NETWORK RECONFIGURATION WITH OPTIMAL PLACEMENT OF CAPACITORS AND DG IN DISTRIBUTION SYSTEM FOR REDUCTION OF ACTIVE POWER LOSS

R. Sanjeevi Naik[1], D. Ravi Kumar[2], G. Sasi Kumar[3], M. Bhagya Lakshmi[4]

[1] PG Scholar, EEE Dept. VNRVJIET, Hyderabad

[2] Associate Professor EEE Dept., VNRVJIET

[3] Associate Professor EEE Dept., VNRVJIET

[4] Assistant Professor EEE Dept., GPCET

sanjunaik246@gmail.com

Abstract

Distribution systems feed inductive loads which leads to higher power losses in the distribution network and poor power factor accompanied by voltage sags. In present days, continuous effort is being made in bringing down the line losses of the electrical distribution networks. For supplying reactive power and maintaining the bus voltage, capacitors equipped distribution systems are used. This results in reduction in losses of the system.

In this paper, an efficient optimization algorithm for selecting the tie-switches using Network Reconfiguration (NR) is considered for Power loss reduction. IEEE 33-Bus RDS is used for the analysis. The load flow analysis is done using Distribution Load Flow and NR algorithms and optimum locations of Distributed Generator (DG) and Capacitors are obtained. The Simulation is done in ETAP software and the obtained results are analyzed.

Keywords: Network Reconfiguration, **Distribution** Load Flow, Distributed Generator

1. Introduction

Distribution systems normally consist of a main feeder and lateral distributors. It acts as a link between high voltage transmission line and the low voltage consumers. The low voltage and high current characteristics of distribution system leads to high power losses compared to that of transmission system. About 13% of total power generated is consumed as power losses at the distribution system.

Network Feeder Reconfiguration is the process of altering the topological structure of distribution feeders by changing the open/closed status of the tie and sectionalizing switches. Optimal Capacitor Placement is a complex combinatorial problem.

Analytical methods have been used in most of the early works of optimal placement of capacitors which require no powerful computing resources. In the recent years optimal placement of capacitor problems has been solved using population based optimization algorithms such as Genetic Algorithm, Particle Swarm Optimization algorithm and Artificial Bee Colony (ABC) algorithm. Distributed Generation is a promising solution for the improvement of efficiency and reliability of a distribution system.

An approach using Distribution Load flow solution and a reconfiguration algorithm is considered in [1] that enhances voltage profile, reliability and Voltage Stability Index besides minimizing losses. Minimization of power loss in Distribution System Using Network Reconfiguration in the presence of Distributed Generation is proposed in [2]. The evaluation of the practicality and accuracy of the capacitor placement algorithms is explained by [3]. An approach that determines the desired locations of capacitors in a radial distribution system to improve voltage profile and reduce power losses is explained in [4]. The distribution load flow is run initially without capacitor placement and then the size and location of capacitor in distribution systems based on GA is determined in [5] for power loss minimization and voltage profile and reliability improvement.

2. Problem Formulation

Optimal placement problem is one example of mixed integer non-linear optimization. Objective Function and constraints of this problem are given by the equations below. Load flow was performed in each mode in order to investigate the losses and electrical and technical constraints in the network.

Objective Function:

$$I_r = \min \sum_{i=0}^{n} (I_i)^2 r_i \quad \dots (1)$$

where I_i and r_i are current and resistance of i^{th} line. In fact, sum of active power losses of lines, between buses, are considered as total losses of the distribution network

Limits on capacitor:

Due to technical and electrical limitations in terms of capacity of compensation capacitors, it is not possible to use these devices with any capacity. Capacitors are not available in every size, practically, standard implementable discrete values were used.

$$C_{min}^{cap} <= C_i^{cap} <= C_{max}^{cap} \quad \dots(2)$$

3. Network Reconfiguration Algorithm

Network Reconfiguration is a feasible method in which power flow is altered by closing or opening the switches in the feeders. It is implemented by closing a tie switch and opening a sectionalizing switch to conserve radial nature of the feeders. The flow chart for the NR algorithm is shown Figure 1.

