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Dynamic Reconfiguration of Distribution Networks Considering the Dynamic Topology Variation

by

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CERTIFICATE OF APPROVAL

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ABSTRACT

Electrical distribution networks undergo dynamic transformations due to continuous alteration and variation of loads. These alterations necessitate engineering studies aimed at optimizing the distribution networks. Reconfiguring networks stands as a critical analysis process essential for enhancing and managing distribution systems (DSs). When starting with a stable initial DS, the distribution feeders can be reconfigured by adjusting switch statuses to enhance operational performance. Changes in the initial topology can occur due to equipment maintenance, system expansion, or fault incidents, with branch additions or removals. In this study, we introduce a dynamic reconfiguration approach that takes into account dynamic variations in the initial topology. This methodology integrates dynamic topology analysis and network reconfiguration to address current distribution network optimization issues. The original DS topology is characterized by a collection of independent topological parameters. Dynamic topology analysis helps to identify changes in the original topology and identify locations that are out of service in order to restore network connectivity. These topological parameters are then updated to determine the initial topology in present time. We identify the best configuration to reduce power losses and improve the voltage profile of the dynamic distribution network in accordance with network reconfiguration. This thesis takes two examples: IEEE 33-bus system & 11kV Distribution feeder under NEA. The provided examples demonstrate the application of the proposed approach for reconfiguring a dynamic distribution network.

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TABLE OF CONTENT

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATION

Abbreviation	**Full Form**
AQPSO	Adaptive Quantum Particle Swarm Optimization
DG	Distributed Generation
DS	Distribution System
IEEE	Institute of Electrical and Electronics Engineers
MATLAB	Matrix Laboratory
MVA	Mega Volt Ampere
MVAR	Mega Volt Ampere Reactive
MW	Mega Watt
NEA	Nepal Electricity Authority

LIST OF SYMBOL

Symbol	Name
Pu	Per unit
I_i	Injected current at bus i
P_i	Active power at bus i
Q_i	Reactive power at bus i
I	Current
V	Node voltage
z	Impedance of the branch
N_{br}	Number of branches

CHAPTER 1. INTRODUCTION

1.1 Background

Electrical distribution networks undergo dynamic transformations due to continuous alteration and variation of loads. These alterations necessitate engineering studies aimed at optimizing the distribution networks. Power loss in the distribution network is one of the challenging issues for utilities in present context. The utilities are required to cater the demand including the power loss in the system which means that there is requirement of generation capability more than the demand in the system. This means that the capital cost as well as running cost of utilities increases reducing the profit. The utilities are applying various techniques to reduce the power loss in the system like reconfiguration of network (which includes transformer allocation, conductor resizing, feeder restructuring), Capacitor placement and distributed generation.

Several methods of reconfiguring networks have been developed to improve Distribution Systems (DS) performance. These methods seek to lessen power loss, improve power quality, and lessen voltage sag inside the DS.

The distribution network directly conveys electrical energy from intermediate transformer substations to consumers. Unlike transmission networks, which often employ loops or radial structures, distribution networks consistently operate in a radial manner. This radial configuration significantly reduces short-circuit currents. The restoration of the network from faults involves manipulating electrical switch pairs on loops. Consequently, the distribution network is equipped with numerous switches. Distribution network reconfiguration (DNR) involves altering the topological arrangement of distribution feeders by adjusting the open/closed status of sectionalizing and tie switches, while adhering to system constraints and meeting operator objectives.

'Ideal Normal Mode' architecture is usually used in practical applications for the initial DSs, where sectionalizing branches are used to connect all loads in a radial network structure. Nonetheless, there are two kinds of occurrences that could cause DSs' original topologies to change:

1. Adding new branches
2. Cutting off branches

These modifications can result in the removal of isolated loads and the disconnection of some healthy loads due to faulted section isolation. The original topology is changed to accommodate new feeders and substations as DSs grow. Consequently, network reconfiguration must account for dynamic changes in the initial topology.

1.2 Problem Statement

The network topology is altered by traditional network reconfiguration in accordance with tie switch locations. When reconfiguring, every bus needs to remain linked to the source node. However, due to nodes and branches being added or removed as a result of faults or system expansions, the initial topology changes dynamically, necessitating a process to restore network connectivity.

In order to optimize system performance, goals like reducing power loss and improving the voltage profile while reconfiguring the network must be taken into account. In order to find the best configuration for maintaining the Distribution System's safe, economical, and reliable operation within framework of evolving initial topology, dynamic topology analysis is utilized in conjunction with a dynamic reconfiguration technique.

1.3 Objectives

The main objective of the study is to maximize the configuration of the dynamic distribution network while taking into account dynamic modifications to the initial topological structure. In order to tackle this issue, a novel approach known as dynamic reconfiguration is presented, which successfully combines network reconfiguration and dynamic topology analysis.

1.4 Scope and Limitations

- ❖ Instead of using a fixed topological network, a new methodology for dynamic reconfiguration in distribution systems (DS) is based on dynamic initial topology.
- ❖ The optimal configuration to reduce power loss and enhance voltage profiles.

However, network reconfiguration requires extensive study of the system which means that the complexity increases with the increase in size of the network.

CHAPTER 2. LITERATURE REVIEW

2.1 The Distribution Power System

A distribution power system is a crucial component of the overall electrical power infrastructure, responsible for delivering electricity from the transmission network to end-users. It plays a vital role in ensuring a reliable and efficient supply of electricity to homes, businesses, and various other entities. The distribution system is the final stage in the journey of electrical power before it reaches its ultimate destination.

Key components and features of a distribution power system include:

1. Substations:

Distribution substations serve as the interface between the transmission and distribution systems. They transform the high-voltage electricity received from the transmission lines into lower voltages suitable for distribution to end-users.

2. Feeders:

Feeders are circuits that carry electricity from the substations to various areas within a community or region. They form the backbone of the distribution system and are responsible for delivering power to neighborhoods, industrial zones, and commercial areas.

3. Transformers:

Distribution transformers are strategically placed throughout the distribution network to further reduce voltage levels and make electricity safe for use in homes and businesses. They convert the medium voltage from feeders into the low voltage required for consumer applications.

4. Distribution Lines:

Overhead and underground distribution lines transport electricity from transformers to individual consumers. Overhead lines are often seen on utility poles, while underground lines are laid beneath the ground for aesthetic and safety reasons.

5. Switchgear and Protection Devices:

To regulate the flow of electricity and provide protection against malfunctions or disruptions, switchgear and protective devices are installed at different locations throughout the distribution system. These devices help isolate faulty sections, ensuring that disruptions are minimized, and safety is maintained.

6. Metering and Control Systems:

Metering systems are employed to measure and monitor the consumption of electricity by end-users. Advanced control systems enable utilities to manage the distribution network more efficiently, responding to changes in demand and optimizing the overall performance of the system.

7. Smart Grid Technologies:

Modern distribution power systems are increasingly incorporating smart grid technologies. These technologies use advanced communication and information technologies to enhance the efficiency, reliability, and sustainability of the power distribution process.

8. Distributed Energy Resources (DERs):

The integration of renewable energy sources, energy storage systems, and other distributed energy resources is becoming more common in distribution power systems. This shift towards decentralized power generation contributes to a more resilient and sustainable energy infrastructure.

Efficient distribution power systems are essential for meeting the growing demands for electricity, improving reliability, and integrating renewable energy sources into the grid. As technology continues to advance, the development of smarter and more adaptive distribution systems will play a pivotal role in shaping the future of electrical power distribution.

Calculating power flow is a crucial numerical analysis, frequently nonlinear, essential for conducting studies on power systems. Implementing proposed techniques to reduce losses in the power distribution network usually involves multiple iterations of power flow analysis algorithms. The methodologies employed for power flow in distribution systems must be tailored to the specific characteristics of the distribution network. This adaptation involves incorporating single-phase and three-phase unbalanced system analysis, along with considering the impact of interconnected distributed generation. In distribution systems, the goals involve minimizing power losses and improving voltage profiles. Therefore, performing power flow analysis is a crucial procedure to acquire the steady-state electrical characteristics of the distribution system resulting from its reconfiguration. Typically, Gauss-Seidel, Newton-Raphson (NR), and its decoupled version are utilized for power flow analysis in transmission systems. Typically, these power flow techniques are employed with a focus on balanced systems, utilizing a single-phase representation for a three-phase system. However, the unique features of distribution systems, such as unbalanced loads, radial topology, frequently un-transposed lines, distributed generation, etc., render the assumptions made in the analysis of transmission systems inapplicable to distribution systems. Therefore, it becomes essential to adopt a power flow method that accounts for three-phase unbalanced networks when applying it to distribution systems. The forward/backward methods, widely used for power flow analysis in distribution systems, can handle unbalanced phase systems. Nevertheless, their applicability is restricted to radial networks, and they lack the capability to account for the impact of distributed generation in both phase frame and sequence frame references. The modified Newton method has proven successful in distribution systems primarily due to its representation of the Jacobian matrix, which is constructed based on the characteristics of the network topology. MATPOWER toolbox is used in this thesis work to compute power flows.

2.2 Review of Research Articles

[1-7] examined the development of diverse network reconfiguration techniques aimed at enhancing the performance of distribution systems (DS). These techniques encompass enhancements in power quality, reduction of power loss, and mitigation of voltage sag, among other goals.

[8, 9] asserted that the original topology of distribution systems (DSs) can undergo modifications due to two cases: adding new branches and cutting off branches. Additionally, [10, 11] discovered that the isolation of a faulted section may lead to the removal of certain isolated loads and the disconnection of some healthy loads.

As distribution systems (DSs) expand, incorporating new substations and feeders into the original topology, dynamic changes in the original topology should be taken into account, as emphasized by [12, 13].

Due to the regular occurrence of scheduled and forced outage in distribution systems, the removal of one or more faulty branches results in the isolation of some healthy branches. In such situations, the prevailing approach involves employing network reconfiguration to ensure a sufficient supply of energy to disconnected branches, as highlighted by [14, 15].

It is imperative to take into account the economic implications of minimizing system power loss while carrying out the service restoration procedure. There is a chance that another topology change will take place when the distribution system (DS) is extended and one or more branches are integrated into the initial system. Several endeavors have been undertaken to enhance power loss minimization and voltage profile through reconfiguration techniques in the context of optimal distribution network planning, as discussed by [19-22].

CHAPTER 3. METHODOLOGY

3.1 Block Diagram

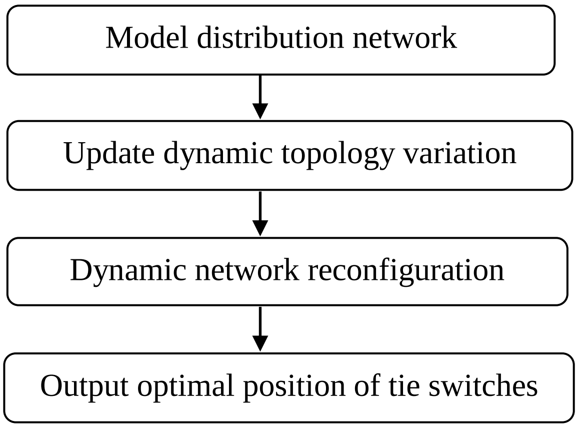

Figure 3.1 Block diagram for methodology

3.2 Dynamic Topology Analysis

3.2.1 Modeling Distribution Network

Bus bars and electrical components (switches, feeders, and protection devices) are represented as nodes and branches, respectively, in a topological graph of a distribution system. System consists of two types of switches: sectionalizing switches that link line segments and tie switches that link two feeders. Switches are represented in the model as tie and sectionalizing branches.

