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Original Article

Reliability and Loss Analysis of Distribution System Before and After Reconfiguration with Optimal Location of DG

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Abstract *- The main objective of this paper is to reduce losses and improve the reliability indices before and after 6 and 33-bus reconfiguration with optimal location of DG. The Loss Sensitivity Factor (LSF) method is used for an Optimised Distribution system for loss reduction and reliability improvement. The cut-set approach is used to obtain the reliability indices like SAIFI, SAIDI, and CAIDI. DG optimal location using Maximum Loadability Index (MLI) before and after reconfiguration for reduction of losses and improvement of Reliability indices. Finally, the obtained results are compared with existing methods.*

Keywords *- Loss Sensitivity Factor (LSF), Maximum Loadability Index (MLI), Radial Distribution System (RDS), Losses, Reliability Performance Indices.*

1. Introduction

Reliable and cost-effective supply is the primary agenda of any power distribution system. It is expected that consumers will always receive power without interruptions, thus making reliability a top priority. The primary performance indicators to evaluate power supply reliability are Customer Average Interruption Duration Index (CAIDI), System Average Interruption Duration Index (SAIDI), Average Service Availability Index (ASAI), and System Average Interruption Frequency Index (SAIFI). These indicators reflect the length of time and frequency of power interruptions that customers encounter. Traditional approaches such as infrastructure upgrades and capacity enhancement are often expensive, and therefore, power utilities prefer economical and flexible alternatives such as Network Reconfiguration (NR) and Distributed Generation (DG). In the NR approach, the topology of the network is dynamically altered to achieve optimal load distribution, reduce system losses, and improve fault isolation. In the DG approach, local generation such as solar, wind, and gas-based power sources, is encouraged near the load centres. This method can significantly enhance voltage regulation, improve voltage stability, and increase the overall reliability of the Distribution System (DS) Reliability indices like CAIDI, SAIFI, and SAIDI are increasingly considered in network reconfiguration processes, which were originally aimed at minimizing power losses and stabilizing voltage [1]. To lower losses and increase the reliability of distribution systems, a Monte Carlo simulation based on a genetic algorithm technique has been used [2, 3]. Genetic Algorithm approach, improved Tabu search method, and Redefined Genetic algorithm employed to reconfigure distribution network for loss minimization and voltage enhancement [15, 17, 18]. MPGSA also obtained the optimal reconfiguration network for the minimization of losses [23]. Numerous studies have also been conducted in [4] on reliability concerns pertaining to distribution system planning, design, and operation. Proper feeder reconfiguration has proven effective in improving system reliability [5]. Distribution network reconfiguration is treated as an operational task, involving the rearrangement of switch statuses with the goal of reducing distribution losses [6].

The process of optimizing feeder configuration includes selecting the best branches or tie switches to be opened, ensuring that the distribution radial network meets the desired performance criteria [7]. An investigative approach for identifying the best placement and size of Distributed Generation (DG) units was introduced [8]. As reliability is a vital issue in distribution networks, the DG effect on system reliability has been thoroughly researched and documented [9]. To determine the optimal (power factors) pf, the PSO technique has been used for DG units to cut down system losses and enhance voltage profiles. And it has been verified on 69-bus and 33-bus networks [10]. An alternative method of analysis for concurrently determining the best location and size of DG, though computationally demanding, was proposed in [11]. Khatod presented an investigative framework targeting optimal capacity selection and location determination for distributed Generation facilities [12]. Ref

[20] introduced a Constriction-factor Particle Swarm Optimisation (Cf-PSO) to address shunt capacitor allocation with the aim of reducing power losses, operating costs, and enhancing voltage stability. Mohamed T. Mouwaf et al. [21] developed a two-stage methodology for enhancing RDN performance through optimized sizing and siting of both DG units and Capacitors, for enhancing the voltage stability and reduction of losses. To increase stability and lower losses, the technique suggests [22] simultaneous feeder reconfiguration and capacitor placement challenges. Whale Optimization Algorithm is found to be optimal placement of single DG as well as multiple DGs in RDS [24]. Network Reconfiguration (NR) has been used to mitigate the real power losses. There is a need to consider reactive power losses and performance matrices when evaluating RDS reliability, both prior to and following DG integration. This paper is organized as follows: Section 2 outlines the problem definition. Section 3 details the procedure for distribution network reconfiguration, DG position, sizing, and reliability performance indicators. Section 4 elaborates on the evaluation of both 6-bus and 33-bus RDSs. The system's efficiency in terms of voltage profile and power losses is examined to assess its overall reliability.

2. Problem Formulation

Reducing energy losses and improving reliability are defined as key targets considering both reconfiguration of the network and integration of DGs, while addressing these optimization targets, various operational constraints such as power limits, voltage levels, current, and performance indices must be satisfied:

$$Maximize\ f = max(\Delta P^{R+G}Loss, \Delta Q^{R+G}Loss, \Delta SAIFI^{R+G}, \Delta SAIDI^{R+G} \quad (1)$$

$$\Delta P^{R+G}\ Loss\ =\ P^{b}\ Loss - P^{R+G}Loss \quad (2)$$

$$\Delta Q^{R+G}Loss =\ Q^{b}\ Loss - Q^{R+G}Loss \quad (3)$$

$$\Delta SAIFI^{R+G}\ =\ SAIFI^{b} -\ SAIFI^{R+G} \quad (4)$$

$$\Delta SAIDI^{R+G} = SAIDI^{b} -\ SAIDI^{R+G} \quad (5)$$

Where *R+G denotes Reconfiguration with DG, and *b denotes base configuration.

