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Energy Loss Minimization by Optimal Siting and Sizing of DG with Network Reconfiguration in Distribution Networks

Rudresh.B.Magadum, D.B.Kulkarni

***Abstract*: The main aim of the distribution system is delivery the power to the consumers. Because of, aging of electrical infrastructure, old control mechanism, increased power demand causing exploitation of the present electrical networks leads to low voltage profile, more active and reactive power loss with various power quality related issues causing poor network operation. In this method maximization of voltage profile with energy loss minimization is carried using network reconfiguration along with optimal siting of the distributed generation (DG). The proposed methodology is carried out on five bus system. The obtained results are impressive interms of voltage stability and power loss reduction.**

Index Terms: Network reconfiguration; percentage power loss; Distributed generation; Voltage profile; Conventional method; voltage stability; reliable; distributed network and power saving.

I. INTRODUCTION

The distribution system is an interconnected network aims to supply the electrical power from source to various loads present in the network [1]. The characteristics of the distribution systems are non uniform loads, low voltage profiles, various ranges of X/R ratios. Most of the distribution networks are either meshed or radial in nature [2], [3].

Due to modernization and increase in population every year 5-10% of load is increasing and with existing electrical infrastructure, supplier is forced to compromise with quality of the power supply [4]. This will accelerates malfunctioning of relays with high power loss in the distribution network [5]. In order to address these issues upgradation of infrastructure is necessary, which should act very quickly and accurately in the system to restore the system services in short span of time [6]-[7].

In this work, network reconfiguration and DG placement are used to address the low voltage profile and high power loss [8]. The line reconfiguration is shifting of loads from one feeding point to another with switches depending on load. The main objectives of the line reconfiguration are.

- Reduce the interrupted power supply to the consumers.
- Minimize the power loss
- Improve the voltage profile
- Reduce the cost
- Minimize the switches

The distributed power generation is also called as on site power generation or dispersed power generation [9] [10]. The optimal sizing and siting of DG boosts the voltage profile with improvement in the power loss reduction [11]. The combination of line reconfiguration in presence of DG will strengthens the network with enhancement of voltage stability [12]. In this paper, five bus systems is taken as a test data. The system is tested with various scenarios like only reconfigurations, only DG and combinations of DG with reconfiguration [14]. In all the scenarios obtained results gives a potentiality to address low voltage profile with minimization of power loss [16].

II.METHODOLOGY

The main two objectives are taken in to account for line reconfiguration and DG placement are,

(i) Enhancement of voltage profile and
(ii) Reduction of total power loss in the electrical network

The total power loss can be computed with following equation [1]:

$$P_{Loss}= \sum_{i=1}^{n} G_i(V_j^{\,2} + V_k^2 - 2V_jV_k\cos(\delta_j - \delta_k)) \quad (1)$$

Where,

n=Total number of lines in the given network

V_j, V_k= Voltage magnitudes at bus j and k

G_i= The conductance of the i^{th} branch which connects between buses j and k.

δ_j, δ_k=j^{th} and k^{th} bus voltge angles

The magnitudes of the bus voltages and angles of the distribution network are to be constrained with range of minimum and maximum values, mandatorily maintained by the network operator. The boundaries of voltage and angles are given by,

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***Correspondence Author(s)**
Rudresh. B. Magadum, Research Scholar, Electrical and Electronics Engineering Department, KLS Gogte Institute of Technology, Belagavi-590008, Karnataka, India.
Dr. D.B.Kulkarni, Professor**,** Electrical and Electronics Engineering Department, KLS Gogte Institute of Technology, Belagavi-590008, Karnataka, India.

$$V_j^{Min} \leq V_j \leq V_j^{Max} \quad (2)$$
$$\delta_j^{min} \leq \delta_j \leq \delta_j^{max} \quad (3)$$