Distribution System typically follows a radial operational pattern. A thorough understanding of a standard distribution network's architecture requires an examination of important topology ideas. To illustrate the connectivity of the topology graph G, we employ a connected tree S_G. Together, the nodes in S_G make up an electrical island S_D. A loop, on the other hand, is a closed path that begins at one node, passes through several nodes, and returns to initial node. Within distribution system, tie branches are closed to create closed loops.

The concept of a loop vector—a group of branches in the network collectively creating a closed path—is introduced in this section. Most importantly, each loop consists of a single tie branch that stands alone from the others. As a result, there are exactly as many loops as tie branches. Branches can be divided into two categories: non-loop branches and loop branches.

It is possible to arrange the set of loop vectors into a matrix called the "loop matrix," or L_{op}. There are n nodes and n_{op} tie branches in a DS. Specifically, the row-column dimension of the loop matrix L_{op} is $n_{op} \times m_{op}$, where m_{op} is the total number of branches in the loop with the maximum number of branches. Every row in L_{op} corresponds to a different loop vector, and every element in a row represents a branch of that loop. The tie branches connected to the loops are indicated by the first column elements.

The following steps are carried out in order to obtain the topological parameters: [26]

1) Examine topology G's standard starting data.

2) Set initial values for electrical island S_{Dk}, connected tree S_{Gk}, root node $v_r = 1$, root node vector $V_r = []$, initial label $k = 1$.

3) Create adjacency matrix $A = (a_{vivj})_{n*n}$ of G. If a branch connects node v_i and node v_j , then $a_{vivj} = 1$. Otherwise, $a_{vivj} = 0$.

4) By examining matrix A, find path P_i from root node v_r to an unmarked node v_i ($i \in (2\ldots n)$)

5) Mark node v_i, then save to S_{Dk}, with matching branches stored to S_{Gk} if path P_i exists; if not, save it to V_r.

6) Verify network access. Proceed to (7) if every node in the system is included in the electrical island S_{Dk}. If not, proceed to (8).

7) Construct the L_{op} loop matrix. Two paths are extracted from a tie branch's root node (v_r) to its end nodes. Next, find the location where the two paths intersect. By beginning at point where paths meet, traveling via group of nodes, then ending at begining node, a closed path is created. Loop matrix L_{op} is produced by all closed paths.

8) The topological parameters should be output if every node has been marked. Otherwise, update the root node v_r , set $k = k + 1$; and return to (4)

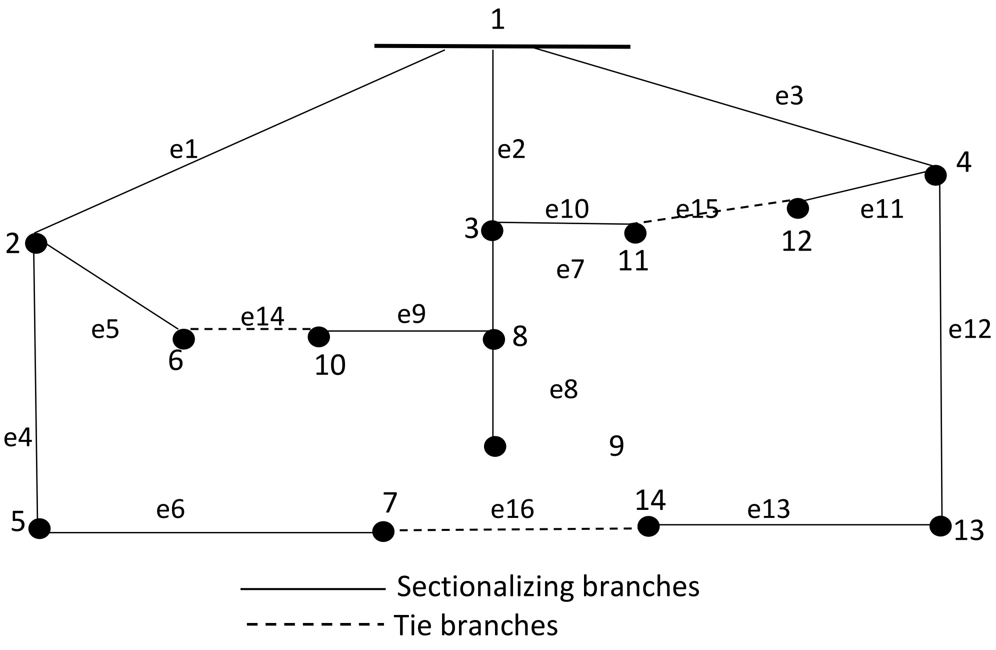

Figure 3.2 General System [26]

Examining Fig. 3.2, we find a basic system consisting of 14 nodes, 3 tie branches, and 13 sectionalizing branches. Connected tree $\boldsymbol{S_G}$ = [e_1–e_{13}], electrical island $\boldsymbol{S_D}$ = [1–14], and L_{op} are achieved.

$$\mathbf{L}_{op}=\begin{bmatrix} e_{14} & e_1 & e_2 & e_5 & e_7 & e_9 & 0 \\ e_{15} & e_2 & e_3 & e_{10} & e_{11} & 0 & 0 \\ e_{16} & e_1 & e_3 & e_4 & e_6 & e_{12} & e_{13} \end{bmatrix} \quad \ldots\ldots\ldots\ldots \ (1)$$

3.2.2. Dynamic Topology Update

There are two different kinds of events that make up the topology changes in the network:

- ❖ Cutting off branch and
- ❖ Adding new branch.

The following is how the changes can be tracked using the topology updating strategy:

Removal of a loop branch:

Loop and non-loop branches are two categories given to branches, as was previously indicated. A faulty branch is permanently disconnected when a fault arises within a system segment. This topology update process discussion takes these two branch types into account.

Changes to the loop matrix, $\boldsymbol{L}_{op}$, result from the removal of loop branch e_i. However, network access is unaffected because branch e_i's terminal nodes are connected via a different path. As the loop matrix serves as the foundation for generating solutions in network optimization, selecting an open loop vector that minimizes the amount of topology parameter changes is the aim.

First, we determine which loop vectors contain the removed branch in order to accomplish this. Subsequently, we pinpoint the open loop vector, denoted as $\boldsymbol{i}_{op}$ characterized by the fewest branches. In an extreme scenario, the removed branch appears in only one loop vector, which is called open loop vector. Any of them could be selected as open loop vector where each loop vector has the same number of branches.

The next steps are updating topological parameters and reestablishing network connection after $\boldsymbol{i}_{op}$ has been identified. Since tie branches are normally open, the network's connectivity is unaffected even if e_i happens to be a tie branch. In this instance, loop $\boldsymbol{i}_{op}$ is eliminated in order to modify the loop matrix, L_{op}.

However, if e_i is a sectionalizing branch, restoring network connectivity requires closing the tie branch within loop $\boldsymbol{i}_{op}$ effectively transforming it into a sectionalizing branch. Moreover, the techniques from the previous section are applied to obtain new topological parameters. After the fault, a loop branch e_1 is removed from the network shown in Fig. 3.2. Branch e_1 is contained in the open loop vector $\boldsymbol{i}_{op}$, which is dotted by [e_{14}, e_1, e_2, e_5, e_7, e_9]. $\boldsymbol{S_G}$ = [e_2–e_{14}] can take the place of the sectionalizing branches [e_1–e_{13}] since the tie branch e14 has been converted to a sectionalizing branch. Finally, the loop matrix $\boldsymbol{L'}_{op}$ and electrical island $\boldsymbol{S_D}$ = [1– 14] are discovered.

$$\mathbf{L'}_{op}=\begin{bmatrix} e_{15} & e_2 & e_3 & e_{10} & e_{11} & 0 & 0 & 0 & 0 & 0 & 0 \\ e_{16} & e_2 & e_3 & e_4 & e_5 & e_6 & e_7 & e_9 & e_{12} & e_{13} & e_{14} \end{bmatrix} \quad \dots\dots\dots (2)$$

Removing non-loop branch:

When a branch without a loop is disconnected, an isolated electrical island is created. Utilizing a radius search method facilitates the identification of this isolated island. A line connecting two nodes in a connected topology, represented by G, is given a weight value w_{ij} if matching nodes creats an edge. Radius given by formula

$$r_G = \min_{u \in V}\ \max_{v \in V} (d(u,v)) \quad \dots\dots\dots (3)$$

Here d(u,v) denotes distance between nodes u and v and V denotes nodes set on graph G.

Cutting off a branch without a loop forms isolated electrical island. Starting at the disconnected branch's terminal node, this island is created by moving through a series of nodes and branches until it reaches the tree's boundary points, which are represented by the notation $n_r = r_G - 1$. Within isolated electrical island, every branch differs from original topology. Methods described in Section 3.1.1 are followed in the generation of new topological parameters.

Branch e_8 is removed, as shown in Fig. 3.2, and the radius search method is then used to locate a new electrical island, S_{D2} = [9]. S_{G1} = [e_1–e_7, e_9–e_{14}] and S_{D1} = [1–8, 10–14] are the topological parameters in current time.

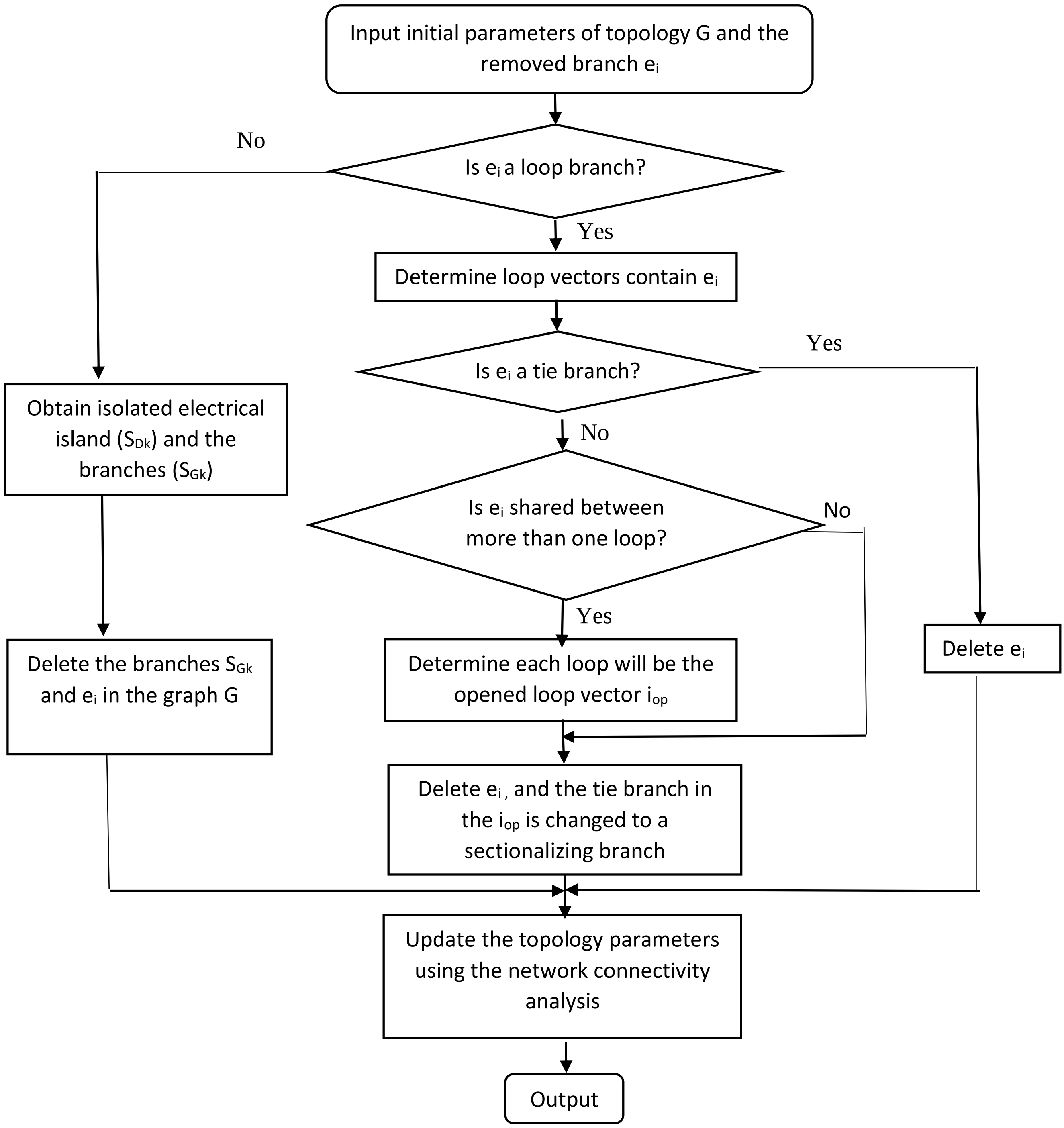

Fig 3.3 Flowchart of Dynamic Topology Update [26]

Consequently, the process of updating dynamic topology is listed in Figure. 3.3 after branch is detached.

