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Impact of V2G Integration on an Urban Distribution Feeder in Nepal. A Case Study of Baneshwor Feeder.

By

Rupesh Kumar Sah

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DEPARTMENT OF ELECTRICAL ENGINEERING
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Pulchowk, Lalitpur

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The undersigned certify that they have read, and recommended to the Institute of Engineering for acceptance, a thesis report entitled **"Impact of V2G on an Urban Feeder in Nepal: A Case of Baneshwor Feeder"** submitted by **Mr. Rupesh Kumar Sah** in partial fulfillment of the requirements for the degree of **Master of Science in Power System Engineering.**

Prof. Dr. Nava Raj Karki
Supervisor
Department of Electrical Engineering

Asst. Prof. Yuba Raj Adhikari
Supervisor and HOD
Department of electrical engineering

Er. Pravin Kumar
External Examiner
Deputy Manager, Nepal Telecom

Assoc. Prof. Dr. Basanta Kumar Gautam
Program Coordinator
Department of Electrical Engineering

Dec, 2023

Tel: +977-1-5443081, Email: doee@pcampus.edu.np, Website: www.doee.pcampus.edu.np

ABSTRACT

The electrification of transportation through Electric Vehicles (EVs) gains momentum in the energy sector. The study emphasizes the increasing strain on distribution feeders, the backbone of local electricity. The addition of high-power electric vehicle charging station in distribution system can cause voltage drops, overloading of transformers and increase outage or disturbances. In Urban areas, clustering of CS can lead to distribution congestion. This thesis aims to placing charging station without physical restructuring of the network and distribution parameter should not violate operating region. Placement of charging station is based on novel Electrical Vehicle Placement Index (EVPI). Genetic algorithm is used for the optimal placement of charging station. This research also focuses on the integration of V2G technology as a dynamic tool for enhancing distribution reliability. A coordinated way of charging and discharging of vehicle. The analysis is carried out in IEEE 33 bus radial distribution system with five different test cases. The test case results strong and weak bus based on reliability index approach. Placement of CS at strong bus keeps the smooth operation while placing at weak bus, deteriorates system performance. Finally, this approach is implemented for real-time Baneshwor feeder distribution system.

Index terms: Electric vehicle charging station (EVCS), Distribution system, Electric vehicle placement index (EVPI), vehicle-to-grid (V2G), Reliability

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LIST OF ABBREVIATIONS

EV:	Electric Vehicle
EVCS:	Electric vehicle Charging Stations
V2G:	Vehicle-to-Grid
MTTF:	Mean time to failure rate
MTTR:	Mean time to repair rate
SAIFI:	System average interruption frequency index.
SAIDI:	System average interruption duration index
CAIDI:	Customer average interruption duration index
ENS:	Energy not supplied
AENS:	Average energy not supplied
COI:	Customer oriented indices
EOI:	Energy oriented indices
SMC:	Sequential Monte-Carlo
NSMC:	Non-sequential Monte-Carlo
SOC:	State of charge
EVPI:	Electric Vehicle placement index
VSI:	Voltage stability indices
P_L:	Active power loss
LSF:	Loss sensitivity factor
BRI:	Bus reliability indices
AIT:	Average interruption time
GA:	Genetic algorithm

1. CHAPTER ONE. INTRODUCTION

1. 1. Background

Electric vehicle is increasing day by day. The recent trend of Electric Vehicles (EVs) is a transformative shift in the automotive industry. The rapid advancement of battery technologies, and power control system has significantly improved the performance, range, and affordability of Electric Vehicles. EVs helps in controlling air pollution in urban area. Electric vehicle has many advantages over Fuel operating vehicle. These vehicles are environmental-friendly and energy saving. According to Bloomberg, Sales of EV cars may increase to 28 million in 2030 and 54 million by 2040 [1]. Nepal has targeted 35% share of EV in transportation [2]. There are only 3800 vehicles registered in Kathmandu by July,2023 mostly due to covid-19 pandemic [3]. By 2030, Nepal has targeted sales of EV increases to cover 90% market of all private EV sales [1]. There is so many problems come in power system when it comes in connection with a large number of EVs. Large number of EV increases strain on distribution network. Large number of EV integration deteriorate the voltage stability, reliability and power quality of the distribution network. Voltage and Reliability of the system decreases. Power loss in the system increases. During peak load time, it is very difficult to provide charging to these vehicles. Although there is sufficient power supply, But due to limited conductor capacity. There is chance of conductor failure, multiple interruption. Real-Time charging management is required not to degrade voltage, reliability efficiency and economics of the electricity services [4].

This paper proposes V2G control scheme into the power system to provide real-time management of charging and discharging. During peak hour, V2G enable the supply of electricity at charging points [5]. Electric vehicle can be effectively used as energy storage device [6]. Discharging to grid increase efficiency and performance of the network. It provides spinning reserve for instantaneous intermittency [7]. Discharging in peak hour is also cost benefit [6]. The price of electricity is high during peak hour and low during off peak hour. Charging EV during off-peak hour and discharging during peak hour. Charging is managed to lesser the impact on the grid and maximize the profit [6]. At present the number of EV is very small, the power system is not affected. When it increases by large number in future will have highly affect the power system [8]. Inversely, when discharge takes by these vehicles will increase the reliability of power system. EV affect the distribution system. Reliability assessment of distribution is determined. Reliability is evaluated when charging is unscheduled and scheduled discharging V2G mode. The effect of V2G can be clearly seen in the distribution system with the increasing penetration of EVs [8]. Very few studies are conducted on evaluating the impact of V2G on urban distribution system. Some assumptions have been made. Charger used for charging is bidirectional. It’s maximum charging and discharging rate is same. Vehicle is distributed according to number of consumers in distribution center. Minimum and maximum SOC of vehicle is 20% and 90%. It is assumed that vehicle would travel 50Km per day. The vehicle mainly travels distance between office and home. Two types of vehicles are considered Tata Nexon and BYD. EVs controlled charging in a reliability analysis tends to be probabilistic, i.e., multiple charging scenario is developed and utilized over the reliability assessment time horizon (hourly basis).

The placement of charging station increases additional strain on the grid infrastructure [9]. To minimize its impact, it should optimally place. Many researches are conducted for optimal placement of charging station. I have used A novel Electric vehicle placement index (EVPI) approach for CS allocation. Charging station is placed in stronger bus. Bus with high voltage profile is strong bus when a single parameter is considered [10]. For various parameter, effect of EV charging load is carried out in [11]. This approach gives more priority to reliability. Impact of CS with reliability index-based approach on urban distribution network is analysis in [12]. With this approach, CS is placed In IEEE 33 bus system with different test cases and then validated on a real-time Baneshwor distribution system in Kathmandu. The mathematical formulation and weightage to the objective function is developed using [13]. Load in the charging is varying throught the day [14-15]. It is peak at 11 am and low at night time. This article proposes the optimal placement of EVCS and design of a test station with vehicle-to-grid(V2G) capability is outlined. It is necessary to maintain the high reliability of the distribution network in any occasion including EV penetration.

1.1.1 Reliability analysis of distribution Network.

At present the number of EV is very small, the power system is not affected. When it increases by large number in future will have highly affect the power system [3a]. Inversely, when discharge takes by these vehicles will increase the reliability of power system. EV affect the distribution system. Reliability assessment of distribution is determined. Reliability is evaluated when charging is unscheduled and scheduled discharging V2G mode. The reliability indices of distribution system are derived from reliability indices for load point, components, line, and the whole system. Various components in the distribution system are Circuit breakers, power transformers, transmission cables, circuit breakers, and dis-connector, and the working status of these components. Component failure rate (λ) and repair rate(μ). After obtaining the failure and repair rate, then other important reliability indices can be derived, which is MTTR and MTTF.

1.1.2 System Reliability indices

This thesis present system reliability indices are used to calculate overall power supply reliability level. This thesis will reflect a brief summary about the system reliability indices. Expected Energy not served (EENS) is load based reliability index. Other indices are System Average interruption duration Index (SAIDI), System Average interruption frequency index (SAIFI), Customer Average interruption Duration Index (CAIDI), Average system Availability index (AENS) and so on.

1.1.3 Reliability Analysis method

There are two methods of finding reliability Sequential Monte-Carlo (SMC) and non-sequential Monte-Carlo (NSMC). In sequential method, simulation proceeds for dynamic systems, time-series data, and situations where new information arrives sequentially. In non-Sequential method simulation are more versatile, applicable to a broader range of problems, and often simpler to implement simulation method is adopted for this thesis. The states are sampled proportional to their probabilities. This method is very powerful tool used to solve complex differential equations [21]. Sequential Monte-Carlo simulation method is used for load modeling.

1.1.4 IEEE 33 bus test system

The IEEE 33-Bus radial distribution system is used for testing the methodology provided in this thesis. The system is very convenient when doing the reliability analysis of the distribution system. This system is sufficient to examine power loss and voltage level of the system. The details of the IEEE 33 bus system are given in S. deb et al.,[9]. This system consists of 32 lines and 33 buses. It has base voltage of 12.66Kv. It has load size of 3.715 Mw and 2.3 Mvar. Load in the system is divided into three parts: Normal load, peak load and off-peak. Normal load and off- peak load used is 80% and 60% of peak load.