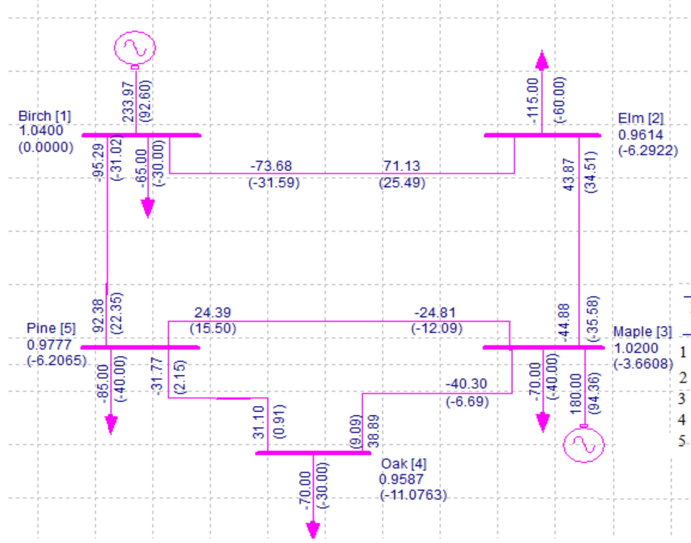
Where,

V_j^{Max}, V_j^{Min} = Max and Min range for bus voltages

δ_j^{max}, δ_j^{min} = Max and Min ranges of bus voltage angles.

The five bus [3] system is taken as test system for the analysis, is shown in Fig.1. The five bus system consists of two generators. In that, the generator connected to bus one act as slack bus with 1.04 p.u. of voltage magnitude and other generator is which is connected to bus three act as PV bus with specified voltage magnitude 1.02 p.u. with 180MW of power generation.

All five buses are connected with the total load of 405MW and six transmission lines are used to interconnect all the buses to supply the power to the loads. For the analysis all bus voltages are taken as 138kV and analysis is carried out using MiPower 9.0 and MATLAB-08.The flow chart of line reconfiguration and DG placement is as shown in Fig.2



Transmission Line Details

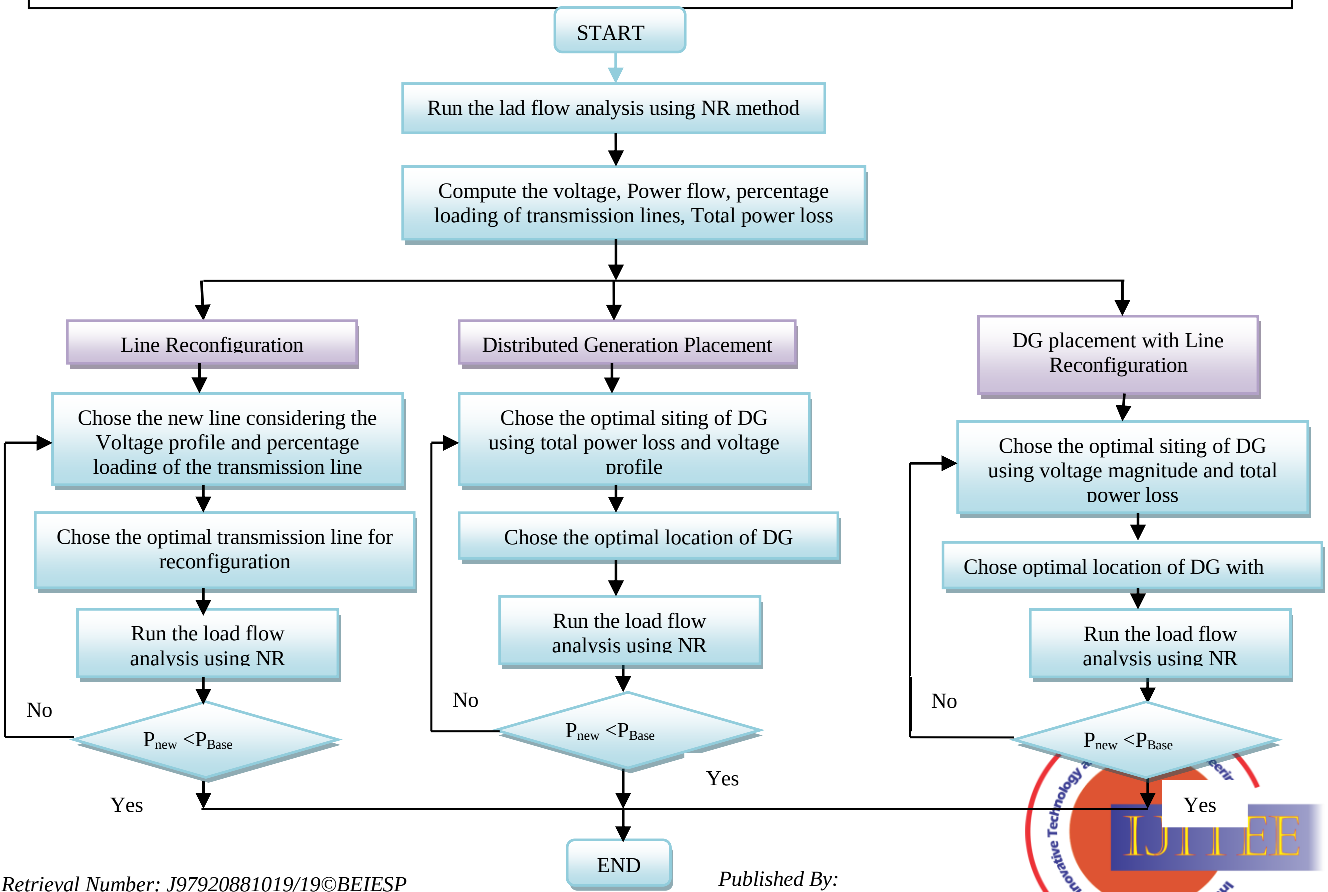
Line, bus to bus	Length km	Length mi	R pu	X pu	Charging Mvar*
1-2	64.4	40	0.042	0.168	4.1
1-5	48.3	30	0.031	0.126	3.1
2-3	48.3	30	0.031	0.126	3.1
3-4	128.7	80	0.084	0.336	8.2
3-5	80.5	50	0.053	0.210	5.1
4-5	96.5	60	0.063	0.252	6.1