Adding new branches:

More feeders and nodes is inserted in existing Distribution System (DS) to satisfy customer requirements. The focus of this approach is on monitoring topology modifications and acquiring the initial network status in current time. The following series of actions is used to identify the topological changes that result from the introduction of a new branch e_i that connects node v_1 to node v_2.

i. Branch e_i is a tie branch if nodes v_1 and v_2 are part of the same electrical island S_D. The branch is typically open to guarantee radial system functionality.

ii. Branches e_i are sectionalizing branches and are typically closed if nodes v_1 and v_2 are part of two distinct electrical islands. In both electrical islands, the tie and sectionalizing branches are combined.

By following these procedures, the network connectivity is examined in order to determine the current topological parameters.

3.3 Dynamic Reconfiguration Methodology

This study's network reconfiguration can be seen as a dynamic challenge, in contrast to conventional reconfiguration problems that usually entail initial topology modifications. In the conventional context of network reconfiguration, repositioning tie switches necessitates maintaining the connection between all buses and the source node, which modifies the topology.

However, this dynamic approach introduces alterations to the initial topology due to node and branch additions or removals following fault incidents or system expansions. This necessitates a process to restore network connectivity. To enhance operational efficiency, network reconfiguration should address objectives related to minimizing power losses and enhancing voltage profiles.

The best configuration is found by combining dynamic topology analysis with reconfiguration technique within the evolving original topology model that ensures the Distribution System (DS) operates in a safe, economical, and high-quality manner.

3.3.1 Problem Formulation

Dynamic reconfiguration’s goal, taking into account the dynamic nature of the initial topology, is to use the dynamic topology analysis to quickly restore network connectivity. Following the restoration of network connectivity, the system's voltage profile enhancement and power loss minimization should be taken into account. The real power, reactive power, and voltage magnitude at the sending end i of a branch are P_i, Q_i, and V_i, respectively, based on the power flow calculation in [23]. The following formula is used to calculate power loss $P_{loss(i,i+1)}$ of branch connecting nodes i with i + 1:

$$P_{loss(i,i+1)} = r_i \frac{P_i^2 + Q_i^2}{V_i^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(4)}$$

where V_i is the voltage amplitude of node i, r_i is the resistance of the branch between nodes i and i+1, and P_i and Q_i are the active and reactive power flows from node i.

The total power loss of a current distribution network $G_r(n,m)$ containing n nodes, m line segments is calculated by adding up all of the line section losses. The following is an expression for the formulation:

$$\min \left(\sum_{i=1, i \in G_r}^{m} k_i r_i \frac{P_i^2 + Q_i^2}{V_i^2} \right) \quad \ldots\ldots\ldots\ldots\ldots\ldots \text{(5)}$$

where k_i is the status of branch e_i ; $k_i = 1$ in the case of closed branch, and $k_i = 0$ in the case of an open branch, where m denotes number of branches in the current network $G_r(n,m)$;

Objective function for improving the system profile is to maximize the minimum node voltage amplitude, which can be computed as follows:

$$\max\left(\min\left(V_i / V_{ref}\right)\right), \quad i \in (1, \ldots, n)) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.. \quad \text{(6)}$$

here V_{ref} represents reference voltage magnitude.

Power loss and enhancing voltage magnitude in system are related. Overall voltage values in the network are improved when power loss is reduced because voltage drop is also reduced. The following is a list of the operational constraints that must be fulfilled:

$$I_i \leq I_{i.max}$$

$$V_{i.min} \leq V_i \leq V_{i.max} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad \text{(7)}$$

$$g \in T_{Gr}$$

Here 'max' represent upper limits and 'min' represent lower limits. Current flowing through branch e_i has been represented by I_i . A network structure is denoted by g. Within the real-time topology G_r, T_{Gr} indicates group of radial network structures.

3.3.2. Optimization Algorithm for Dynamic Reconfiguration

An approach to reconfiguration is presented, that integrates network reconfiguration and dynamic topology analysis to address the optimization problem of the DS while accounting dynamic topology change.

Finest arrangement for reducing power loss and improving the voltage amplitude is determined by reconfiguring the network after a topology change. We formulate the problem as a complex combinatorial optimization problem. Building upon the concepts of particle swarm optimization, an adaptive quantum particle swarm optimization (AQPSO) algorithm has been provided to solve this issue. Dynamic modification of AQPSO's variables is made possible by the dynamic topology variation. The tie branch is indicated by the first element in each column when looking at updated loop matrix L′op. Sectionalizing branches and tie branches create the loop within each column. A series of decimal numbers, starting at 1 to total number of line segments in column, are used for representing branches inside the loop. At least one branch inside the loop must be opened in order to guarantee a radial system assembly. The particle vector represented by $x = (x_1, x_2, \dots, x_j)$ is a solution. The identification number of the branch that is meant to open is represented by particle *j*'s position x_j. Following the principles outlined in [24], the adaptive quantum particle swarm optimization (AQPSO) is capable of attaining the optimal solution through continuous updates to particle's position. The vector $x_{jd} = (x_{j1}, x_{j2}, \dots, x_{jD})$ represents the particle *j* solution vector inside D-dimensional search space. Expression $p_{jd}(t) = (p_{j1}, p_{j2}, \dots, p_{jD})$ represents the current best position of particle *j* during iteration *t*. $\text{mbest}(t) = (\text{mbest}_{j1}, \text{mbest}_{j2}, \dots, \text{mbest}_{jD})$ is the notation for the global best position. Particle *j's* revised position is altered using equation given below, that uses its previous position $x_{jd}(t)$ to determine the position $x_{jd}(t + 1)$ within iteration $t + 1$.

$$x_{jd}(t+1) = round(p_{jd}(t) \pm \beta * |mbest(t) - x_{jd}(t)| * In\,(1/u)) \quad \dots\dots\dots\dots\dots (8)$$

$$mbest(t) = \frac{1}{M} \sum_{j=1}^{M} P_{jd(t)} \quad \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (9)$$

The initial and updated positions for particle *j* are denoted as $x_{jd}(t)$ and $x_{jd}(t + 1)$, respectively, in this case. Uniformly distributed random numbers within the range [0,1] are indicated by u and φ. The integral calculation makes use of the round() function, and the algorithm's speed of convergence is controlled by β.

The following describes the process for dynamic reconfiguration: [26]

i. Standard topology G is initialized, and initial parameters $\mathbf{S_G}$, $\mathbf{S_D}$, and $\mathbf{L_{op}}$ are identified.
ii. Step (3) should be followed if a topology change is found; if not, step (4) should be followed.
iii. Get network connectivity back. Current stage promptly assesses network's connectivity and the status of branches through dynamic topology analysis. It is possible to obtain the new loop matrix L ′op and new topology Gr by preserving the branch states.
iv. Revise AQPSO's parameters. Define the solution particle vector as $x = (x_1, x_2, \ldots, x_j)$ using matrix $L'op$ or Lop. Next, use M vectors to create a random population P.
v. Analyze each particle's radiality in population P, where each answer denotess a possible topology candidate. One way to conceptualize the topology graph is as an adjacency matrix A_r. The determinant of A_r is used to calculate the radiality of solutions. Proceed to step (5) if the determinant of A_r equals 1 or −1. If not, place particle's pbest to C.
vi. Each particle's fitness values is calculated as (pbest) and save as (mbest) particle with highest fitness value.
vii. Position vectors for each particle is adjusted in accordance with (8) and (9).
viii. Keep going through stages (6) and (7) till the completion of a criterion. The best solution shown by the resulting x*.
ix. Look at changes to the original topology. Proceed to step (2) if there is a change, and output x* otherwise.

3.4 System Under Consideration, Tools and Software

3.4.1 System Considered

3.4.1.1 IEEE 33 test bus System and Distribution feeder under NEA

The IEEE 33-bus test system of MATPOWER is selected to evaluate the performance of proposed model. After being evaluated on IEEE 33-bus system, the model will be then validated on Distribution feeder under Nepal Electricity Authority.

Case I: IEEE 33 Bus System

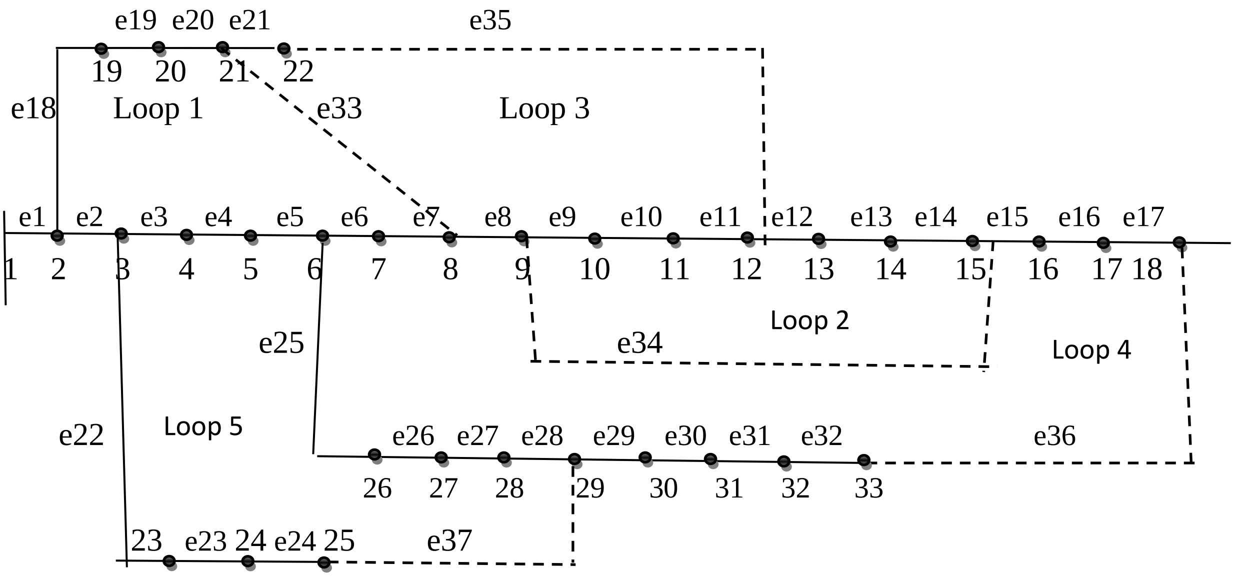

Figure 3.4: Single Line Diagram of IEEE 33 Bus System [26]

Under typical conditions, the initial configuration of the 33-bus system is illustrated in Figure 3.4, with detailed system data provided in Appendix-A. In this setup, switches e_1–e_{32} are normally closed, while switches e_{33}–e_{37} are normally open. The initially connected tree is denoted as $\mathbf{S_G} = [e_1 – e_{32}]$, and the loop matrix Lop is described as follows.