4. Results and Analysis

4.1. 33-Bus RDS with Base configuration

The block diagram of IEEE 33-Bus RDS with base configuration is shown in Figure 2. Line data and Load data of the 33 bus RDS are taken from [1]. The base configuration of 33-Bus RDS is implemented in ETAP Software and the obtained results are given Table 1 and Table 2.

4.2 33-Bus RDS with Network Reconfiguration

From the simulation results of 33-bus RDS for Base Configuration, total active power loss of the system is 202.7 kW. The VSI difference between two sides of the tie switch in between 22-12 is largest so this tie-switch is to be closed first. As VSI of 22 is greater than VSI of 12, the switch in the branch 12-11 is opened, now the total Active Power Loss is 156.7283 kW. The procedure is repeated until the final optimal configuration is achieved. Thus the Active Power Loss is 143.15 kW after reconfiguration and the final optimal configuration is shown in Figure 3, and the results are given in Table 3 and Table 4.

4.3 33-Bus RDS with Network Reconfiguration and Capacitors

Capacitors are placed at different buses in 33-Bus RDS. The size of the capacitor is selected as 300 kVAR. Capacitors are placed at buses 1, 2, 3, 4, 5, 27, where the Active Power Loss is relatively more. 33-Bus RDS without and with NR is implemented in ETAP with capacitors and the obtained Active Power Loss is given in Table 5.

