Implementation of Network Reconfiguration Technique for Loss Minimization on a Standard 16 Bus Distribution System

Shivakumar L. N., Kiran Kumar G. R., Marulasiddappa H. B.

Abstract—Due to deregulation and restructuring it is expected that a large number of distributed generators will be connected to the distribution network. This will result in power distribution systems having locally looped networks and bi-directional power flows affecting existing operational schemes. The distribution system reconfiguration is one of the important control schemes which can be affected by the presence of distributed generators.

This paper presents a simple approach for distribution reconfiguration with distributed generators. The distributed generators are considered as constant power sinks and the loss minimization algorithm has usual constraints along with line capacity constraint which limits the reverse power flow of distributed generators. Standard switching indices are used for network reconfiguration and the algorithm is tested on a on a standard 16 bus system.

Index Terms— Distributed generation (DG), Network reconfiguration, Loss reduction

I. INTRODUCTION

The power system for many years was vertically and centrally operated. The electric power is transmitted and distributed to consumers over long distance transmission and distribution lines. With the impending deregulated environment faced by the electric utility industry and recent advances in technology, several distributed generation (DG) options are fast becoming economically visible. Some of the reasons for the sudden upsurge in the implementation of DG technologies are listed below [1].

- Deregulation of the electric utility industry.
- Public opposition to building new transmission lines on environmental grounds.
- Public awareness of the environmental impacts of electric power generation.
- Increase in public desire to promote "green" technologies.
- Awareness of the potential of DG to enhance the security of electric supply by creating mini and micro grids.

When regulations on power supply are relaxed and a number of DGs are introduced into the power system, unexpected problems may occur in power system operation and planning. DGs will increase the complexity of controlling, protecting and maintaining the distribution systems [2].

There are several operational schemes in power distribution systems and one of these is network reconfiguration.

Manuscript received January 15, 2014.

Mr.Shivakumar LN, Electrical and Electronics Engineering Department, VTU/ PESITM, Shimoga, India.

Mr.Kiran Kumar GR., Electrical and Electronics Engineering Department, VTU/ PESITM, Shimoga, India.

Mr.Marulasiddappa HB, Electrical and Electronics Engineering Department, VTU/ PESITM, Shimoga, India.

Feeder reconfiguration for loss reduction is a very important function of automated distribution system to reduce distribution feeder losses and improve system security. There are a number of closed and normally opened switches in a distribution system, and the number of possible switching operations is tremendous. Thus feeder reconfiguration becomes complex decision making and time consuming process for system operators. Network reconfigurations basically modify the network structure of distribution feeders by changing the open/close status of sectionalizing (normally closed) and tie (normally open) switches. To implement this process efficiently many algorithms have been developed [3-5]. With DGs, network reconfiguration becomes more complex since distribution network changes from single source to multiple sources.

II. PROBLEM FORMULATION

The reconfiguration is a complicated combinatorial and constrained optimization problem owing to the enormous number of candidates switching combinations in distribution systems. The problem of network reconfiguration is formulated as below.

From [3], the power loss in the series circuit element i j between the buses i and j is given by

$$P_{loss(i,j)} = R_{i,j}(|V_j - V_i| \, |Y_{ij}|)^2 \qquad (1)$$

Where

R_{ij}: branch resistance between bus i and bus j

V_i (V_j) :bus i (j) voltage

Y_{ij}: branch admittance between bus i and bus j

In general, network reconfiguration for loss minimization could be formulated as

$$\text{Min} \sum P_{loss(i,j)} = \sum R_{i,j}(|V_j - V_i| \, |Y_{ij}|)^2 \qquad (2)$$

Satisfying the following constraints

- Radial network constraint: Distribution network should be composed of radial structure considering operational point of view.
- Isolation constraint: All nodes are energized.
- Voltage constraint: Voltage magnitude at each node must lie within the permissible limits.
- Current constraint: Current magnitude of each branch must lie within the permissible limits.
- In loss reduction with DG the reverse power of DG cannot exceed the corresponding line capacity limits.

III. SOLUTION METHODOLOGY

In network reconfiguration problems with DG, knowing the installation node and capacity of DG, reconfiguration could be solved by existing loss

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

reduction techniques. DGs are represented as constant power sinks and therefore they can be represented as negative load [5]. Taking this aspect into consideration the most appropriate switching combinations are determined using the switching indices developed from previous work [3]. The switching indices are obtained in the following manner.

All the tie switches are closed in the network to form as many loops as the number of tie switches. In the meshed network each loop has a best opening point for minimum loss. By opening that switch radial topology in that loop is regained. The procedure is repeated for all other loops.

The switching indices are obtained for all the branches in the looped state.