$\mathbf{L}_{op}$=

$$\begin{bmatrix} e_{33} & e_2 & e_3 & e_4 & e_5 & e_6 & e_7 & e_{18} & e_{19} & e_{20} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ e_{34} & e_9 & e_{10} & e_{11} & e_{12} & e_{13} & e_{14} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ e_{35} & e_2 & e_3 & e_4 & e_5 & e_6 & e_7 & e_8 & e_9 & e_{10} & e_{11} & e_{18} & e_{19} & e_{20} & e_{21} & 0 & 0 & 0 & 0 & 0 & 0 \\ e_{36} & e_6 & e_7 & e_8 & e_9 & e_{10} & e_{11} & e_{12} & e_{13} & e_{14} & e_{15} & e_{16} & e_{17} & e_{25} & e_{26} & e_{27} & e_{28} & e_{29} & e_{30} & e_{31} & e_{32} \\ e_{37} & e_3 & e_4 & e_5 & e_{22} & e_{23} & e_{24} & e_{25} & e_{26} & e_{27} & e_{28} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix} \quad .. (10)$$

Case II: Kohalpur Feeder (Practical Feeder)

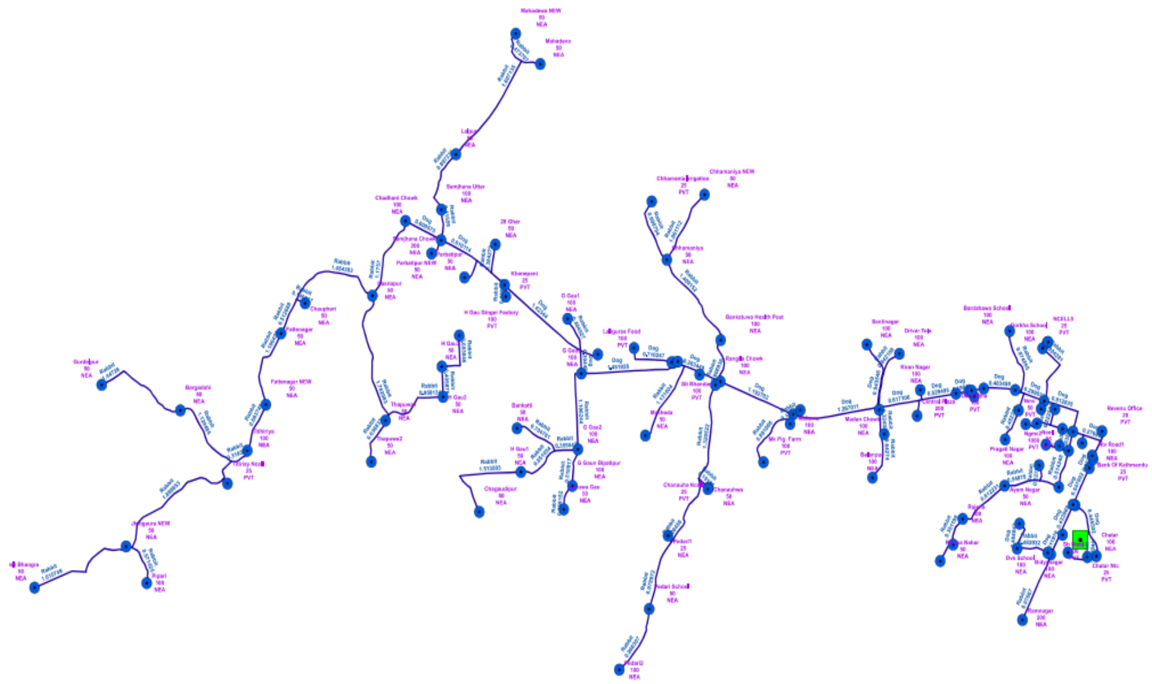

Figure 3.5: Single Line Diagram of 65 bus Kohalpur Feeder

3.4.2 Tools and software

The technological advancement in computer architecture, software and programming tools have made the modelling and analysis of power system easy. In the past, the modelling and analysis were difficult, time-consuming and inaccurate. Many software tools use the mathematical model to simulate the performance of a power system to that of the real component. MATLAB have been used in this thesis for solving the optimization problem along with MATPOWER 7.1 environment.

CHAPTER 4. RESULT AND DISCUSSION

4.1 IEEE 33-bus system

This thesis considers two examples: IEEE 33-bus system and 11kV Distribution feeder under NEA. The provided examples demonstrate the application of the proposed approach for reconfiguring a dynamic distribution network. In this system, the substation voltage is set at 1.0 per unit, with voltage limits ranging from 0.913 to 1 p.u. Lower limit of voltage is set after getting minimum node voltage from load flow analysis. We do not set higher voltage value for both lower and higher voltage limits as we could not build up voltage just by changing the tie switch connection and the iteration will not converge. The branch current constraint is 500 amperes (A), and P_{loss} represents the active loss of the network, while V_{min} signifies the minimum voltage among all nodes. For dynamic reconfiguration optimization algorithm, population size denoted as ***P*** is 50 and number of iteration is 20.

Relays and circuit breakers are examples of protective devices that work to isolate faults in distribution systems (DSs) and isolate specific downstream branches from being connected to the current topology. These scenarios serve as examples of how to fix network connectivity issues and figure out the topological structure after removing a branch or branches. The reconfiguration results, guided by current time topology, are presented in Table 4.1.

Case 1: Network reconfiguration without faults: Here an investigation is conducted on a fault-free system. Assuming the regular operation of the initial topology, in which every nodes are linked to create the starting topology through sectionalizing branches, network reconfiguration represents an optimal optimization problem. As a result, the issue is resolved by following the procedures described in Section 3.3 without utilizing the dynamic topology update. Table 4.1 displays the results of the best configuration for this scenario. In comparison to the initial topology, there is a reduction in losses by 190.3 kW, and the minimum voltage value is enhanced to 0.91421 p.u.

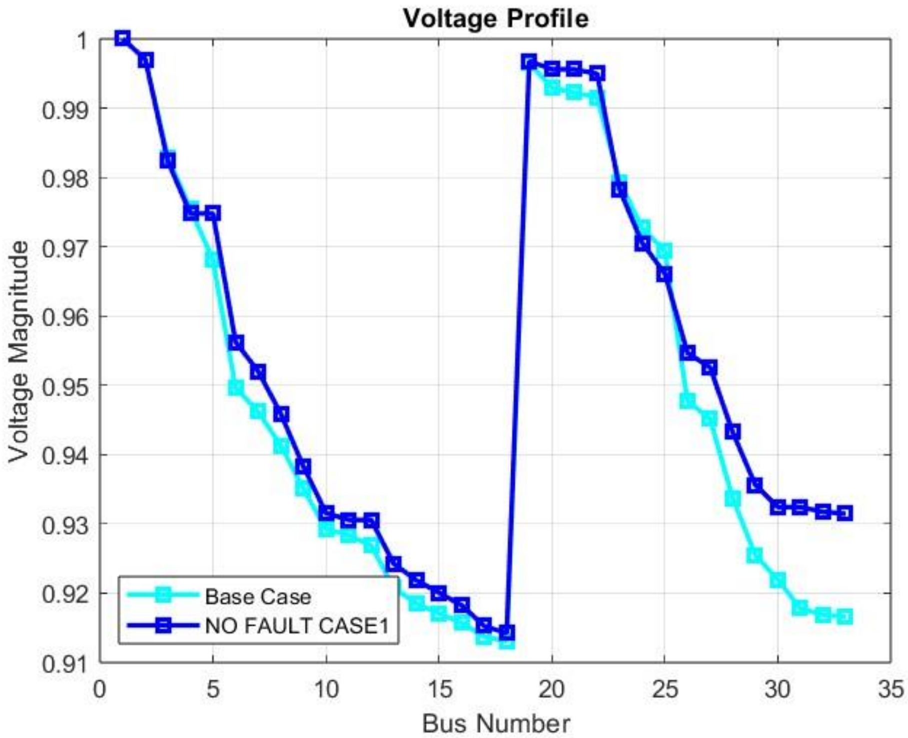

Figure 4.1: Voltage Profile of reconfigured network without fault case

***Case 2: Network reconfiguration accompanied by single branch fault*:** The current sectionalizing branch connecting nodes 26 and 27 is removed in order to address long term fault on segment e_{26}; as a result, nodes 27–33 are left without energy. Updating original topology and bringing back electric energy to healthy loads is the goal. Despite the fact that loops 4 and 5 share a branch, e_{26}, vector 5 has been chosen to be an open vector i_{op} since it contains fewest line segments. By shutting tie branch e_{37}. the power supply to the area without supply can be reestablished. The revised group of sectionalizing branches is represented by the notation $S_G = [e_1 – e_{25}, e_{27}–e_{32}, e_{37}]$. Below is a description of the loop matrix after network connectivity has been restored. Our method determines that the ideal configuration in this revised initial topology is $[e_3, e_8, e_9, e_{16}, e_{37}]$, with a power loss of 176.35 kW. By utilizing switch operations, the decision-maker can re-establish network connectivity and attain an optimal solution, thereby improving the operational efficiency of the system. Figure 4.2 depicts the voltage profile of the reconfigured network. Following the isolation of faulty branch e_{26}, the system is divided into two groups.

$\mathbf{L'}_{op} =$

$$\begin{bmatrix} e_{33} & e_2 & e_3 & e_4 & e_5 & e_6 & e_7 & e_{18} & e_{19} & e_{20} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ e_{34} & e_9 & e_{10} & e_{11} & e_{12} & e_{13} & e_{14} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ e_{35} & e_2 & e_3 & e_4 & e_5 & e_6 & e_7 & e_8 & e_9 & e_{10} & e_{11} & e_{18} & e_{19} & e_{20} & e_{21} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ e_{36} & e_3 & e_4 & e_5 & e_6 & e_7 & e_8 & e_9 & e_{10} & e_{11} & e_{12} & e_{13} & e_{14} & e_{15} & e_{16} & e_{17} & e_{22} & e_{23} & e_{24} & e_{29} & e_{30} & e_{31} & e_{32} & e_{37} \end{bmatrix} \quad \text{.. (11)}$$