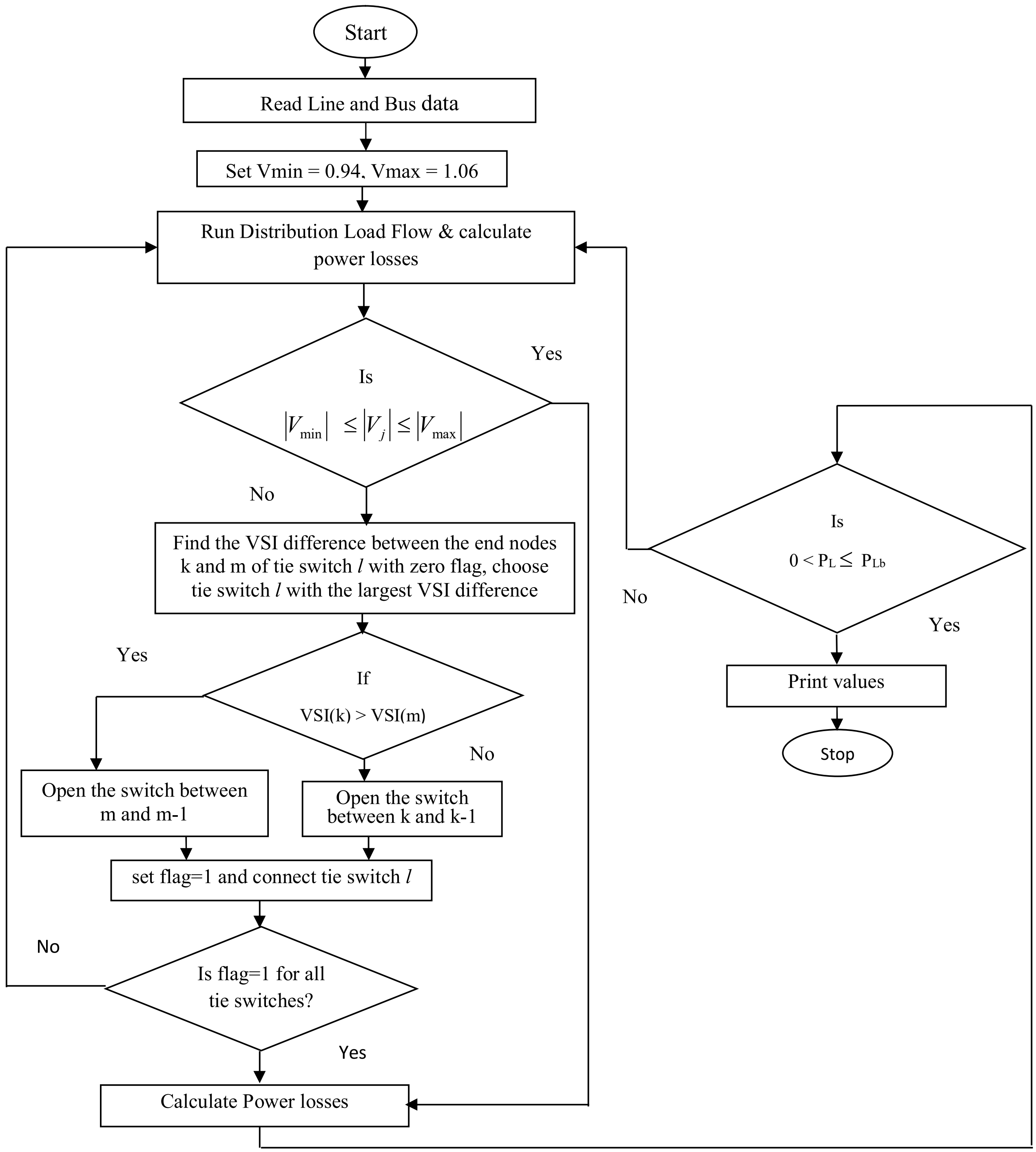


Figure 1. Flowchart for Network Reconfiguration algorithm

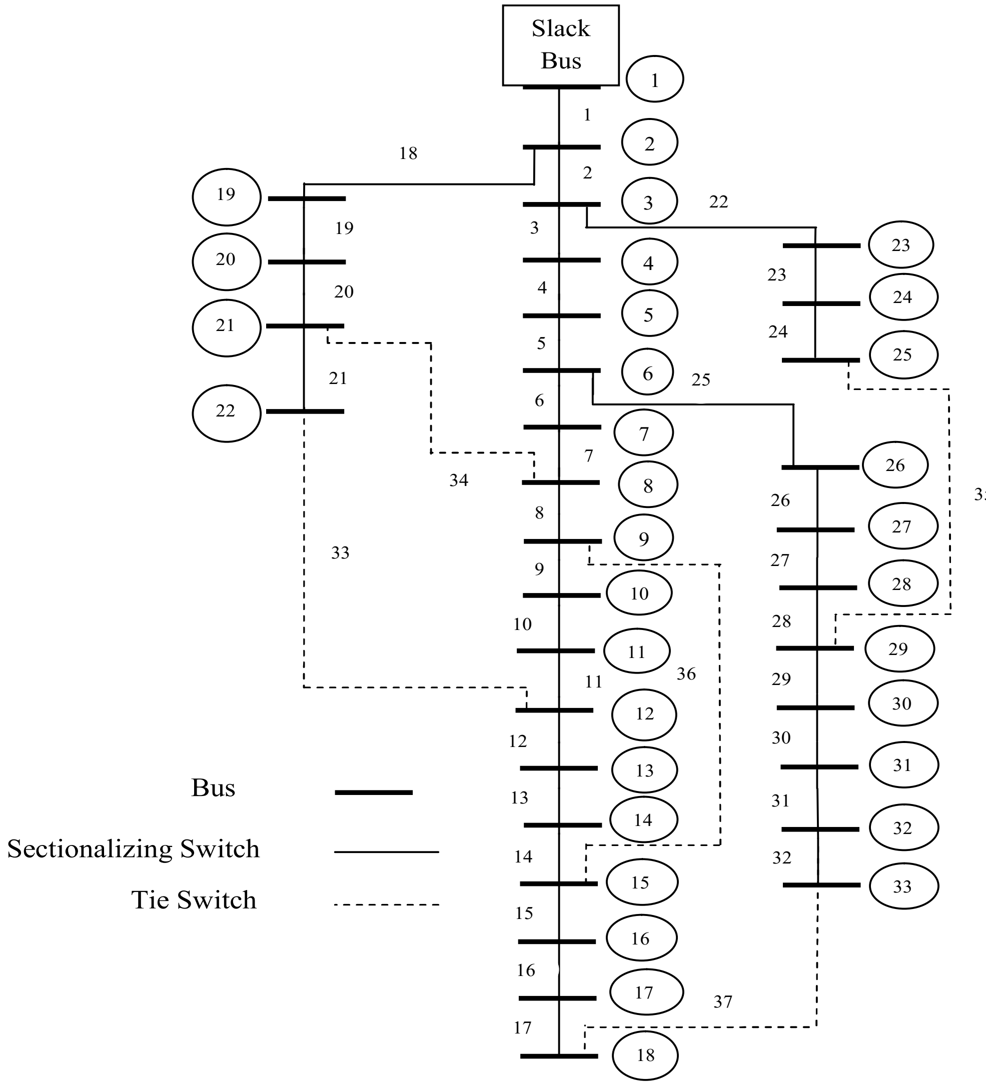


Figure 2. Block diagram of 33 Bus RDS with Base configuration

4.4. 33-Bus RDS with Network Reconfiguration and DG

There are several benefits by installing a DG unit at an optimal location, these include increasing voltage profile, minimization of line losses. DG is placed