Subjected to

$$V_{min,i}\ \leq\ V_i\ \leq\ V_{max,i}$$

$$0\ \leq\ SAIFI^{R+G}\ \leq\ SAIFI^{b} \quad (6)$$

Where P_{Loss} is the overall power loss of all branches during network reconfiguration, and P_{Loss} DG is the overall power loss of all branches following the installation of the DG

- P^{R+G} Loss is the after reconfiguration with DG real power loss
- Q^{R+G} Loss is the after reconfiguration with DG reactive power loss
- $SAIFI^{R+G}$ is the Systems Average Interruption Frequency Index after reconfiguration with DG.
- P^{b} Loss is the power loss of the base configuration.
- Q^{b} Loss is the reactive power loss of the base configuration.
- $SAIFI^{b}$ is the Systems Average Interruption Frequency Index of the base configuration.

3. Methodology for Reconfiguration and DG Placement of the Distribution System

The proposed methodology is developed and implemented for distribution systems to reduce power losses as well as enhance reliability performance indices.

3.1. Distribution Reconfiguration Algorithm

The algorithm is developed and implemented to reduce real power losses and enhance reliability performance indices, as illustrated in Figure 1. The Network Reconfiguration Algorithm (NRA) is based on the Loss Sensitivity Factor (LSF). The distribution network –LSF is calculated for each bus using the load flow method. This factor, as described in [8], is given by Equation 6.

$$\frac{\partial P_L}{\partial P_n} = 2\sum_{n=1}^{i}(\alpha_{mn}P_n - \beta_{mn}Q_n) \quad (6)$$

3.2. DG Placement and Size Algorithm

The placement and sizing of the DG algorithm is developed and implemented to minimize power losses as well as improve reliability performance indices, as presented in Figure 2. In the suggested algorithm, the optimal DG placement is determined using the Maximum Loadability Index (MLI). In a radial distribution network, the MLI values of each branch/line are determined by load flow analysis using Equation 7. The bus with the lowest MLI value on the m–n line is the nth bus where the DG is positioned. The DG sizing is then refined through an iterative approach. The process continues until the most effective DG size is obtained, targeting minimum total power loss while ensuring that all system constraints (Equations 8-10) are satisfied.

$$\mathrm{MLI} = \frac{V_m^2[-(r_{mn}\cdot P_{mn} +\ x_{mn}\cdot Q_{mn}) + \sqrt{[r_{mn}^2 + x_{mn}^2][{P_{mn}}^2 + Q_{mn}^2]}}{2\cdot(x_{mn}\cdot P_{mn} - r_{mn}\cdot Q_{mn})\text{^}2} \geq 1 \quad (7)$$

$$Min\ P_L =\ \sum_{i=1}^{n} {I_i}^2 R_i \quad (8)$$

$$0\ \leq\ P_G\ \leq\ P_{Load} \quad (9)$$

$$Vmin \leq Vi \leq Vmax \qquad i = 2,3\ldots \quad (10)$$

The entire DG allocation and sizing process flowchart is depicted in Figure 2.

