

## Electrical Power Distribution Simulator

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### Abstract

The objective of design, construction and operation of distribution system is to achieve quality of supply and economy and the engineer has been encountering many difficulties of manual calculations through the sheer volume of operations required, complex networks and dynamic phenomena. To overcome the difficulty, various tools have been developed like reduced scale models, analogue models and simulation models. A graphical user interface or simulation tool for a Distribution Substation has been developed. The aspects of minimization of losses and voltage profile improvement of the radial distribution system are kept in view while designing the tool along with reconfiguration of distribution network and optimal capacitor placements. The Tellegen theorem algorithm approach and Adjoint Network methods are used to obtain the load flow solution for the radial distribution with only main feeder and laterals also. This tool gives the pictorial representation of the bus arrangement and their corresponding voltages of the Distribution Substation feeder and the power losses.

### Introduction

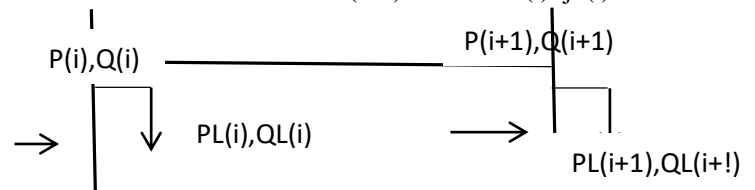
The Engineer in the Distribution Substation requires the first hand information of the Substation for further analysis such as planning for the expansion of the system, designing the protection equipment for the system and load forecasting. The information he requires includes the Substation feeder information like the rating of the Transformer, the feeder buses arrangement, their line impedances, load data at the buses, Voltages at the buses and power losses of the system. Many researchers obtained different algorithms to obtain the voltages and power losses with the given data. An attempt is made to obtain the solution with the already executed algorithms. The representation of the input data of the system along with the respective solutions with graphical representation of buses of the feeder is executed in this paper. The bus number along with their voltages give a quick overall picture of the substation. Load flow solution [6-7] is required first before solving any other problem in Radial distribution network. [1-2] give the load flow solution of the distribution network with main feeder and laterals dealt in this paper. Reconfiguration of

the network [3] and [8] gives a better solution for the network compared with the existing network. Adjoint Network [9] of a network is applied in this

paper to obtain load flow solution for load changes. Optimal placement of capacitor is another issue of the distribution networks [4,10], which is dealt in this paper using Adjoint Network and Particle Swarm Optimization methods.

### Electrical Power Distribution Simulator

A radial distribution network is considered as the test system. The  $i$ th and  $(i+1)$ th nodes are represented in the diagram. The currents injected at the nodes are  $P(i), Q(i)$  and  $P(i+1), Q(i+1)$ . The loads at these nodes are given by  $PL(i), QL(i)$  and  $PL(i+1), QL(i+1)$ . The impedance of the  $i$ th branch connected between  $i$ th and  $(i+1)$ th node is  $r(i)+jx(i)$ .



**Fig 1. Equivalent network of the  $i$ th branch**

The Electric Distribution Simulator is developed using Matlab. The GUI tool is a graphical user interface tool which enables us to design according to our requirements. The Callbacks are called during the execution period. These callbacks include the code required for simulation. Five different considerations of the distribution system are taken into consideration. They are as follows

- i. Load flow solution of Radial Distribution Network using Tellegen theorem
- ii. Load flow solution of Radial Distribution Network with laterals using Tellegen theorem
- iii. Reconfiguration of Radial Distribution Network
- iv. Load flow solution of Radial Distribution Network with load changes using Tellegen theorem and Adjoint Network method
- v. Optimal Capacitor Placement of Radial Distribution Network using Adjoint Network and Particle Swarm Optimization