at three optimal locations in 33-bus radial distribution system with 0.1070 MW (18) and 0.5724 MW (17), 1.0462 MW (33) and the Active Power loss is given in Table 6.

4.5. 33-Bus RDS with Network Reconfiguration, Capacitors and DG

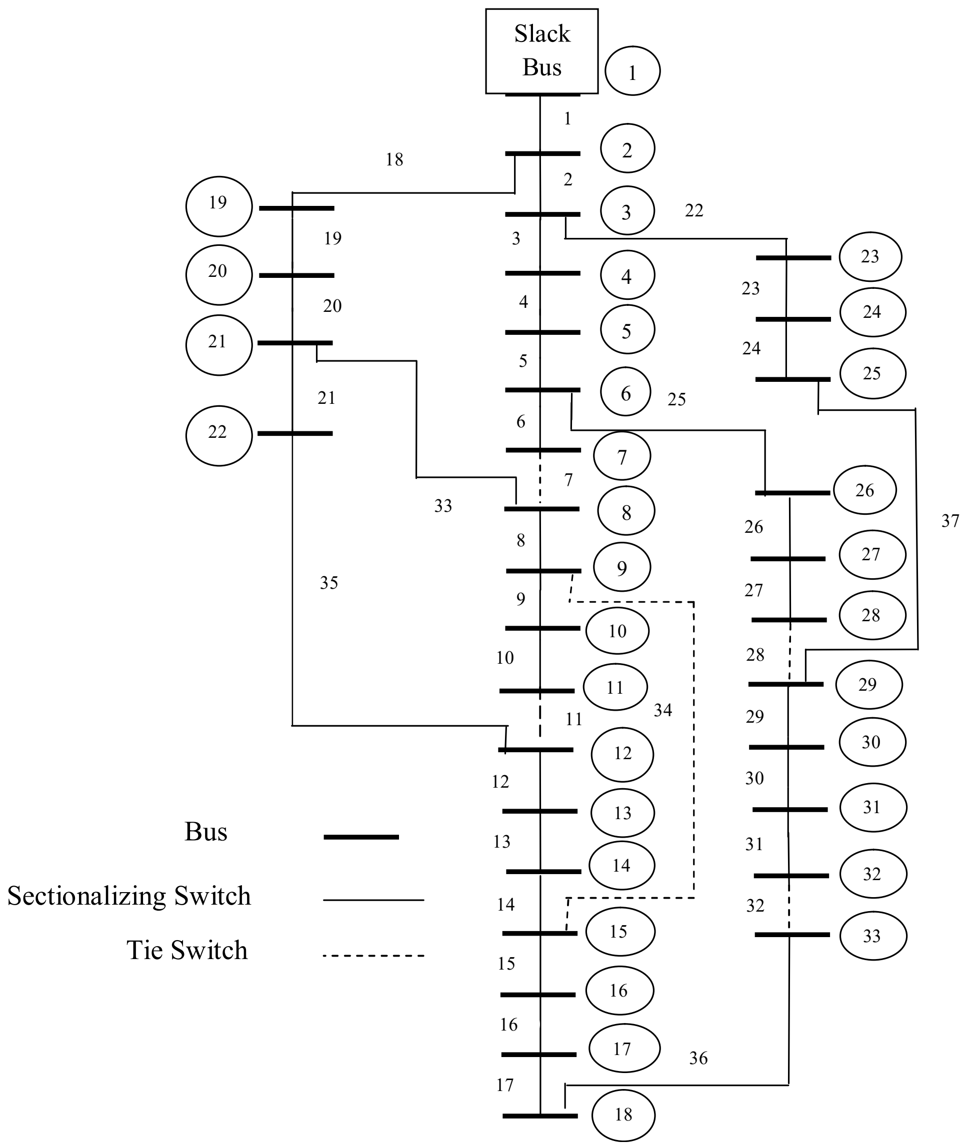
Combination of NR, Capacitors and DG are considered in IEEE-33 Bus RDS and the obtained Power loss is compared with previous cases in Table 7.