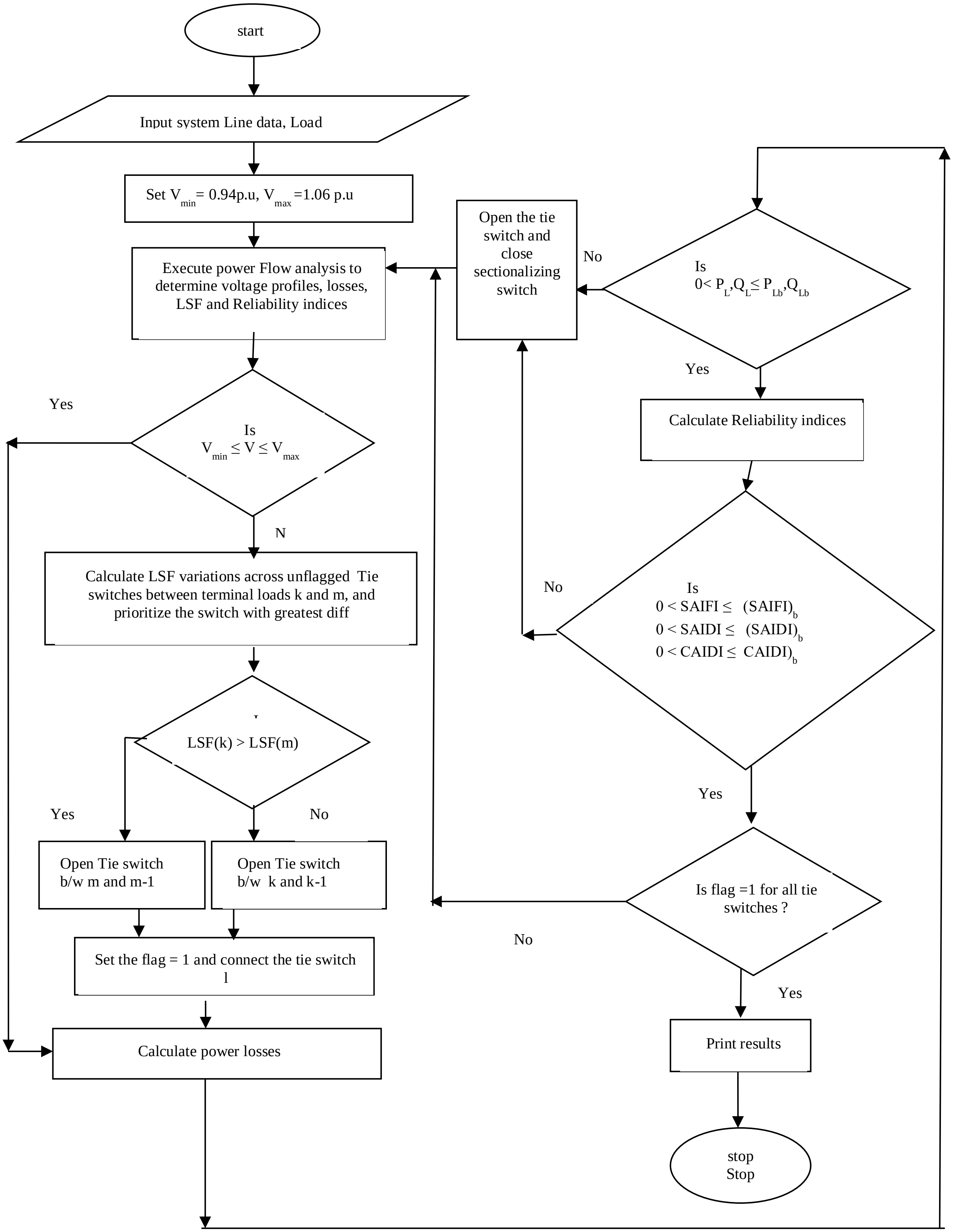

Fig. 1 Distribution reconfiguration algorithm

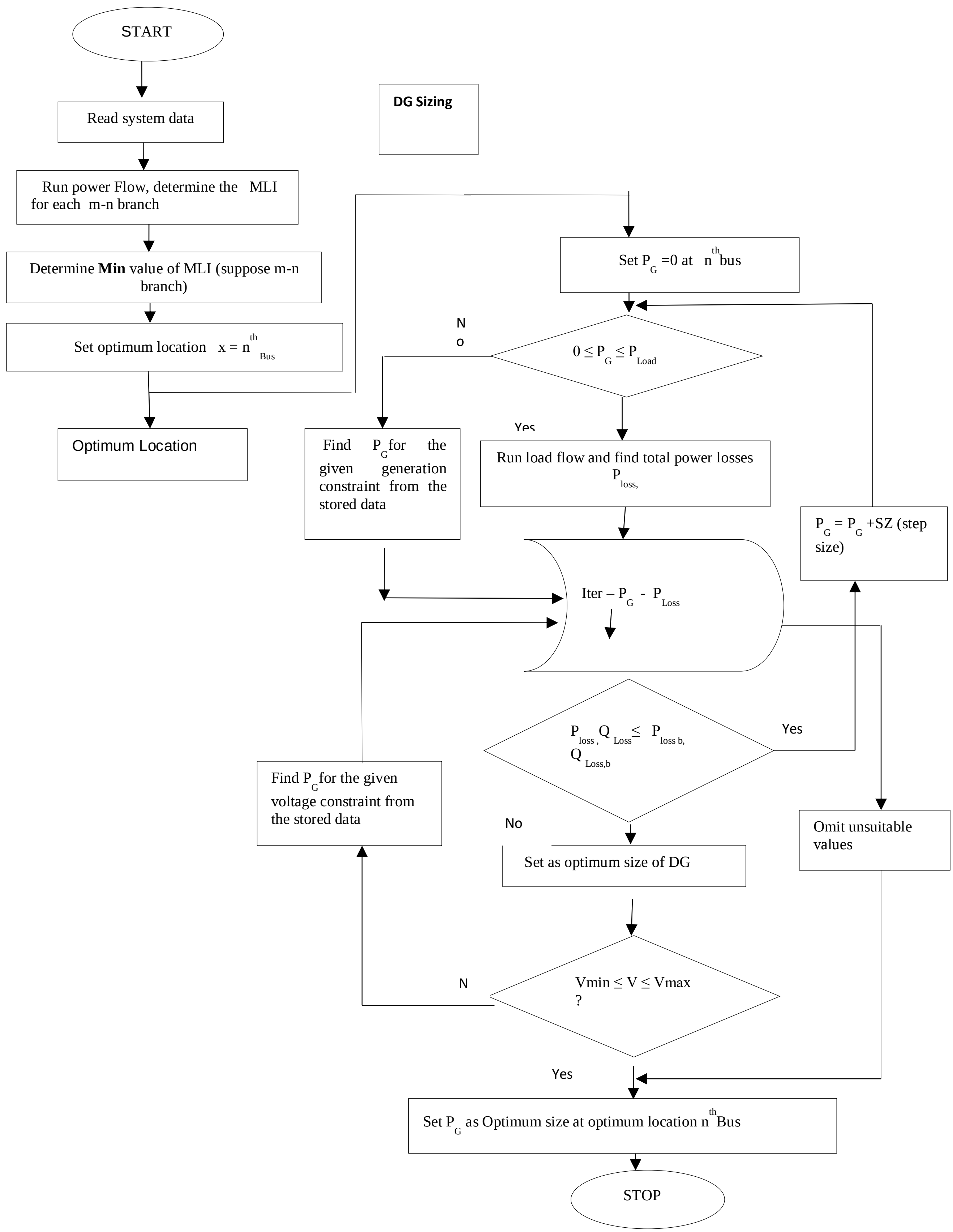

Fig. 2 DG allocation and flow chart algorithm

3.3. Reliability Evaluation of Distribution System

The distribution network reliability is defined by its capability to consistently deliver an uninterrupted supply to consumers. Lines, cables, bus bars, disconnects (or isolators) are the elements of RDN. For a customer connected at any load point, all components between the supply point and that load must be operational. Therefore, the principles of series systems and the cut-set approach can be directly applied to analyze reliability in these systems.

The cut-set approach is particularly suitable for approximate reliability analysis. In this method, elements within a cut-set are considered to be connected in parallel, while the cut-sets themselves are arranged in series when viewed from the perspective of the reliability logic diagram [13]. This requires representing the system using Parallel-Series Configurations (PSC) to evaluate Basic Probability Indices (BPIs) such as failure average rate (FT) (λ), outage average duration (r), and annual average outage time (U), which are also referred to as load point indices.

