node numbering and depends on the position of the node, the time taken by the CPU is much lesser as compared to earlier proposed algorithms as shown below.

Table 6.6. Comparison between the proposed method and the previously proposed method.

Method	**CPU Time**
Proposed Method	1.00
Das & Nagi [8]	1.85-2.55 ≈ 2.15
Das & Gosh [9]	1.45-1.95 ≈ 1.55
Das & Ranjan [10]	1.55-1.95 ≈ 1.65
Zhu & Tomsovic [11]	2.1-4.5 ≈ 3.78

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