Fig 2, represents the Simulator window with the above said tasks



Fig 2. A GUI window of Electric Power Distribution Simulator

**A. Load flow solution of radial distribution network using tellegen theorem**

System data is read i.e, the Substation Voltage, number of buses, line and load data. The data is entered in the text boxes and tables available in the window. The algorithm [1] used for radial distribution network with main feeder using Tellegen theorem is executed. A flat voltage profile is assumed during the beginning at all the nodes. All the loads and line losses are lumped at the station bus or node1. Knowing the voltage at the ith node, the (i+1)th node voltage is obtained by

$$V(i+1) = \frac{V(i) \times V(i) - \sqrt{(P(i)^2 + Q(i)^2)(r(i)^2 + x(i)^2)}}{V(i)} \quad (1)$$

The algorithm is executed until the lumped power and losses calculated by using obtained voltage values converge.

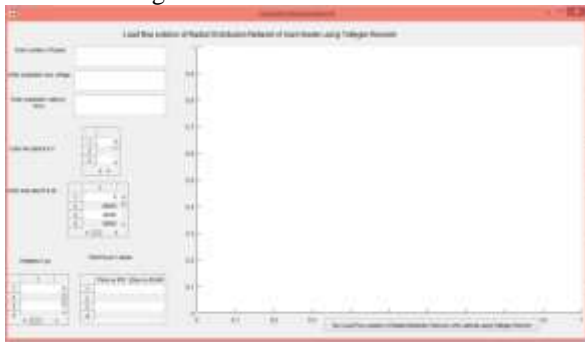


Fig 3. GUI window for load flow solution of radial distribution network

**B. Load Flow Solution Of Radial Distribution Network With Laterals Using Tellegen Theorem**

The algorithm used in main feeder is also used here, but it is done in two stages[2]. Firstly all the loads at laterals are lumped together and the algorithm is executed. Now the source node of the lateral is taken as the source and again the algorithm is executed. Here an additional data is required. The data is source node, start node and end node. Source node indicates at which node

the lateral is connected. Start node indicates the first node of lateral after the source node. End node indicates the last node of the lateral. The number of rows of this data depends on the number of laterals.

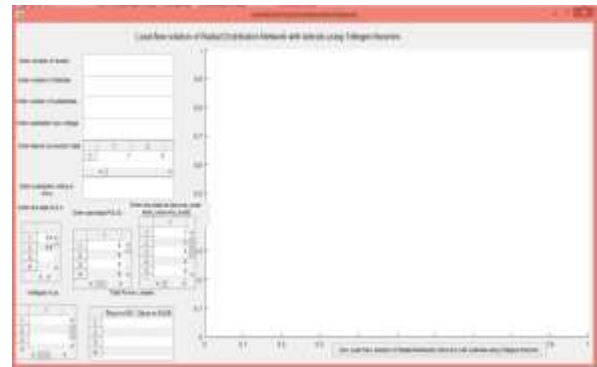


Fig 4. GUI window for load flow solution of radial distribution network with laterals

**B. Reconfiguration Of Radial Distribution Network**

In order to minimize the losses in Radial Distribution Network, the system is reconfigured [3] by closing a tie switch and opening a sectionalizing switch. In doing so, the configuration which gives the minimum losses is chosen. It requires the basic data in addition with the loop data, i.e, which buses form the loop when each tie switch is closed. The ampacity data of each line should also be taken into consideration during the execution. Tie and sectionalizing switches starting and ending node data is also required. The algorithm stated in [3] is used for solving this problem.

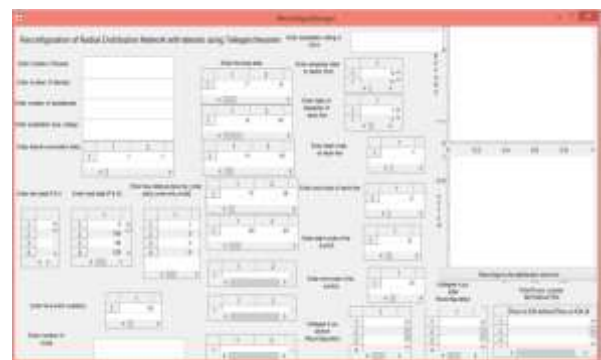


Fig 5. GUI window for Reconfiguration of radial distribution network

**D. Load Flow Solution Of Radial Distribution Network With Load Changes Using Tellegen Theorem And Adjoint Network Method**

In order to obtain the voltage profile and power losses whenever the load changes, the algorithm has to be executed for every change in load. Adjoint Network method[11] requires the load flow solution of actual network and adjoint network, from which load changes at a particular node can be calculated.

