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**INSTITUTE OF ENGINEERING**

**PASCHIMANCHAL CAMPUS**

**A PROJECT FINAL REPORT ON**

**Impact analysis of Electrical Vehicle Charging Station on Radial Distribution Network:**

**A Case study on Khaireni Feeder, Lekhnath**

**Submitted By:**

**Shreedhar Dangi**

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**Impact analysis of Electrical Vehicle Charging Station on Radial Distribution Network:**

**A Case study on Khaireni Feeder, Lekhnath**

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**ABSTRACT**

Interest in battery-operated electric vehicles (EVs) is rising due to growing concerns about the unsustainable use of fossil fuels and efforts to fulfill the Sustainable Development Goals (SDG). Charging stations are the main infrastructure needed for this technology to thrive, but the effect that this load has on the distribution network is being overlooked in some way. Voltage swings and power outages are likely when the load from EV chargers is added to the current power system. This study examined how the Khaireni distribution network of Lekhnath DCS will be affected by the addition of an EV charging load. The system modelling was performed using MATLAB.

Voltage stability, reliability, and power loss (VRP) characteristics of the line were analyzed both before and after load addition in order to determine the effects of EV charging station load placement on the distribution network.

Voltage stability Factor for different buses are calculated which provides us result that Bus 2 is least sensitive Bus (4.8166%), Bus 29 is most sensitive Bus (36.614%) and Bus 9 is average sensitive Bus (28.1154%). Three cases are considered for EV charging station modelling with 3 points and have 142Kw capacity. The power flow and reliability indices in three cases are compared with Base case and result are observed.

This study shows random placement of EV charging station loads cause severe effect on network parameters like voltage, power loss and network reliability.

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# **LIST OF ABBREBRATIONS**

ABC Aerial Bundled Conductor

AC Alternating Current

ACSR Aluminum Conductor Steel Reinforced

CAIDI Customer Average Interruption Duration Index

DC Direct Current

DCS Distributed Control System

CS Charging Station

EV Electrical Vehicle

EVCS Electrical Vehicle Charging Station

INPS Integrated Nepal Power System

HT High Tensile

NEA Nepal Electricity Authority

SDG Sustainable Development Goals

SAIDI System Average Interruption Duration Index

SAIFI System Average Interruption Frequency Inde

VRP Voltage Stability, Reliability and Power loss

# **CHAPTER ONE: INTRODUCTION**

## **1.1 Background**

In recent years, air pollution and climate change issues have pushed people worldwide to switch to using electric vehicles (EVs) instead of gas-driven vehicles [1]. Electrical vehicle (EV) is a vehicle similar to automobile which is mainly powered by an electrical motor that draws current from rechargeable storage battery, fuel cell or other source of electric current.

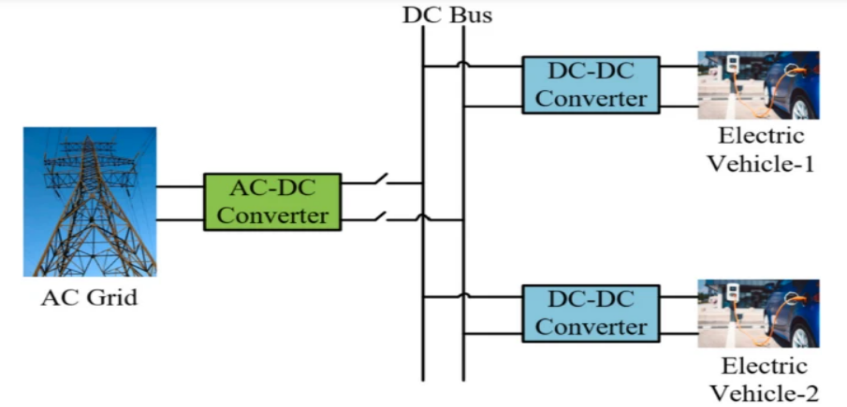


Figure 1.1.1: Typical Structure of Distribution Network with EV

The International Energy Agency (IEA) reports a substantial surge in global EV stock, surpassing 10 million over the last decade, with projections estimating an escalation up to 300 million by 2030 [2]. With its integral benefits, electric vehicles have emerged as the primary emerging mode of transportation in recent times. The availability of EV charging stations is a prerequisite for the success of EV technology. To overcome these issues, nowadays various researchers and engineers are exploring and proposing to adopt the mitigation techniques and use the required technologies to minimize its negative impact on the power distribution system. The impact such as poor voltage profile, transformer aging, total harmonic distortion, and power losses are associated with the charging of EV[3].

With the increase in generation of electricity, NEA has made plans to maximize the consumption of electricity by encouraging the charging of EVs during off peak and medium peak period through the reduction of tariffs in such periods. NEA has planned to install fast charging stations every 30km along national and provincial highways with basic charging station at every interval of 15km [13]. Charging during peak load period will definitely have impacts on Distribution System impacting Voltage Profile and Line Loss but increased EV penetration during off peak period will also have negative impacts on Distribution System, it will introduce harmonics in the system and eventually reduce the Power Quality of the system.

The load brought on by EV charging is significant enough to alter reliability and voltage profile. If ignored, it might significantly reduce system reliability and result in a network outage. Researchers have looked into the possible effects that the loads from charging stations may have on the distribution network. When the various EV penetration scenarios were examined on the LV distribution network, it was discovered that the placement of numerous charging stations negatively impacted the node voltage profile and that the high EV charging loads negatively impacted the voltage profile of the weaker buses [20]. Determining the best location for EV charging stations inside a distribution network thus becomes crucial.In this project Khaireni Feeder of Lekhnath Power Grid is taken into consideration.

Operational parameters (Voltage Stability and Power Loss) are calculated and assessed for the feeder distribution network both before and after the EV charging load conditions. Using the operating characteristics, optimization algorithms are employed to determine the best location for EV charging stations inside the distribution network.

In this project work, a methodology for modelling and analyzing of load flow, power loss a voltage profile analysis along with Relaibilty assesssment on a in a distribution system due to EVs will be done. The distribution network is analyzed before and after the installations of EV charging stations with the calculation and analysis of operational parameters (Voltage Profile and Power Loss and Reliabilty)

## **1.2 Problem Statement**

The demand for energy will rise as the number of electric vehicles increases, and the peak daily load curve's profile will inevitably change. This change will not always be beneficial to the distribution network.

The development in EV-based mobility will result in a huge increase in the demand for electricity, which poses a serious threat to the power networks. Power systems are engineered to manage anticipated demand with distinct attributes contingent on the grid code and standard. The utility company always provides customers with the necessary electricity since it is aware of the load profile in each given area. Electric power generation and consumption are constantly managed and observed in balance. Therefore, in order to enhance the grid's functionality and guarantee stability and dependability, new contemporary technology must be compatible with it.

The impact of charging on the power system depends on where it is on the grid and how it is charged. They do not pose a problem if they are charged slowly at low voltage system. However, during the fast and uncontrolled charging the different power quality parameters like voltage unbalances, harmonic distortions, frequency variations, voltage drop and line loss are quantified and their rise or fall are restricted by a number of relevant standards. An excessive flow of currents may cause voltage stress and corona, resulting to insulation failure. Presence of harmonic current also negatively impact its protective relay equipment, metering equipment and switch gear. Higher pick-up values than setting would dictate results in slow operation of relaying equipment and result in unexpected operation [3].

## **1.3 Objectives**

### 1.3.1 Main objectives

The main objective of this project is to study the Impact of EV Charging Station on radial distribution network of Khaireni feeder in Lekhnath, Pokhara.

### 1.3.2 Specific objectives

* To perform the base case load flow and observe the voltage profile and power loss of standard IEEE 33 Test bus and then Khaireni radial feeder of Lekhnath using backward forward sweep algorithm in MATLAB
* To conduct load flow and observe the voltage profile and power loss in a feeder with EV charging station.
* To study Reliabilty assessment of the system after injection of EV charging station in Khaireni Feeder.

## **1.4 Limitations**

* Charging duration and charging period of time is not considered.
* The impact of renewable resources like wind and solar power in the network is not considered.
* EV modelling hasnot done, rather to realize the EV charging station a lumped load model has been used.
* Frequency and duration of trips caused by integration of EV charging station hasnot been realized as it would happen in real world

## **1.5 Report Organization**

## The first chapter deals with a brief introduction of the project background, problem statement, objectives, scope and limitation and report organization.

## In the second chapter, the brief of review of different literature during the study regarding the project is presented.

## The third chapter provides description of the methodology followed in the course of the study in brief.

## In the fourth chapter, the results obtained are presented and discussed in detail. The fifth chapter presents conclusions of the study and recommendations for the further additions that can be done in the study.

# **CHAPTER TWO: LITERATURE REVIEW**

The investigation for this project started with a thorough analysis of the body of research on the subject of EV charging stations' effects on power distribution feeders. This involved a comprehensive review of research on load profiles, voltage stability, and power quality, as well as an analysis of the relationships between these elements and the incorporation of EV charging infrastructure. The basis for gaining a thorough comprehension of the topic area was laid by this review.

C. Birk Jones proposed OpenDSS software to analysis power flow simulations for each EV charging feeder. It included the pre-processing of grid data to understand feeder characteristics and support grid simulations [4]. MohammadA.Obeidat put forwarded CYME power engineering software for Effect of Electric Vehicles Charging Loads on Realistic Residential Distribution System [5]. Jubair Yusuf presented Impact Analysis of Electrical Vehicles Integration to the Residential Distribution Grid [6]. Anamika Dubey investigates Time-of-Use (TOU) Pricing and Smart Charging Algorithms to Mitigate EV Load Impacts [7].

