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Reconfiguration of Radial Distribution System for Loss reduction and Reliability enhancement with DG Placement

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Abstract

The objective of this paper is minimizing power losses and reliability enhancement of reconfigured Radial Distribution System(RDS) with placement of Distribution Generation. LSF method is adopted for the best combinations of switches as well as placement of DG for minimization of losses. Cutest approach is used for reliability enhancement. This method has been applied to a IEEE 33-bus radial distribution system and the obtained results are analyzed.

Keywords: Loss sensitivity Factor(LSF), Network Reconfiguration, Cutset approach Reliability Indices, Distribution Generation

I. INTRODUCTION

Electrical distribution systems are facing the problem of ever increasing load. In addition to supplying power to the increased load, there is a necessity of improving distribution system reliability, and overall efficiency. Reconfiguration is another method to reduce losses and improve the overall system reliability. Distributed generation are a promising solution for the improvement of efficiency and reliability of a distribution system. The impact of DG on power losses varies with network topology and location, as well as type of DG size [1]. Analytical expression was considered for DG placement in [2] for power loss reduction. PSO technique adopted for different types of DG placement in [3].Switches are closed /opened to establish optimal network using a heuristic algorithm in [4,5,6] Many techniques such as genetic algorithm (GA)[7], improved tabu search [8] and Harmony search algorithm(HSA) used in[9] for reduction of active power loss using Network Reconfiguration Reliability evaluation techniques for Distribution system planning studies and operation are presented in [10].

This paper presents a LSF based Network reconfiguration technique in the presence of distributed generation. Rest of the paper is organized as follows: Section II gives Problem illustration formulation, Section III an application of LSF for network reconfiguration problem and Placement of DG. Section IV describes result and analysis of 33-bus RDS and finally, the major contributions and conclusions are summarized in section V.

II. METHODOLOGY

A. Problem Formulation

The problem is so formulated to get the maximum P_{Loss} reduction in the distributed system which is considered to be sum of power loss reduction due to reconfiguration as well as installation of DG, which is subjected to power flow, voltage, current and reliability indices as shown below:

$$\text{Maximize } f = \max \Delta P_{Loss}$$

i) Node voltages: and current limits:

$$Vi,min \le Vi \le Vi,max$$

$$\text{and } I \le I_b$$

Here Vimin and Vimax are the permissible voltage limits at i^{th} node.

ii)Reliability indices and power losses

$$0 < P_L \le P_{Lb} \;;$$

$$0 < SAIFI < (SAIFI)_b;\; 0 < SAIDI < (SAIDI)_b;$$

$$0 < CAIDI < (CAIDI)_b;\; 0 < ASUI < (ASUI)_b;$$

Where $(SAIFI)_b$,$(SAIDI)_b$,$(CAIDI)_b$,$(ASUI)_b$ are base case indices and SAIFI, SAIDI, CAIDI, ASUI are indices are Network Reconfiguration after DG placement.

The power flow analysis is carried out by Forward and Backward Sweep Algorithm[3].The power flows and voltages constraints have to be satisfied while minimizing the power losses and maximizing the reliability.

B. Reliability evaluation

Reliability analysis also plays a key role in planning for up-gradation of the distribution network, thus meeting new and ever-increasing demands. To evaluate reliability of system, load point indices are used.

i) Average failure rate(λ_S)

$$\lambda_S = \sum_{i=1}^{N} \lambda_i \quad \text{f/yr} \tag{1}$$

ii) Average annual outage (U_s)

$$U_s = \sum_{i=1}^{N} \lambda_i r_i hrs/yr \tag{2}$$

iii)Average outage time (r_s)

$$r_s = \frac{U_s}{\lambda_s} hrs \tag{3}$$

Where(λ_i) is the component failure rate i, and (r_i)is component repair time i. To consider the significance of a system outage, customer orientated indices can be evaluated, they are given by

(i) System Average Interruption Frequency Index(SAIFI):

$$\text{SAIFI} = \frac{\text{total no. of customer interruptions}}{\text{total no. of customer served}}$$

$$\text{SAIFI} = \frac{\sum \lambda_i N_i}{\sum N_i} \text{ interruptions/customer} \tag{4}$$

Where$\lambda_i$is the failure rate and N_i is the no. of customers at load point i.