Figure 3(a) illustrates a PSC where each cut-set consists of *m* components connected in parallel. Figure 3(b) shows *n* cut-sets connected in series, and Figure 3(c) presents the simplified resultant cut-set. The notation Ccnm represents the *m*th component in the nth cut-set. Reliability indices are calculated at each component, each cut-set, and the overall system level. Finally, customer-oriented performance indices are evaluated by combining the BPIs at each load point with the number of customers connected.

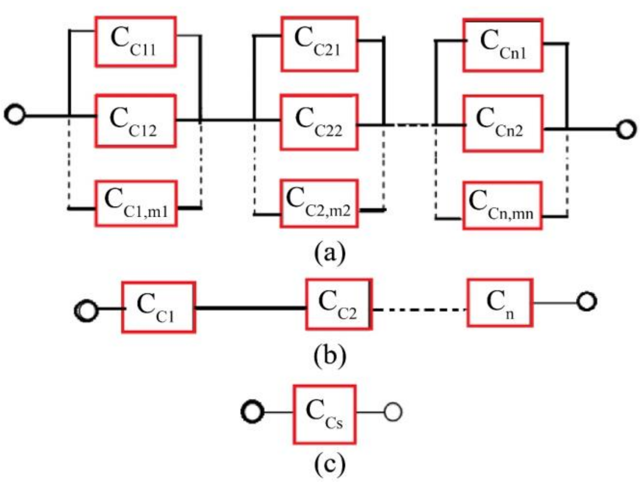

Fig. 3 Cutest Approach PSC of the system in, (a) with equivalent diagrams in (b) and (c).

3.4. Load Point Indices (LPI)

LPIs are used to compute reliability indices Load Point Indices (LPIs) are:

3.4.1. Failure Average Rate (λ)

The average no.of service interruptions occurring at the load point within a specific time.

3.4.2. Average Outage Time (r)

The mean duration of each an interruption within a specific time.

3.4.3. Average Annual Outage Time (U)

Average time of unavailability experienced by all service interruptions at the load point during a specific time.

- Let λcij and rcij represent the jth component of the ith cut-set's FR and RT, respectively.
- Let r_{ci} and λ_{ci} be the (Mean Outage Time) MOT and (Equivalent Failure Rate) EFR, respectively, of the i^{th} cut-set.
- Let r_{cs}, U_{cs}, and λ_{cs} be the (Mean Outage Time) MOT, AAOT, and (Effective Failure Rate) EFR, respectively, of the system.

The r_{ci} can be written as:

$$r_{ci} = \frac{\prod_{j=1}^{m} r_{cij}}{\sum_{j=1}^{m}\left(\prod_{\substack{k=1 \\ k=j}}^{m} r_{cik}\right)} \text{ for i = 1 to n} \quad (11)$$

λci can be written as

$$\lambda_{ci} = \left(\prod_{j=1}^{m_i} \lambda_{cij}\right)\left(\sum_{j=1}^{m_i}\left(\prod_{\substack{k=1 \\ k\neq j}}^{m_i} r_{cik}\right)\right) \text{ for i=1 to n} \quad (12)$$

Now, λ_{cs} can be written as:

$$\lambda_{cs} = \sum_{i=1}^{n} \lambda_{ci} \quad (13)$$

r_{cs} can be written as:

$$r_{cs} = \frac{\sum_{i=1}^{n} \lambda_{ci} r_{ci}}{\sum_{i=1}^{n} \lambda_{ci}} \quad (14)$$

U_{cs} can be written as:

$$U_{cs} = \sum_{i=1}^{n} \lambda_{ci} r_{ci} \quad (15)$$

In this context, λsys represents the system's failure rate at the ith load point Usys denotes the yearly outage time for the system at load point i, the variables λk, rk, correspond to the rate of failures and anticipated restoration time for distributor elements. S consists of multiple distributor segments connected sequentially to the load point.

Reliability indices calculated according to classical three main principles are: average outage period, mean failure rate and mean annual outage time.

3.5. Customer-Oriented Performance Indices

The indices are mostly used as follows:

3.5.1. System Average Interruption Frequency Index (SAIFI)

This indicator determines the average number of prolonged disruptions (lasting more than five minutes) that occur during a given time frame, usually a year. One of the commonly used indices is calculated as Total customer interruptions as a percentage of total customers serviced

$$\text{SAIFI} = \frac{\sum N_i \lambda_{sys,i}}{\sum N_i} \text{f/yr} \quad (16)$$

Where Ni represents the ith load point customer count.

3.5.2. System Average Interruption Duration Index (SAIDI)

Customers' average interruption time is represented by this index and is typically reported on an annual basis. SAIDI is one of the most widely used reliability indices. It is calculated as the ratio of time spent on customer interruptions to the total number of customers served.

$$\text{SAIDI} = \frac{\sum N_i U_{sys,i}}{\sum N_i} \text{ hr/yr} \quad (17)$$

3.5.3. Customer Average Interruption Duration Index (CAIDI)

This index indicates the average time a consumer remains without power whenever an interruption occurs. It is calculated as the ratio of the duration of customer interruptions to the total number of interruptions.

$$\text{CAIDI} = \frac{\sum N_i U_{sys,i}}{\sum N_i \lambda_{sys,i}} \text{ hr} \quad (18)$$

3.5.4. Average Service Availability Index (ASAI)

It indicates the proportion of the year that the typical consumer has access to electricity. The number of hours in a calendar year is represented by the number 8760.

$$\text{ASAI} = \frac{\sum 8760 * N_i - \sum N_i U_{sys,i}}{\sum N_i} \quad (19)$$

4. Results and Discussion

Load flow analysis with and without Distributed Generation (DG), both before and after network reconfiguration, is performed for different case studies to compare power losses and reliability performance indices in 6-bus and 33-bus RDN.