Adjoint network has the same elements and topology as the actual network. Voltage sources are replaced by short circuits. The node where the voltage change has to be observed is injected by a current source of one ampere in the adjoint network. The network is then simulated. The voltage values obtained from the actual and the adjoint network are calculated and utilized in calculation of voltage change at the observed by using the equation

$$\Delta V_p = \sum_{k \neq p} (V_k \{ (\frac{\partial I_k}{\partial P_k}) \Delta P_k + (\frac{\partial I_k}{\partial Q_k}) \Delta Q_k \}) \quad (2)$$

Where  $p$  is the observed node and  $k$  represents the non observed nodes,  $I_k$  represents the current in the  $k$ th node,  $\Delta P_k$  and  $\Delta Q_k$  represent the load changes. '~' represents the quantities related to Adjoint Network.



Fig 6. GUI window for Load flow solution of Radial

Distribution Network with load changes using Tellegen theorem and Adjoint Network method

**E. Optimal Capacitor Placement Of Radial Distribution Network Using Adjoint Network And Particle Swarm Optimization**



Fig 7. GUI window for Optimal Capacitor Placement of Radial Distribution Network using Adjoint Network and Particle Swarm Optimization

Power Loss Index and Voltage Sensitivity Index Power Loss Index gives the loss index of power losses when reactive power is injected at that particular bus.  $\frac{\partial P_L}{\partial Q}$  is obtained by injecting the reactive power  $Q$  at each bus and Power losses  $P_L$  are calculated. Instead of running the load flow

algorithm every time a capacitor is placed, Adjoint network of the actual network is obtained. From the actual and the adjoint network, Voltage sensitivity indices  $\frac{\partial V}{\partial Q}$  are obtained. This reduces the time of computation.

With the obtained voltage sensitivities, power losses and hence power loss index is obtained. After obtaining the indices, they are normalized. Buses with higher values of Voltage sensitivity index gives more stable solution of the network. That is as the reactive power is injected at the bus, if voltage at that bus increases then the system is more stable. Buses with higher values of Power loss index will indicate that losses can be reduced maximum at these locations. Buses with higher values of Voltage Sensitivity and Power Loss Index are selected. Particle Swarm Optimization technique is used in order to obtain the size of capacitor at the selected locations.

**Results and Discussion**

A 11KV Radial distribution system with feeder is simulated

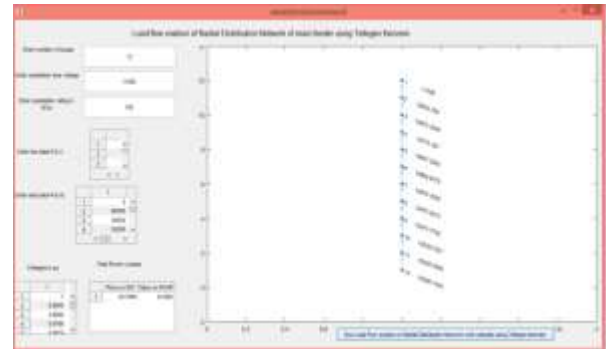
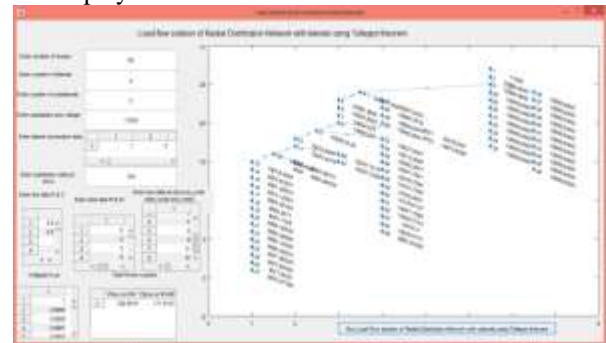
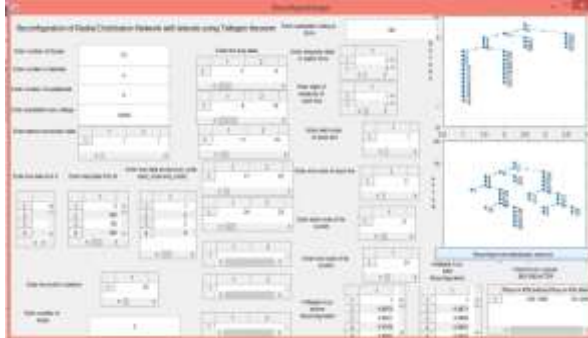