Table 1. Load Flow results for 33-Bus RDS of Figure 2

Bus No.	Voltage Magnitude (p.u)	Phase Angle (p.u)	VSI (p.u)	Bus No.	Voltage Magnitude (p.u)	Phase Angle (p.u)	VSI (p.u)
1	1	0	1	18	0.9131	-0.0086	0.6951
2	0.997	0.0003	0.9882	19	0.9965	0.0001	0.6934
3	0.9829	0.0017	0.9331	20	0.9929	-0.0011	0.972
4	0.9755	0.0028	0.9053	21	0.9922	-0.0014	0.9692
5	0.9681	0.004	0.8781	22	0.9916	-0.0018	0.9668
6	0.9497	0.0023	0.8127	23	0.9794	0.0011	0.9529
7	0.9462	-0.0017	0.8014	24	0.9727	-0.0004	0.895
8	0.9413	-0.0011	0.7851	25	0.9694	-0.0012	0.8829
9	0.9351	-0.0023	0.7644	26	0.9477	0.003	0.8761
10	0.9292	-0.0034	0.7456	27	0.9452	0.004	0.798
11	0.9284	-0.0033	0.7429	28	0.9337	0.0055	0.7599
12	0.9269	-0.0031	0.7381	29	0.9255	0.0068	0.7336
13	0.9208	-0.0047	0.7187	30	0.922	0.0086	0.7225
14	0.9185	-0.0061	0.7117	31	0.9178	0.0072	0.7095
15	0.9171	-0.0067	0.7074	32	0.9169	0.0068	0.7067
16	0.9157	-0.0071	0.7032	33	0.9166	0.0066	0.7058
17	0.9137	-0.0085	0.697				