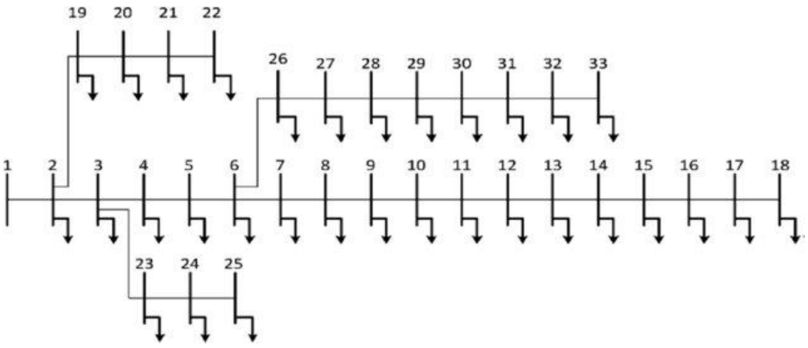

Figure 1.1. IEEE-33 Bus Test System

1.1.5 Vehicle-to-Grid Technology

When EVs are penetrated in the distribution, the distribution voltage, reliability deteriorated. With V2G technology, reliability, voltage and loss can be improved. In uncoordinated charging, EV user connected for charging when their SOC falls below a certain level. User do not think about system load whether it is peak load or off-peak load. Therefore, there should proper controlled scheduling of charging and discharging. V2G control scheme is applied for such phenomenon. during peak hour, charging of EV increases the burden of system and also probability of faults increases. So, at peak load there should not charging, only discharging takes place. But all the vehicle cannot go for discharging. So, we consider 10% Ev charging even in peak condition. The EV is allowed to charge during off peak load because there is no burden and also less possibilities of faults. To implement this process, tariff rate favors this system. As per NEA rules, during peak load time tariff rate is high and during off peak load tariff rate is low. So, there is economic benefit also for user. Hence this system can improve the system performance and also reliability of the system can be improved.

1.1.6 Data in power System reliability

Input data should more accurate in the reliability analysis. Most of the Inaccurate does not give good result. All the work dies. High-quality data is required for analysis. The basic parameter to calculate reliability are Failure rate, repair rate and maintenance rate. Some other data requires are: The information about physical arrangement and connectivity of power system components, Switching configuration, weather data (weather condition may affect the reliability of the power system, such as storms, temperature etc.), operational data(operational state of power system including control settings, operating limits), Event data like fault records, Disturbance records.

In load modeling, necessary data is obtained using the Monte-Carlo simulation technique. As the number of simulations, the expected values move closer to the accurate value. The mean and the deviation and can be reduced by some sampling process.

Bus data, Line data and outage data of IEE-33 Bus system data is taken from [13]. Similar data of Baneshwor feeder is collected from Baneshwor distribution center. Engineer of feeder was cooperative to provide these data.

1.1.7 Simulation and Case Studies

Simulation studies and case studies play a significant role in assessing the impact of EV integration, including V2G, on distribution system reliability. These studies employ various modeling techniques, such as power flow analysis, Monte Carlo simulations, and optimization algorithms, to evaluate system performance, identify potential issues, and assess the effectiveness of reliability enhancement strategies in the context. Five cases develop for placing charging station at different bus and three cases are developed for charging strategy.

1. 2. Problem Statement

The placement of charging station increases additional strain on the grid infrastructure. The main problem is the distribution network parameters are degraded by placing EV.. EVCS downgraded reliability, power quality and voltage stability of the distribution system. Some of other problems are:

- Charging EVs can introduce harmonic distortions and affect power quality. This can result in issues such as increased total harmonic distortion (THD) and interference with other sensitive electronic equipment connected to the grid.
- The additional load from multiple charging EVs can lead to overloading of transformers and distribution cables. This can result in equipment overheating, reduced efficiency, and increased maintenance costs.
- The concentration of charging stations in specific areas or neighborhoods can cause congestion in the distribution system. This may require infrastructure upgrades to accommodate the increased load and prevent localized system bottlenecks.
- The increased load from EV charging stations may pose challenges to grid resilience and reliability.
- Efficient load balancing and demand response mechanisms become crucial with a large number of EVs. Smart charging strategies and technologies may be required to optimize charging schedules and minimize the impact on the grid.

1. 3. Objectives

This research aims to calculate and enhance reliability indices. The main objective of this thesis is to increase the reliability of the system along with grid stability, voltage regulation and power quality. More specific objectives are:

- To design the EV behavioral Probabilistic load model including different charging scenarios and EV types and using sequential Monte-Carlo simulation method.
- To Placement of Charging station with novel approach based on EVPI.
- To find the optimal location of charging station using GA.
- To Carry out reliability analysis of the system after CS placement.
- To Explore the concept of vehicle-to-grid (V2G) technology to alleviate peak demand, enhance grid reliability and system balancing.

1. 4. Scope

- Air Quality improvement: Examine Increased Number of EV on local Air quality in urban areas.
- Grid performance: Evaluate parameters such as grid stability, voltage regulation, and power quality with the addition of CS.
- Energy optimization: Investigate the potential for V2G to optimize energy distribution in urban areas, particularly during peak demand periods.
- Cost-benefit analysis: economic analysis to determine the costs and benefits associated with V2G integration. Consider factors such as infrastructure investment, operational costs, and potential savings in grid management.
- Charging/discharging Strategies:
- Planning and policy recommendations: propose policy recommendations that can facilitate the effective integration of V2G technology into urban distribution networks.

1. 5. Outline of the thesis

The following is an outline of the thesis report:

Chapter I: Introduction: Electric vehicle status in different countries. Number of electric vehicles in future scenario. Introduction to the reliability, power loss and voltage affected by CS.

Chapter II: Literature Review: Past works and research conducted by various authors on impact on distribution system by the addition of EVCS and V2G integration.

Chapter III: Methodology: Illustrates novel based approach on the reliability index for placing the CS. This section deals with mathematical formulation of EVPI. It also explains about V2G control strategy. Design framework for V2G scheduling. It is directly applied to the Baneshwor feeder. Explanation of the overall methodology followed to fulfill the objective of this thesis work.

Chapter IV: Results and Discussion: Shows the results on the impact on the distribution feeder after placing EVCS and implementing V2G with different test cases. The results are validated against the results in the reference papers. This methodology demonstrates in real-time Baneshwor feeder to improve the power loss, voltage profile and reliability of the system.

Chapter V: Conclusion: Summary of the works performed. Present and future aspects of the work.

1. 6. Limitation of thesis

- Data Limitations: Limited access to quality real world data from distribution center, charging stations, and Electric vehicle usage.
- The thesis may not capture the impact of Charger in the distribution feeder.
- The optimization algorithm may have limitation in specific scenarios
- The thesis relies on a case study approach, the findings might be specific to that particular case and not easily transferable to other contexts.
- Economic, political, or environmental changes may have had an impact on the research context.

2. CHAPTER TWO. LITERATURE REVIEW

2. 1. Introduction

The integration of electric vehicles (EVs) into the distribution system introduces new challenges and opportunities for enhancing system reliability. As EV adoption continues to grow, it is crucial to investigate the impact of EV charging on the distribution system and explore strategies for improving its reliability. This literature review aims to examine existing research on the reliability enhancement of the distribution system considering electric vehicles. By exploring relevant literature, this review sets the foundation for understanding the current state of knowledge, identifies research gaps, and highlights key areas of focus for the proposed thesis.

[4]-[7]: Real time management of the system by the penetration of V2G. Economic analysis is also considered.

[8]: Reliability performance on sequential monte-Carlo simulation.

[9]-[11]: The main constraints for enabling CS consists of high-charging rate batteries, high power charging infrastructure and grid impacts. These technical aspects have been studied in literature individually.

[12],[13]: A novel electric vehicle placement index (EVPI) is used to determine The potency of reliability-index based approach for allocating EVCS in various buses.

[14][15]: Analysis the impact of PEV on reliability. The suggested framework involves distinctive handling techniques and inventive load models to precisely gauge the influence of Plug-in Electric Vehicle (PEV) load models on reliability

[17]-[19]: Optimal placement of Charging station on the basis of voltage, reliability and power loss using optimization technique. GA is used for the optimally placed.
[20]: Stability of the system determined by Voltage stability indices. Bus with VSI less than zero leads the system to collapse. Design mathematical formulation for VSI.

[21]: to examine the impact of EV on distribution system charging and controlled

charging with and without vehicle-to-grid(V2G) scheme have been considered

2. 2. Reliability in Distribution Systems

Distribution system reliability is a crucial aspect of power delivery, ensuring continuous and quality electricity supply to consumers. The literature reveals various reliability indices, such as System Average Interruption Duration Index (SAIDI), System Average Interruption Frequency Index (SAIFI), and Customer Average Interruption Duration Index (CAIDI), which are commonly used to assess the performance and reliability of distribution systems [23]. Studies have emphasized the importance of improving these indices to meet the increasing demand for reliable power supply.

2. 3. Electric Vehicle Integration Challenges

The integration of electric vehicles introduces new challenges to distribution systems. Research indicates that the significant increase in EV adoption can lead to higher peak demand, increased stress on distribution infrastructure, and potential overloading of transformers and distribution lines. The literature also highlights the potential impact of uncoordinated charging of EVs on the distribution grid, which can result in voltage fluctuations and reliability issues. Charging station are placed with that bus having minimum deviation [22]. Therefore, it is crucial to develop strategies and solutions to mitigate these challenges and ensure a seamless integration of EVs into distribution systems.

2. 4. V2G Integration

Vehicle-to-Grid (V2G) technology enables bidirectional power flow between electric vehicles and the grid. The literature emphasizes that V2G integration presents a significant opportunity for enhancing the reliability of distribution systems. V2G-enabled vehicles can support the grid during peak demand by supplying excess energy stored in their batteries [21]. This helps reduce strain on the distribution infrastructure and enhances overall system reliability. Additionally, V2G technology enables EVs to provide backup power during outages, contributing to system resilience and reliability.

3. CHAPTER THREE. METHODOLOGY

3.1 Introduction

The research will be conducted under the following methodology.