Fig 8. Output of 12 bus radial distribution network The above figure shows the input data and output data in one single window. A 11 KV Distribution substation with 12 bus feeder is simulated. After entering the data at a click of the push button, the outputs and plot are displayed. The interconnections of the buses with their bus numbers and their respective voltages are shown in the plot screen. Power losses obtained are 20.77 KW and 8.04 KVAR and are displayed in the table. Voltages in pu are displayed in the table.



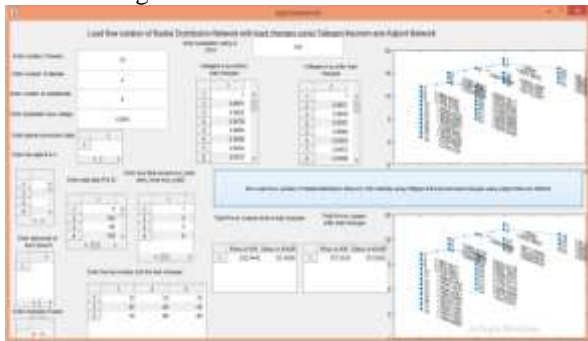
**Fig 9. Output of 69 bus radial distribution network with laterals**

A 11KV Distribution substation supplying a feeder with laterals is simulated here. 69 buses with 8 laterals is simulated here. Along with the line and load data, the node at which lateral is connected is entered as 1 otherwise 0(lateral connection data). Total real power losses are 392.8KW and reactive power losses are 171.1KVAR. Voltages and power losses are displayed in the table. The main feeder and the lateral connections along with the bus numbers and voltages are displayed in the plot.



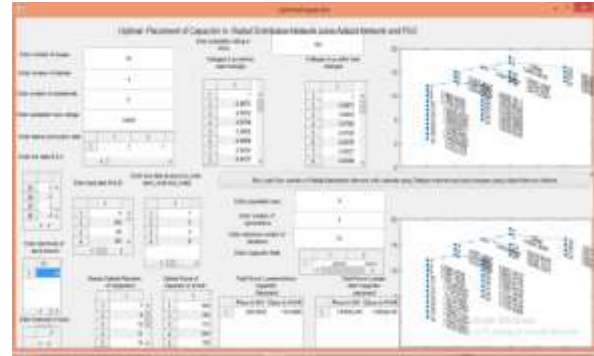
**Fig 10. Output of 33 bus Radial Distribution Network**

A 33 bus 11KV Distribution substation is used in this problem for reconfiguration. Tie switch data, sectionalizing switch data, loop data are entered in the tables. The interconnection of buses before and after reconfiguration are displayed in separate plots. Voltages in pu and power losses before and after the reconfiguration are displayed in tables. Power losses after reconfiguration are 181 KW.