(ii) System Average Interruption Duration Index (SAIDI):

$$\text{SAIDI} = \frac{\text{sum of customer interruption duration}}{\text{total no. of customer served}}$$

$$\text{SAIDI} = \frac{\sum U_i N_i}{\sum N_i} \text{ Hours/Customer} \tag{5}$$

Where U_i is the annual outage time of ith load point.

(iii) Customer Average interruption Duration Index:

$$\text{CAIDI} = \frac{\text{sum of customer interruption duration}}{\text{total no. of customer interruptions}}$$

$$\text{CAIDI} = \frac{\sum U_i N_i}{\sum \lambda_i N_i} \text{ Hours/interruption} \tag{6}$$

WhereU_i is the annual outage time λ_i is the failure rate, and N_i is the no.of customers at ithload point.

(iv) Avg. service availability Index (ASAI):

$$\text{ASAI} = \frac{\text{customer hours of available service}}{\text{customer hours demanded}}$$

$$\text{ASAI} = \frac{\sum \mathrm{N_i(8760) - U_i N_i}}{\sum \mathrm{N_i(8760)}} \tag{7}$$

(v)Avg. service unavailability Index (ASUI):

$$\text{ASAI} = 1 - \text{ASAI}$$

$$\text{ASAI} = \frac{\sum U_i N_i}{\sum N_i(8760)} \tag{8}$$

Where 8760 is the no.of hours in a year.

III LOSS SENSITIVITY FACTOR METHOD

Loss sensitivity factor method has been widely used to solve the capacitor allocation problem and new in the field of DG allocation has been reported in [2].

A Loss sensitivity Factor

The real power loss[3] in the system is given by Eqn.(9)

$$\mathrm{P_{Loss}} = \sum_{j=1}^{N}\sum_{i=1}^{N} \alpha_{ij}\left(\mathrm{P_i P_j} + \mathrm{Q}_i \mathrm{Q_j}\right) + \beta_{ij}\left(\mathrm{Q_i P_j} - \mathrm{P_i Q_j}\right) \tag{9}$$

The Loss sensitivity factor [3] of real power loss with respect to real power injection from the DG is given by

$$\alpha_i = \frac{\partial \mathrm{p_{Loss}}}{\partial \mathrm{P_i}} = 2\alpha_{ii}\mathrm{P_i} + 2\sum_{j=1, j\neq i}^{N}\left(\alpha_{ij}\mathrm{P_j} - \beta_{ij}Q_{\mathrm{j}}\right) \tag{10}$$

B. Network Reconfiguration Algorithm

Network reconfiguration is one of the feasible methods in which power flow is varied by ON or OFF the switches on the feeders. It is incorporated by opening a sectionalizing switch and closing a tie switch to protect feeder radial structure.

An LSF based Reconfiguration algorithm is proposed for distribution system which reduces the active power loss.

The proposed algorithm is shown as flow chart in Fig. 1.

The flow chart of Network Reconfiguration algorithm shown in Fig. 1.