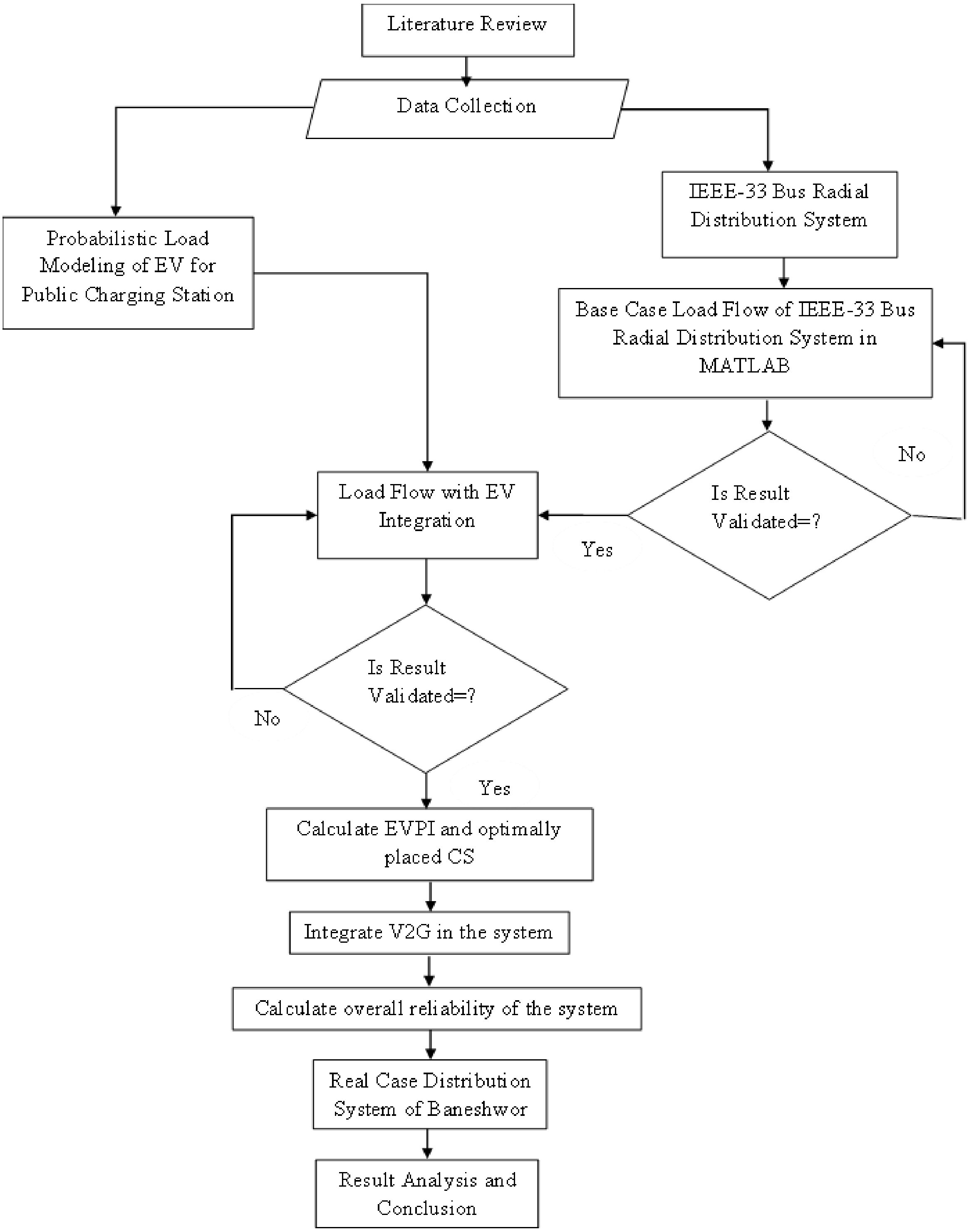

Figure 3.1. Flowchart of the methodology.

In this chapter, electric vehicle load model is presented in probabilistic approach using Monte-Carlo simulation method.

3.2 Data processing

Data processing aims to get a complete and correct data set before further analysis. Contact with Substation to collect data. For the missing data fill data for the same hour one week ago and after taking the average value.

3.3 Modelling of load demand

The load in a charging station is not constat all the time. Vehicle at charging station is high sometime and low sometime. It is not necessary that charging station peak load time and system peak load time is same. To know the peak time of CS, this load model is developed. From various research over a year of vehicle data is collected to design the load model. The load demand probability density function is:

$$\boldsymbol{f(P_L) = \frac{1}{\sigma\sqrt{(2\pi)}} e^{-\frac{(P_L-\overline{P_L})^2}{2\sigma^2}}} \tag{1}$$

Where is the standard deviation $\boldsymbol{\overline{P_L}}$ is the average and $\boldsymbol{\sigma}$. The average load demand in each hour can be calculated.

3.4 EV load modeling

EV load is modeled considering parameters of EV are EV charging power (P_{EV}), SOC of the battery, charging start time (T_{sc}) and charging duration period (T_{dc}). Modeling charging station load based on monte Carlo simulation. After examining the charging behavior of a single EV driving pattern and, the second step is generating the load profile. To extract different EV's status from the probability function, the simple sampling method is used here. In addition, the number of EV that are charged in charging station is also included in research. Data of two Charging stations Sindhuli and Samakushi is considered and apply for the modelling. Factor affecting EV charging load in detail as follows:

3.4.1 Initial SOC of the battery

Ev owners will recharge their vehicle when they reach their destination with SOC<80%. They also discharge in peak time with SOC not to be less than 30 %.

$$E_0 = \left(1 - \frac{d}{L_{max}}\right) * 100\% \tag{2}$$

Where, L_{max} is the maximum distance that can be travelled with full charge, d indicates total traveled distance by vehicle since last charge.

In this paper, travelled distance by vehicle is assumed due to lack data, of EV travel statistics. Under this assumption, the probabilistic character of EV daily travel distance is obtained based on the 2009 National Household Travel Distance Survey (NHTS) of the U.S. Department of Transportation.

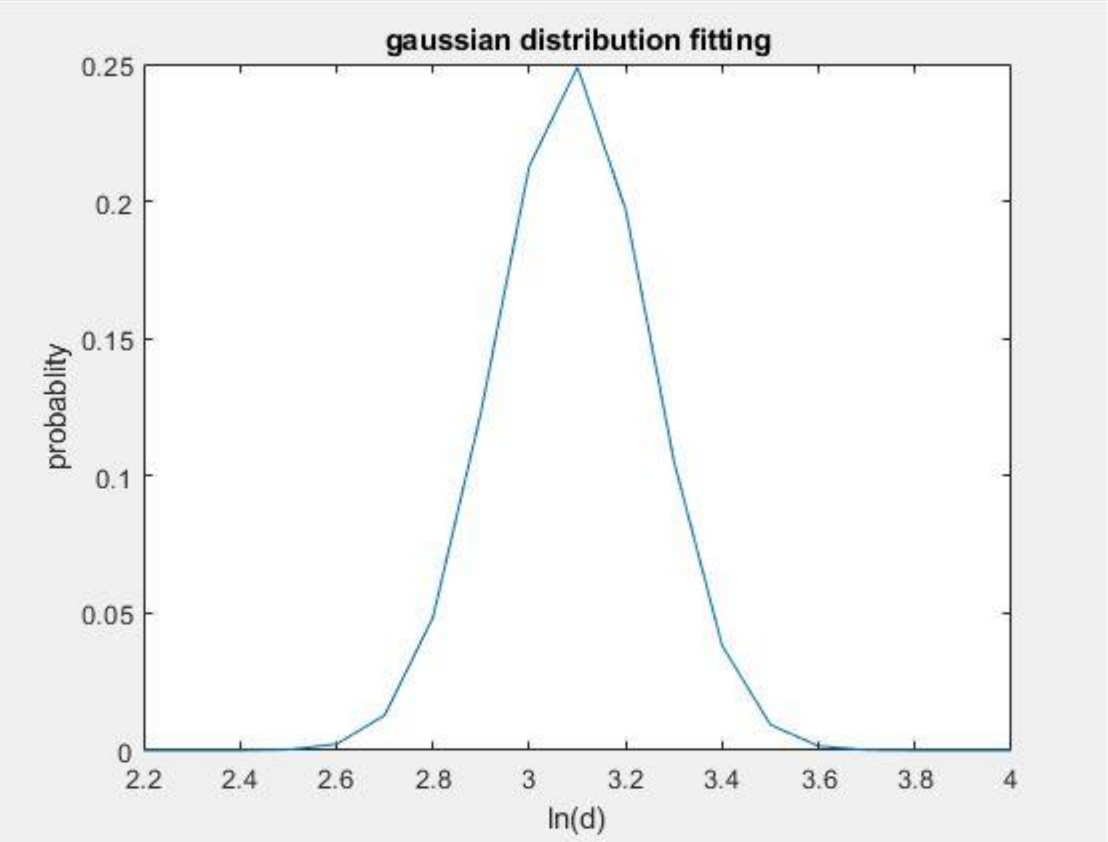

Figure 3.2 Probability dense function of daily traveling distance

Horizontal coordinate value in above figure is natural logarithm of the EV daily driving distances. From a logarithmic normal distribution, EV daily driving distances can be found, whose probability density function can be expressed as

$$f_d(x) = \frac{1}{d\sigma_d\sqrt{2\pi}} \exp\left[-\frac{(lnd - \mu_d)^2}{2\,{\sigma_d}^2}\right]$$

Where, mean (μ_d) is 3.09 and standard deviation (σ_d) is 0.16. Probabilistic value of the SOC of the EV can be obtained from above equation.