The case studies are as follows:

- Case 1. Evaluation of a 6-Bus RDS by Comparing reliability indices and Losses before and after integrating DG.
- Case 2. Assessment of reconfigured 6-Bus RDS focusing on the variation of reliability indices and Losses with and without DG.
- Case 3. Analysis of a 33-Bus through a Comparison of reliability indices and system losses prior to and following DG installation.
- Case 4. Assessment of reconfigured 33-Bus RDS focusing on the variation of reliability indices and Losses with and without DG.

4.1. 6-Bus RDS Comparison of Real Power Losses and Reliability Indices before and after DG

6-bus RDS as shown in Figure 4, using the load flow approach, the losses without and with DG are determined, and reliability indices are calculated using the cut-set approach. The DG location is placed using the DG algorithm as shown in Figure 2. Obtained Losses and reliability indices are tabulated in Tables 1 and 2, respectively. As per the DG algorithm, Line 2 has a minimum MLI, and a DG size of 344 kW is placed at bus 3.

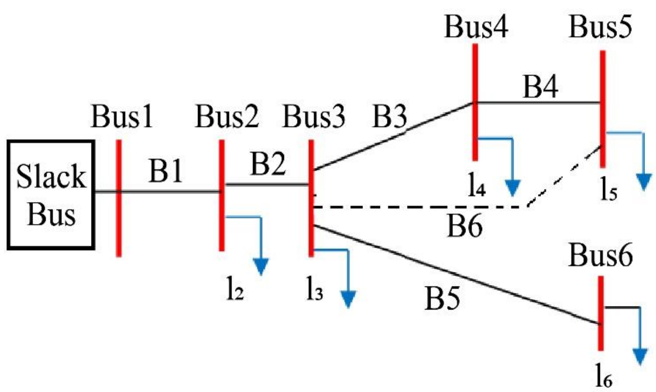

Fig. 4-Bus standard RDS with DG placement

Table 1. 6-bus RDS Power loss Assessment for base case and after DG placement

Losses	Base case	Base case with DG	% Losses Reduced
APL kW	0.6961	0.2607	62.5
RPL kVar	0.362	0.147	59.39
ApPL kVA	0.7838	0.2993	61.81

From Table 1, it is inferred that deploying DG at bus 3 in the 6-bus system leads to a reduction in APL, RPL, and ApPL losses by 62.5% 59.39%, and 61.81% respectively.

Table 2. 6-bus RDS Power loss Assessment: base case and after DG placement

Index	Base case	Base case with DG	% Reduction
CAIDI hr	0.785	0.5952	24.17%
SAIDI hr/yr	0.388	0.1564	23.18%
SAIFI f/yr	0.4945	0.2627	46.87%
ASAI	4.43E-05	1.79E-01	59.59%

From Table 2, it is observed that CAIDI, SAIDI, SAIFI, and ASAI indices experience declines of 24.17%, 23.18%, 46.87 %, and 59.59% respectively. This confirms a notable enhancement in system reliability following DG implementation.

4.2. 6-Bus Reconfigured RDS Comparison of Power losses and Reliability Indices before and after DG

An optimised reconfigured 6-bus RDS is obtained using the procedure outlined in Figure 1. The reconfigured RDS network after DG integration is represented in Figure 5. Losses are calculated with and without DG placed at bus3, and reliability indices are obtained via the cut-set evaluation technique. The Obtained Losses and reliability indices are tabulated in Tables 3 and 4, respectively. As per the DG algorithm, Line 2 shows the lowest MLI, and the DG unit rated at 215 kW is allocated to bus 3.

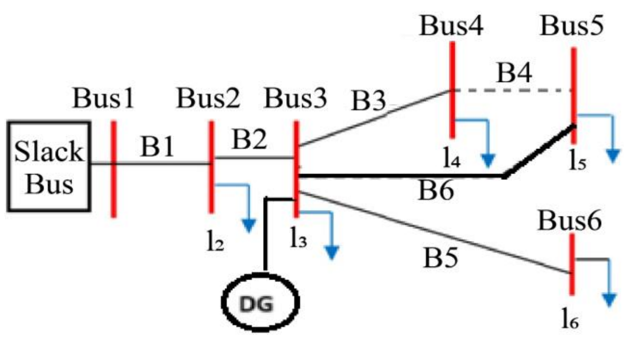

Fig. 5 Reconfigured 6-bus RDS after DG placement

Table 3. 6-bus Reconfigured RDS Power loss assessment without and with DG

Losses	Reconfigured RDS	Reconfigured RDS with DG	% losses Reduced
APL kW	0.645	0.206	68.04
RPL kVar	0.342	0.119	65.27
ApPL kVA	0.7303	0.238	67.43

From Table 3, the results show that following DG implantation, active, reactive, and apparent power losses decreased by 68.04 percent, 65.27 percent, and 67.43 percent, respectively.

Table 4. 6-bus Reconfigured RDS reliability indices assessment without and with DG

Index	Reconfigured RDS	Reconfigured RDS with DG	% Reduction
CAIDI hr	0.769	0.5447	29.16
SAIDI hr/yr	0.3619	0.1309	63.82
SAIFI f/yr	0.4707	0.2389	49.24
ASAI	4.13E-05	1.48E-05	64.16

From Table 4, CAIDI, SAIDI, SAIFI, and ASAI exhibit respective reductions of 29.16%, 63.82%, 49.24%, and 64.16%, further reinforcing the positive impact of DG on system reliability.