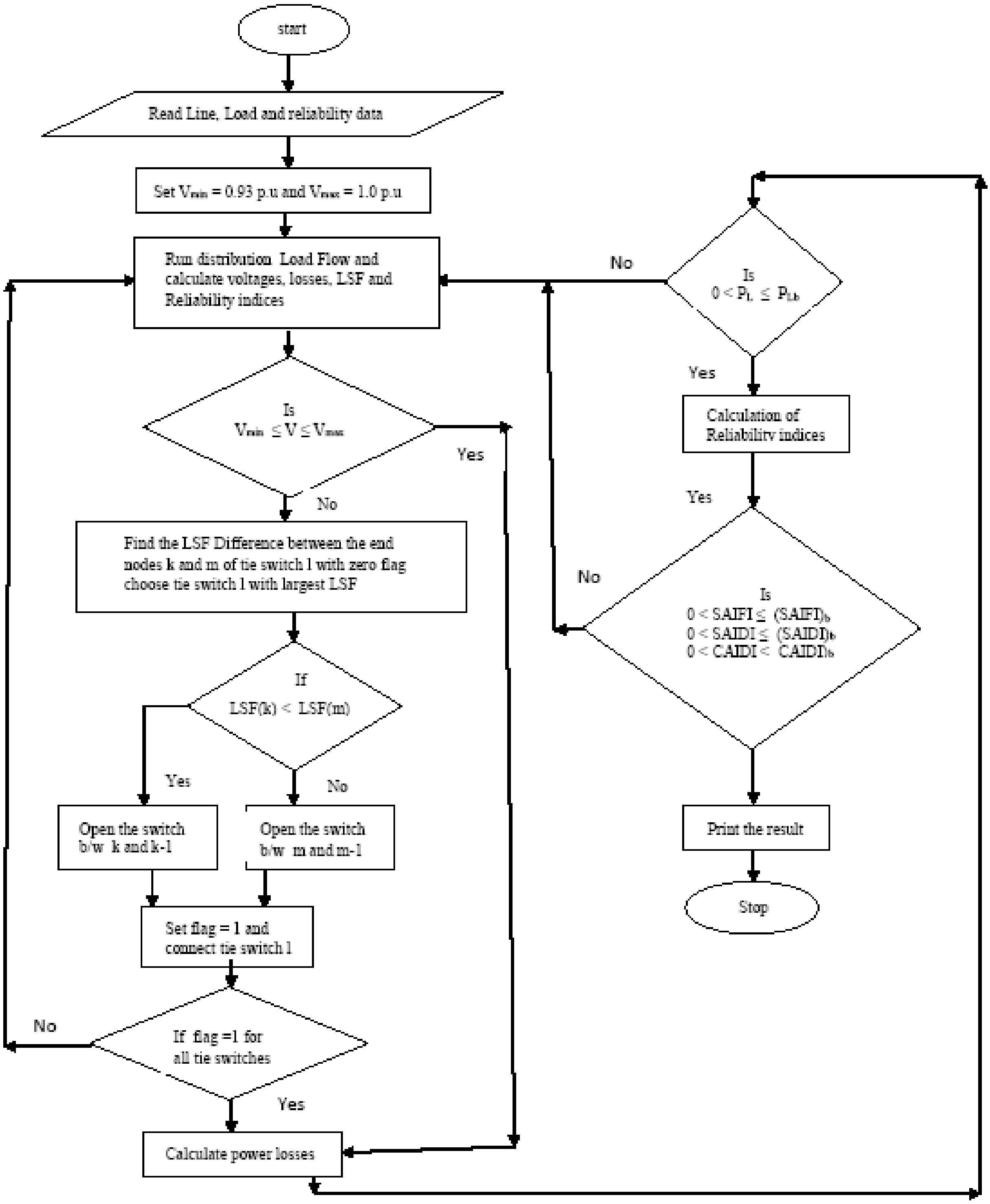

Fig. 1 Flow chart of NR algorithm

The proposed algorithm searches for better switching combinations that further improves voltage stability and losses by considering a tie switch and its neighboring sectionalizing switches one at a time and continues the search process until there is no further improvement in voltage stability, real power losses and reliability.

IEEE 33-Bus Radial Distribution system shown in Fig. 2 is considered. Line, Load and Reliability data are considered from [9] Run the load flow and determine the LSF for all buses.