3.4.2 Charging start time

The ending time of the last travel, denote as T_{sc} is start time for charging the EV. Parameter T_{sc} is variable whose probabilistic character can be derived from the NHTS of the U.S. department of Transportation as shown in figure below

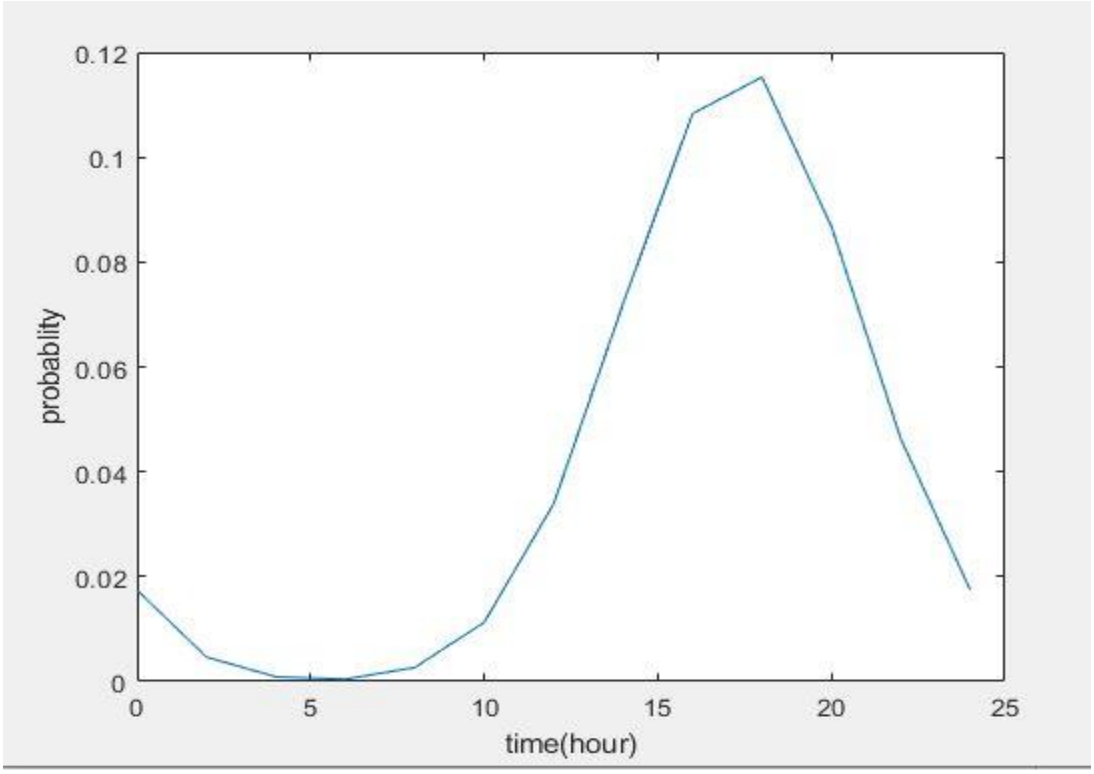

Figure 3.3 Probabilistic character of the charging start time

The probabilistic character of the charging start time can be quantified as

$$f_{T_{sc}}(x) = \begin{cases} \dfrac{1}{\sigma_{sc}\sqrt{2\pi}}\exp\left[-\dfrac{(x-\mu_{sc})^2}{2\,\sigma_{sc}{}^2}\right], (\mu_{sc}-12) < x < 24 \\ \dfrac{1}{\sigma_{sc}\sqrt{2\pi}}\exp\left[-\dfrac{(x+24-\mu_{sc})^2}{2\,\sigma_{sc}{}^2}\right], 0 < x < \ (\mu_{sc}-12) \end{cases} \quad (3)$$

3.4.3 Charging Duration period

Charging duration period is calculated by multiple parameters, i.e., SOC of the EV, EV charging power, EV battery capacity and charging efficiency. It can be estimated as

$$T_{dc} = \frac{(1-E_0)C_{battery}}{P_{charge} * \eta} \quad (4)$$

Where, $C_{battery}$ is the capacity of the EV battery, η is a charging efficiency which mainly depends on battery type.

Monte carlo simulation is applied for the solutions for uncertainty problems based on probability statistics. The flowchart of the methodology is illustrated in figure below:

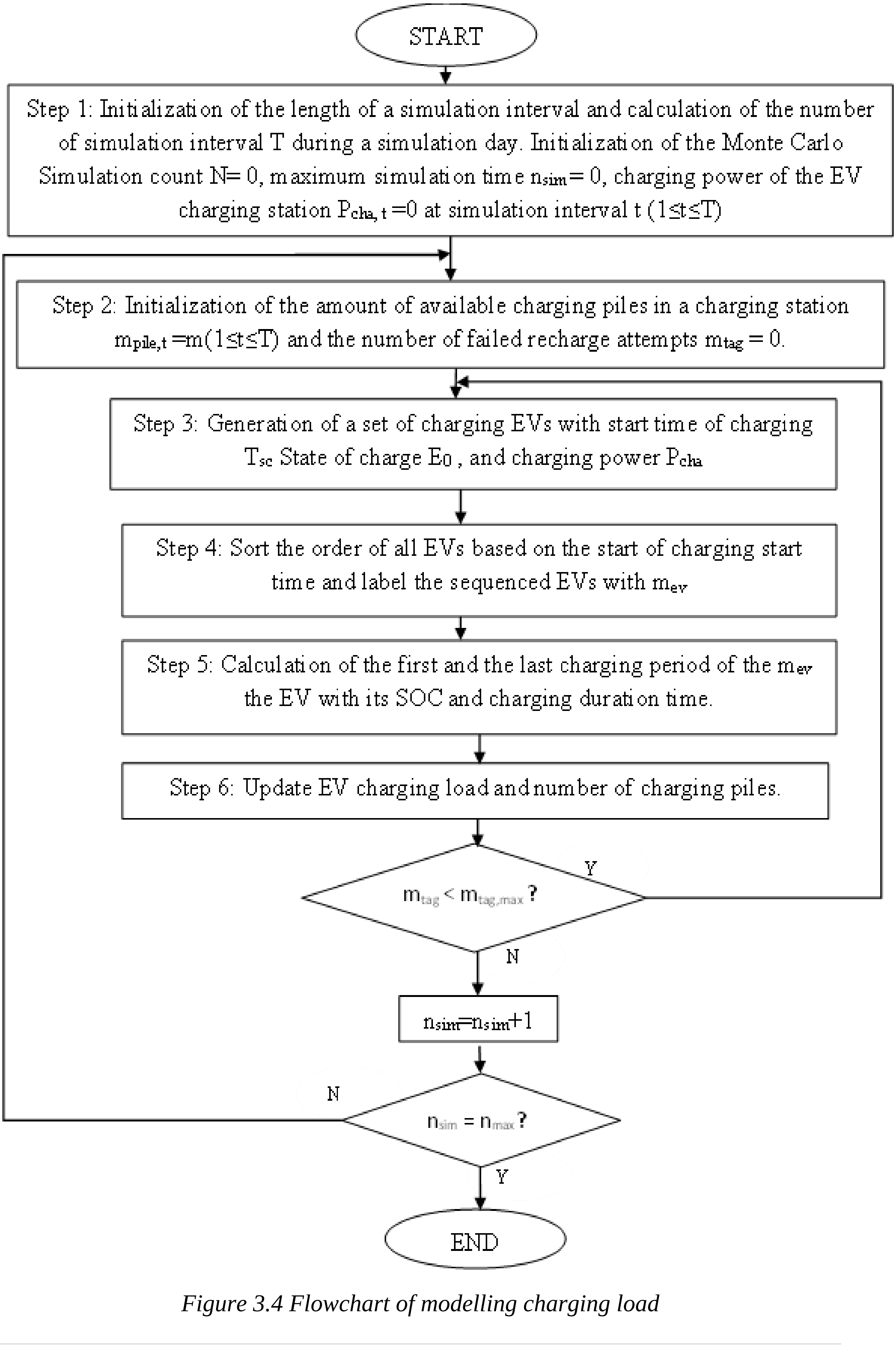

Figure 3.4 Flowchart of modelling charging load

In the figure 3. 4. charging load of an EV charging station is proposed in 7 steps. These steps are described in detail as below.

Step 1: initializing monte Carlo simulation. T_{step} is the length of simulation interval. The number of simulations interval in a day can be obtained from

$$T = \frac{24 * 60}{T_{step}} \tag{5}$$

consider there are m piles for charging in a charging station. In a simulation interval Charging power of the charging stations denoted as P_{cha} is initially assumed to be zero.

Step 2: Update the simulation count $n_{sim} = n_{sim} + 1$ after each simulation. Set number of charging pile at the charging station m_{pile} to be m. it is then decrease by 1 after each set up of charge. Let $m_{tag} = 0$, that represent there is not available any charging piles in a station.

Step 3: Generating random number of N_{ev}, EVs as well as initial SOC, start charging time, and travelling distance. As there is mainly fast charging prefer by consumer. So taking only fast charger.

Step 4: Sorting the EV based on the start charge time, so that provide service to charging who comes first.

Step 5: start the charging of battery between start and end simulation interval.

$$t_{start} = \left[\frac{t_{sc} * 60}{T_{step}}\right] \tag{6}$$

$$t_{end} = \left[\frac{(t_{sc} + t_{dc}) * 60}{T_{step}}\right] \tag{7}$$

Step 6: charging stops, if the charging pile is not available. If there is vacant pile then go to step 5 and charge.

$$P_{cha,t} = P_{cha,t} + \frac{P_{charge}}{n_{max}} \tag{8}$$

Step 7: when n_{sim} reaches to n_{max} stop monte Carlo simulation and get the EV charging load.

3.5 Voltage stability indices

The voltage stability index designed by Eminoglu et al [11] is used in this thesis. The Voltage Stability Index (VSI) is a measure of the stability of voltage magnitudes at different buses in an electrical power system. To assess the ability of the power system and to maintain voltage stability under various operating conditions and disturbances, this is used. Distribution load flow is carried out. Forward/backward sweep method is used. The following equations shows criterion for voltage stability determination.

$$SI(r) = 2{V_s}^2{V_r}^2 - {V_r}^4 - 2\,{V_r}^2(PR + QX) - |z|^2(P^2 + Q^2) \qquad (9)$$

The above equation is stability criterion.