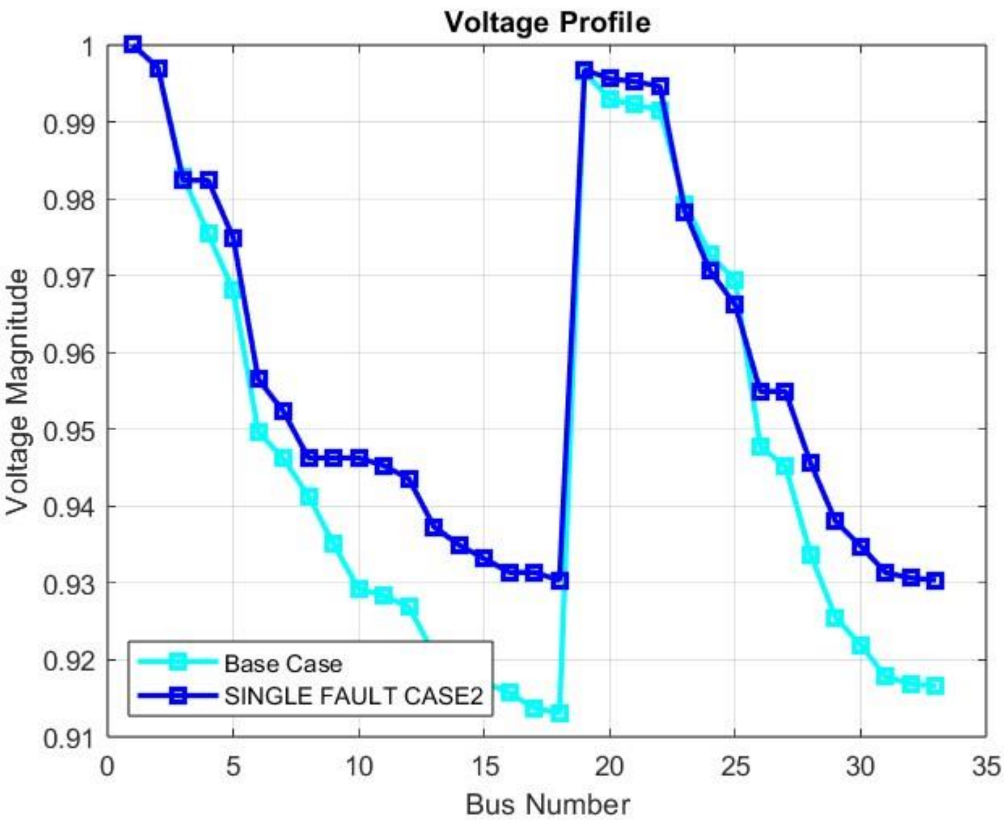

Figure 4.2: Voltage Profile of reconfigured network for single fault case

Case 3: Network reconfiguration accompanied by double-branch fault: Let's consider scenario where a fault happens on lines e_{12} & e_{14}. Upon isolating branches e_{12} and e_{14}, power feed to loads at nodes 13–18 is disrupted. While loads without supply can be reestablished, nodes 13 and 14 remain without power. As a result, the initial topology splits into two smaller electrical islands. Connected topology's loop matrix is given below. Following reconfiguration, a power loss of 180 kW is attained. System's voltage profiles in both initial and ideal scenarios are shown in Figure 4.3. Branch e_{34} can be closed to restore electrical energy to the loads at nodes 15–18 through dynamic reconfiguration. The real-time system's minimum voltage magnitude is 0.9380 p.u.

$\mathbf{L'}_{op}$ =

$$\begin{bmatrix} e_{33} & e_2 & e_3 & e_4 & e_5 & e_6 & e_7 & e_{18} & e_{19} & e_{20} & 0 & 0 & 0 & 0 & 0 & 0 \\ e_{35} & e_2 & e_3 & e_4 & e_5 & e_6 & e_7 & e_8 & e_9 & e_{10} & e_{11} & e_{18} & e_{19} & e_{20} & e_{21} & 0 \\ e_{36} & e_6 & e_7 & e_8 & e_{34} & e_{15} & e_{16} & e_{17} & e_{25} & e_{26} & e_{27} & e_{28} & e_{29} & e_{30} & e_{31} & e_{32} \\ e_{37} & e_3 & e_4 & e_5 & e_{22} & e_{23} & e_{24} & e_{25} & e_{26} & e_{27} & e_{28} & 0 & 0 & 0 & 0 & 0 \end{bmatrix} \quad \ldots\ldots (12)$$

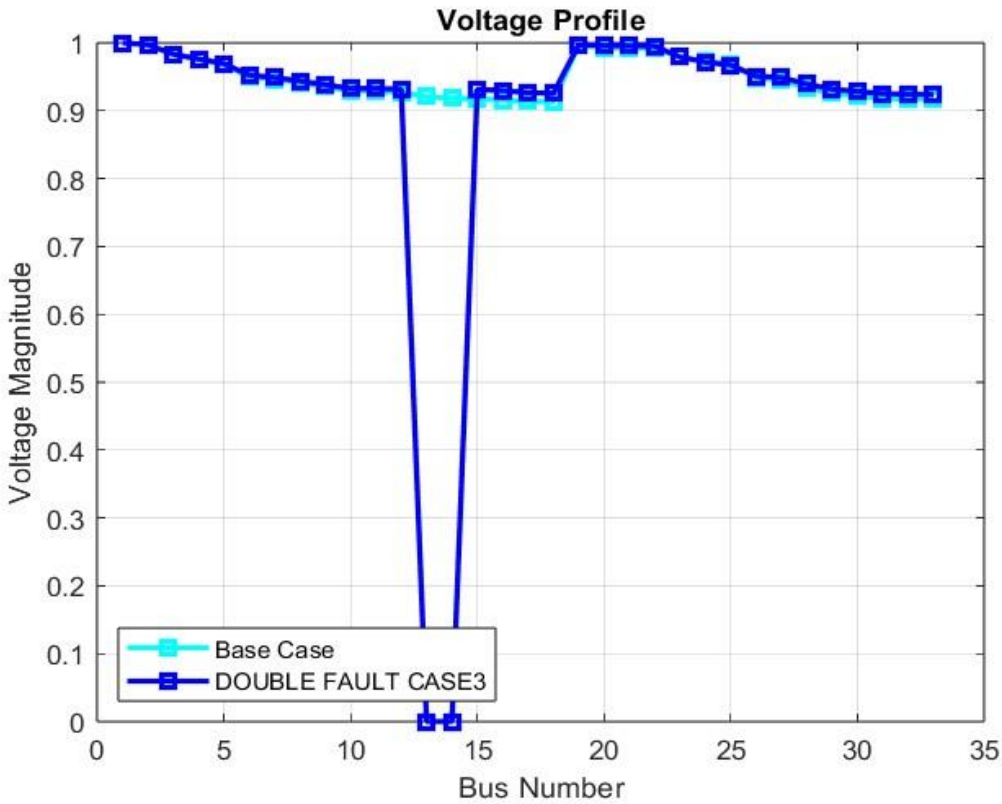

Figure 4.3: Voltage Profile of reconfigured network for double fault case

Case 4: Network reconfiguration accompanied by node fault: Assuming that there is a fault at node 6 in the system illustrated in Figure 3.4, branches e_5, e_6, and e_{25} are removed in order to isolate the fault. As a result, the loads in the node set (nodes 6–18, 26–33) are not receiving power. According to the procedures detailed in the dynamic topology update, Node 6 has been identified as the location of a fault. Regrettably, the restoration of power to Node 6's load is contingent upon the resolution of this fault. Nevertheless, there is a viable solution for remaining nodes (nodes 7–18, 26–33) that are currently without a power. Closing tie branches designated as e_{33} and e_{37}, it is possible to reinstate power to these nodes. This strategic maneuver allows for the timely restoration of power to the affected nodes while acknowledging that the repair of the fault at Node 6 is a prerequisite for the comprehensive resolution of the system's issues. The updated loop matrix is provided below. The opening of branches e_{11}, e_{12}, e_{16}, and e_{34} is advised by the suggested algorithm, resulting in a 155.92 kW overall power loss. Furthermore, the suggested method achieves a minimum voltage magnitude of 0.9378 p.u.

L'$_{op}$ =

$$\begin{bmatrix} e_{34} & e_9 & e_{10} & e_{11} & e_{12} & e_{13} & e_{14} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ e_{35} & e_8 & e_9 & e_{10} & e_{11} & e_{21} & e_{33} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ e_{36} & e_2 & e_8 & e_9 & e_{10} & e_{11} & e_{12} & e_{13} & e_{14} & e_{15} & e_{16} & e_{17} & e_{18} & e_{19} & e_{20} & e_{33} & e_{22} & e_{23} & e_{24} & e_{37} & e_{29} & e_{30} & e_{31} & e_{32} \end{bmatrix} \quad ..(13)$$

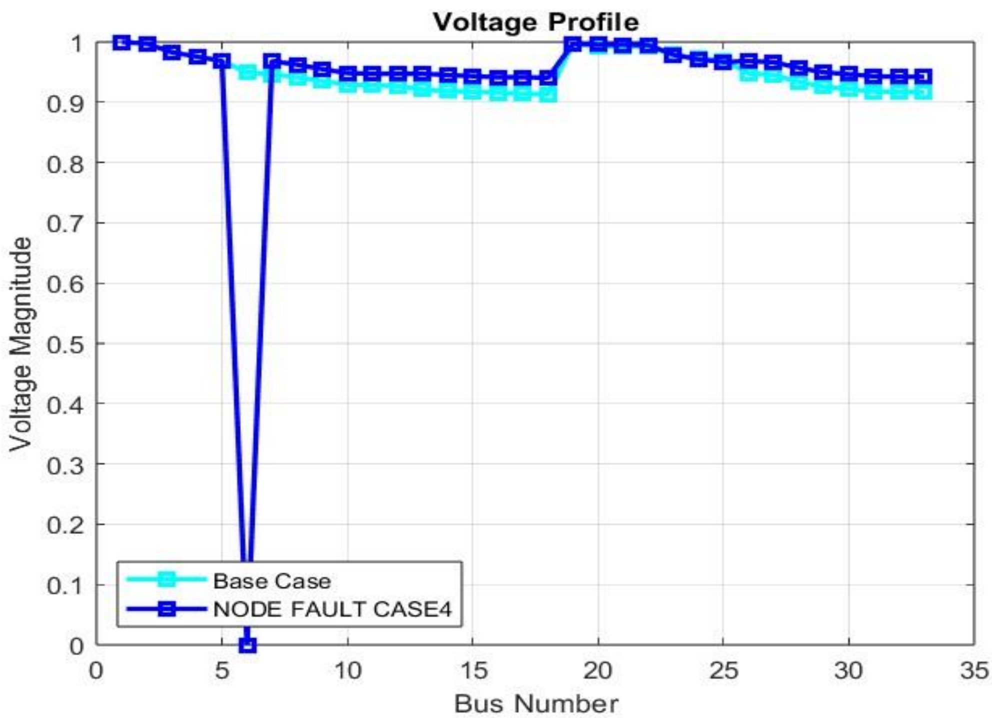

Figure 4.4: Voltage Profile of reconfigured network for node fault case

Table 4.1 Summary of results for IEEE 33 Bus System

Item	Condition	Final Open Switches	P_{loss}, kW	V_{min}, p.u.
Case 1 (fault free)	Without reconfiguration	e_{33}-e_{37}	202.68	0.91309
	After reconfiguration	e_4,e_{11},e_{20},e_{30},e_{34}	190.3	0.91421
Case 2 (single fault, e_{26})	Without reconfiguration	e_{33}-e_{36}	180.04	0.9301
	After reconfiguration	e_3, e_8,e_9,e_{16},e_{37}	176.35	0.93035
Case 3 (double fault, e_{12} and e_{14})	Without reconfiguration	e_{33},e_{35},e_{36},e_{37}	182.13	0.9310
	After reconfiguration	e_{10}, e_{18},e_{34},e_{37}	180	0.9380
Case 4 (node 6 fault)	Without reconfiguration	e_{34},e_{35},e_{36}	162.87	0.9236
	After reconfiguration	e_{11}, e_{12},e_{16},e_{34}	155.92	0.9378

4.2 65-bus Kohalpur Feeder (Practical Feeder)

The substation voltage is set at 1.0 per unit, with voltage limits ranging from 0.82135 to 1 p.u. Lower limit of voltage is set after getting minimum node voltage from load flow analysis. We do not set higher voltage value for both lower and higher voltage limits as we could not build up voltage just by changing the tie switch connection and the iteration will not converge. The branch current constraint is 500 amperes (A), and P_{loss} represents the active loss of the network, while V_{min} signifies the minimum voltage among all nodes. For dynamic reconfiguration optimization algorithm, population size denoted as ***P*** is 50 and number of iteration is 20.