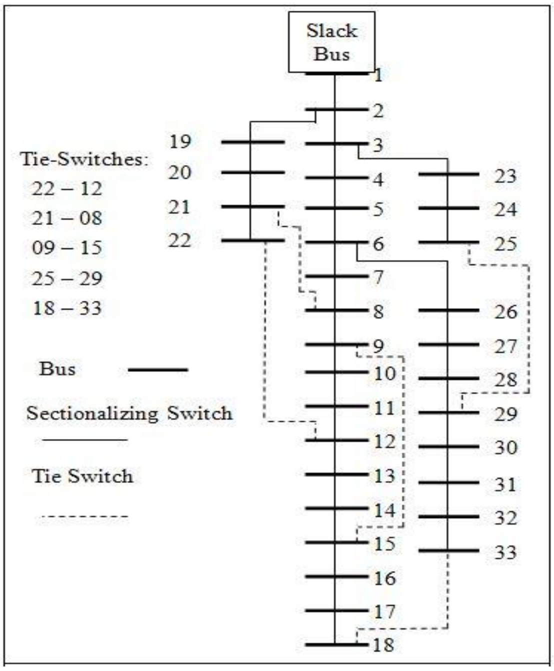

Fig. 2 Single line diagram of IEEE 33-bus RDS for base Configuration

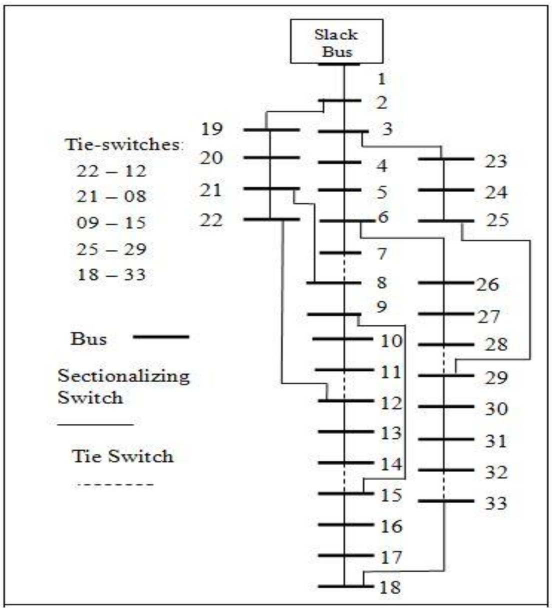

Fig.3 Single line diagram of 33-bus RDS with Reconfiguration

C. Optimal placement of a DG

There are several benefits by installing a DG unit at an optimal location, which includes minimization of line losses and improvement of Reliability.

IV. RESULTS AND ANALYSIS

Following are 4 cases are considered for the analysis.

Case 1: Base configuration

Case 2: Reconfigured system

Case 3: Base configuration with DG placement

Case 4: Reconfigured system with DG placement.

Load flow analysis is done with MATLAB and voltage magnitude and LSF values are given in Table1 and real loss for base configuration is 202.34 kW.

The algorithm given in section III is applied to IEEE 33 – Bus RDS The LSF difference between the tie switches 25-29 is maximum, hence this tie switch is to be closed first. As the LSF of 22 is more than the LSF of 29, the switch in the branch 28-29 should be opened. The real power loss is 172.01 KW. Now, the next tie switch which is to be closed is 9-15,and the switch between 14-15 is opened with real power loss of 166.14KW. Now, the next tie switch to be closed is 18-33, and the switch to be opened is 33-32 with a real power loss of 155.62 KW. The procedure is repeated until the final optimal configuration is achieved with real power loss of 137.53 KW. The final optimal configuration is shown in Fig. 3 and converged values of voltage and LSF are given in Table 2.

TABLE 1: CONVERGED VALUES OF BUS VOLTAGES MAGNITUDE, LSF, BEFORE RECONFIGURATION

Bus no	Voltage (volts)	Loss Sensitivity factor	Bus no	Voltage (volts)	Loss Sensitivity factor
1	1	0.00519	18	0.91316	0.00012771
2	0.99703	0.00431	19	0.99651	0.00211302
3	0.98295	0.01051	20	0.99293	0.00045087
4	0.97548	0.01298	21	0.99222	0.00233601
5	0.96808	0.01655	22	0.99159	0.0040978
6	0.9497	0.00948	23	0.97936	0.00474819
7	0.94621	0.00982	24	0.97269	0.00370522
8	0.94137	0.00287	25	0.96937	0.00827093
9	0.93511	4.3E-05	26	0.94777	0.00311782
10	0.9293	0.00104	27	0.94521	0.00344163
11	0.92844	0.00011	28	0.93378	0.00603113
12	0.92694	0.00097	29	0.92556	0.00209428
13	0.92083	0.00319	30	0.92201	0.00162933
14	0.91857	0.00136	31	0.91785	0.0031726
15	0.91715	0.00116	32	0.91694	0.00334036
16	0.91579	0.00184	33	0.91665	0.00364528
17	0.91376	0.00085			

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TABLE 2: CONVEREGED VALUES OF LSF, VOLTAGE MAGNITUDE AND PHASE ANGLE AFTER RECONFIGURATION