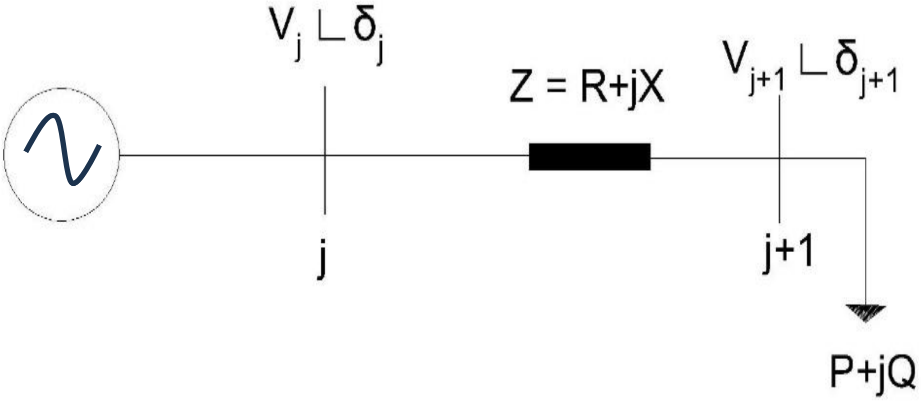

Figure 3.5 single line diagram of a two-bus distribution system

Figure 3.6 shows the steps for calculating VSI of the buses of the system.

Step 1: After selecting the system, Load flow analysis of the system is carried out in Matlab using Forward/backward sweep method. Voltage, power loss of each bus is obtained.

Step 2: After calculating voltage, we know resistance of line, and load in bus. VSI of each bus is calculated using eq (9).

Step 3: EV are added in the system. EV consumes power from grid for charging. Load equivalent to number of EV in charging is added in bus. According to test cases, load is added to equivalent load bus.

Step 4: Again, run distribution load flow and calculate VSI of the system.

Step 5: Continue the iteration until VSI less than zero. The process stops

Step 6: Compute the margin of the system. The final value of VSI is obtained.

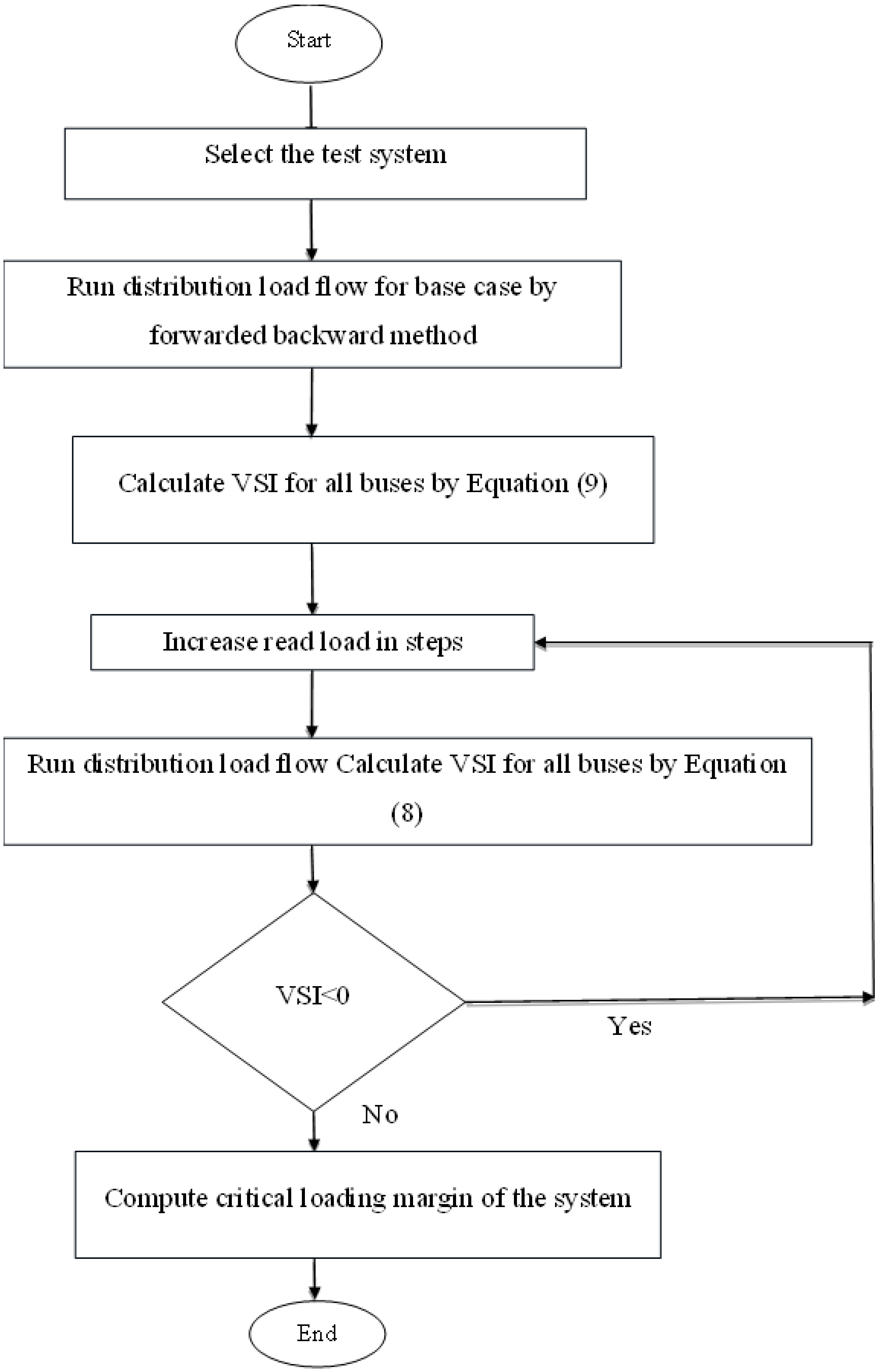

Figure 3.6 The flowchart illustrating the methodology of computation of VSI.

3.6 Reliability analysis of distribution network

The continuous supply of electricity satisfactorily over a period of time is called the reliability.it means lower the failure of system, more is the reliability. It is actually the satisfaction of customer. To evaluate the reliability of system, following parameters required are: Data of repair rate (µ), repair rate (µ), average outage duration rate (U_j), and number of consumers of the buses (N_i).

$$SAIFI = \frac{\sum \lambda_j N_j}{\sum N_j} \tag{10}$$

$$SAIDI = \frac{\sum U_j N_j}{\sum N_j} \tag{11}$$

$$CAIDI = \frac{\sum U_j N_j}{\sum \lambda_j N_j} \tag{12}$$

$$ENS = \sum L_j U_j \tag{13}$$

$$AENS = \frac{L_j U_j}{\sum N_j} \tag{14}$$

SAIFI is System Average Interruption Frequency Index that defines how many times a customer in the system experience interruption over a particular time. It illustrates the condition of the system in terms of interruption. SAIDI is System Average Interruption Duration Index that defines duration of interruption per customer served. It illustrates the condition of the system in terms of duration of interruption. CAIDI is Customer Average Interruption Duration Index that defines Average interruption duration time for those customers interrupted during a year. It illustrates average outage duration that any given customer would experience. ENS is energy not supplied gives the total energy not supplied by the system. It illustrates an indicator of energy deficiency of the system. AENS is Average Energy Not Supplied regarded as the average system load curtailment index. It gives an idea of how much energy is not served during particular time period.

After formulating the Electric Vehicle (EV) model, the subsequent phase involves integrating this model into the distribution grid for conducting reliability analyses under various scenarios. In the context of electric buses, their adherence to a strict operational schedule and limited operational flexibility, especially during faults, constrains their ability to inject power, ensuring they do not disrupt regular operations. Consequently, this thesis treats electric buses merely as typical load demands rather than potential power suppliers.

To simulate random failure states of components, the sequential Monte-Carlo method is employed. The component's failure model adopts a two-state structure within a Markov model, encompassing failure and operational states. This model, depicted in Figure 3.2, incorporates λ and μ as the failure and repair rates of the component, respectively.

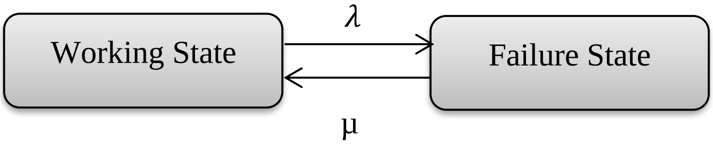

Figure 3.7 Two state failure model

3.7 Power quality

Power loss in the distribution system increases for EV charging. Additional EV loads de-rate the quality of power. It also raises harmonics in the system. The supply voltage of the system fluctuates due to harmonics. Mathematical expression for power loss is given in equation below

$$P_{EV} = \sum_{j=1}^{n} {i_j}^2 r_j \tag{15}$$

Loss Sensitivity Factor (LSF) helps in calculating the overall increase in system loss in the distribution network with the establishment of EVCS. The mathematical formulation for computing LSF is given in equation

$$LSF = \frac{2P_{EV}R_i}{{V_{EV}}^2} \tag{16}$$

Where P_{EV}, V_{EV}, and R_i are real power injected due to charging load, the voltage the and resistance of ith branch due to additional EV load, respectively. It quantifies how a change in active power at a specific bus affects the total active power losses in the system. The LSF helps power system operators and planners make decisions about generation and load dispatch to minimize losses and improve system efficiency. Higher the value of LSF, the possibilities to voltage college in the system increases. It's important to note that LSF values vary for different buses in the power system. Buses with the highest absolute magnitude of LSF are typically the most sensitive to changes in active power, and these values guide operational decisions to optimize the power system's performance.