4.3. 33-Bus RDS Comparison of Power Losses and Reliability Indices before and after DG

33-bus RDS, as shown in Figure 6, using the load flow approach, determined the losses without and with DG. DG location is obtained using the Maximum Loadability Index (MLI) algorithm as shown in Figure 2. As per the DG algorithm, Line 5 has a minimum MLI, and a DG size of 2600 kW is placed at bus 6.

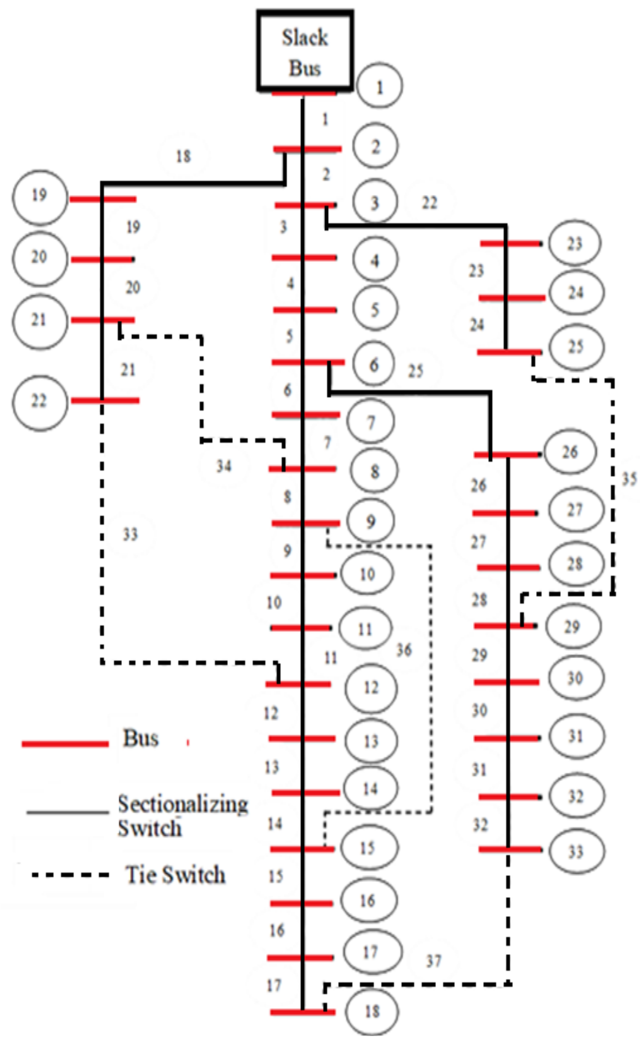

Fig. 6 Normal Configuration of IEEE 33-bus RDS

As Table 5 illustrates, the installation of 2.6 MW DG at bus 6 in the 33-bus RDS normal configuration leads to a reduction in active, reactive, and apparent power losses by 48.6%, 44.62 %, and 47.1% respectively.

DG placement is at bus 6, approximately a single DG size of 2.6 MW. The proposed MLI technique gives a power loss of 103.9kW and a 48% loss reduction compared to the base case, while the other two methods reduce their power losses by 45%. WOA and the repeated load flow method have the same power loss but a small difference in DG sizes.

Table 5. 33-bus RDS power losses assessment for base case with DG placement

Losses	Base case	Base case with DG	% Loss Reduced
APL kW	202.7	103.9	48.6
RPL kVar	134.9	74.7	44.62
ApPL kVA	243.19	128.05	47.1
Method	Power Loss in kw	DG Optimal location and size in MW	Vmin (volt)
Base case wo DG	202.7	-	0.9131
Repeated load flow method with DG [8]	111	6, 2.6 MW	0.94
WOA method with DG [24]	111	6, 2.589 MW	0.942
Proposed MLI method	103.9	6, 2.6 MW	0.95

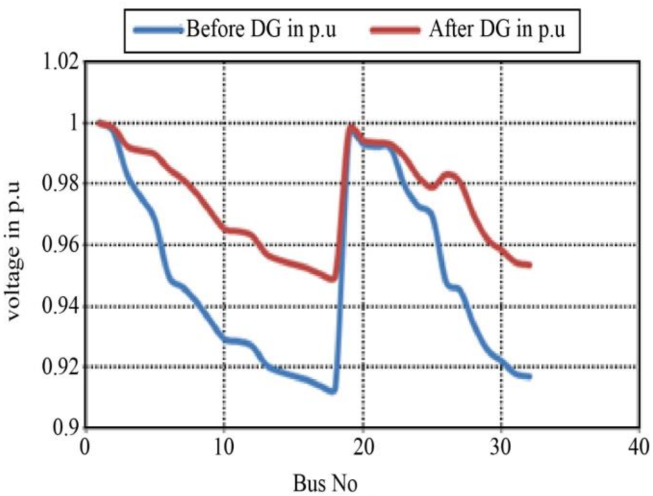

Fig. 7 Voltage Magnitude comparison before and after DG placement

According to Figure 7, the minimum voltage magnitude increases from 0.913 p.u. to 0.95 pu. after placing the DG at bus 6. The reduction of active power loss and minimum voltage levels achieved through the proposed method align closely with those obtained from repeated load flow in [8]. Furthermore, it confirms that reactive and apparent losses also decreased using this approach. Using the cut-set approach, the IEEE 33-Bus RDS reliability indices are computed for the base case, and after the DG is connected at the 6th bus. Table 6 presents a performance index assessment. According to Table 6 in the 33-Bus RDS performance indices, CAIDI, SAIDI, SAIFI, and ASAI. DG at optimal placement is reduced by 15.33%, 3.17%, 13.02%, and 15.4%, respectively. Table 7 shows that as the system's size increases, complexity also increases; the computed reliability indices with a single DG do not provide similar performance. For improved reliability, it is therefore desirable to install more DGs at strategic locations.