Bus no	Voltage (volts)	Loss Sensitivity factor	Bus no	Voltage (volts)	Loss Sensitivity factor
1	1	0.00327787	18	0.9215	0.01089980
2	0.99822	0.00267688	19	0.99775	0.00485867
3	0.99031	0.00264525	20	0.99628	0.01156757
4	0.98852	0.00282829	21	0.99607	0.01282046
5	0.98704	0.00382270	22	0.99569	0.00271763
6	0.9839	0.00222024	23	0.98528	0.00104207
7	0.98327	0.00174826	24	0.97558	0.00285835
8	0.9687	0.01479400	25	0.96662	0.00071673
9	0.95739	0.00766122	26	0.98363	0.00112377
10	0.95608	0.00605527	27	0.98337	0.00257105
11	0.95595	0.00237328	28	0.98285	0.00577824
12	0.991	0.00830471	29	0.96166	0.00148454
13	0.98849	0.00954603	30	0.9578	0.00328864
14	0.98772	0.00582121	31	0.94988	0.00949627
15	0.93559	0.01931557	32	0.94855	0.00872127
16	0.9295	0.01212282	33	0.92117	0.01134655
17	0.92339	0.00260173			

4.2 IEEE 33-Bus RDS with DG

DG size of 2.49MW is placed at optimal location of 6 bus for Base configuration of RDS and DG size of 0.78 MW is placed at Optimal location of 31 bus for Reconfigured RDS. IEEE 33 – Bus RDS with DG for Base and Reconfigured cases are shown in Fig. 4 and Fig. 5 respectively. Converged values of voltage and LSF are given in Table 3.