3.8 Charging Station Allocation Based on Bus Reliability Index

Before deciding where to allocate charging stations, it's crucial to understand the reliability of the existing electrical distribution network. BRI helps assess the reliability of individual components within this network. Components with low BRI values are more prone to failures and may need infrastructure upgrades or additional backup power sources, which could influence the allocation of charging stations.

$$BRI = \frac{AIT_i}{max_{jB}\{AIT_j\}} \tag{17}$$

Where AITi is the average interruption time of the ith bus, j denote the bus with maximal AIT and B is the total count of buses in the system,

AIT of the ith bus is evaluated as

$$\text{AIT} = \lambda i \cdot \text{Ui} \tag{18}$$

Where λi and Ui are the average failure rate and average outage duration of the ith bus. The bus with the smallest BRI value is designated as a strong bus. Six test cases are considered for allocation of charging station. Cases are defined in Table I. The power absorbed by charging stations is assumed to be 80KW. Case 1 considering the base case without charging station in the system. In case 2, EVCS is placed at Bus no 11, which is the strongest bus serve 20EV. In case 3, CS is placed at Bus no 3 which is neither weak Bus nor strongest bus, serving 20EV. In case 4, CS is placed at Bus no 11 and Bus no 15 which is strongest and second strongest Bus, serving 20 EV in each bus. In case 5, EVCS is placed at Bus 25 which is weakest Bus of the system, serving 20EV. In case 6, Two EVCS is placed at Bus 25 and Bus 29 which is weakest and second weakest buses of the system. Each test case is analyses with all the distribution parameter.

Table 0.1 Six test cases for placing CS analysis

Case no.	Description	Increase in load (KW)	No of charging pile
1	Base load	---	--
2	CS at Bus 11	1600	20
3	CS at Bus 3	1600	20
4	CS at Bus 15 and Bus 11	3200(1600 KW each)	40
5	CS at Bus 25	1600	20
6	CS at Bus 29 and Bus 25	3200(1600 KW each)	40

3.9 Charging station placement based on EVPI

The severity level of EVPI is used for the analysis of effect of charging loads. It more focuses on reliability. EVPI gives the identification of bus whether it is stronger or weak. The Bus with lesser value of EVPI is strongest bus and Bus with higher value of EVPI is weakest bus. The mathematical expression of the EVPI is in (18)

$$EVPI = W_{VSI} * A + W_{RI} * B + W_{LSF} * C. \tag{19}$$

Where W_{VSI}, W_{LSF} and W_R, are the weights to VSI, LSF and reliability respectively. *A, B and C* represent the values of VSI, reliability and LSF denoted as equation below.

$$A = \frac{VSI_{base}}{VSI_{EV}}. \tag{20}$$

$$B = W_{COI} * \frac{COI_{EV}}{COI_{base}} + W_{EOI} * \frac{EOI_{EV}}{EOI_{base}} \tag{21}$$

$$C = \frac{LSF_{EV}}{LSF_{base}} \tag{22}$$

Where EOI and COI denotes the energy-oriented indices AENS and customer-oriented indices: SAIFI, SAIDI, CAIDI respectively. VSI_{EV}, COI_{EV}, EOI_{EV}, and LSF_{EV} are VSI, reliability and LSF after the allocation of charging stations. VSI_{base}, COI_{base}, EOI_{base}, and LSF_{base} are base value of VSI, reliability and LSF before the allocation of charging stations. The threshold of EVPI gives information about how many charging station can be placed in the charging station. The threshold limit for placing charging stations denotes by $EVPI_T$ is expressed as in equation below;

$$EVPI_T = BRI_T\left(\frac{W_{VSI}}{W_R} + \frac{W_{LSF}}{W_R}\right) \quad (23)$$

BRI_T is the threshold limit of BRI for buses. In the reliability-based index approach, distribution reliability indices are more critical, valuable than voltage stability and power loss.

Table 0.1 Electric Vehicle CS input Parameters

S.N	Parameters	Values
1	CS delivering current	200A
2	Battery capacity	Nexon, Hyundai Kona,BYD, MG,
3	N_{slot}	5
4	Grid frequency	50Hz
5	Grid voltage	0.433KV
6	K	1.1
7	*cosØ*	0.95

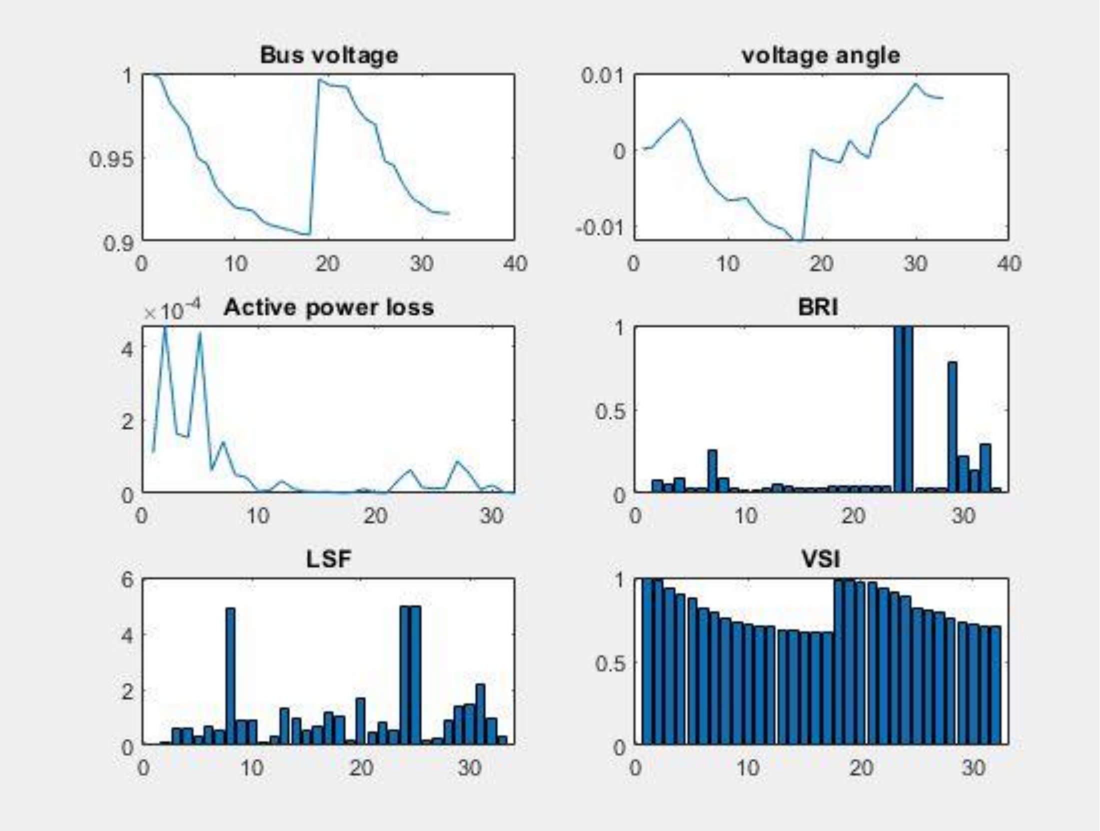

figure 3. 1 Base value of bus voltage, Voltage angle, power loss, BRI, LSF and VSI of IEEE 33 bus system

3.10 V2G integration on the distribution system.

Vehicle parameter off TATA NEXON is considered in this thesis.

Table 0.1 TATA NEXON EV parameter

S.N	Parameters	Values
1	EV charging capacity	3.3 Kw wall box charger (7.2 Kw fast charger also available
2	Battery capacity	40.5 Kwh
3	Charging time (3.3Kw charger)	15 hours
4	Charging time (7Kw AC fast charger)	6.5 hours
5	Charging time (50Kw DC fast charger)	56 minutes
6	Full charge range	453 Km
7	Motor power	100 KW
8	Motor torque (Nm)	250
9	Battery warranty	8 Years

In the table 3.4, Coordinated charging and discharging strategy is presented. Three test cases are assumed.

Table 0.1 Test cases for V2G strategy

Test cases	strategy
Case I	10% charging only
Case II	70 % charging only
Case III	V2G

In case I, no discharging takes place. Vehicles are assumed to travel between home and office. No more charging required by vehicle. To travel 50 km only 10% of total charge is enough. Only 3 hour of charging is sufficient. So, there is no need to follow any charging schedule. Randomly charging vehicle is assumed.

In case II, Assumed the vehicles have to travel long distance. It maximum discharges it’s 70% of charging for smooth operation of battery. All the vehicle cannot be in such mode. But this condition assumed to make worst case scenario.

In case III, Vehicles are performed V2G. scheduled charging and discharging because electricity price is high during peak hour and low during off-peak hour.

Table 0.2 V2G control strategy

Time	Total power(MW)	Scheduled chg/Dhg	Charging-3KW-100	unscheduled 10% charging	Result p	70 % charging daily	Result p	Discharge-2.5-150	Resultant P
1	1.2	C	0.294	0.02	1.22	0.1063	1.3063	0	1.494
2	1	C	0.294	0	1	0.1063	1.1063	0	1.294
3	1	C	0.294	0	1	0.1063	1.1063	0	1.294
4	1.2	C	0.294	0	1.2	0.1063	1.3063	0	1.494
5	1.2	C	0.294	0	1.2	0.1063	1.3063	0	1.494
6	1.5	C	0.294	0	1.5	0.1063	1.6063	0	1.794
7	2.1	C	0.294	0.08	2.18	0.236	2.336	0	2.394
8	2.8	D	0.0294	0.08	2.88	0.236	3.036	0.294	2.5354
9	2.4	0.9D	0.0294	0.08	2.48	0.236	2.636	0.2646	2.1648
10	2.6	0.5D	0.0294	0	2.6	0	2.6	0.147	2.4824
11	2.7	0.5D	0.0294	0.02	2.72	0.081	2.781	0.147	2.5824
12	2.6	D	0.0294	0.02	2.62	0.081	2.681	0.294	2.3354
13	2.6	D	0.0294	0.02	2.62	0.081	2.681	0.294	2.3354
14	2.6	D	0.0294	0	2.6	0.081	2.681	0.294	2.3354
15	1.7	C	0.294	0	1.7	0.081	1.781	0	1.994
16	2.6	D	0.0294	0	2.6	0.081	2.681	0.294	2.3354
17	2.6	D	0.0294	0	2.6	0.081	2.681	0.294	2.3354
18	2.5	N	0.0294	0	2.5	0	2.5	0	2.5294
19	2.6	0.5D	0.0294	0	2.6	0	2.6	0.147	2.4824
20	2.7	D	0.0294	0.08	2.78	0.236	2.936	0.294	2.4354
21	2.4	D	0.0294	0.08	2.48	0.236	2.636	0.294	2.1354
22	2	C	0.294	0.08	2.08	0.236	2.236	0	2.294
23	1.5	C	0.294	0.02	1.52	0.1063	1.6063	0	1.794
24	1.8	C	0.294	0.02	1.82	0.1063	1.9063	0	2.094

4. CHAPTER FOUR. RESULTS AND DISCUSSION

The test station is modeled in Matlab /Simulink. Monte-Carlo simulation is applied to model daily EV charging load. This is firstly model using NHTS data and then using data of charging stations in Nepal. Number of EV charging and number of charging attempt failed in simulation are considered. Giving 10 charging piles m=10; The power capacity of EV battery = 40 Kwh, P_{fast} = 50Kw (60KW in Nepal), The charging efficiency is taken to be 0.95 and the average distance travelled by a fully recharged vehicle is 200Km, i.e L_{max} = 200Km. As well known about Monte Carlo simulation, a greater number of simulations will always give more accurate results. The following figures shows the designed EV charging load curve for 50, 200, 1000, 2000 and 10,000 simulation times.