Switching Index= (Voltage index) * (Ohmic index) (3)

The voltage index

$$\mu_V(n) = exp^{-\frac{\omega(\Delta V n)^2}{(\Delta V_{av}^2)}} \quad (4)$$

$\Delta V n$: the voltage drop between two terminals of Branch N

ΔV_{av}^2 : the mean square voltage drop of all branches for a chosen loop

ω : weighing factor

The ohmic index

$$\mu_Z(n) = exp^{-\omega(\frac{R|Y|^2}{R_{av} Y_{av}^2})} \quad (5)$$

R_{av} : the average branch resistance for a chosen loop

Y_{av} : the average branch admittance for a chosen loop

ω : weighing factor

The weighing factor ω is such that the weightage to open a branch progressively decreases as we move away from the tie branch in either direction of the loop starting from the tie branch.

The switching indices are arranged in the descending order and those branches having largest index values are the candidate branches for reconfiguration. However, since the problem of reconfiguration is a complicated combinatorial and constrained optimization problem the best solution may not be obtained from opening the braches with largest index values. The best option could be further down in the order of switching indices and therefore it can be found by determining the losses for a selected number of options in the descending order of switching indices. The combination which gives the minimum loss is the best option.

Based on the above solution methodology a solution algorithm is presented and the flow chart is as shown in fig 1.

1. Read the network data, switch data, DG data and nodes of DG injection
2. At the nodes of DG injection, modify the load data with DGs as power sinks i.e., negative load.
3. Close all the switches to form meshed network and run AC load flow.
4. From the load flow data, compute the switching indices for all the branches of each loop, arrange them in the descending order.
5. Consider the loop near the source loop and open the branch with highest switching index and run the AC load flow.
6. Check for constraint violation.
7. If any constraint is violated, ignore that branch for opening and go to step 5.
8. Repeat steps 5,6,7 for a selected number of switching indices in the descending order and choose the switch with minimum power loss.
9. Retain the radial topology of the loop and repeat steps 5,6,7 and 8 for all the loops in the network.
10. Obtain the final reconfiguration report.

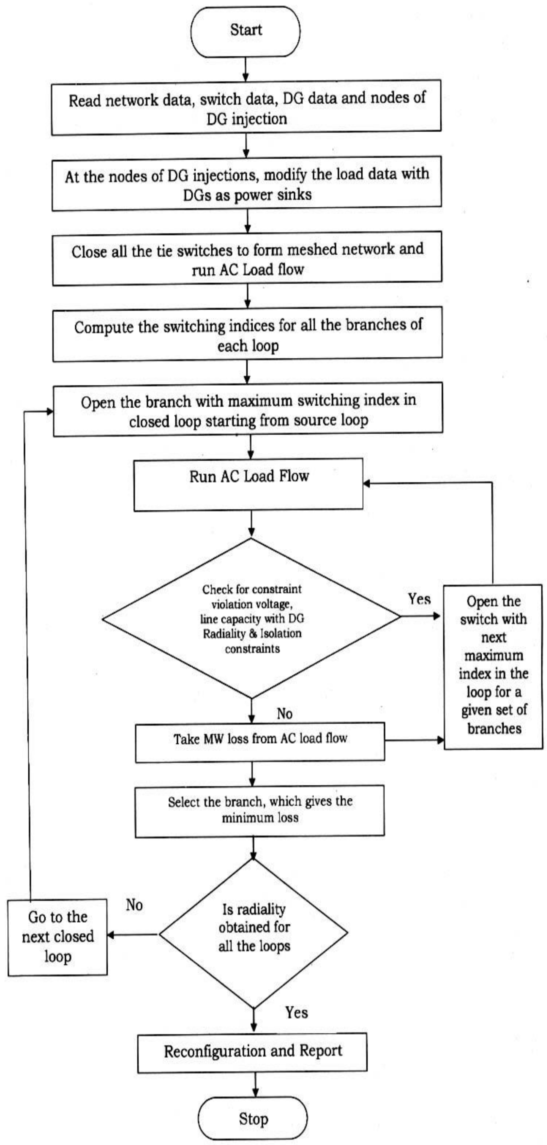

Fig. 1. Flow chart for reconfiguration with DG

IV. CASE STUDY AND NUMERICAL RESULTS

Typical 16 bus system:

The developed algorithm has been applied to a standard 16 bus radial distribution system with DG injection. The Initial network without DG units is shown in figure 2 where the tie branches are S15, S21 and S26.

The DG injection nodes and capacity are given in table I.

TABLE I
INSTALLATION NODE AND CAPACITY OF DG

Node	CAPACITY (MW/PF)
9	7/0.8

The Optimum network without DG units, Initial network with DG units and Optimum network with DG units are shown in figures 3, 4 and 5 respectively.