Yanning Lia and Alan Jenna investigates on The Impact of Charging Location on Feeder Overload [8]. InamNutkani and HamishToole provides a concept on Impact of EV charging on electrical distribution network (Voltage stability,Network demand and Thermal capacity) and mitigating solutions[9]. Afoma Ihekwaba and Charles Kim explains his concept on Electrical Vehicle impact on Grid Voltage Regulation using heavily loaded IEEE-13 Node Test Circuit [10]. L.G. González uses computational tool Psim to model the AC/DC and DC/DC power converter for Impact of EV fast charging stations on the power distribution network of a Latin American intermediate city[11].

Sanchari Deb reviews on the impact of EV charging station load on voltage stability, reliability, power losses, and economic losses of the distribution network[12].

A technique for choosing PHEV charging station locations that takes the commercial distribution network's voltage sensitivity factor into account was covered by Rahman et al. in 2013[19]. The approach provided a PV curve analysis of the particular system. The PV curve was used to determine the voltage sensitivity factor of each bus connected to the system, even though it also showed the maximum loading capacity of the system. According to the analysis, the ideal bus for placing the charging station is the one with the lowest percentage change in VSF. Some metrics that show an Electrical Distribution Network's dependability were covered by Okorie et al. (2015)[21]. The customer-oriented reliability indices are provided by the indicators like ENS and AENS, while the energy-oriented reliability indices are provided by the System Average Interruption Frequency Index (SAIFI), System Average Interruption Duration Index (SAIDI), Customer Average Interruption Duration Index (CAIDI).The network's dependability can be ascertained using any one of these metrics.

# **CHAPTER THREE: METHODOLOGY**

## **3.1 General**

The entire project is broken up into several sections. The first section deals with choosing the site and gathering data of the Khaireni feeder of the Lekhnath DCS. The examination of load flow occurs in two stages: first, without any EV load, and second, with EV load generated at random. Voltage profile analysis ,loss determination and reliability indices analsis are included in the final stage. The impact analysis of EV charging station on Distribution Feeder is done using backward forward sweep method in MATLAB. The diagram below displays the overall workflow.

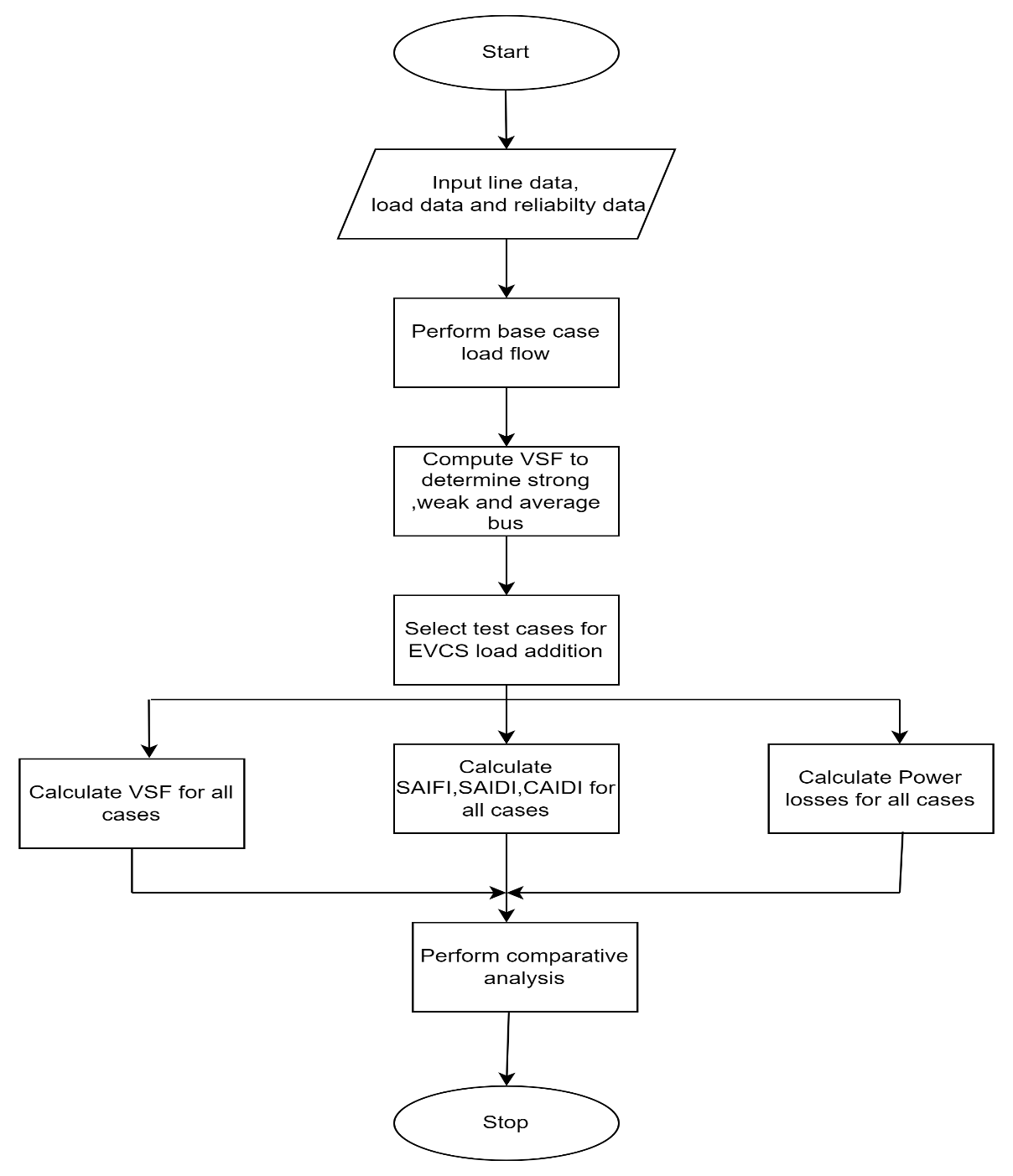


Figure 3.1.1: Flowchart of purposed project

## **3.2 Site Selection**

The Khaireni feeder of the Pokhara Grid substation, which is situated in the Pokhara Metropolitan city and SuklaGandaki Municipality is chosen for this study project. The Pokhara Grid substation feeds the Khaireni feeder. Figure below displays the satellite image route of Khaireni feeder. A large number of commercial buildings offer the potential for a high volume of electric vehicle traffic. Electric vehicles need a charging station, which may be placed anywhere in the feeder. The IEEE 33-bus Test System's forward-backward sweep approach in MATLAB is used to perform the effect study. The Khaireni radial feeder, provided by Pokhara Grid Switching Station, is the subject of this investigation. This 11kV system uses Dog conductors in addition to ACSR Rabbit and Weasel conductors to distribute power to both residential and business loads. In the system, the transformers are regarded as the buses or load points. 11 kV lines are used as distribution lines, with transformers acting as load points or buses and grid substations supplying the line as sources. Data required for this project work is gathered from the Pokhara Grid substation, Lekhnath DCS and is analyzed based on requirements. Additionally, the assumptions account for the data's unavailability. There are 29 Distribution Transformers in Khaireni Feeder. The Khaireni Feeder is shown below

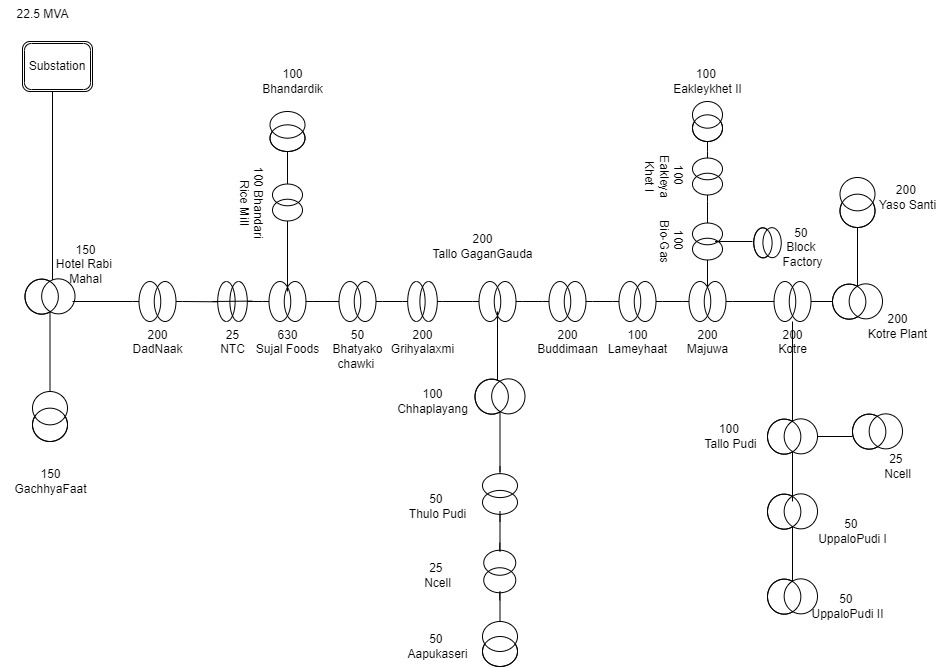


Figure 3.2.1: Transformer Location of Khaireni Feeder

Khaireni feeder is radial distribution network supplied by the Pokhara Grid substation. Single line diagram of Khaireni feeder is shown in figure below.