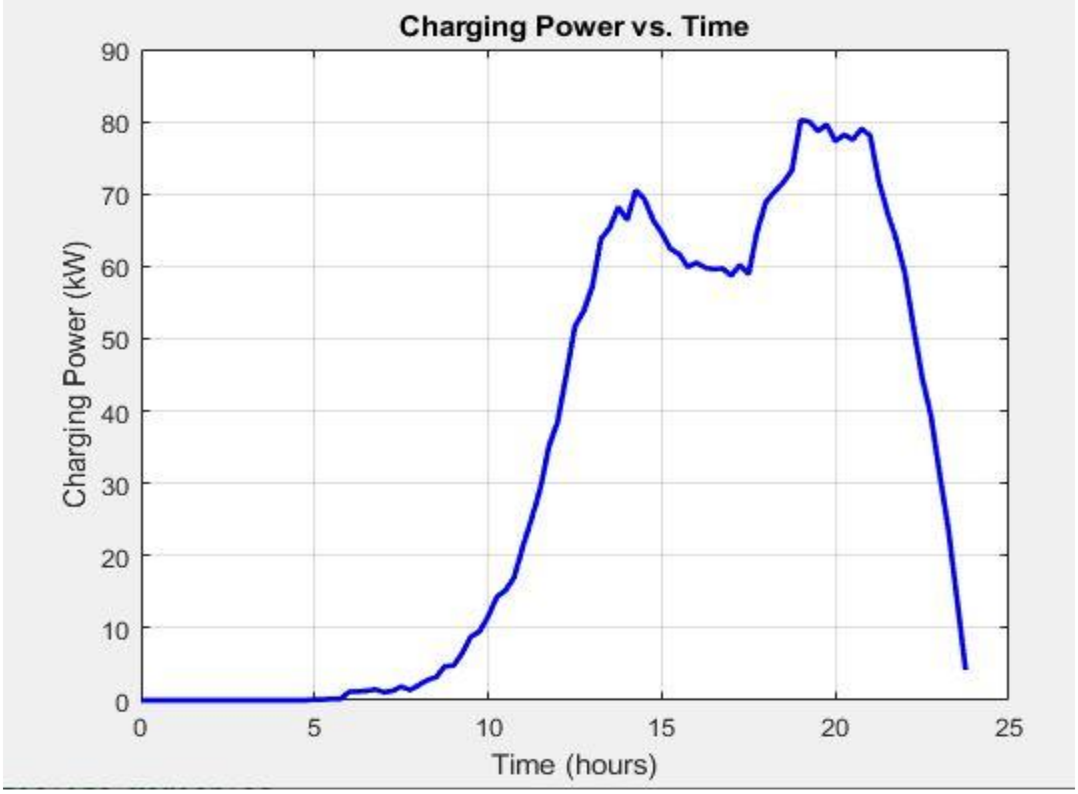

figure 4. 1 charging load curve under 50 simulations

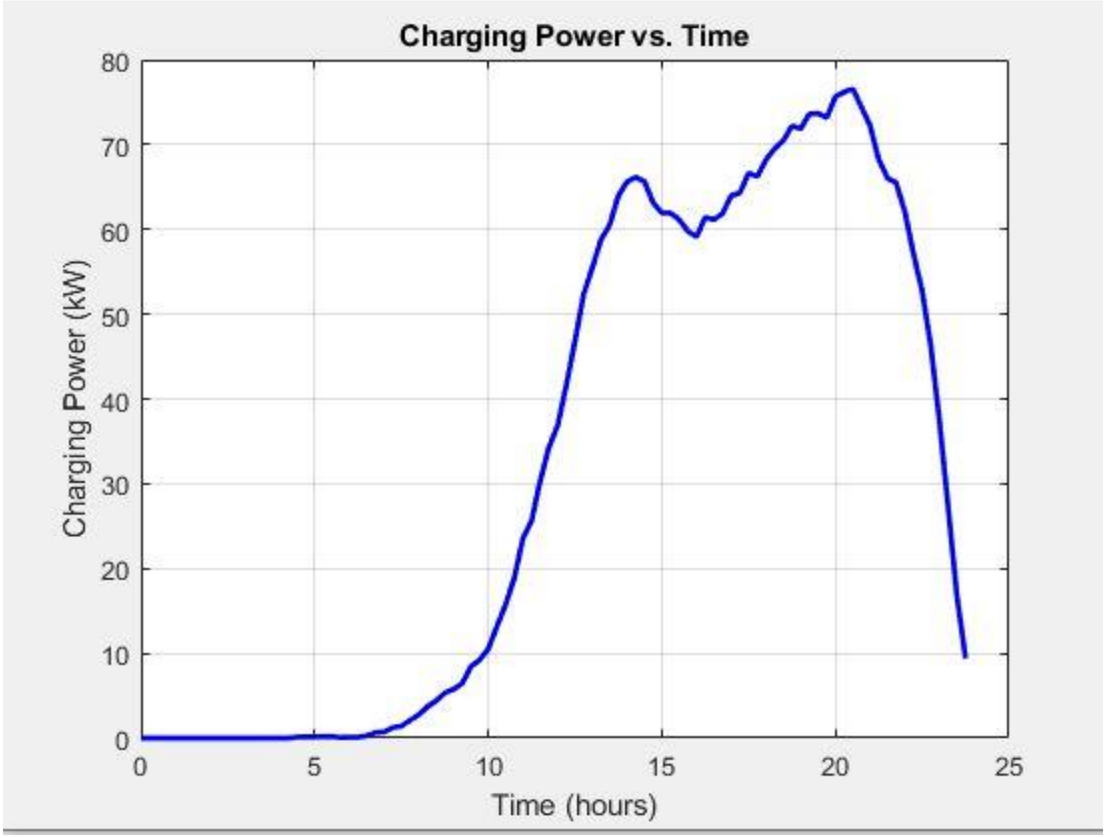

figure 4. 2charging load curve under 200 simulations

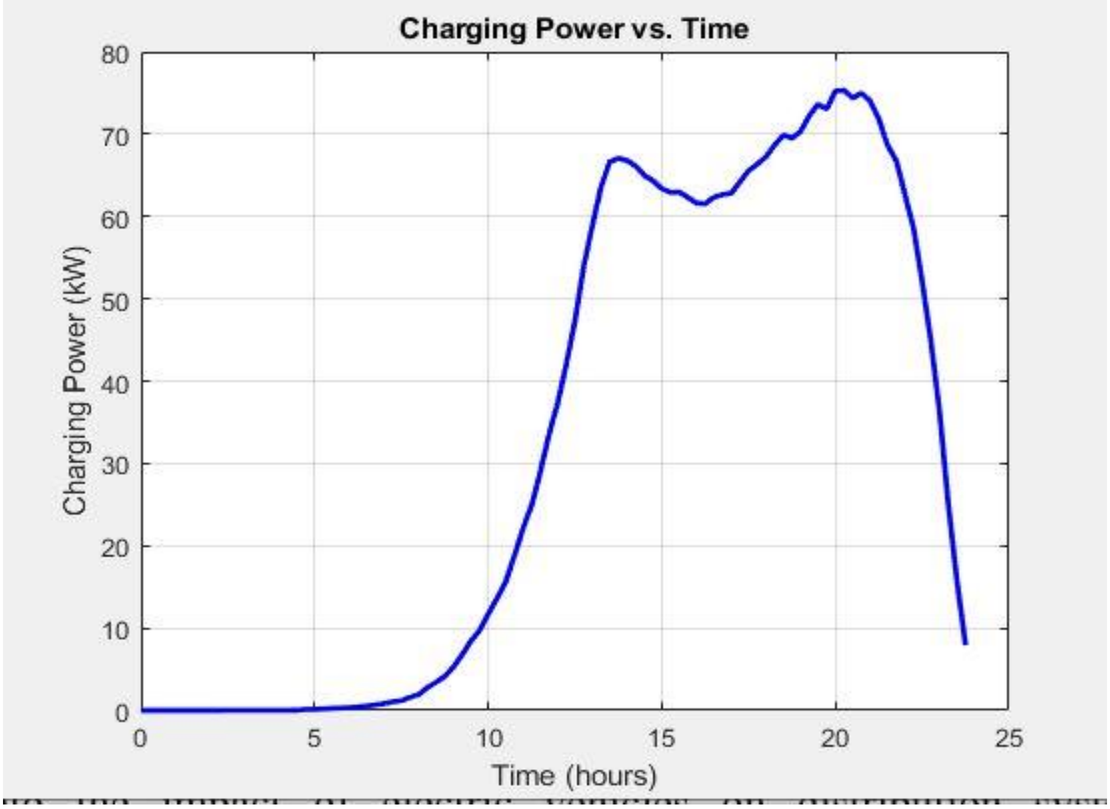

figure 4. 3 charging load curve under 1000 simulations

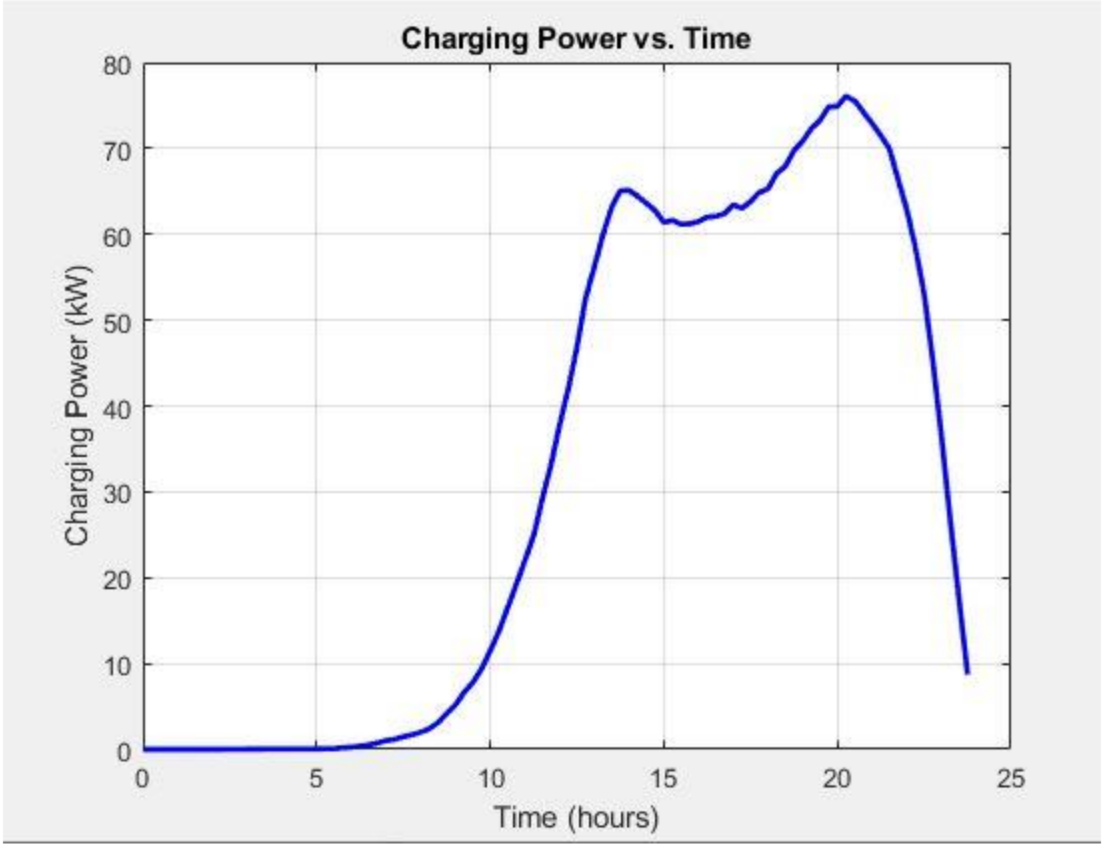

figure 4. 4charging load curve under 2000 simulations

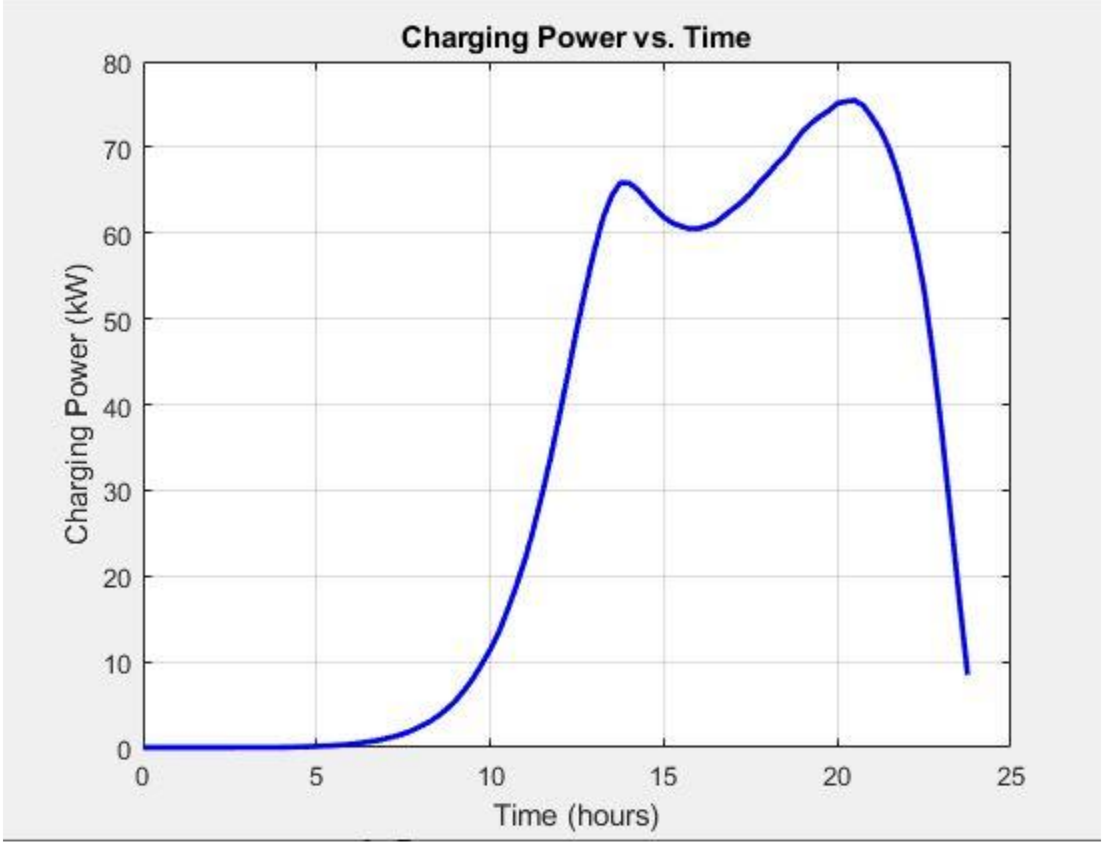

figure 4. 5charging load curve under 10000 simulations