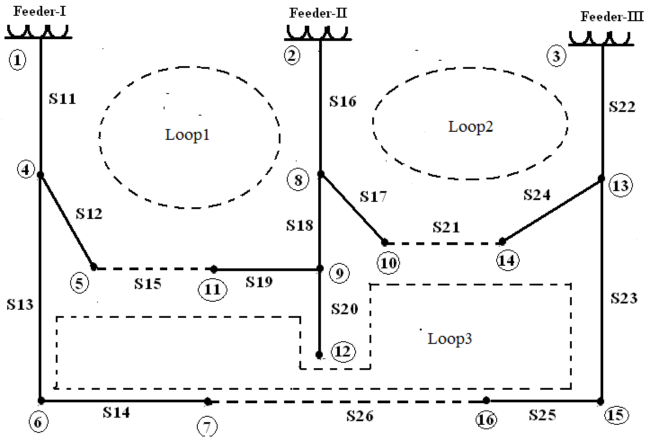

Fig. 2. Initial network without DG units

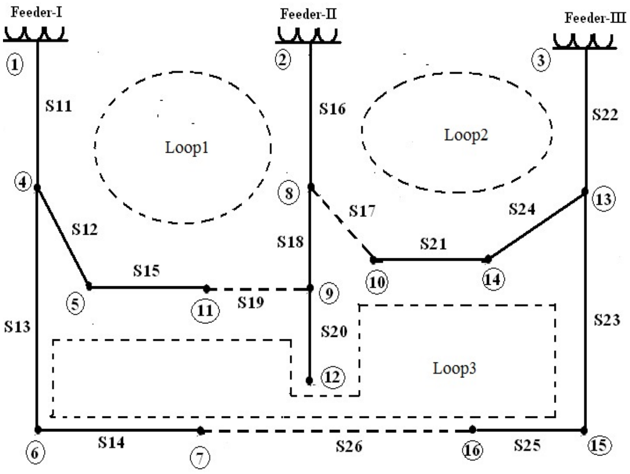

Fig. 3. Optimum network without DG units

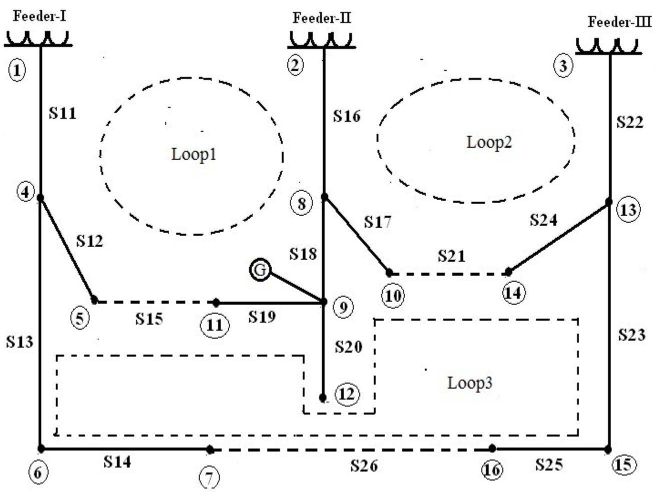

Fig. 4. Initial network with DG units

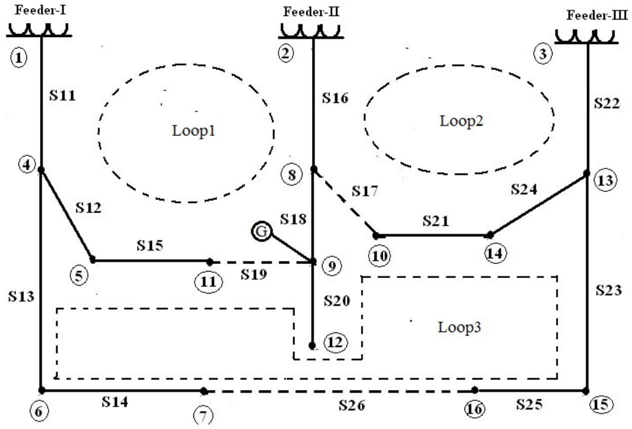

Fig. 5. Optimum network with DG units

From simulation results the open switches, losses and percentage loss reduction in each case are tabulated in the table II.