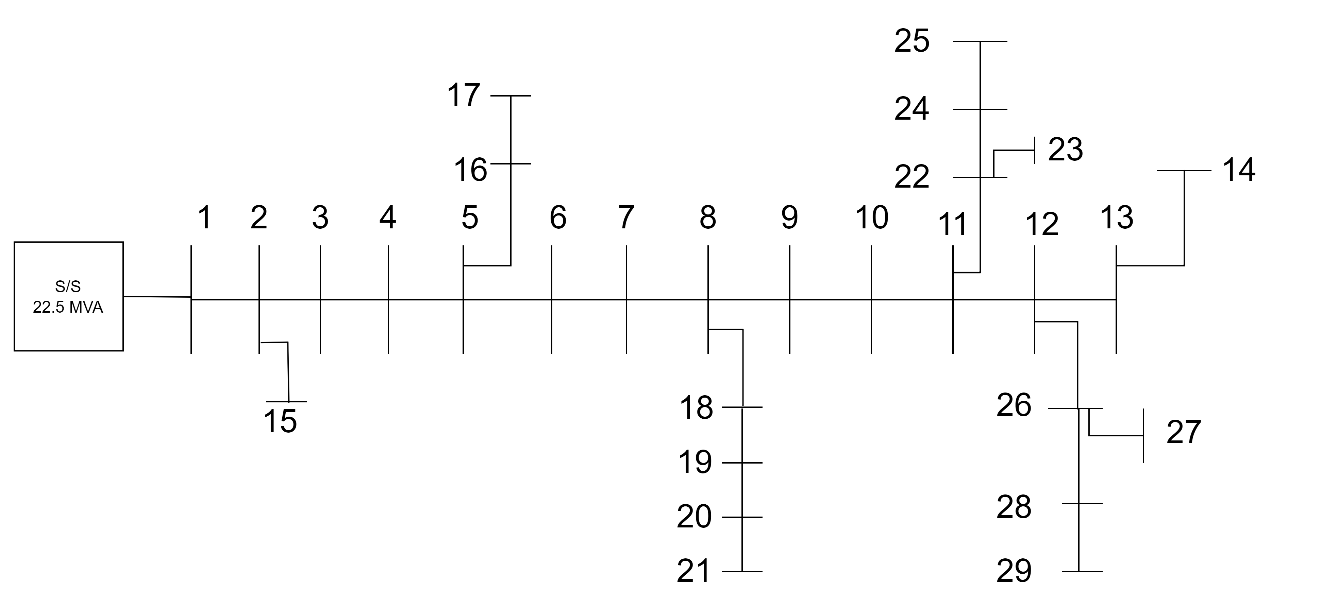


Figure 3.2.2:Single Line Diagram of Khaireni Feeder

## **3.3DataCollection**

### **3.3.1 Distribution System**

The distribution system selected for EV impact research is the feeder of the Pokhara Grid Substation located in Lekhnath,Pokhara, Nepal. NEA, Lekhnath Distribution Center, Pokhara Grid Substation Center, are the sources of various distribution network data, including type of conductors, consumer number, line length, and distribution transformer capacity. The Khaireni distribution feeder primarily uses ACSR Dog, Rabbit and Weasel conductor. The distribution transformer's position and line length are extracted from the GIS route map using Arch map software and site visit. The feeder is 21.74 km long overall and has a radial length.There are 5731 consumers in this feeder.The number of trips ,duration of trip and total number of consumer in each bus is obtained from Leknath DCS.

### **3.3.2 IEE-33 Bus Test Distribution Network System**

The standard test bus system is the IEEE-33 bus system MATLAB is used to simulate it. The system's starting bus takes into account the substation that supplies electricity to the radial network which Figure 5 illustrates. Sectionalizing switches and tie switches are used to manipulate radial networks. Although distribution networks are often linked, radial networks are occasionally employed for more cost-effective reasons. Radial networks are typically constructed for power delivery in remote areas. Any fault in any radial network point disrupts the network's power supply as a whole. Thus, the radial network's stability is lacking. Different switches, such as normally open and normally closed switches, make up a radial network. The first bus in this system is a swing bus with a voltage of 1 pu, and it is of no load.

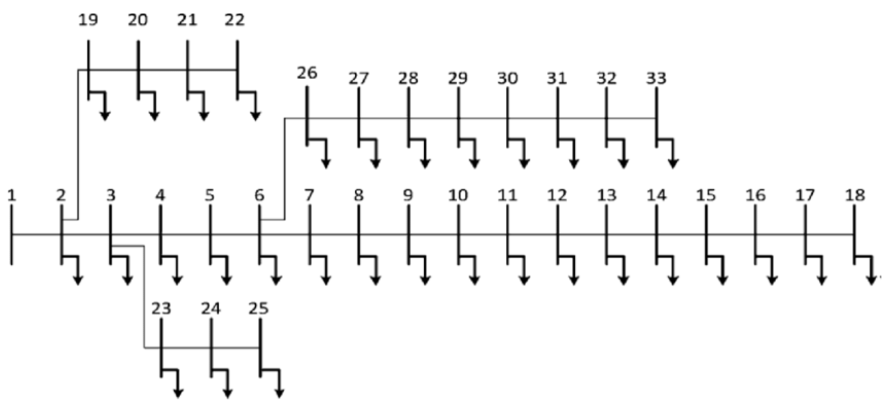


Figure 3.3.1: IEE 33 Test Bus System

## **3.4 Forward Sweep**

The forward sweep method helps to find voltage magnitudes and phase angles at each bus, which are crucial for assessing the performance and stability of power system. The magnitude and phase angle of voltage at each node are determined by using equation 3.1

Vk+1 = 𝑉k −𝑍kIk  [3.1]

where, Current passes through branch is Ik and the value of impedance between node k and k+1 is Zk.

## **3.5 Backward Sweep**

In backward sweep, branch current is updated in each section by taking into consideration the previous iteration voltage at each node. It starts from branch at last node and move towards the branch connected to root node.

The backward and forward sweep equations are determined frequently until result reached acceptable limit. The complete flow chart for load flow analysis of selected distribution system is shown in figure below

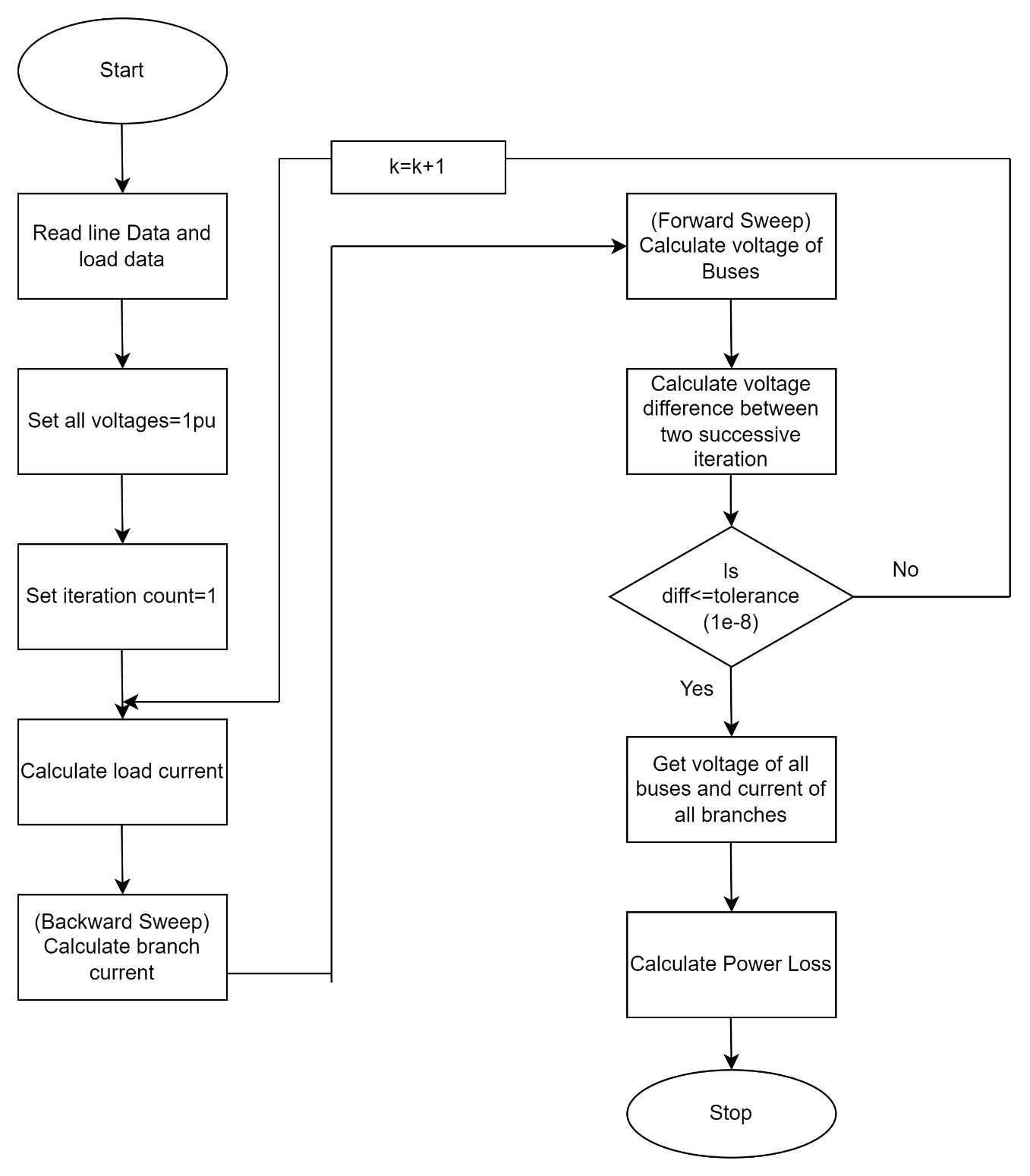


Figure 3.5.1: Flow chart for load flow analysis

Following are the steps can be employed to describe the method for already above-mentioned system power loss calculation.

Step 1: Initializing from giving input of line data (R, X) and bus data (P,Q) of the system

Step 2: Voltage of each node is considered as 1 pu.

Step 3: Calculate each load current

Step 4: Branch current values are determined by using equation of backward sweep method.

Step 5: In forward sweep method the value of voltage and phase angle is corrected.

Step 6: The calculation in backward and forward propagation is done continuously until our criteria of result are reached.