*At 138 kv, 100 MVA base

Schedule Generation and Loads

Bus	Generation P, MW	Generation Q, MVAR	Load P, Mw	Load Q Mvar	V, pu	Remarks
1	-	-	65	30	1.04	Slack bus
2	0	0	115	60	1.00	Load bus
3	180	-	70	40	1.02	PV bus
4	0	0	70	30	1.00	Load bus
5	0	0	85	40	1.00	Load bus

Fig.1 Five bus system with line data



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Case-i. Network Reconfiguration

For the given five bus system the line reconfiguration is carried out considering the voltage magnitude and percentage loading of the transmission lines is as shown in Fig.3. The line between bus two and bus four giving enhanced voltage profile with 33.16% power loss reduction is as shown in Table. I.

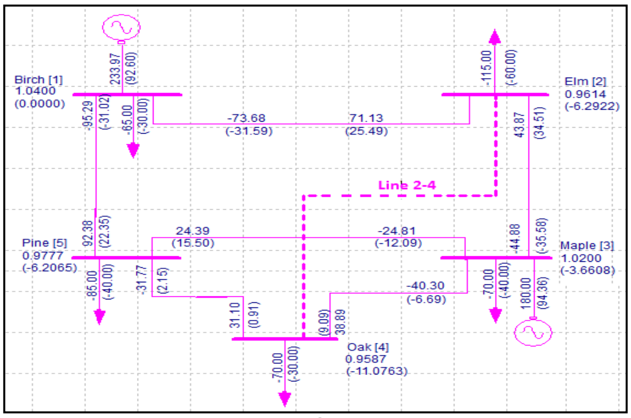

Fig.3 Line Reconfiguration (Line2-4)

TABLE.I
LINE RECONFIGURATION

Bus.No	Base case	Line Reconfiguration			
		Line 2-5	Line 2-4	Line 1-4	Line 1-3
1	1.04	1.04	**1.04**	1.04	1.04
2	0.961	0.962	**0.972**	0.955	0.965
3	1.02	1.02	**1.02**	1.02	1.02
4	0.92	0.92	**0.987**	0.942	0.92
5	0.968	0.969	**0.977**	0.975	0.968
Power Loss (MW)	9.674	9.323	**6.466**	9.023	9.569

Case-ii. Distributed Generation placement.

The generation of power upto 15-25% of total load near to the load centre plays vital role in cut down of active power loss. The given system tested with connecting 70MW at various nodes of the network considering the power loss and voltage profile is as shown Fig.4. The integration of DG at bus-4 gives 51.04% of total power loss reduction is shown in Table.II.

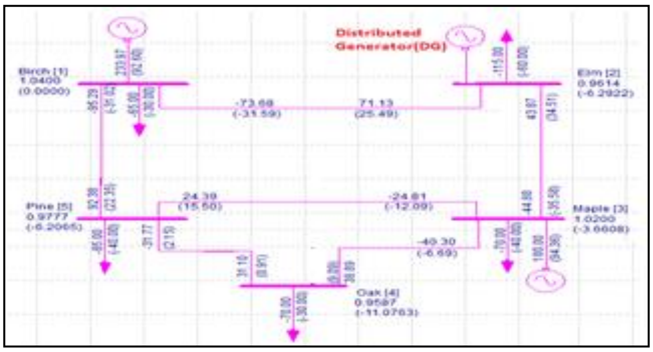

Fig.4 Distributed generation placement

TABLE.II
DISTRIBUTED GENERATIOR PLACEMENT

Bus No.	Base case	DG Placement		
		Bus-2	Bus-4	Bus-5
1	1.040	1.040	**1.040**	1.040
2	0.961	1.000	**0.981**	0.962
3	1.020	1.020	**1.020**	1.020
4	0.920	0.920	**1.000**	0.941
5	0.968	0.969	**0.980**	1.000
Power Loss (MW)	9.6741	6.2802	**4.736**	6.193