TABLE II TEST RESULTS

CASE	OPEN SWITCH	LOSS (MW)	LOSS REDUCTION (%)
Initial network without DG	S15, S21, S26	0.5114	-
Optimum network without DG	S17, S19, S26	0.4661	8.86
Initial network with DG	S15, S21, S26	0.2387	53.32
Optimum network with DG	S17, S19, S26	0.2289	55.24

From the results of the case study on IEEE 16 bus system, the loss reduction effects of DG units can be summarized as follows:

1. There is about 55% loss reduction in the optimized network with DG units as compared with the initial network without DG. A substantial improvement in feeder voltage levels can also be observed from the load flow studies. These prove the loss reduction support of DG units in distribution networks.
2. In order to maximize the loss reduction effects, the DG units should be integrated into the distribution automation center and they should be located at the most optimal locations.

V. CONCLUSION

This paper presents a simple approach for distribution reconfiguration with distributed generators. The distributed generators are considered as constant power sinks and therefore they are represented as negative loads. Switching indices are used for network reconfiguration. The switching indices are arranged in the descending order and those branches having largest index values are the candidate branches for reconfiguration.

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

However, since the problem of reconfiguration is a complicated combinatorial and constrained optimization problem the best solution may not be obtained from opening the braches with largest index values. The best option could be further down in the order of switching indices and therefore it can be found by determining the losses for a selected number of options in the descending order of switching indices. The combination which gives the minimum loss is the best option.
The developed algorithm is applied to a standard 16 bus system. It is interesting to note that there is about 55% loss reduction in the optimized network with DG units as compared with the initial network without DG.

APPENDIX

TABLE III
LOAD DATA FOR 16 BUS SYSTEM

Line	R (pu)	X (pu)
1-4	0.075	0.10
4-5	0.080	0.11
4-6	0.090	0.18
6-7	0.040	0.04
2-8	0.110	0.11
8-9	0.080	0.11
8-10	0.110	0.11
9-11	0.110	0.11
9-12	0.080	0.11
3-13	0.110	0.11
13-14	0.090	0.12
13-15	0.080	0.11
15-16	0.040	0.04
5-11	0.040	0.04
10-14	0.040	0.04
7-16	0.090	0.12

TABLE IV
LINE DATA FOR 16 BUS SYSTEM BASE VALUES=23KV,100 MVA

Load	P (MW)	Q (MVar)
L4	2.0	1.6
L5	3.0	1.5
L6	2.0	0.8
L7	1.5	1.2
L8	4.0	2.7
L9	5.0	3.0
L10	1.0	0.9
L11	0.6	0.1
L12	4.5	2.0
L13	1.0	0.9
L14	1.0	0.7
L15	1.0	0.9
L16	2.1	1.0

REFERENCES

1. Pathomthat Chiradeja, R.Ramakumar, "An Approach to Quantify the Technical Benefits of Distributed Generation", IEEE Transactions on energy conversion, Vol.19,No.4, December 2004.
2. Joon-Ho Choi, Jae-Chul Kim "Network Reconfiguration at the power distribution system with dispersed generations for loss reduction", IEEE 2000, pp 2363-2367.
3. Whei-Min Lin, Hong-Chan Chin, " A new approach for distribution feeder reconfiguration for loss reduction and service restoration, IEEE transactions on power delivery, Vol. 13, No. 3, July 1998.
4. Hong-Chan Chin, Kun-Yuan Huang, " A simple distribution reconfiguration algorithm for loss minimization", IEEE 2000, pp607-611
5. Joon-Ho Choi, Jae-Chul Kim, Seung-II Moon, "Integrating strategy of dispersed generation to automation distribution centre for distribution network reconfiguration", international Conference on Electrical Engineering, 2002 .

AUTHORS PROFILE

Shivakumar LN received his B.E. degree (Electrical Engineering) in 2008 from VTU. M.Tech.(Power Systems) in 2010 from VTU. He joined the department of Electrical & Electronics Engineering PESITM, in 2010 and is currently Assistant Professor in PESITM, Shimoga, His research interests are in the area of power system, control systems. He has published several papers in national journals. He is a life time member of MISTE.

Kiran Kumar GR received his B.E. degree (Electrical Engineering) in 2009 from VTU. M.Tech.(Computer Application in Industrial Drives) in 2011 from VTU. He joined the department of Electrical & Electronics Engineering HMSIT, in 2011 and is currently Assistant Professor in PESITM, Shimoga, His research interests are in the area of high voltage, control systems. He has published several papers in national journals. He is a life time member of MISTE.

Marulasiddappa HB received his B.E. degree (Electrical Engineering) in 2005 from UBDT. He joined the department of Electrical & Electronics Engineering UBDT,Davangere in 2005, also recieved his M.Tech. degree (Power Electronics) in 2009 from UBDT. He joined the department of Electrical & Electronics Engineering PESITM, in 2010 and is currently Assistant Professor in PESITM, Shimoga, His research interests are in the area of Power Electronics, control systems. He has published several papers in national journals. He is a life time member of MISTE.