**Fig 11. GUI window for Output of load flow solution of 33 bus radial distribution network with load changes**

Load changes at 12, 25 and 30 nodes are made and load flow solution of the distribution network is obtained by Adjoint Network Method. The losses before and after load changes are tabulated. Changes in Voltages of a 12.6KV, 33 bus system after load changes can be viewed in the plots. Power losses with the specified load changes are 187.25KW



**Fig 12. GUI window for Optimal placement of capacitors in Radial Distribution Network**

Optimal locations of capacitors are obtained using the Adjoint network method and size is obtained using Particle Swarm Optimization technique. A 12.6KV, 33 bus system is simulated. First plot gives voltages of before placement of capacitor and second plot gives voltages after capacitor placement. Population size is taken as 6, Number of generations as 5 and maximum number of iterations are taken as 10. Capacitor limits also have to be entered. Optimal locations of capacitors and their sizes are obtained and displayed in tables. Power losses before and after optimal capacitor placement are also displayed. After Capacitors placement the power losses have reduced to 165KW.

### Conclusions

An Electric Power Distribution simulator has been developed which solves the Radial Distribution Network considerations. At a glance the Distribution Engineer can view both the data and the pictorial view of the substation with their node numbers and their corresponding voltages, which is the exclusive feature of this simulator. With the given data, the simulator develops the picture of the substation connection diagram. The interconnection of the nodes is clearly viewable in these windows. It looks into the important considerations like reconfiguration, load flow when load changes and optimal capacitor placement.

### References

1. G.Pranava, GurramRavindranth and K.Ramesh Reddy, "Tellegen Theorem based Load Flow Solution of Radial Distribution Network" First International Conference on Recent Innovations in engineering and Technology(ICRIEAT 2016), pp. 919-922, 2016.
2. G.Pranava, GurramRavindranth and K.Ramesh Reddy, "Tellegen theorem based Load Flow Solution of Radial Distribution Network with Laterals" *International Conference on Power and Advanced Control Engineering (ICPACE)*, pp.99-103, 2015.

3. G.Pranava, GurramRavindranth and K.Ramesh Reddy, " Reconfiguration of Radial Distribution Network using Tellegen Theorem" *International Journal of Research and Scientific Innovation (IJRSI), Volume 3, Issue 8, pp. 2016145-149, August 2016.*
4. Manish Gupta and Balwinder Singh Surjan, "Optimal placement of Capacitorsfor loss minimization in 33 bus radial distribution system using Genetic Algorithm in MATLAB environment" *International Journal of Advanced Research in Computer Engineering and Technology, Vol 1, Issue 8, October 2012, pp 122-127.*
5. D.Das, "Reconfiguration of Radial Distribution Networks", *Indian Institute Of Technology, Kharagpur 721302, December 27-29, 2002*
6. K.Prakash and M.Sydulu, "Topological and primitive Impedance based Load flow method for radial and weakly meshed Distribution systems" *Iranian Journal of electrical and Computer engineering, Vol 10, No 1, Winter-Spring 2011*
7. D.Das,H.S. Nagi, D.P.Kothari, "Novel method for solving radial distribution networks" *IEE Proc.-Gener.Transm.Distrib.,Vol.141,No.4, July 1994, pp291-298.*
8. MesusE.Baran, Felix F.Wu, "Network Reconfiguration in Distribution Systems for Loss reduction and load balancing", *IEEE transactions on Power Delivery, Vol.4, No.2, April 1989,pp 1401-1407.*
9. Stephen W.Director and Ronald A.Rohrer, "The Generalized Adjoint Network and Network Sensitivities", *IEEE Transactions on Circuit Theory, vol CT-16, No.3, August1969, pp318-323*
10. Anwar S. Siddiqui, "Determination Of Size And Location Of Capacitors For Placement On A Radial Distribution System Using Fuzzy Technique", *International Journal on Power System Optimization and Control, 3 (1) January-June 2011, pp. 1-8; ISSN: 0975-3982.*
11. RavindranathGurram, B.Subramanyam, "Sensitivity analysis of radial distribution network-adjoint network method" *Electrical Power and Energy Systems, 1999, pp 323-326*