Case-iii. Line Reconfiguration with DG placement

The combination of line reconfiguration with DG placement is tested on given network considering the voltage magnitudes, percentage loading of transmission lines and total power loss. For DG placement and interconnection of new transmission lines each bus and new lines are considered as candidates and load flow is carried out with all the possible combination is shown in Fig.5. Table.3 shows the DG is fixed at bus-2 followed by reconfiguration. The combination of DG at bus-2 with new line between bus 1 and 4 boosts the voltage profile with 57.53% of power loss reduction. Table.4 represents the fixed DG at bus-4 with new line between bus 2 and 4 gives 56% cut down of power loss with better voltage profile. Fig.6 represents the comparison of voltage profile considering the line reconfiguration, DG placement and DG with line configuration. The combination of DG with line will boosts the voltage profile throughout the network, this will leads to suppression of power loss is shown in Fig.7.

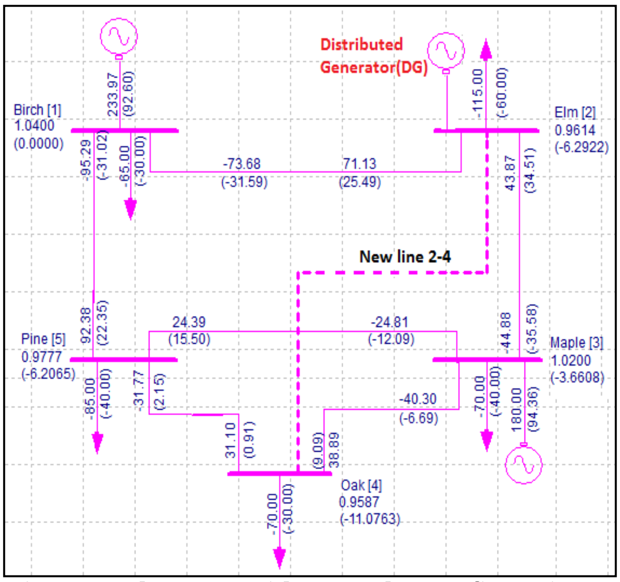

Fig.5. DG placement with network reconfiguration.

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TABLE.III
DG (BUS-2) WITH LINE CONFIGUARATION

Bus No.	DG placed at bus-2			
	Line 1-3	Line 1-4	Line 2-4	Line 2-5
1	1.040	1.040	1.040	1.040
2	1.000	1.000	1.000	1.000
3	1.020	1.020	1.020	1.020
4	0.920	0.987	0.966	0.927
5	0.969	0.997	0.982	0.980
Power Loss (MW)	6.337	**4.109**	4.642	5.736

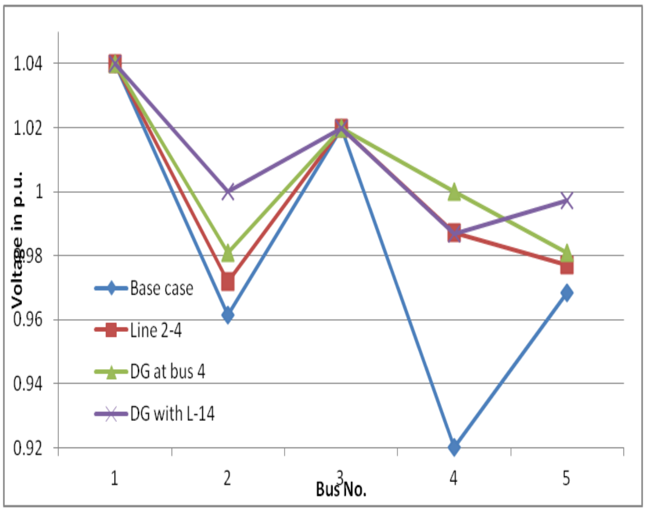

Fig.6 Voltage profile of five bus system

TABLE.III
DG (BUS-4) WITH LINE CONFIGUARATION

Bus No.	DG placed at bus-4			
	Line 1-3	Line 1-4	Line 2-4	Line 2-5
1	1.040	1.040	1.040	1.040
2	0.962	0.962	0.975	0.971
3	1.020	1.020	1.020	1.020
4	1.000	1.004	1.000	1.000
5	0.991	0.992	0.991	0.986
Power Loss (MW)	4.791	4.848	**4.264**	4.541