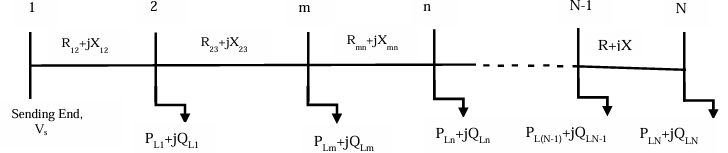
Step 7: Power losses is calculated by latest updated value of voltage and current after criteria met value obtained.

Step 8: At last calculated power losses and voltage level are saved.

Step 9: Stop the process.

## **3.6 Calculation with Base Case**

In this calculation, load flow analysis is carried by using collected line data and load data of Khaireni feeder. The line data (resistance R and reactance X ) and load data(active power P and reactive power Q) of feeder will be provided during simulation. For load flow analysis backward-forward sweep method is used.



During load flow analysis the value of load data and line data are input parameters. Considering initially each node voltage as 1˂0˚. Then calculate each load current by using formula:

=()\* for j=2,3,4………..N  [3.2]

After calculating each load current, calculate branch current by using back-ward sweep method as

=+Summation of all branch current after bus n [3.3]

Then by using forward sweep method all node voltages calculated as

=-Zmn  [3.4]

## **3.7 Distribution Network operational parameters**

Voltage stability, reliability, and power losses (VRP) are the distribution system network's three main operational parameters. This index aids in the analysis of the distribution network's reaction to the addition of a charging load. Every index is calculated and examined independently, taking into account both the loading conditions before and after. Thus, it can be concluded that when there are any kind of network disruptions, this index offers details about the three main working parameters of the network. Voltage, reliability, and power loss (VRP), the distribution line network's three primary operating factors, are taken into account under this effort. An summary of the key operating parameter calculations is given in this section.

### **3.7.1 Voltage Stability Index**

The voltage conditions in the line, taking into account voltage fluctuations and drop, are provided by the voltage stability. According to Kessel and Glavitsch (1986)[17], voltage stability is the power system's ability to maintain a constant voltage at each system bus under normal load conditions as well as when external disturbances are applied. A system must have voltage levels that are within allowable bounds under all load scenarios in order to be considered stable. This study computes the Voltage Sensitivity Factor (VSF) and Voltage Stability Index (VSI) for the investigation of voltage stability indices.The network's dependability can be ascertained using any one of these metrics.

### 3.7.1 Voltage Sensitivity Factor (VSF)

VSF denotes the ratio of voltage change (dV) to the change in active load(dP). It is the measure sensitivity of the system voltage with stepwise loading increment. Mathematically, it is expressed as

VSF= | | Ɐ P < Pmax [3.5]

High value of VSF indicates lesser voltage stability, that means even with small changes on loading behavior, there is significant change in voltage drop (Deb et al., 2018).

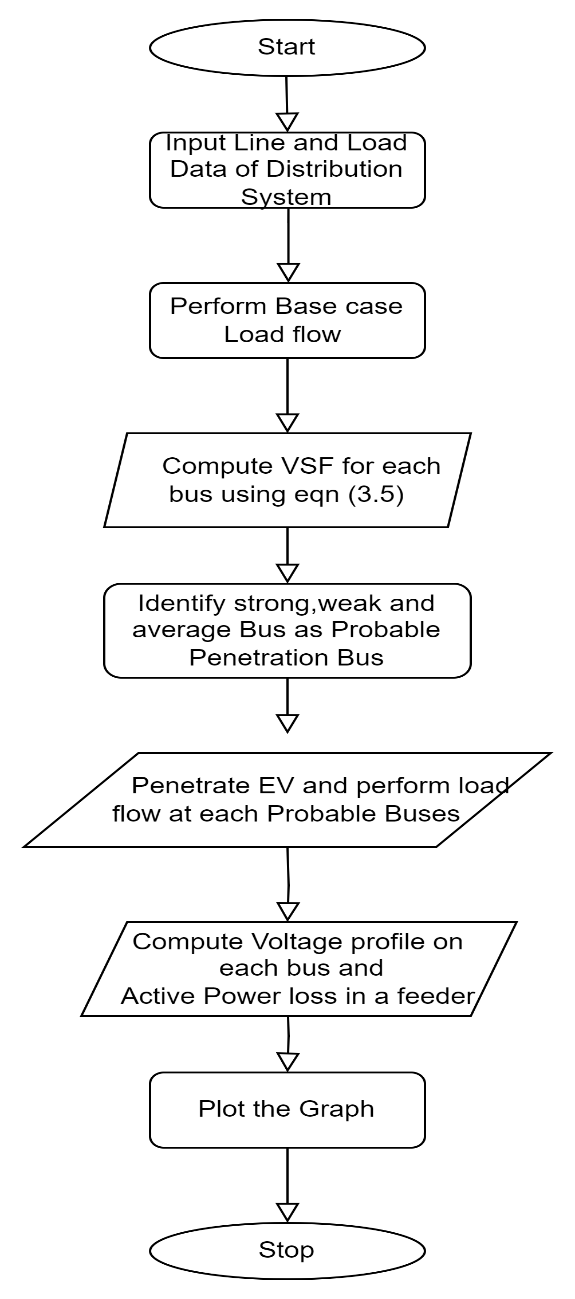


Figure 3.7.1: VSF Determination

### **3.8 Reliability Indices**

From an engineering perspective, system dependability is the capacity of the system to perform its intended function under various operating situations over the course of its expected lifetime. From the perspective of the customer, however, a consistent power supply in their homes and workplaces is considered reliable.  The length of time and frequency of interruptions at the load point are crucial factors in determining dependability indices in both situations.

The client and energy orientations are the two categories into which the reliability indices can be separated. These categories are divided into smaller groups. The primary subcategories of customer-oriented reliability indices that are used in this study are SAIFI, SAIDI, and CAIDI. ENS and AENS are the two subcategories within the energy-oriented category. The indices are defined as follows:

* **SAIFI**: It can be defined as a number of times a customer encounters system interruption in a certain time period. It signifies the condition of system based on interruption. Mathematically,

SAIFI = ; [3.6]

Nj = customer number at jth -bus,

λj = rate of failure at jth -bus

* **SAIDI:** It can be defined as average duration of interruption per served customer. It signifies the system condition on the basis of interrupted duration. Mathematically,

SAIDI = ; [3.7]

uj = duration of interruption at jth -bus

* **CAIDI**: It can be defined as the average duration time of interruption faced by the customers interrupted during a year. It provides the average duration of outage experience by any customer. Mathematically,

CAIDI = [3.8]

### **3.9 Power Losses**

When EV charging load is added to a distribution line, power loss becomes a major concern. Put more simply, power loss is a system's or line's I2R loss. According to Yuvaraj et al. (2023)[18], a larger load addition results in higher power consumption and increased power loss, which could jeopardize the distribution system's ability to achieve power security. Reducing power outages is essential to maintaining system stability and effectiveness. Selecting ideal sites that produce a noticeably smaller change in power loss even with the addition of load is an efficient way to appropriately handle the power loss caused by EVCS load addition. Mathematical modeling can be used to calculate the network's power loss. The total power losses can be given by

= [3.9]

where, Pt = total power loss

Pj = power loss at bus

## **3.9 Calculation in EV load Connected Case**

It is anticipated that the expansion of EVCS load addition and integration on distribution networks would accelerate. It is necessary to investigate how the power distribution network behaves when such an expected demand is included. This study examines how distribution metrics such as voltage stability, power loss, and reliability vary when various load addition scenarios are taken into account. The most and least affected parameters with the addition of load are identified by comparing and analyzing the behavior of the VRP indices before and after load addition. Four Scenarios are created for analysing impact of EV load on Khaireni feeder. Each charger will have 142 kW capacity with 3 points (2DC and 1AC charging) providing the power of 60 kW for DC and 22kW for AC charging.

The bus to where EV load is to be connected is determined through VSF analysis. Following the analysis of the system under base case conditions and with varying loads, the effect of adding an EVCS load is examined. Various scenarios are taken into consideration in order to predict the EVCS load on the current system. One bus from the lower VSF group, also known as the strong group, one bus from the average group, and two buses from the weaker group are included in the examples. This is done in order to build a variety of platforms that can be used to represent the EVCS load in the network, which is made up of both sensitive and high load sites. Table 1 provides a summary of the cases.

Table 3.9.1: Cases considered for impact analysis of EV charging

|  |  |  |
| --- | --- | --- |
| **Cases** | **Description** | **Load Increment (kW)** |
| 1 | 1 Charger in strong Bus group: Bus 2 | 142 |
| 2 | 1 Charger in weak Bus group: Bus 29 | 142 |
| 3 | 2 Charger in strong and average Bus group: Bus 2 and Bus 9 | 284 |