The cases demonstrate how to fix a network after one or more branches are removed and how to figure out the topological structure. The reconfiguration results, guided by current time topology, are presented in Table 4.2.

Case 1: Network reconfiguration without faults: An analysis of a fault-free system is being conducted in this instance. Under the assumption that the initial topology, which is formed by joining all nodes through sectionalizing branches, operates normally, the reconfiguration of the network constitutes an optimal optimization problem. As a result, the issue is resolved without utilizing the dynamic topology update by following the procedures described in Section 3.3. Table 4.2 displays the findings of the best configuration for this scenario. Losses are reduced by 145.94 kW compared to the original topology, and minimum voltage value has been increased to 0.87981 per unit.

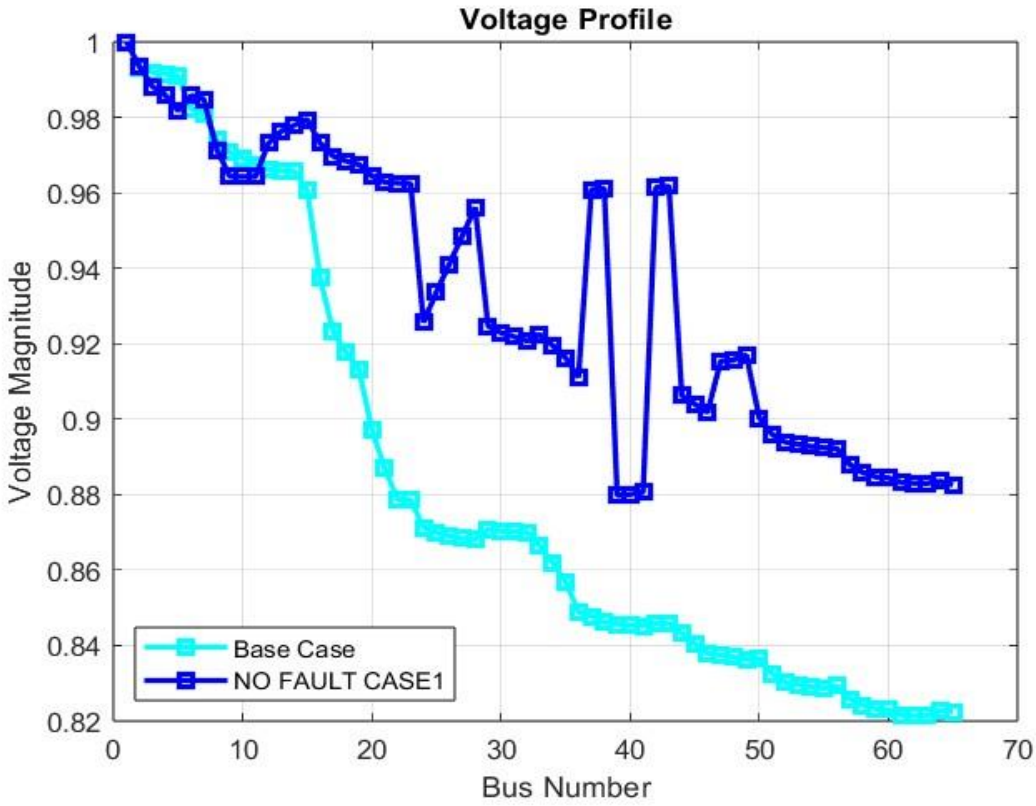

Figure 4.5: Voltage Profile of reconfigured network without fault case

***Case 2: Network reconfiguration accompanied by single branch fault*:** The current sectionalizing branch connecting nodes 26 and 27 is removed in order to address a permanent fault on line e_{26} resulting in some healthy nodes being without power. The goals are to update the original topology and bring back electric energy to healthy loads. In this revised initial topology, our method identifies the optimal configuration as [e_{12}, e_{26},e_{42},e_{45},e_{57}], with a power loss of 240.24 kW. By utilizing switch operations, the decision-maker can re-establish network connectivity and attain an optimal solution, thereby improving the operational efficiency of the system. Figure 4.6 depicts the voltage profile of the reconfigured network and the network reconfiguration leads to an improvement in voltage amplitude.

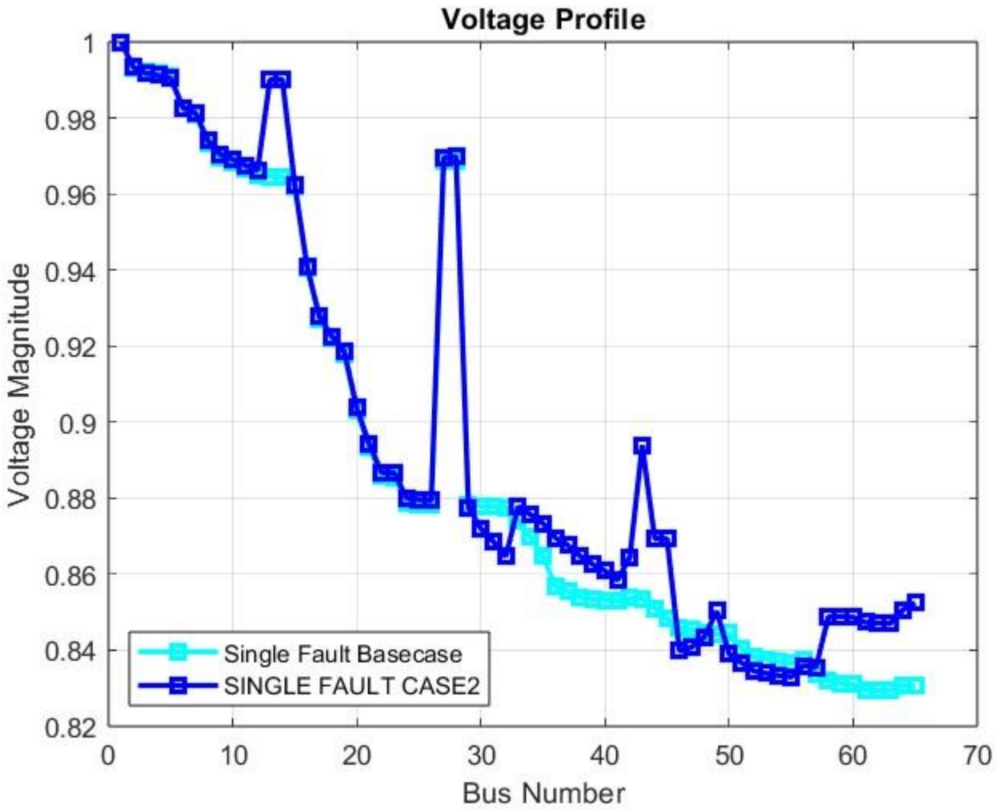

Figure 4.6: Voltage Profile of reconfigured network for single fault case

Case 3: Network reconfiguration accompanied by double-branch fault: Let's look at an example where there is a fault on lines e_{12} and e_{26}. Following reconfiguration, a power loss of 207.19 kW is attained. Systems voltage profiles in both initial and ideal scenarios are shown in Figure 4.7. The real-time system's minimum voltage magnitude is 0.85035 p.u.

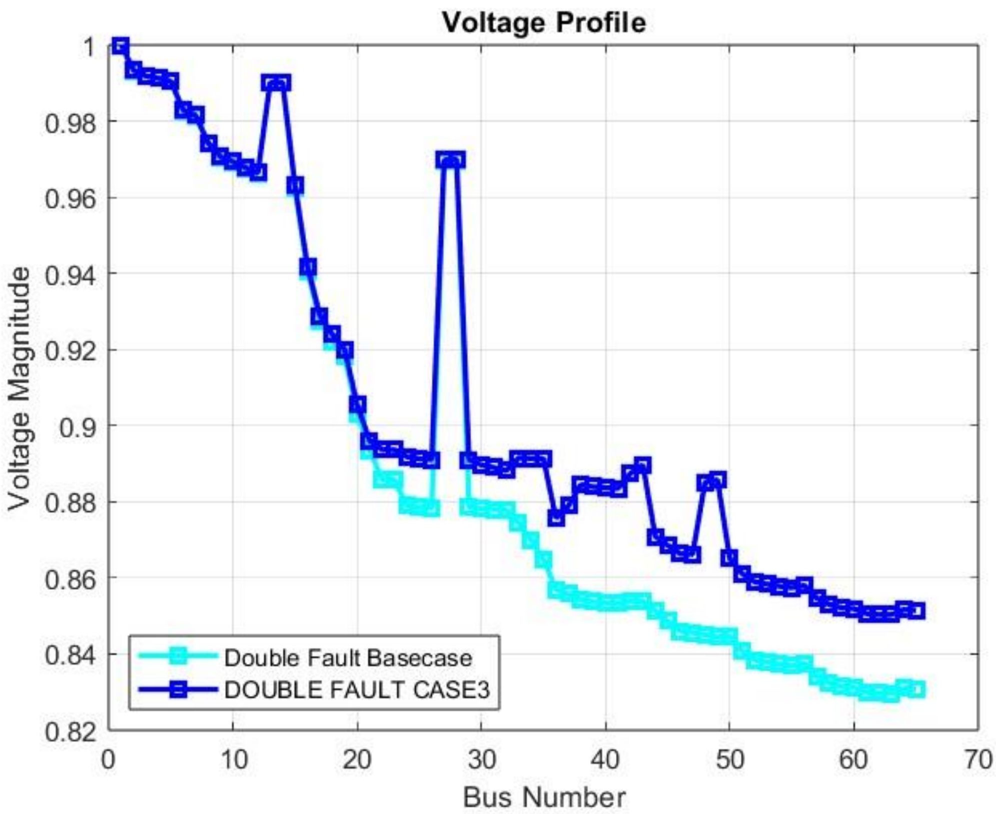

Figure 4.7: Voltage Profile of reconfigured network for double fault case

Case 4: Network reconfiguration accompanied by node fault: Assuming that there is a fault at node 6 in the system illustrated in Figure 3.5, branches e_5 and e_6 are removed in order to isolate the fault. As a result, the loads in the node set (nodes 6–65) are not receiving power. According to the procedures detailed in the dynamic topology update, Node 6 has been identified as the location of a fault. Regrettably, the restoration of power to Node 6's load is contingent upon the resolution of this fault. Nevertheless, there is a viable solution for the remaining nodes (nodes 7–65) that are currently without a power supply. By closing the tie branche e_{65}, it is possible to reinstate power to these nodes. The opening of branches $e_{5,}$ $e_{23,}$ e_{30}, e_{36}, and e_{58}, is advised by the suggested algorithm, resulting in a 242.15 kW overall power loss. Furthermore, the suggested method achieves a minimum voltage magnitude of 0.8732 per unit.