Table 6. Performance Indices assessment after DG Placement

Index	Base case	with DG	% Reduction
CAIDI (hr)	0.85	0.823	3.17
SAIDI (hr/yr)	2.04	1.726	15.33
SAIFI (f/yr)	2.41	2.096	13.02
ASAI	2.33E-4	1.97E-04	15.4

Table 7. Performance Indices Assessment of 6-bus and 33-bus RDS after DG placement

Index	6 - bus	33 - bus
CAIDI	0.5952	0.823
SAIDI	0.1564	1.726
SAIFI	0.2627	2.096
ASAI	1.79e-05	1.97e-04

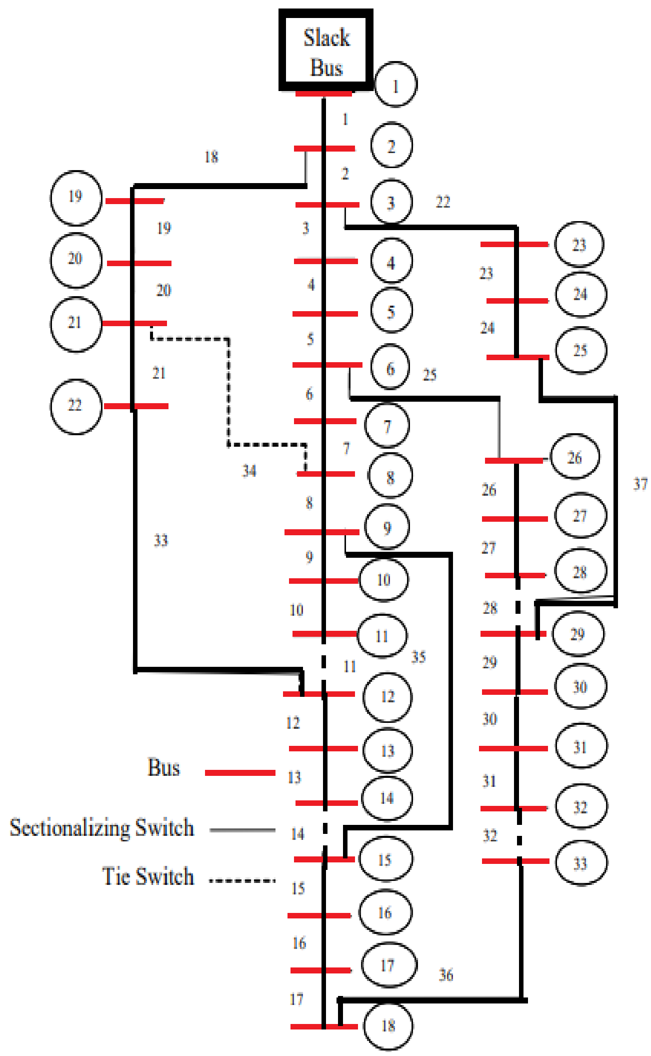

Fig. 8 IEEE 33-bus RDS–Reconfigured Configuration

4.4. 33 Bus Reconfigured RDS Comparison of Power Losses and Reliability Indices before and after DG

Reconfigured 33-bus RDS as depicted in Figure 8, assessed using load flow approach to compute power losses with and without DG placement, reliability indices are again determined using cut-set evaluation strategy.

Table 8. Comparison of power losses before and after reconfiguration with existing methods

Method	Tie Switches	Loss in kWs	% Loss Reduction	After NR V min
Base case	33,34,35, 36,37	202.7	----	0.9131
GA[15]	33,9,34, 28,36	141.6	30.15	0.9378
RGA[18]	07,09,14, 37,32	139.46	31.2	0.9378
ITS[17]	7,9,14, 37,36	139.2	31.29	0.9336
MPGSA [23]	07,09,14, 32,37	139.5	31.16	0.9343
LSF method	28,14,32, 11	139.6	31.14	0.933

From Table 8, 33- bus RDS minimum voltage and active power loss values obtained and which are approximately equal to the results stated in [15, 17, 18, 24] approving the validity of the proposed approach moreover, the proposed LSF based NR algorithm considerably reduce the reactive and apparent power losses in addition reliability indices of system is enhanced further validate the effectiveness of this method in enhancing the overall network performance.

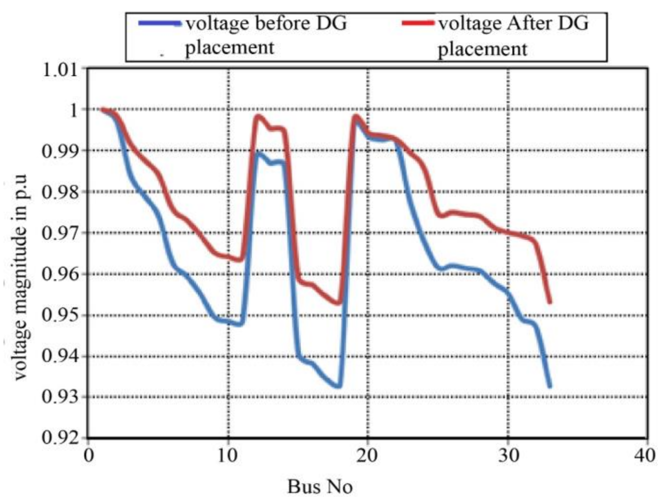

Fig. 9 33-bus Reconfigured RDS Voltage Magnitude plot after DG

Tables 9 and 10 and Figure 9 present the obtained losses and voltage magnitudes before and after DG, respectively. Figure 9 shows that following DG placement at bus 24, the voltage minimum rises from 0.93 p.u. to 0.9524 pu. According to the DG algorithm, bus 24 has a DG size of 1875.5 kW, and Line 23 has a minimal MLI.