# **CHAPTER FOUR: RESULT AND DISCUSSION**

## **4.1 Load Flow Analysis of Khaireni Feeder in Base Case**

Table 4.1.1: Voltage Profile and Power Losses in Khaireni Feeder in Base Case

|  |  |  |  |
| --- | --- | --- | --- |
| **Bus No** | **Voltage (pu)** | **Branch No** | **Active Power Loss (KW)** |
| 1 | 1 |  | 0 |
| 2 | 0.992512 | 1-2 | 15.89692308 |
| 3 | 0.991133 | 2-3 | 2.697596215 |
| 4 | 0.987671 | 3-4 | 6.388371908 |
| 5 | 0.984666 | 4-5 | 5.506276942 |
| 6 | 0.970643 | 5-6 | 19.14691442 |
| 7 | 0.970018 | 6-7 | 0.835602036 |
| 8 | 0.968879 | 7-8 | 1.393550307 |
| 9 | 0.960687 | 8-9 | 8.020016719 |
| 10 | 0.960326 | 9-10 | 0.31130346 |
| 11 | 0.958084 | 10-11 | 1.805205556 |
| 12 | 0.955393 | 11-12 | 1.301965673 |
| 13 | 0.954197 | 12-13 | 0.280721898 |
| 14 | 0.953843 | 13-14 | 0.050678891 |
| 15 | 0.992448 | 2-15 | 0.006583058 |
| 16 | 0.983635 | 5-16 | 0.142950849 |
| 17 | 0.983592 | 16-17 | 0.002978728 |
| 18 | 0.967995 | 8-18 | 0.14020334 |
| 19 | 0.967667 | 18-19 | 0.028862732 |
| 20 | 0.967143 | 19-20 | 0.02772269 |
| 21 | 0.967121 | 20-21 | 0.000770263 |
| 22 | 0.955981 | 11-22 | 0.582405219 |
| 23 | 0.955948 | 22-23 | 0.00131926 |
| 24 | 0.954779 | 22-24 | 0.190399078 |
| 25 | 0.954514 | 24-25 | 0.018972078 |
| 26 | 0.953799 | 12-26 | 0.256670603 |
| 27 | 0.953788 | 26-27 | 0.000197987 |
| 28 | 0.953267 | 26-28 | 0.038054597 |
| 29 | 0.953134 | 28-29 | 0.00475676 |
|  |  |  | **65.08** |

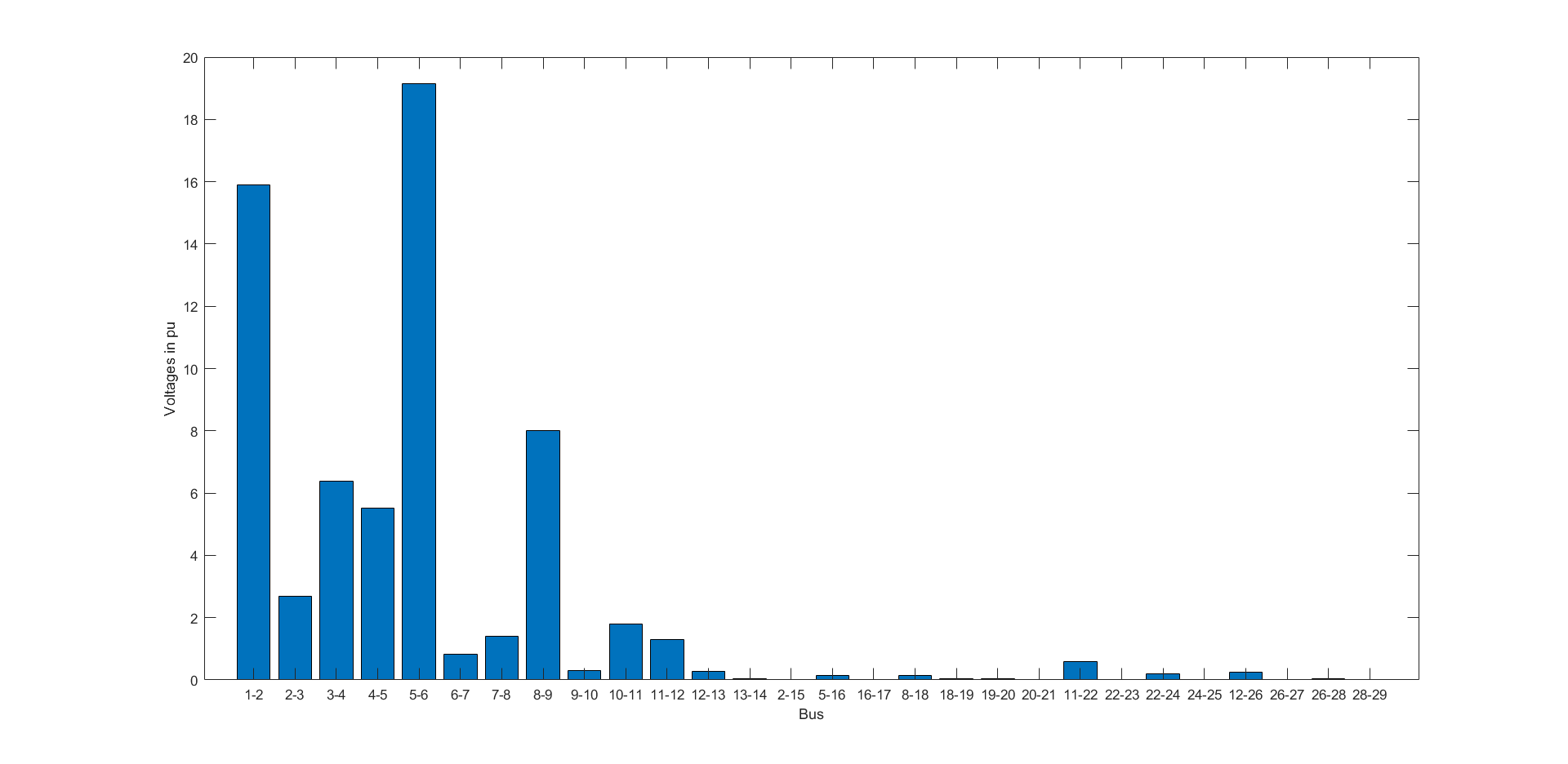


Figure 4.1.2: IEE 33 Tsgdgdgbcxvvzdrfest Bus System

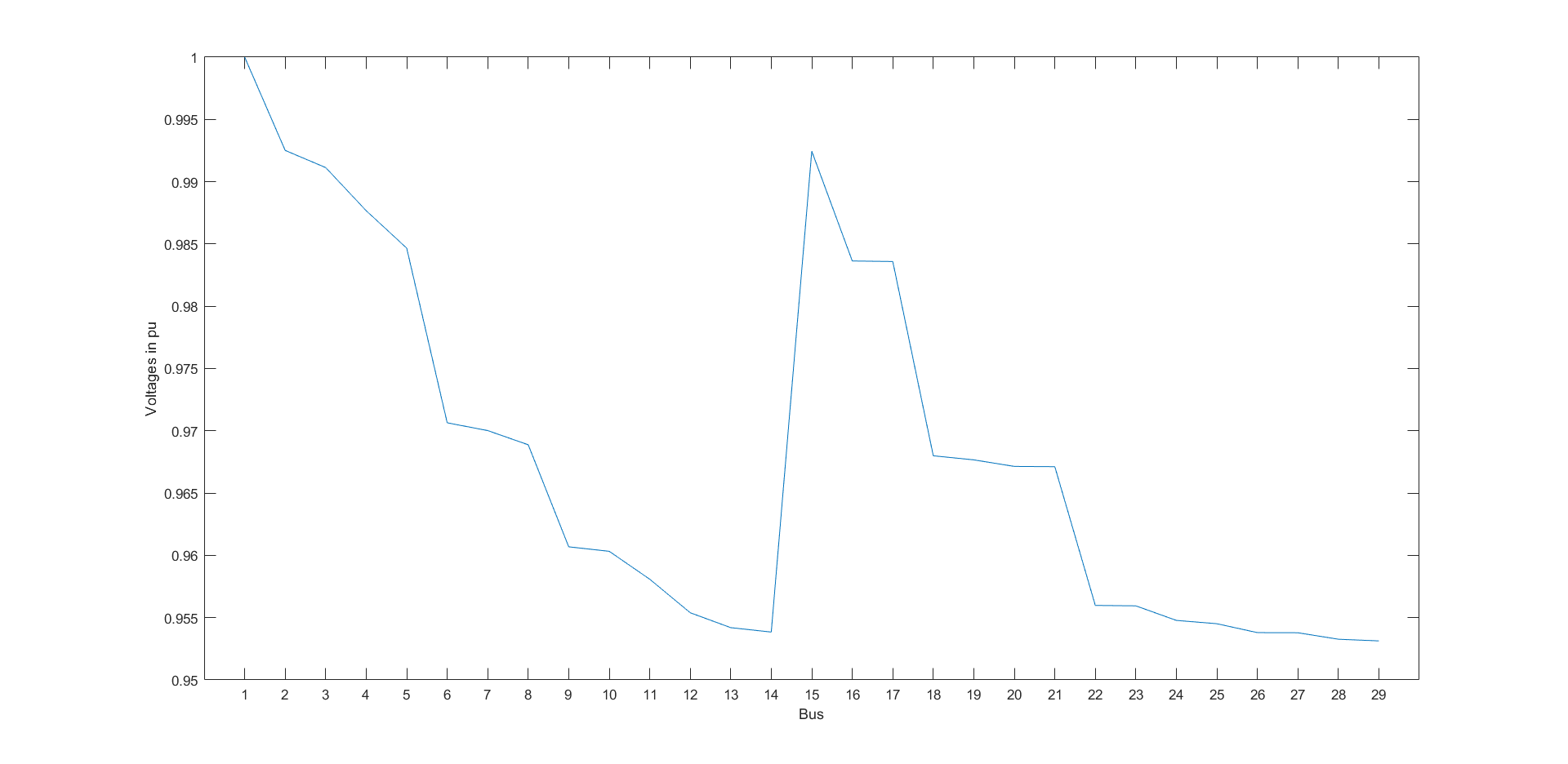


Figure 4.1.2: Voltage Profile of Khaireni Feeder

The proposed Backward/Forward sweep algorithm is used on Khaireni radial distribution system using MATLAB coding.Khaireni feeder bus radial distribution network consists of 29 nodes and 28 branches. The base voltage for this system is 11 kV and base MVA is 100. The tolerance is 10-8 p.u. The Total Real power loss is 65.07 KW.The maximum voltage drop occurs in Bus no 29 which is of value 0.953134 pu.

## **4.2 Determination of Strong and weak Buses**

## The system's load flow analysis was completed, and the base case voltage was noted.The calculation of the voltage sensitivity factor allowed for the identification of the line's strong and weak buses. Higher VSF values indicate more sensitivity to load addition, whereas lower VSF values indicate resilience to load addition-related fluctuations.