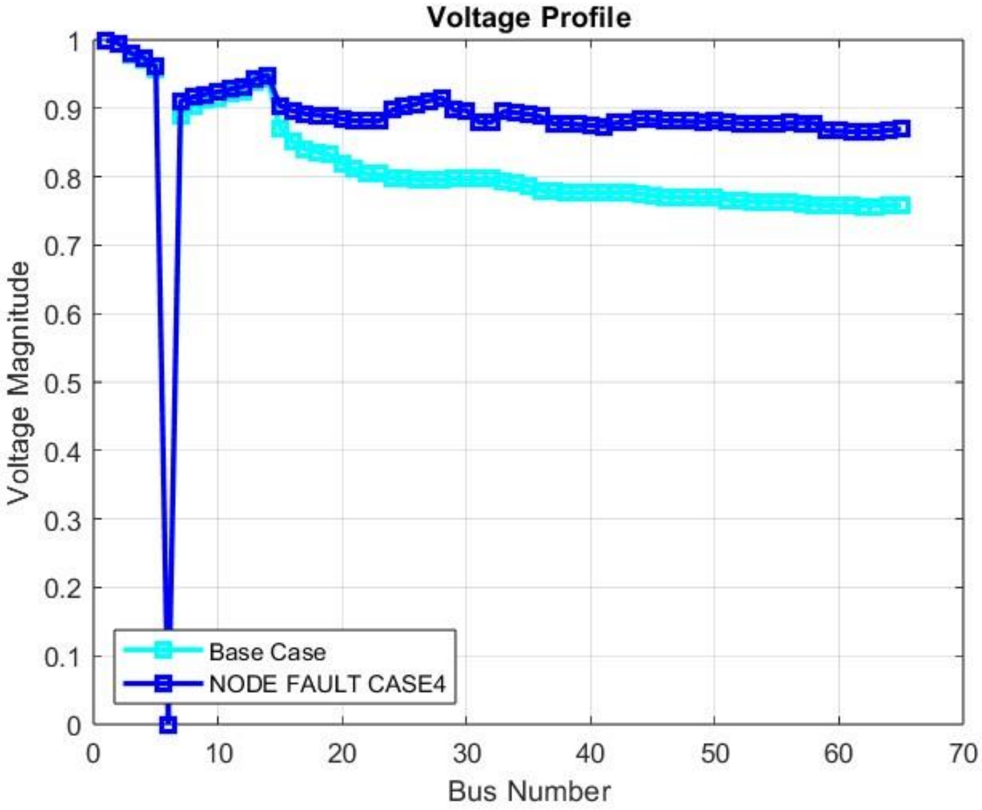

Figure 4.8: Voltage Profile of reconfigured network for node fault case

Table 4.2 Summary of results for 65-bus Kohalpur Feeder (Practical Feeder)

Item	Condition	Final Open Switches	P_{loss}, kW	V_{min}, p.u.
Case 1 (fault free)	Without reconfiguration	e_{65}-e_{69}	261.91	0.82135
	After reconfiguration	e_{11},e_{23},e_{36},e_{38},e_{46}	145.94	0.87981
Case 2 (single fault, e_{26})	Without reconfiguration	e_{26}, e_{65},e_{67},e_{68},e_{69}	243.40	0.8106
	After reconfiguration	e_{12}, e_{26},e_{42},e_{45},e_{57}	240.24	0.8294
Case 3 (double fault, e_{12} and e_{26})	Without reconfiguration	e_{12}, e_{26},e_{67},e_{68},e_{69}	238.17	0.8297
	After reconfiguration	e_{12}, e_{26},e_{35},e_{47}, e_{69}	207.19	0.85035
Case 4 (node 6 fault)	Without reconfiguration	e_{66},e_{67},e_{68},e_{69}	255.60	0.8362
	After reconfiguration	e_5, e_{23},e_{30},e_{36}, e_{58}	242.15	0.8732

CHAPTER 5. CONCLUSION AND FUTURE WORKS

5.1 Conclusion

A new approach to dynamic reconfiguration in distribution systems (DS) is introduced, focusing on dynamic changes in the initial topology rather than a fixed network structure. This method restores DS network connectivity by dynamically analyzing topology when changes in the initial configuration are identified. Connected tree, loop matrix, and electrical islands are then updated in accordance with the current topology. In order to minimize power loss and improve voltage profiles, the suggested method finds the best configuration by aligning with the existing network structure.

Two distribution system's were used to test the suggested approach, taking into account various initial topology change events as the network was reconfigured. According to simulation outputs, this approach quickly reestablish network connection after a topology change. Furthermore, the approach shows that it can reliably determine the best configurations for various dynamic topologies. This approach provides better performance and more flexibility than traditional methods. As a result, this approach can be readily applied to the dynamic variation in network topology during the reconfiguration of distribution systems

5.2 Future works

In this thesis, work is carried out in the distribution network without Distributed Generation (DG). So, the works can be carried out considering Distributed Generation (DG) in the distribution network.

REFERENCES

[1] Xu, Y., Dong, Z.Y., Wong, K.P., et al. (2013) ‘Optimal capacitor placement to distribution transformers for power loss reduction in radial distribution systems’, *IEEE Transaction on Power System*, 28, (4), pp. 4072–4079

[2] Tian, Z., Wu, W., Zhang, B. (2016) ‘Mixed-integer second-order cone programing model for VAR optimisation and network reconfiguration in active distribution networks’, *IET Generation, Transmission. Distribution*, 10, (8), pp. 1938– 1946

[3] Gupta, N., Swarnkar, A., Niazi, R. (2014) ‘Distribution network reconfiguration for power quality and reliability improvement using genetic algorithms’, *International Journal of Electrical Power Energy System,* 54, (54), pp. 664–671

[4] Mendonza, J.E., Lopez, M.E., Coello, A.C., et al. (2009) ‘A microgenetic multiobjective reconfiguration algorithm considering power losses and reliability indices for medium voltage distribution networks’, *IET Generation Transmission Distribution,* 3, (9), pp. 825–840

[5] Alonso, F.R., Oliveira, D.Q., Zambroni de Souza, A.C. (2015) ‘Artificial immune systems optimization approach for multiobjective distribution system reconfiguration’, *IEEE Transaction on Power System*, 30, (2), pp. 840–847

[6] Andervazh, M.R., Olamaei, J., Haghifam, M.R. (2013) ‘Adaptive multi-objective distribution network reconfiguration using multi-objective discrete particles swarm optimization algorithm and graph theory’, *IET Generation, Transmission. Distribution*, 7, (12), pp. 1367–1382

[7] Imran, A.M., Kowsalya, M. (2014) ‘A new power system reconfiguration scheme for power loss minimization and voltage profile enhancement using fireworks algorithm’, *International Journal of Electrical Power Energy System,* 62, (1), pp. 312–322

[8] Singh, N., Glavitsch, H. (1991) ‘Detection an identification of topological errors in online power system analysis’, *IEEE Transaction Power System*, 6, (1), pp. 324–331

[9] Jazebi, S., Haji, M.M., Naghizadeh, R. (2014) 'Distribution network reconfiguration in the presence of harmonic loads: optimization techniques and analysis', *IEEE Transaction on Smart Grid,* 5, (4), pp. 1929–1936

[10] Silva, N.S.D., Costa, A.S., Clements, K.A., et al. (2016) 'Simultaneous estimation of state variables and network topology for power system real-time modeling', *Electric Power System Research*, 133, pp. 338–346

[11] Sarma, N.D.R., Ghosh, S., Rao, K.S.P., et al. (1994) 'Real time service restoration in distribution networks-a practical approach', *IEEE Transaction on Power Delivery.*, 9, (4), pp. 2064–2070

[12] Tzur, M., Drezner, E. (2011) 'A look-ahead partitioning heuristic for a new assignment and scheduling problem in a distribution system', *European Journal of Operational Research*, 215, (2), pp. 325–336

[13] Reichl, J., Kollmann, A., Tichler, R., et al. (2008) 'The importance of incorporating reliability of supply criteria in a regulatory system of electricity distribution: an empirical analysis for Austria', *Energy Policy*, 36, (10), pp. 3862– 3871

[14] Dimitrijevic, S., Rajakovic, N. (2018) 'Considering of healthy MV busbar feeders in the service restoration of distribution networks', *Electrical. Engineering*, 98, (2), pp. 97–107

[15] Gholami, M., Moshtagh, J., Ghadernejad, N. (2015) 'Service restoration in distribution networks using combination of two heuristic methods considering load shedding', *Journal of Modern Power System and Clean Energy*, 3, (4), pp. 556–564

[16] Kumar, Y., Das, B., Sharma, J. (2008) 'Multiobjective, multiconstraint service restoration of electric power distribution system with priority customers', *IEEE Transaction on Power Delivery*, 23, (1), pp. 261–270

[17] Jorge, M.B., Héctor, V.O., Miguel, L.G., et al. (2014) 'Multi-fault service restoration in distribution networks considering the operating mode of distributed generation', *Electric Power System. Research*, 116, (11), pp. 67–76

[18] Sudhakar, T.D., Srinivas, K.N. (2010) 'Prim's algorithm for loss minimization and service restoration in distribution networks', *International Journal of Electrical and Computer Engineering*, 2, (1), pp. 43–62

[19] Asakura, T., Genji, T., Yura, T., et al. (2013) ‘Long-term distribution network expansion planning by network reconfiguration and generation of construction plans’, *IEEE Transaction on Power System.*, 18, (3), pp. 1196–1204

[20] Li, R., Ma, H.Z., Wang, F.F., et al. (2013) ‘Game optimization theory and application in distribution system expansion planning, including distributed generation’, *Energies*, 6, (2), pp. 1101–1124

[21] Sedghi, M., Ahmadian, A., Aliakbar-Golkar, M. (2016) ‘Assessment of optimization algorithms capability in distribution network planning: review, comparison and modification techniques’, *Journal on Renewable Sustainable Energy Review*, 66, (4), pp. 415–434

[22] Heidari, S., Fotuhi-Firuzabad, M., Kazemi, S. (2014) ‘Power distribution network expansion planning considering distribution automation’, *IEEE Transaction Power System*, 30, (3), pp. 1–4

[23] Baran, M.E., Wu, F.F. (1989) ‘Network reconfiguration in distribution systems for loss reduction and load balancing’, *IEEE Transaction on Power Delivery*, 4, (2), pp. 1401–1407

[24] Andervazh, M., Olamaei, J., Haghifam, M. (2013) ‘Adaptive multi-objective distribution network reconfiguration using particles swarm optimization algorithm and graph theory’, *IET Generation, Transmission, Distribution*, 7, (4), pp. 1801–1810

[25] Zhang, D., Fu, Z., Zhang, L. (2007) ‘An improved TS algorithm for loss-minimum reconfiguration in large-scale distribution systems’, *Electric Power System Research*, 77, (6), pp. 685–694

[26] Wen, J., Tan, Y., Jiang, L., Lei, K. (2017) "Dynamic reconfiguration of distribution networks considering the real-time topology variation", *IET Generation, Transmission & Distribution*,

Appendix-A

Bus data for IEEE 33-Bus Radial Distribution Network

S.N	Bus	Load P (kW)	Load Q (kVAR)	S.N	Bus	Load P (kW)	Load Q (kVAR)
1	1	0	0	23	23	90	50
2	2	100	60	24	24	420	200
3	3	90	40	25	25	420	200
4	4	120	80	26	26	60	25
5	5	60	30	27	27	60	25
6	6	60	20	28	28	60	20
7	7	200	100	29	29	120	70
8	8	200	100	30	30	200	600
9	9	60	20	31	31	150	70
10	10	60	20	32	32	210	100
11	11	45	30	33	33	60	40
12	12	60	35				
13	13	60	35				
14	14	120	80				
15	15	60	10				
16	16	60	20				
17	17	60	20				
18	18	90	40				
19	19	90	40				
20	20	90	40				
21	21	90	40				
22	22	90	40				