Table 2. Active Power Loss of 33-Bus RDS for base configuration

Configuration	Active Power Loss (kW)
Base case	202.7



Tie switches: 12 – 11; 29 – 28; 33 – 32; 9 – 15; 7 – 8

Figure 3. Block diagram of 33 Bus RDS with Network Reconfiguration

Table 3. Load Flow results for 33-Bus RDS of Figure 3

Bus No.	Voltage Magnitude (p.u)	Phase Angle (p.u)	VSI (p.u)	Bus No.	Voltage Magnitude (p.u)	Phase Angle (p.u)	VSI (p.u)
1	1.00000	0.00000	1.00000	18	0.94032	-0.01984	0.78181
2	0.99707	0.00025	0.98833	19	0.99507	-0.00039	0.78064
3	0.98698	0.00171	0.94874	20	0.97818	-0.00533	0.95186
4	0.98519	0.00167	0.94204	21	0.97353	-0.00741	0.86065
5	0.98370	0.00159	0.93638	22	0.96846	-0.01002	0.85671
6	0.98055	0.00058	0.92442	23	0.97962	0.00227	0.86123
7	0.97992	- 0.00010	0.92206	24	0.96489	0.00251	0.90907
8	0.96661	-0.01000	0.91463	25	0.95359	0.00360	0.85469
9	0.96518	-0.01033	0.81211	26	0.980270	0.00055	0.82450
10	0.96423	-0.01051	-0.01051	27	0.98001	0.00052	0.92234
11	0.96416	-0.01049	0.84623	28	0.97949	0.00030	0.92145
12	0.95723	-0.01393	0.82415	29	0.94857	0.00415	0.91854
13	0.95041	-0.01550	0.81582	30	0.94537	0.00586	0.78594
14	0.94781	-0.01694	0.80699	31	0.94196	0.00459	0.79391
15	0.94606	-0.01761	0.80107	32	0.94129	0.00428	0.78412
16	0.94429	-0.01801	0.79510	33	0.93999	-0.01991	0.78481
17	0.94135	-0.01964	0.78523				

Table 4. Active Power loss 33-Bus RDS with NR

Configuration	Active Power Loss(kW)
Base case	202.7
With NR	143.15

From Table 4, it can be observed that the active power loss is reduced from 202.7kW to 143.15kW with NR.

Table 5. Active Power loss 33-Bus RDS with NR and Capacitor

Configuration	Active Power Loss (kW)
Base case with Capacitors	162.18
NR with Capacitors	134.09

From Table 5, it can be observed that the active power loss is reduced from 202.76kW to 162.18kW with capacitors and without NR and 134.09kW with capacitors and with NR.

Table 6. Active Power Loss of 33-Bus RDS with NR and DG

Configuration	Active Power Loss (kW)
Base case with DG	122.79
NR with DG	94.11

From Table 6, it can be observed that the active power loss is reduced from 202.7kW to 122.79kW with DG and without NR and 94.11kW with DG and with NR.

Table 7. Active Power Loss of 33-Bus RDS with NR, Capacitors and DG

Configuration	Active Power Loss (kW)
Base Case	202.7
NR	143.15
Base Case with Capacitors	162.18
NR with Capacitors	134.09
Base case with DG	122.79
NR with DG	94.11
NR with Capacitors and DG	85.66

From Table 7, it can be observed that the active power loss is reduced from 202.7kW to 85.66kW with NR, Capacitors and DG.

CONCLUSION

A reconfiguration scheme for reduction of active power loss of radial distribution system has been developed. This methodology based on a simple VSI has been found to reduce the system power loss without any additional equipment cost. The effectiveness of the proposed methodology is applied to IEEE 33-bus radial distribution system. A combined methodology for placement and sizing of capacitor banks and DG in the distribution system, in order to reduce the active power loss is presented. Optimum position for the installation of capacitor banks and DG without and with NR are obtained.

References

[1] D. Ravi Kumar and V. Sankar, "Loss reduction and reliability optimization in electrical distribution system using network reconfiguration", The Journal of CPRI, Vol. 11, No.2, pp.259-268, June 2015.

[2] R. Srinivasa Rao, K. Ravindra, K. Satish and S. V. L. Narasimham, "Power Loss Minimization in Distribution System Using Network Reconfiguration in the presence of Distributed Generation" IEEE Transactions on Power Systems, Vol. 28, Issue 1, pp. 317-325, February 2013.

[3] Ng HN, Salama MMA, Chikhani AY, "Classification of Capacitor allocation techniques", IEEE Transactions on Power Delivery, Vol.15, Issue 1, pp.387-392, Jan. 2000.

[4] Prashanta Sarkar, Soumesh Chatterjee, Saheli Ray, "Optimal Placement of Capacitor for Voltage Support and Minimizing Overall Cost in Radial Distribution System", International Journal of Computer Applications, Vol.65, No.2, pp. 1-5, March 2013.

[5] S.Chandrashekhar Reddy, P.V.N.Prasad, A.Jaya Laxmi, "Placement of Distributed Generator, Capacitor and DG and Capacitor in Distribution System for Loss reduction and Reliability Improvement", Journal of Electrical Engineering, Vol. 13(4), pp. 329-337, January 2013.