Table 4.2.1: VSF of Different Buses at Base case

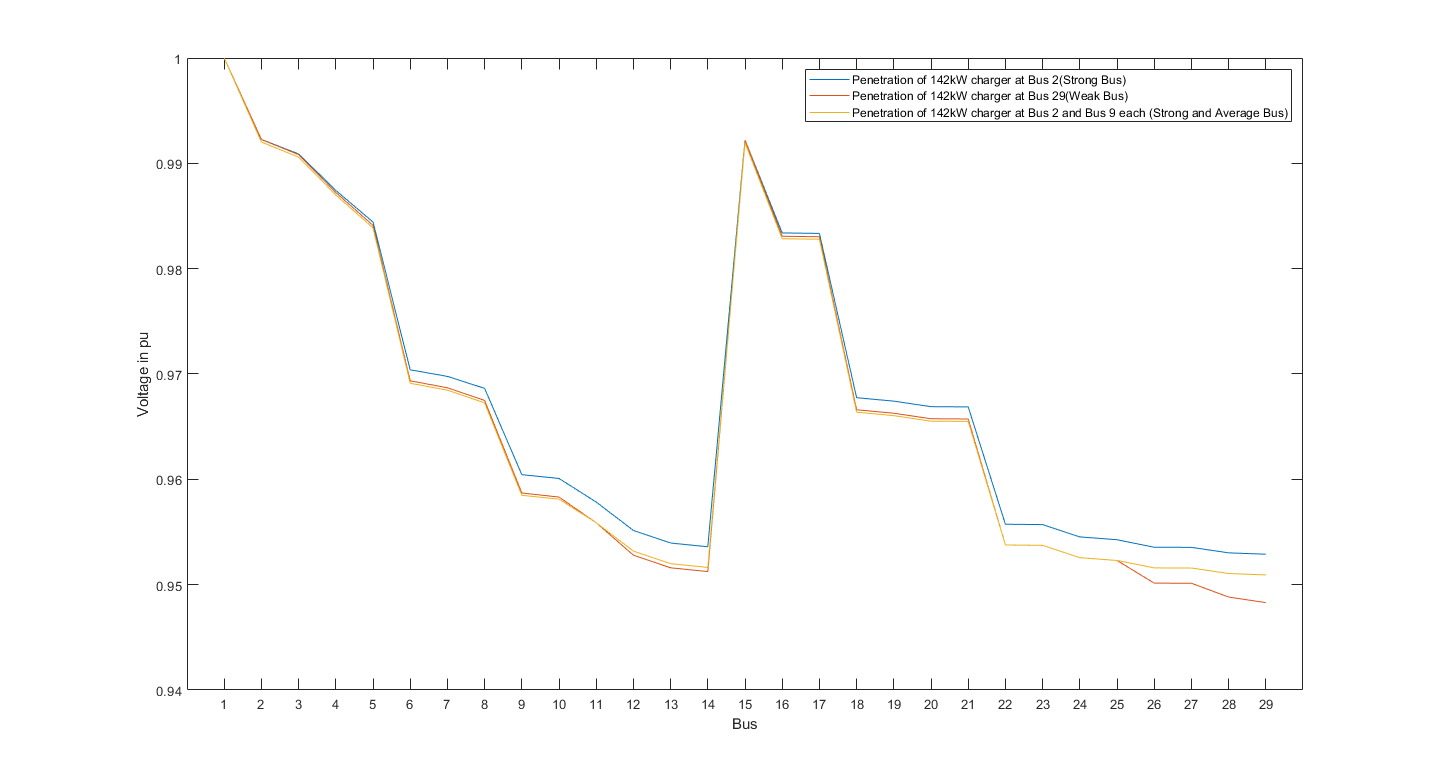
|  |  |
| --- | --- |
| **Bus No** | **Sensitivity (%)** |
| **29** | **36.614** |
| 28 | 36.3252 |
| 27 | 35.2221 |
| 26 | 35.1748 |
| 25 | 34.904 |
| 24 | 34.6057 |
| 23 | 33.1703 |
| 22 | 33.0883 |
| 14 | 32.8552 |
| 13 | 32.647 |
| 12 | 32.1087 |
| 11 | 30.1069 |
| 10 | 28.3933 |
| **9** | **28.1154** |
| 21 | 26.2206 |
| 20 | 26.1732 |
| 19 | 24.6739 |
| 18 | 23.831 |
| 8 | 22.1377 |
| 7 | 21.2428 |
| 6 | 20.7707 |
| 17 | 11.1384 |
| 16 | 11.0919 |
| 5 | 9.9777 |
| 4 | 8.0275 |
| 3 | 5.7162 |
| 15 | 4.8625 |
| **2** | **4.8166** |
| 1 | 0 |

From above table it is clear that Bus 2 is least sensitive Bus (4.8166%), Bus 29 is most sensitive Bus (36.614%) and Bus 9 is average sensitive Bus (28.1154%). Here Bus 1 is slack Bus.

## **4.3 Load flow Analysis of Khaireni Feeder**

Table 4.3.1:Voltage Profile before and after penetration of EV charging station in different cases

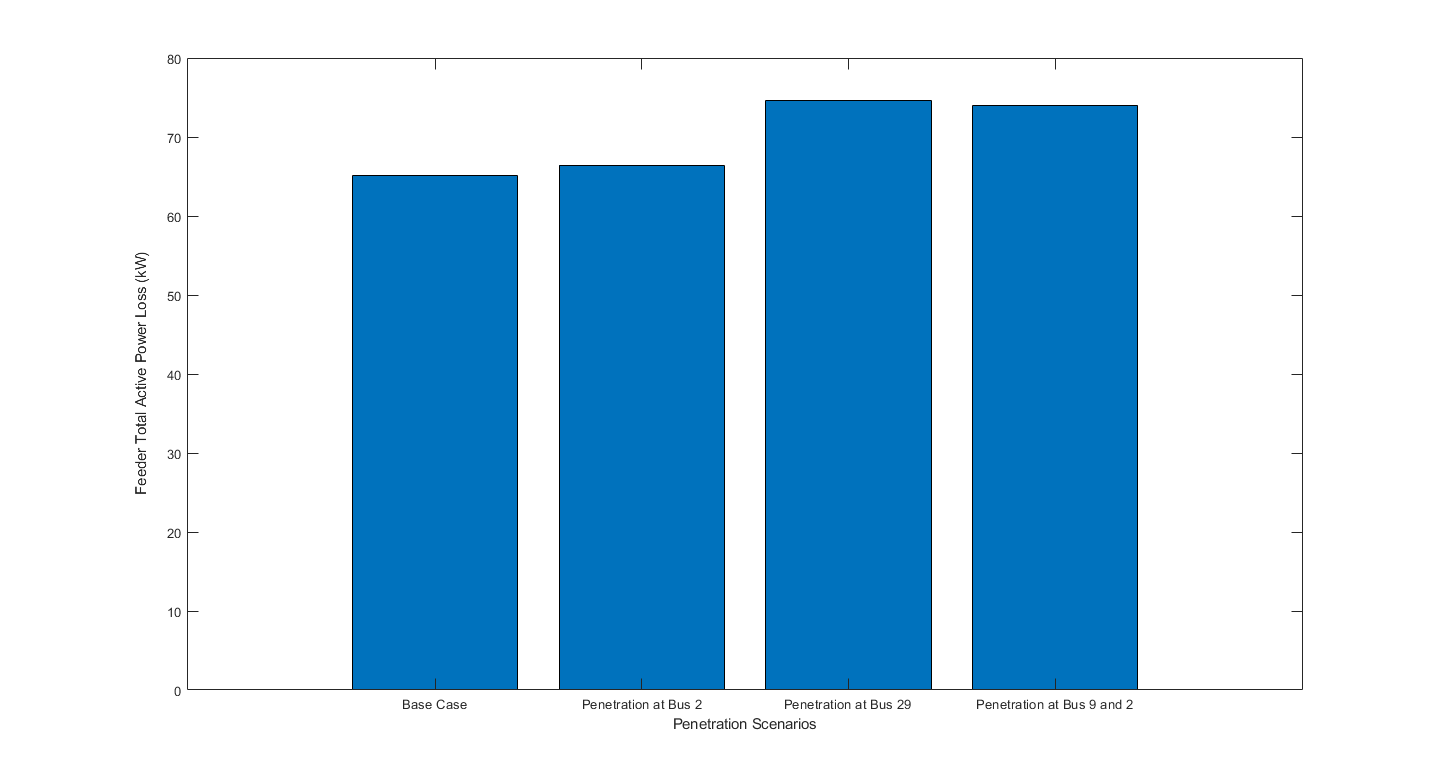
|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Bus No** | **Base Case** | **Case 1** | **Case 2** | **Case 3** |
| 1 | 1 | 1 | 1 | 1 |
| 2 | 0.992512 | 0.992269 | 0.992257 | 0.992017 |
| 3 | 0.991133 | 0.99089 | 0.990828 | 0.990588 |
| 4 | 0.987671 | 0.987428 | 0.987231 | 0.986992 |
| 5 | 0.984666 | 0.984423 | 0.984108 | 0.983871 |
| 6 | 0.970643 | 0.970399 | 0.969351 | 0.969121 |
| 7 | 0.970018 | 0.969774 | 0.968694 | 0.968464 |
| 8 | 0.968879 | 0.968635 | 0.967489 | 0.96726 |
| 9 | 0.960687 | 0.960443 | 0.958706 | 0.958483 |
| 10 | 0.960326 | 0.960082 | 0.958315 | 0.958122 |
| 11 | 0.958084 | 0.95784 | 0.955878 | 0.955879 |
| 12 | 0.955393 | 0.955149 | 0.952796 | 0.953188 |
| 13 | 0.954197 | 0.953953 | 0.9516 | 0.951992 |
| 14 | 0.953843 | 0.953598 | 0.951245 | 0.951637 |
| 15 | 0.992448 | 0.992205 | 0.992193 | 0.991953 |
| 16 | 0.983635 | 0.983391 | 0.983076 | 0.982839 |
| 17 | 0.983592 | 0.983348 | 0.983033 | 0.982796 |
| 18 | 0.967995 | 0.967751 | 0.966603 | 0.966374 |
| 19 | 0.967667 | 0.967423 | 0.966275 | 0.966046 |
| 20 | 0.967143 | 0.966899 | 0.96575 | 0.965521 |
| 21 | 0.967121 | 0.966877 | 0.965729 | 0.965499 |
| 22 | 0.955981 | 0.955736 | 0.953768 | 0.95377 |
| 23 | 0.955948 | 0.955703 | 0.953735 | 0.953736 |
| 24 | 0.954779 | 0.954534 | 0.952562 | 0.952564 |
| 25 | 0.954514 | 0.954268 | 0.952296 | 0.952298 |
| 26 | 0.953799 | 0.953554 | 0.950145 | 0.95159 |
| 27 | 0.953788 | 0.953543 | 0.950134 | 0.951579 |
| 28 | 0.953267 | 0.953022 | 0.948824 | 0.951057 |
| 29 | 0.953134 | 0.952889 | 0.948297 | 0.950924 |