Branch data for IEEE 33-Bus Radial Distribution Network

Sending End Bus	Receiving End Bus	Resistance (ohm)	Reactance (Ohm)	Sending End Bus	Receiving End Bus	Resistance (ohm)	Reactance (Ohm)
1	2	0.0922	0.047	20	21	0.4095	0.4784
2	3	0.493	0.2511	21	22	0.7089	0.9373
3	4	0.366	0.1864	3	23	0.4512	0.3083
4	5	0.3811	0.1941	23	24	0.898	0.7091
5	6	0.819	0.707	24	25	0.896	0.7011
6	7	0.1872	0.6188	6	26	0.203	0.1034
7	8	0.7114	0.2351	26	27	0.2842	0.1447
8	9	1.03	0.74	27	28	1.059	0.9337
9	10	1.044	0.74	28	29	0.8042	0.7006
10	11	0.1966	0.065	29	30	0.5075	0.2585
11	12	0.3744	0.1238	30	31	0.9744	0.963
12	13	1.468	1.155	31	32	0.3105	0.3619
13	14	0.5416	0.7129	32	33	0.341	0.5302
14	15	0.591	0.526	21	8	2	2
15	16	0.7463	0.545	9	15	2	2
16	17	1.289	1.721	12	22	2	2
17	18	0.732	0.574	18	33	0.5	0.5
2	19	0.164	0.1565	25	29	0.5	0.5
19	20	1.5042	1.3554				

Tie Lines for IEEE 33-Bus Radial Distribution Network

Sending End Bus	Receiving End Bus	Resistance (ohm)	Reactance (Ohm)
20	7	2	2
14	8	2	2
21	11	2	2
32	17	0.5	0.5
28	24	0.5	0.5

Bus data for Kohalpur Feeder

S.N	Bus	Load		S.N	Bus	Load	
		P (kW)	Q (kVAR)			P (kW)	Q (kVAR)
1	1	0	0	34	34	0.672	0.086935
2	2	49.03073951	22.09033	35	35	22.65542	10.18195
3	3	54.17601395	24.34815	36	36	30.78183	13.83418
4	4	48.01964873	21.58131	37	37	48.75841	21.91333
5	5	95.54678824	42.94128	38	38	41.12452	18.48246
6	6	54.38394091	24.4911	39	39	31.27434	14.05552
7	7	1.4392	0.696322	40	40	24.62546	11.06734
8	8	40.63201046	18.26111	41	41	16.99157	7.636465
9	9	50.0808849	21.63616	42	42	49.74343	22.35603
10	10	23.23913254	9.572761	43	43	34.47565	15.49428
11	11	2.8	0.386869	44	44	0	0
12	12	501.76	334.5138	45	45	26.10299	11.73138
13	13	7.896	3.638519	46	46	50.48219	22.68805
14	14	37.67695516	16.93303	47	47	53.191	23.90545
15	15	2.8	0.386869	48	48	46.54212	20.91727
16	16	53.43725012	24.01613	49	49	42.60205	19.1465
17	17	14.0308	6.796854	50	50	38.90823	17.4864
18	18	110.6821948	24.86088	51	51	32.25935	14.49822
19	19	36.44568211	16.37966	52	52	37.92321	17.0437
20	20	76.58518336	34.41943	53	53	47.77339	21.47064
21	21	32.01309915	14.38754	54	54	39.40074	17.70774
22	22	46.78837568	21.02795	55	55	47.28088	21.24929
23	23	14.5866	7.065683	56	56	32.25935	14.49822
24	24	52.6984863	23.68411	57	57	31.76684	14.27687
25	25	35.05935376	14.88508	58	58	18.9616	8.521852
26	26	31.76684454	14.27687	59	59	48.51216	21.80266
27	27	45.55710264	20.47458	60	60	2.8	0.386869
28	28	52.6984863	23.68411	61	61	25.61048	11.51003
29	29	48.51215795	21.80266	62	62	52.94474	23.79478
30	30	28.81178924	12.94879	63	63	20.19288	9.075219
31	31	0	0	64	64	16.2528	7.304444
32	32	23.14793323	10.4033	65	65	25.11797	11.28869
33	33	56.7812	27.49896				

Branch data for Kohalpur Feeder

Sending End Bus	Receiving End Bus	Resistance (Ohm)	Reactance (Ohm)	Sending End Bus	Receiving End Bus	Resistanc e (Ohm)	Reactance (Ohm)
1	2	0.1950	0.1446	33	34	0.2661	0.3758
2	3	0.4626	0.6533	36	37	0.3461	0.3124
3	4	0.2626	0.1946	36	38	0.6002	0.4449
4	5	0.5310	0.3936	38	39	0.5753	0.4265
2	6	0.2715	0.3835	38	40	0.5462	0.4049
6	7	0.0362	0.0511	40	41	0.8213	0.6088
7	8	0.7956	0.6405	38	42	0.2772	0.2055
8	9	0.4407	0.3267	42	43	0.1949	0.1445
9	10	0.1906	0.1413	36	44	0.4722	0.6670
7	11	0.2188	0.2130	44	45	0.2794	0.2071
7	12	0.1962	0.1961	44	46	0.2376	0.2880
7	13	0.3795	0.5360	44	46	0.0357	0.0504
13	14	0.2455	0.1820	46	47	0.2255	0.1672
7	15	0.7993	0.7924	47	48	0.4868	0.3609
7	16	0.9085	0.9281	48	49	1.1291	0.8370
7	17	0.5117	0.7227	46	50	0.1641	0.2318
17	18	0.1989	0.2809	50	51	0.6379	0.4729
18	19	0.1687	0.2382	51	52	0.9561	0.7087
19	20	0.7148	0.7029	52	53	0.3455	0.2561
19	21	0.5246	0.3888	52	54	0.5199	0.3854
19	22	0.3463	0.4891	54	55	0.5909	0.4380
22	23	0.4781	0.3544	51	56	0.8651	0.6413
22	24	0.3260	0.4604	51	57	1.0673	0.7912
24	25	0.6143	0.4553	57	58	0.6003	0.4450
25	26	0.5461	0.4048	58	59	0.3710	0.2750
26	27	0.5312	0.3937	59	60	0.1733	0.1284
27	28	0.5243	0.3886	60	61	1.0248	0.7596
24	29	0.3293	0.2441	61	62	0.3101	0.2298
29	30	0.7646	0.5668	61	63	0.8767	0.6499
30	31	0.4931	0.3655	59	64	0.7834	0.5807
30	32	0.5758	0.4268	64	65	0.7853	0.5821
24	33	0.3293	0.2441				

Tie Lines for Kohalpur Feeder

Sending End Bus	Receiving End Bus	Resistance (ohm)	Reactance (Ohm)
4	8	0.5	0.5
9	21	0.5	0.5
21	25	0.5	0.5
31	49	2	2
41	62	2	2

Assigning Bus Numbers for Kohalpur Feeder

S.N.	PLACE	TO	Coordinates	Bus Number
1	Sh Steel	PVT	(28.1846854,81.6840718)	1
2	Chatar Ntc + Chatar nea	PVT	(28.1821682,81.6880401)	2
3	Bidyanagar	NEA	(28.1825739,81.6850123)	3
4	Dvs School	NEA	(28.1827576,81.6770967)	4
5	Ramnagar	NEA	(28.1741907,81.6783484)	5
6	Ntv Road1	NEA	(28.1939742,81.6883684)	6
7	Revenu Office	PVT	(28.1973776,81.6895797)	7
8	Ayam Nagar	NEA	(28.1902429,81.6747685)	8
9	Rajena	NEA	(28.1859936,81.6684603)	9
10	Rajena Nahar	NEA	(28.1807874,81.6652395)	10
11	Ncell	PVT	(28.1953902,81.6830292)	11
12	Ngmc2	PVT	(28.1977793,81.6776828)	12
13	Nmc	PVT	(28.1993990,81.6765045)	13
14	Pragati Nagar	NEA	(28.1958107,81.6745737)	14
15	NCELL5	PVT	(28.2078090,81.6806560)	15
16	Gorkha School	NEA	(28.2070113,81.6798475)	16
17	OM Kattha	PVT	(28.2010269,81.6666743)	17
18	Central Plaza	PVT	(28.1981307,81.6607759)	18
19	Madan Chowk	NEA	(28.1986187,81.6548480)	19
20	Santinagar	NEA	(28.2063957,81.6525369)	20
21	Belanpur	NEA	(28.1904120,81.6542039)	21
22	Maituwa	NEA	(28.1975414,81.6414975)	22
23	Mk Pig Farm	PVT	(28.1916170,81.6371980)	23

24	Rangila Chowk	NEA	(28.2010429,81.6300116)	24
25	Chanauhwa	NEA	(28.1882187,81.6288210)	25
26	Pedari1	NEA	(28.1821775,81.6228246)	26
27	Pedari School	NEA	(28.1732498,81.6203421)	27
28	Pedari2	NEA	(28.1657646,81.6160727)	28
29	Bankatuwa Health Post	NEA	(28.2060390,81.6298045)	29
30	Chhamaniya	NEA	(28.2153655,81.6209777)	30
31	Chhamania Irrigation	PVT	(28.2222978,81.6182734)	31
32	Chhamaniya NEW	NEA	(28.2234432,81.6264369)	32
33	Sit Bhandar	PVT	(28.2017639,81.6267523)	33
34	Laliguras Food	PVT	(28.2035659,81.6108378)	34
35	Macheda	NEA	(28.1940904,81.6186931)	35
36	G Gau3	NEA	(28.2011615,81.6083913)	36
37	G Gau1	NEA	(28.2076666,81.6059327)	37
38	G Gau2	NEA	(28.1920240,81.6083193)	38
39	Bankatti	NEA	(28.1941750,81.5987431)	39
40	H Gau1	NEA	(28.1889428,81.5995945)	40
41	Chagaudipur	NEA	(28.1838900,81.5933943)	41
42	G Gaun Bipatipur	NEA	(28.1875897,81.6076777)	42
43	Guruwa Gau	NEA	(28.1847092,81.6064784)	43
44	H Gau Ginger Factory	PVT	(28.2049927,81.5891968)	44
45	28 Ghar	NEA	(28.2161528,81.5942637)	45
46	Parbatipur	NEA	(28.2120102,81.5896525)	46
47	Samjhana Uttar	NEA	(28.2200212,81.5856670)	47
48	Lalpur	NEA	(28.2267755,81.5876017)	48
49	Mahadeva	NEA	(28.2381499,81.6001282)	49
50	Chadhani Chowk	NEA	(28.2184433,81.5801662)	50
51	Hasnapur	NEA	(28.2092387,81.5754710)	51
52	Thapuwa1	NEA	(28.1942992,81.5782833)	52
53	Thapuwa2	NEA	(28.1892599,81.5763375)	53
54	H Gau2	NEA	(28.1974992,81.5870620)	54
55	H Gau3	NEA	(28.2011456,81.5866903)	55
56	Chaupheri	NEA	(28.2079070,81.5650792)	56
57	Fattenagar	NEA	(28.2041340,81.5615293)	57
58	Fattenagar NEW	NEA	(28.1954671,81.5596045)	58
59	Titihiriya	NEA	(28.1898280,81.5570080)	59

60	Titiriay Ncell	PVT	(28.1857438,81.5541283)	60
61	Jhingaura NEW	NEA	(28.1775512,81.5387834)	61
62	Pipari	NEA	(28.1732697,81.5422074)	62
63	Kareli Bhangra	NEA	(28.1720327,81.5248238)	63
64	Bargadahi	NEA	(28.1942410,81.5463764)	64
65	Gurdelpur	NEA	(28.1968412,81.5339998)	65

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Dynamic Reconfiguration of Distribution Networks Considering the Dynamic Topology Variation

by

Sabin Mainali

A THESIS

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DEPARTMENT OF ELECTRICAL ENGINEERING

LALITPUR, NEPAL

December, 2023