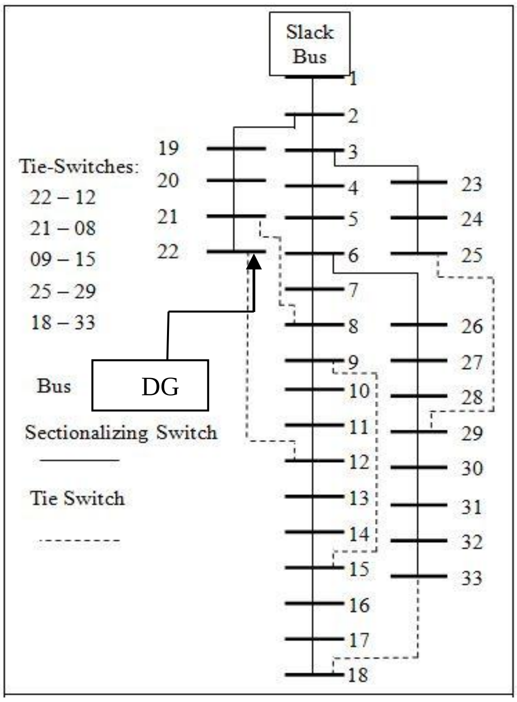

Fig. 4 Single diagram of 33-bus RDS with DG

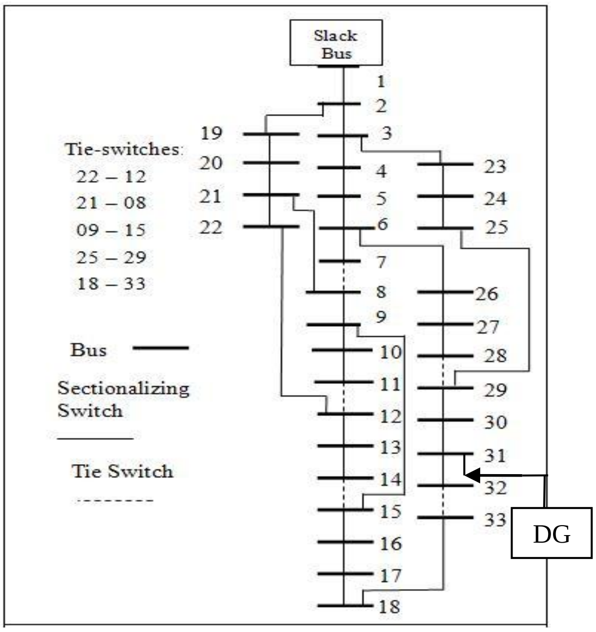

Fig. 5 Single line diagram of Reconfigured 33-bus RDS with DG

TABLE 3: CONVERGED VALUES OF BUS VOLTAGE MAGNITUDE FOR BASE CASE AND RECONFIGURATION WITH DG

Bus no	Base case DG at 6	NR case DG at 31		Base case DG at 6	NR case DG at 31
	Voltage (volts)	Voltage (volts)	Bus no	Voltage (volts)	Voltage (volts)
1	1	1	18	0.94846	0.968
2	0.99848	0.99822	19	0.99795	0.99776
3	0.99215	0.99032	20	0.99438	0.99629
4	0.99042	0.98853	21	0.99368	0.99607
5	0.98902	0.98705	22	0.99304	0.9957
6	0.98367	0.98391	23	0.9886	0.98529
7	0.98031	0.98328	24	0.98199	0.97559
8	0.97564	0.9821	25	0.9787	0.96663
9	0.96961	0.97747	26	0.98181	0.98363
10	0.96401	0.97618	27	0.97934	0.98337
11	0.96318	0.97605	28	0.96833	0.98285
12	0.96174	0.991	29	0.96041	0.96167
13	0.95585	0.98849	30	0.95699	0.9578
14	0.95367	0.98772	31	0.95298	0.94989
15	0.95231	0.96881	32	0.9521	0.94855
16	0.95099	0.9676	33	0.95183	0.96768
17	0.94904	0.96979			

4.3 Comparison of voltage magnitudes

Comparison of voltage magnitudes for Base and Reconfigured cases without and with DG is shown in Fig. 6.

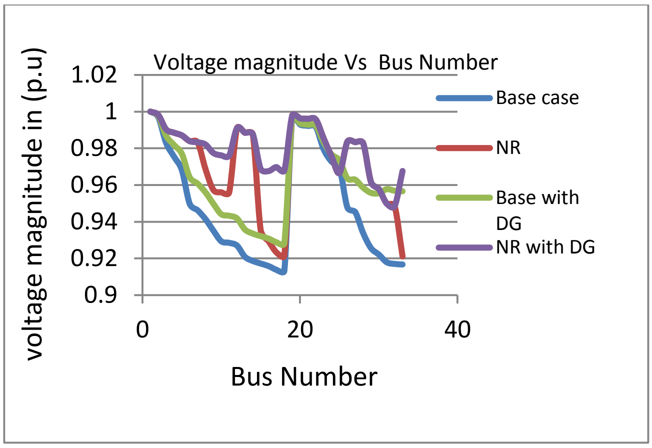

Fig. 6 Comparison of Voltage Magnitudes for Base case, Reconfigured case, DG and Reconfiguration with DG

4.4 Power Loss Analysis

The comparison of power losses for Base and Reconfigured cases is given in Table 4, it can be observed that, after final network reconfiguration, the real power loss has been reduced to 137.53KW.

TABLE 4: VARIATION IN THE POWER LOSSES OF 33-BUS RDS FOR BASECASE AND RECONFIGURATION

Power loss	Before NR	After NR	%Decrease
Real power loss(KW)	202.3	137.53	32.15

The comparison of real power losses with the existing methods in given in Table 5. .

TABLE 5: COMPARISON OF POWER LOSSES WITH OTHER METHODS

Method	Tie switches	Loss in kW)	% loss reduction
Base Configuration	33,34,35,36,37	202.7	-
GA[7]	7,9,14, 37,32	141.6	30.15
RGA[11]	7,9,14, 37,32	139.5	31.2
ITS [8]	7,9,14,37,36	139.2	31.29
HSA[9]	7,10,14,37,36	138.06	31.89
Proposed LSF Method	28,14,32,11,7	137.53	32.15

The comparison of power losses for Base and Reconfigured ases without and with DG is given in Table 6.

TABLE 6: VARIATION IN THE POWER LOSSES OF 33-BUS RDS FOR BASE CASE AND RECONFIGURATION WITH DG

Power loss	Base case with DG	After NR	Base case with DG	After NR with DG
Real power loss(KW)	202.3	137.53	104.01	103.54
DG size(kW)	-	-	2490	780

Comparison of power losses for base case, network reconfiguration, DG placement and reconfiguration with DG is given in Fig. 7.