 Figure 4.3.1: Voltage profile before and after penetration of EV charging station in different cases

Equation 3.5 is used to determine the Voltage Stability Index for both base case and various scenarios of EVCS load addition following load flow analysis. It has been noted that as more load is added to the system, the value of VSI steadily drops. Table 4.3.1 summarizes the voltage variance caused by the load augmentation on each bus. Compared to the base case, case 1, it is noted that the voltage steadily drops in cases 2 and 3.

## **4.4 Impact on Power Loss**

The power loss is calculated directly through load flow analysis in this study. The active power loss on each bus are summed up to calculate total power loss in the case. The total active power loss for the several cases are tabulated in Table 5 below.

Table 4.4.1: Active Power loss(KW) before and after penetration of EV charging station in different cases

|  |  |  |  |
| --- | --- | --- | --- |
| **Base Case** | **Case 1** | **Case 2** | **Case 3** |
| 65.078 | 66.43271 | 74.60054 | 74.01463 |

Figure 4.4.1: Active power loss before and after penetration of EV charging station in different cases

The system's power loss increased as the load from EV charging stations was added. When EV chargers are added to the weakest busses in the model (Case 2), the power loss is greatest. Even though a bus is sturdy, the concentration of load on it results in increased power loss. Thus, dividing the load among the buses considerably lowers power loss i.e Case 3 compared to Case 2.

## **4.5 Impact on Reliability Indices**

The influence of EVCS load augmentation is studied by the calculation of the dependability indices SAIFI, SAIDI, CAIDI. For each case listed in Table 1, the computation is completed.   
Table 6 displays the results of the unitary technique used to compute the reliability indices for various instances in terms of failure rate and outage length.

Table 4.5.1: Reliabilty Indices before and after penetration of EV charging station in different cases

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Reliability Indices** | **Base Case** | **With Penetration Scenario** | | |
| **Case 1** | **Case 2** | **Case 3** |
| **SAIFI** | 253.42 | 240.58 | 241.0625 | 229.94 |
| **SAIDI** | 63.0625 | 59.788 | 59.968 | 56.94 |
| **CAIDI** | 0.2488 | 0.2485 | 0.2487 | 0.2477 |

According to the above table, there is an increase in Case 2, however cases 1, 3 show decreasing values for SAIFI and SAIDI from base value. The following factors may contribute to the decline in the value of reliability indices such as SAIFI, SAIDI, and CAIDI:

• Balance of loads   
• Diversity of loads

The more dependable system exhibits a nearly constant line of SAIDI and SAIFI, which show the outage time and failure rate at loaded conditions. Thus, it is evident that the additional EVCS load has a major impact on SAIFI and SAIDI. Additionally, the CAIDI value is nearly constant across all test scenarios, indicating that this reliability measure is either least affected or not changed at all.

# **CHAPTER FIVE: CONCLUSION AND RECOMMENDATION**

The impact with the addition of EV charging station load in this feeder line is studied by making several cases. The system's weak and strong buses were determined by the VSF computation. that Bus 2 is least sensitive Bus (4.8166%), Bus 29 is most sensitive Bus (36.614%) and Bus 9 is average sensitive Bus (28.1154%). The system is further affected when EVCS is integrated into a weak bus. To increase system stability, reliability, and efficiency, the weak buses should have the fewest charging stations available to them, according to changes in power loss, reliability indices, and voltage stability. Power loss is shown to be the primary factor to be taken into account when placing EV charging stations in distribution feeders, followed by reliability indices and voltage stability.

With the increased load addition on the line, the voltage profile keeps on degrading and power loss increases.The Base case Power loss is 65.078Kw which goes on increasing with increase in EV charger load.When penetration of 142Kw EV charging station at strong Bus power loss is 66.4327Kw, penetration of 142Kw EV charging station at weak Bus power loss is 74.6Kw and penetration of 142Kw each EV charging station at strong Bus and average Bus power loss becomes 74.01Kw.

There is an increase in reliability indices in Case 2, however in cases 1and 3 shows decreasing values for reliability indices like:SAIFI and SAIDI from base value.The CAIDI is almost constant for all three cases (0.24).

The integration of distributed generation can improve the situation for the location of EV charging stations, accommodating a larger number of users and also enhancing the system's overall dependability, voltage deviation, and power loss. This can be the focus of future study. Because the power loss is the study's most affected parameter, it is given more weight while creating the optimization function. The best places to deploy EVCS are identified by adding restrictions to the VRP index optimization problem.

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# **APPENDIX**

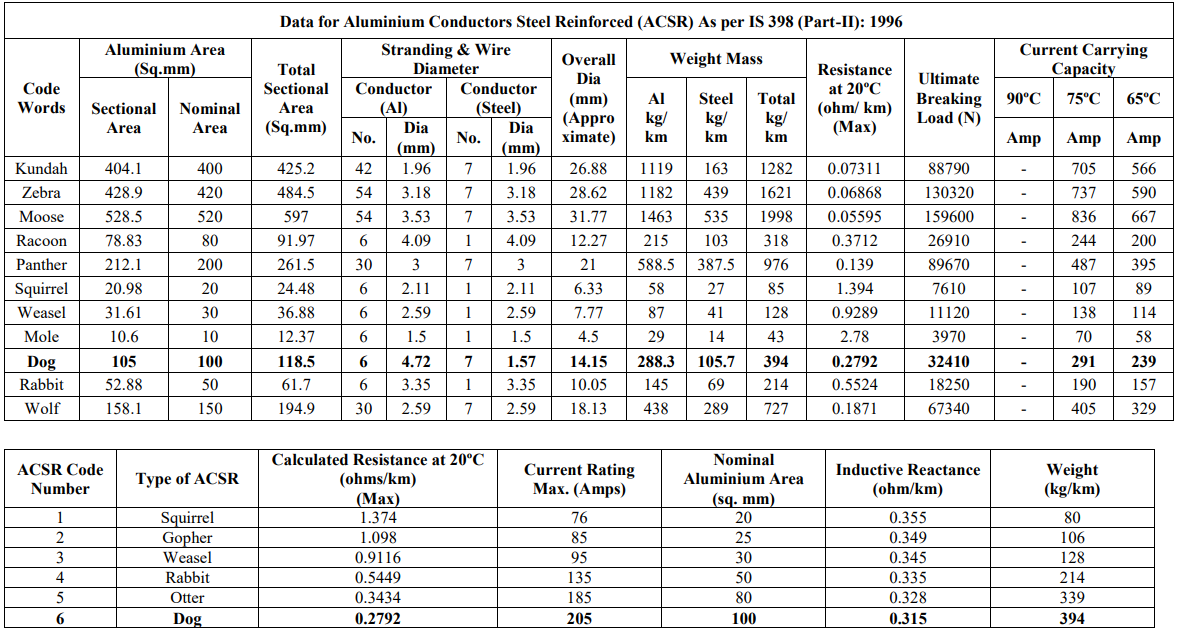
Table A.1: Specification of ACSR Conductor