Table 9. Reconfigured RDS Minimum Voltage Magnitude, and after DG placement

Parameter	Reconfigured RDS	Reconfigured RDS with DG	% Enhanced
Minimum Voltage (p.u)	0.93	0.9532	2.2

It can be shown from Table 9 and Figure 10 that the minimum voltage increases by 2.2% with DG.

Table 10. 33-bus Reconfigured RDS with DG Power loss assessment

Losses	Reconfigured RDS	Reconfigured RDS with DG	%Reduction
APL kW	139.6	83.5	40.18
RePL kVAR	94.1	66.2	34.97
ApPL kVA	172.71	106.55	38.14

According to Table 10, installing a 1857.5 kW DG at bus 24 in Figure 8 achieves a reduction of 40.18% in active power loss, 29.63% in reactive power loss, and 38.14% in apparent power loss for the reconfigured 33-bus RDS.

4.5 Reliability Evaluation of Reconfigured 33-Bus RDS after DG Placement

When a DG is placed at the 24th bus in Figure 6, the IEEE 33-Bus RDS reliability indices are compared before and after. The following describes the process for evaluating RDS reliability following DG placement:

- Step 1: Figure 3(a) illustrates the Parallel Series Configuration (PSC).
- Step 2: Utilizing Equations 11 and 12, determine the Failure Rate (FR) and Repair Time (RT) for each cut-set, according to Figure 3(b). The FR and RT at each ith load are represented by λci and rci, respectively, where i = 1, 2.
- Step 3: Once the DG is connected in parallel to the ith load,as shown in Figure 10, compute the FR and RT again using Equations 11 to 12.

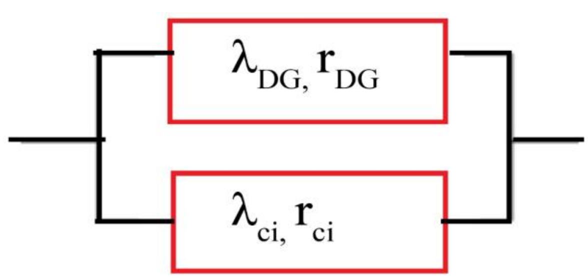

Fig. 10 DG connected in parallel to the ith load

- Step 4: After placing the DG as indicated in Figure 11, draw the updated PSC of the system of Figure 3(b).
- Step 5: Calculate the system EFR and ERT using Equations 13 to 15.

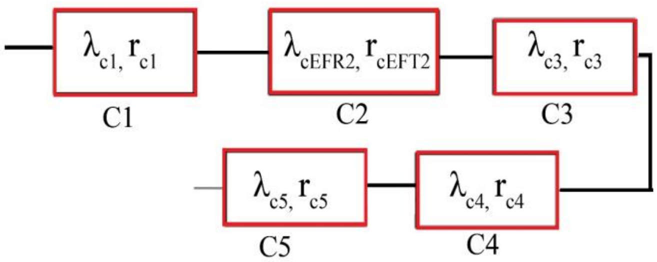

Fig. 11 System of Figure 3, (a) Modified PSC following DG placement

- Step 6: Finally, calculate the customer-oriented performance indices.

Table 11. Performance Indices Assessment for 33–bus Reconfigured RDS and after DG

Index	Reconfigured RDS	Reconfigured RDS with DG	% Decrease
CAIDI	0.754	0.7307	3.1
SAIDI	1.634	1.5469	5.5
SAIFI	2.167	1.9786	8.6
ASAI	1.87e-4	1.65e-04	11.7

Table 11 indicates that the improvement of CAIDI, SAIDI, SAIFI, and ASAI on the 33-Bus RDS is reduced by 3.1%, 5.5%, 8.6%, and 11.7%, respectively, with DG optimum placement. Thus, there is an improvement in reliability.

5. Conclusion

Loss minimisation for different systems, the formation and application of the Network Reconfiguration, and the computational process for the ideal placement and dimensions of DG have been the main areas of work. Performance indicators and basic probability indicators are evaluated using the Cut-set Approach. A method for reconfiguring distribution systems using LSF has been developed and applied to IEEE 33-bus and 6-bus RDS, and it has been found that the proposed method enhances the voltage profile, stability margin, system reliability, and decreases the power losses of the system.

Only for IEEE 33-bus and 6-bus systems is Network Reconfiguration with and without DG installation taken into consideration to demonstrate the superiority of the suggested approach. According to the findings, better outcomes are obtained by installing DG and reconfiguring the network. The impact of DG placement on reliability indices, voltage stability margin, and power loss reduction has been investigated.

The combined application of reconfiguration and the DG placement algorithm yields considerable benefits. Active and reactive power losses decrease by 58.7% and 50.7% respectively, while voltage profiles strengthen by 5% (from 0.9131 to 0.9532 p.u). Reliability performance also improves across all metrics, with SAIFI, SAIDI, CAIDI, and ASAI showing a reduction by 17.9%, 24.5%, 14.1%, and 29.18%, respectively.

Loss minimization through reconfiguration inherently offers economic benefits because a reduction in kW loss directly reduces the cost of energy wasted in the network.

5.1. Future Work

Although multiple DG Coordination has been carried out in the literature, the present work mainly focuses on only DG placement to demonstrate the performance of the proposed optimization technique. An extension of subsequent work will be handled with two or more DGs.

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