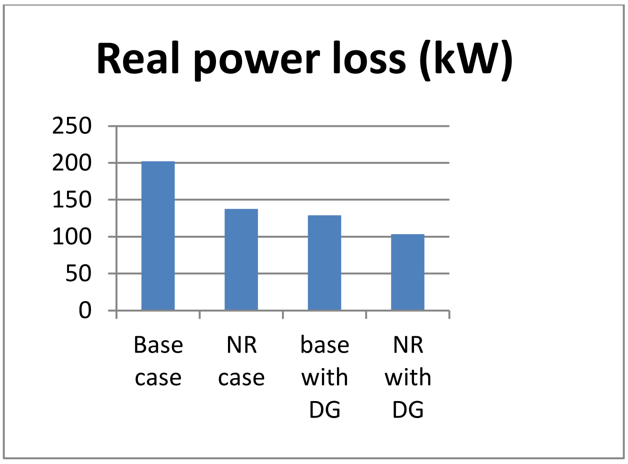

Fig.7 Comparison of power losses for all four cases

4.5 Reliability Analysis

The Reliability indices SAIFI, SAIDI, ASUI and CAIDI of the 33-bus RDS have been calculated using cutest approach. The Reliability indices of the system before and after reconfiguration are compared in Table 7. The Reliability indices of the system for Base Case and after DG placement one compared in Table 8. The Reliability indices of the system after reconfiguration and reconfiguration with DG placement are compared in Table 9.

COMPARISION OF RELIABILITY INDICES FOR BASE CASE AND AFTER RECONFIGURATION:

TABLE 7: VARIATION IN THE RELIABILITY OF 33-BUS RDS FOR BASE CASE AND RECONFIGURATION

Index	Before NR	After NR	%Decrease
SAIFI (f/yr)	2.4126	2.3336	3.2
SAIDI (hr/yr)	2.0436	1.4573	28.6
CAIDI (hr)	0.8470	0.6245	22.3
ASUI	2.3328e-04	1.6635e-04	28.6

TABLE 8: VARIATION IN THE RELIABILITY OF 33-BUS RDS FOR BASE CASE AND DG INSTALLATION

Index	Base Case	DG placement	%Decrease
SAIFI (f/yr)	2.4126	2.096	13.12
SAIDI (hr/yr)	2.0436	1.7269	15.49
CAIDI (hr)	0.8470	0.8239	2.72
ASUI	2.3328e-04	1.97e-04	15.4

TABLE 9: VARIATION IN THE RELIABILITY OF 33-BUS RDS FOR RECONFIGURATION AND RECONFIGURATION WITH DG

Index	After NR	NR with DG units	%Decrease
SAIFI (f/yr)	2.3336	2.27	2.7
SAIDI (hr/yr)	1.4573	1.42	2.5
CAIDI (hr)	0.6245	0.62	0.64
ASUI	1.6635e-04	1.628e-04	2.1

Comparison of reliability indices for base case, network reconfiguration, DG placement and reconfiguration with DG is given in Fig. 8.

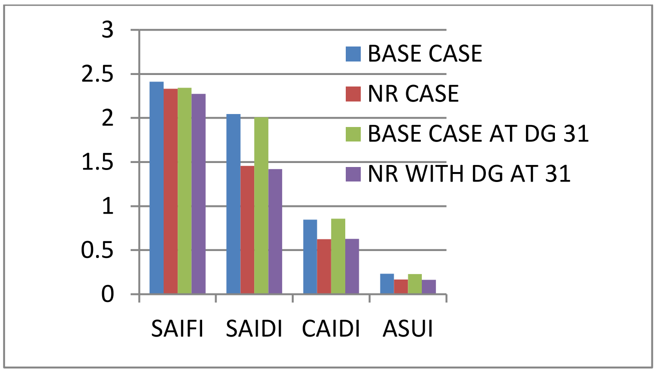

Fig. 8 Comparison of reliability indices for all four cases

IV. CONCULUSION

In this paper, an algorithm for reconfiguration with LSF has been developed. This algorithm is applied to IEEE 33 Bus Radial Distribution System. IEEE 33-Bus RDS Base configuration with DG Installation and Reconfiguration of the system with DG Installation cases are analyzed with MATLAB Programming. The results show that Network reconfiguration showed the better results than base configuration with the installations of DG. The impact of DG locations on the reduction of power loss has been obtained. The improvement of reliability from base case to NR case, base case to base with DG and NR case to NR case with DG has been observed.

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