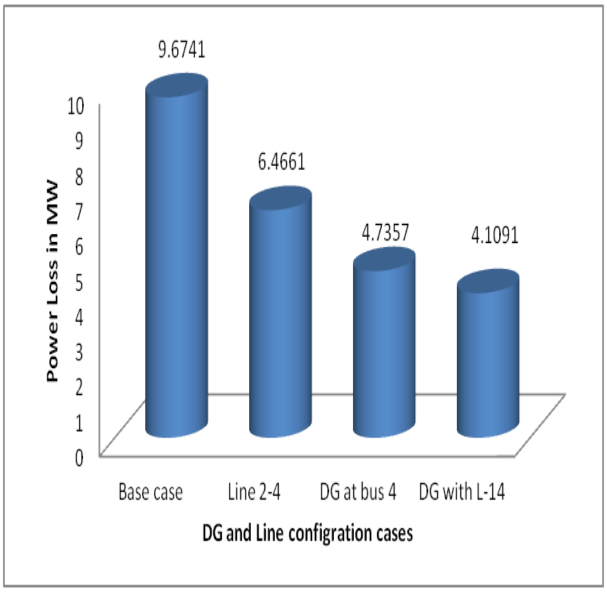

Fig.7 Power loss comparison

TABLE.IV
PERCENTAGE POWER LOSS REDUCTION AT VARIOUS TEST CASES

	Description	Bus/Line	Losses Before (MW)	Losses After (MW)	Power Saving (MW)	Percentage Loss Reduction
Case-i	**Line Reconfiguration**	Line2-4	9.674	6.466	3.208	33.16
Case-ii	**DG placement**	Bus-4	9.674	4.736	4.938	51.04
		Bus-5	9.674	6.193	3.481	35.98
Case-iii	**DG with Reconfiguration**	**DG at 2** **Line 1-4**	**9.674**	**4.109**	**5.565**	**57.53**
		DG at 4 Line 2-4	9.674	4.265	5.410	55.92
		DG at 5 Line 1-4	9.674	4.865	4.809	49.71

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Table.IV shows the comparison of power loss at various test cases. The line reconfiguration alone will make 33.16% of active power reduction. The line reconfiguration is very effective and immediate solution for improvement of power system operation with minimum investment. The placement of correct size of DG depending on given network specifications size of the DG will be decided. Which will plays main role in cut potential cut down of power loss with improvement of the voltage profile and also supports the increase in the power demand. The siting of single DG at bus 2 causes 51% power loss minimization. The multiple use of DG helps in further loss minimization in the network. The combination of DG with network reconfiguration leads to 57.5% power loss minimization. This will boosts the enhancement of voltage stability and makes the reliable, stable operation of the power systems.

III.CONCLUSION

The line reconfiguration and DG placement is chosen for improvement of voltage profile with cut down of active power loss and is tested on five bus system. Depending on the network line reconfiguration or DG placement or combination of DG with line reconfiguration can be used healthy operation. The obtained results are highly impressive and immediate solution for enhancement of voltage stability of the network. It can be used for any existing electrical infrastructure for reliable, efficient and stable operation of the power system.

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AUTHORS PROFILE

Mr.Rudresh.B.Magadum was born in Sankeshwar, Karnataka, India Jul 09, 1987. He obtained his B.E and M.Tech from VTU Belagavi in 2010 and 2012 respectively. Presently he is pursuing Ph.D at KLS Gogte institute of technology, Belagavi. His area of interests includes distributed generation, micro grid, smart grid, power quality and HVDC.

Dr. D.B. Kulkarni was born in Belagavi, Karnataka, India on Feb 10, 1966. He obtained his B.E and M.E degrees from Walchand college of Engineering, Sangli, Maharashtra, India in 1986 and 1993 respectively & Ph.D in the area of Power quality from VTU, Belagavi in 2012.Currently working as professor in Electrical and Electronics Engineering department, KLS Gogte Institute of Technology, Belagavi. His areas of interest include Power quality, FACTS, HVDC transmission and Power systems.

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