Table A.2: Khaireni Feeder Length and Conductor Type

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Bus ID** | **Branch Number** | **From Bus** | **To Bus** | **Length (km)** | **Type of Conductor(mm2)** |
| Substation |  |  | 1 |  |  |
| Hotel Ravi Mahal | 1 | 1 | 2 | 0.75 | Dog |
| DadaNaak | 2 | 2 | 3 | 0.15 | Dog |
| NTC Office | 3 | 3 | 4 | 0.4 | Dog |
| Sujal Foods | 4 | 4 | 5 | 0.35 | Dog |
| Bhatyako Chawki | 5 | 5 | 6 | 3 | Dog |
| Grihyalaxmi | 6 | 6 | 7 | 0.1 | Dog |
| Tallo Gagangauda | 7 | 7 | 8 | 0.2 | Dog |
| Buddiman | 8 | 8 | 9 | 1.8 | Dog |
| Lameyhaat | 9 | 9 | 10 | 0.09 | Dog |
| Majuwa | 10 | 10 | 11 | 0.6 | Dog |
| Kotre | 11 | 11 | 12 | 1.4 | Dog |
| Kotre Pole Plant | 12 | 12 | 13 | 1.1 | Dog |
| Hotel Ravi Mahal | 13 | 13 | 14 | 0.4 | Rabbit |
| Sujal Foods | 14 | 2 | 15 | 0.1 | Rabbit |
| Bhandari Rice Mill | 15 | 5 | 16 | 1.2 | Rabbit |
| Tallo Gagangauda | 16 | 16 | 17 | 0.1 | Rabbit |
| Chhaplayang | 17 | 8 | 18 | 0.9 | Rabbit |
| Thulo Pudi | 18 | 18 | 19 | 0.6 | Rabbit |
| Ncell | 19 | 19 | 20 | 1.8 | Rabbit |
| Majuwa | 20 | 20 | 21 | 0.1 | Rabbit |
| Bio Gas | 21 | 11 | 22 | 0.9 | Weasel |
| Bio Gas | 22 | 22 | 23 | 0.1 | Weasel |
| Eakleya Faat I | 23 | 22 | 24 | 0.9 | Weasel |
| Kotre | 24 | 24 | 25 | 0.6 | Rabbit |
| Tallo Pudi | 25 | 12 | 26 | 2 | Rabbit |
| Tallo Pudi | 26 | 26 | 27 | 0.1 | Rabbit |
| Uppalo Pudi I | 27 | 26 | 28 | 1.4 | Rabbit |
| Uppalo Pudi II | 28 | 28 | 29 | 0.6 | Rabbit |

|  |  |  |
| --- | --- | --- |
| **Transformer Location** | **With Load Factor(kVA)** | **Transformer Capacity (kVA)** |
| Hotel Ravi Mahal | 120 | 150 |
| DadaNaak | 160 | 200 |
| NTC Office | 20 | 25 |
| Sujal Foods | 504 | 630 |
| Bhatyako Chawki | 40 | 50 |
| Grihyalaxmi | 160 | 200 |
| Tallo Gagangauda | 160 | 200 |
| Buddiman | 160 | 200 |
| Lameyhaat | 80 | 100 |
| Majuwa | 160 | 200 |
| Kotre | 160 | 200 |
| Kotre Pole Plant | 160 | 200 |
| Hotel Ravi Mahal | 160 | 200 |
| Sujal Foods | 120 | 150 |
| Bhandari Rice Mill | 80 | 100 |
| Tallo Gagangauda | 80 | 100 |
| Chhaplayang | 80 | 100 |
| Thulo Pudi | 40 | 50 |
| Ncell | 20 | 25 |
| Majuwa | 40 | 50 |
| Bio Gas | 80 | 100 |
| Bio Gas | 40 | 50 |
| Eakleya Faat I | 80 | 100 |
| Kotre | 80 | 100 |
| Tallo Pudi | 80 | 100 |
| Tallo Pudi | 20 | 25 |
| Uppalo Pudi I | 40 | 50 |
| Uppalo Pudi II | 40 | 50 |
|  | **2964** | **3705** |

Table A.3: Transformer Length and Capacity of Khaireni Feeder

Table A.4: Line Data of Khaireni Feeder

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Branch Number** | **From Bus** | **To Bus** | **Length (km)** | **R(ohm)** | **X(ohm)** |
| 1 | 1 | 2 | 0.75 | 0.205875 | 0.23625 |
| 2 | 2 | 3 | 0.15 | 0.041175 | 0.04725 |
| 3 | 3 | 4 | 0.4 | 0.1098 | 0.126 |
| 4 | 4 | 5 | 0.35 | 0.096075 | 0.11025 |
| 5 | 5 | 6 | 3 | 0.8235 | 0.945 |
| 6 | 6 | 7 | 0.1 | 0.02745 | 0.0315 |
| 7 | 7 | 8 | 0.2 | 0.0549 | 0.063 |
| 8 | 8 | 9 | 1.8 | 0.4941 | 0.567 |
| 9 | 9 | 10 | 0.09 | 0.024705 | 0.02835 |
| 10 | 10 | 11 | 0.6 | 0.1647 | 0.189 |
| 11 | 11 | 12 | 1.4 | 0.3843 | 0.441 |
| 12 | 12 | 13 | 1.1 | 0.30195 | 0.3465 |
| 13 | 13 | 14 | 0.4 | 0.21796 | 0.134 |
| 14 | 2 | 15 | 0.1 | 0.05449 | 0.0335 |
| 15 | 5 | 16 | 1.2 | 0.65388 | 0.402 |
| 16 | 16 | 17 | 0.1 | 0.05449 | 0.0335 |
| 17 | 8 | 18 | 0.9 | 0.49041 | 0.3015 |
| 18 | 18 | 19 | 0.6 | 0.32694 | 0.201 |
| 19 | 19 | 20 | 1.8 | 0.98082 | 0.603 |
| 20 | 20 | 21 | 0.1 | 0.05449 | 0.0335 |
| 21 | 11 | 22 | 0.9 | 0.82044 | 0.3105 |
| 22 | 22 | 23 | 0.1 | 0.09116 | 0.0345 |
| 23 | 22 | 24 | 0.9 | 0.82044 | 0.3105 |
| 24 | 24 | 25 | 0.6 | 0.32694 | 0.201 |
| 25 | 12 | 26 | 2 | 1.0898 | 0.67 |
| 26 | 26 | 27 | 0.1 | 0.05449 | 0.0335 |
| 27 | 26 | 28 | 1.4 | 0.76286 | 0.469 |
| 28 | 28 | 29 | 0.6 | 0.32694 | 0.201 |

Table A.5: Load Data of Khaireni Feeder

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Branch Number** | **From Bus** | **To Bus** | **Length (km)** | **PL (KW)** | **QL**  **(KVAR)** |
| 1 | 1 | 2 | 0.75 | 103.2 | 61.2 |
| 2 | 2 | 3 | 0.15 | 137.6 | 81.6 |
| 3 | 3 | 4 | 0.4 | 17.2 | 10.2 |
| 4 | 4 | 5 | 0.35 | 433.44 | 257.04 |
| 5 | 5 | 6 | 3 | 34.4 | 20.4 |
| 6 | 6 | 7 | 0.1 | 137.6 | 81.6 |
| 7 | 7 | 8 | 0.2 | 137.6 | 81.6 |
| 8 | 8 | 9 | 1.8 | 137.6 | 81.6 |
| 9 | 9 | 10 | 0.09 | 68.8 | 40.8 |
| 10 | 10 | 11 | 0.6 | 137.6 | 81.6 |
| 11 | 11 | 12 | 1.4 | 137.6 | 81.6 |
| 12 | 12 | 13 | 1.1 | 137.6 | 81.6 |
| 13 | 13 | 14 | 0.4 | 137.6 | 81.6 |
| 14 | 2 | 15 | 0.1 | 103.2 | 61.2 |
| 15 | 5 | 16 | 1.2 | 68.8 | 40.8 |
| 16 | 16 | 17 | 0.1 | 68.8 | 40.8 |
| 17 | 8 | 18 | 0.9 | 68.8 | 40.8 |
| 18 | 18 | 19 | 0.6 | 34.4 | 20.4 |
| 19 | 19 | 20 | 1.8 | 17.2 | 10.2 |
| 20 | 20 | 21 | 0.1 | 34.4 | 20.4 |
| 21 | 11 | 22 | 0.9 | 68.8 | 40.8 |
| 22 | 22 | 23 | 0.1 | 34.4 | 20.4 |
| 23 | 22 | 24 | 0.9 | 68.8 | 40.8 |
| 24 | 24 | 25 | 0.6 | 68.8 | 40.8 |
| 25 | 12 | 26 | 2 | 68.8 | 40.8 |
| 26 | 26 | 27 | 0.1 | 17.2 | 10.2 |
| 27 | 26 | 28 | 1.4 | 34.4 | 20.4 |
| 28 | 28 | 29 | 0.6 | 34.4 | 20.4 |
|  |  |  |  | **2549.04** | **1511.64** |

Table A.6: Reliabilty Indices Data of Khaireni Feeder

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Bus No** | **Bus name** | **Number of Consumers** | **No of Trip/year** | **Duration of trip/year** |
| 1 | Substation | 5731 | 225 | 59.7 |
| 2 | Hotel Ravi Mahal | 1 | 10 | 1 |
| 3 | Gachyyafat | 1 | 20 | 1.6 |
| 4 | DadaNaak | 600 | 35 | 2 |
| 5 | NTC Office | 1 | 10 | 2 |
| 6 | Sujal Foods | 1 | 28 | 2 |
| 7 | Bhandari Rice Mill | 100 | 35 | 2.4 |
| 8 | Bhandardik | 600 | 28 | 3 |
| 9 | Bhatyako Chawki | 500 | 45 | 3.6 |
| 10 | Grihyalaxmi | 1 | 34 | 3.6 |
| 11 | Tallo Gagangauda | 500 | 35 | 4 |
| 12 | Chhaplayang | 100 | 24 | 4 |
| 13 | Thulo Pakha | 100 | 22 | 4 |
| 14 | Ncell | 1 | 10 | 6 |
| 15 | Apukaseri | 70 | 20 | 6 |
| 16 | Buddiman | 600 | 27 | 3 |
| 17 | Lameyhaat | 350 | 32 | 4 |
| 18 | Majuwa | 400 | 28 | 4 |
| 19 | Bio gas | 1 | 15 | 4 |
| 20 | Block Factory | 1 | 15 | 4 |
| 21 | Eaklyekhet I | 200 | 25 | 2 |
| 22 | Eaklyekhet II | 250 | 12 | 2 |
| 23 | Kotre | 600 | 28 | 3 |
| 24 | Tallo Pudi | 300 | 16 | 5 |
| 25 | Ncell | 1 | 8 | 5 |
| 26 | Uppalo Pudi I | 250 | 16 | 4 |
| 27 | Uppalo Pudi II | 200 | 16 | 4.4 |
| 28 | Kotre Pole Plant | 1 | 20 | 3 |
| 29 | Yaso Santi | 1 | 10 | 3 |
| **Total Number of Consumers** | | **5731** |  |  |
|  |  |  |  |  |