The charging load curve plotted for Ratnapark charging station is shown below: The peak load time of CS is different than in US case. The peak load is between 10 AM to 4 PM. The similar load curve is assumed for Baneshwor feeder.

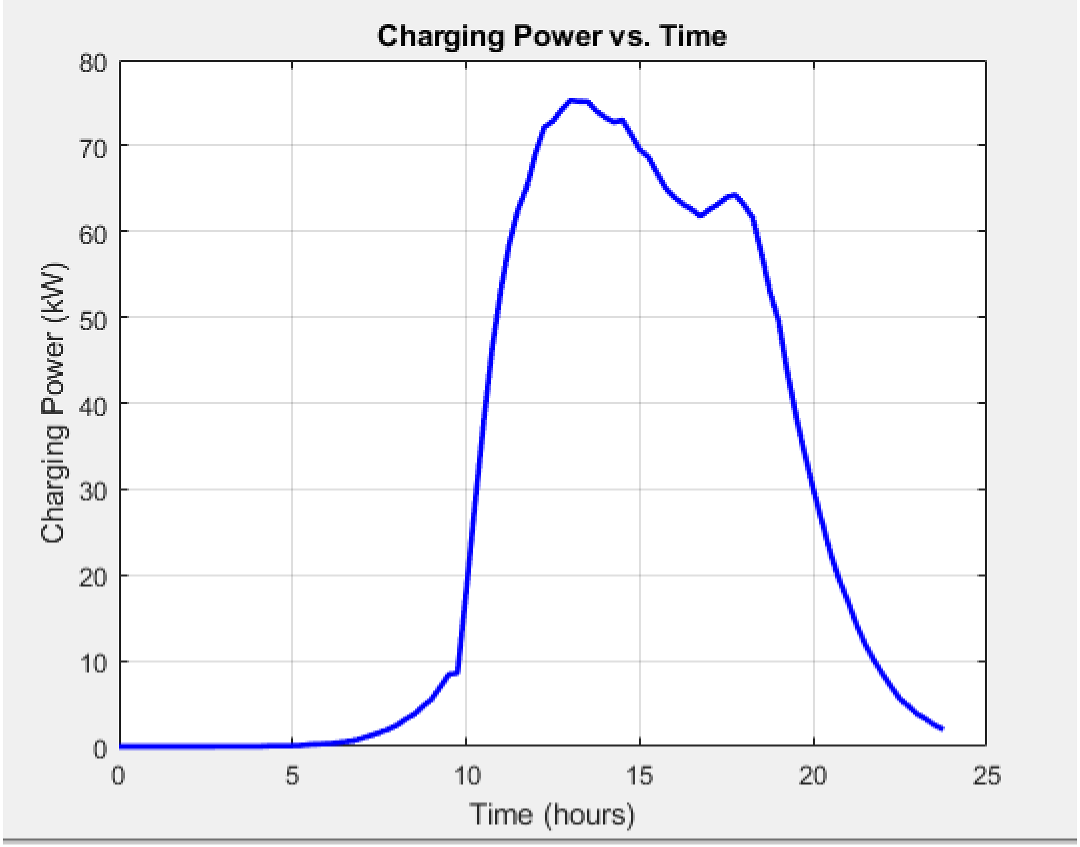

figure 4 6 load curve of charging station Ratnapark with 10000 simulation.

4.1.Impact of EV charging station load and on distribution network

The impact of EV charging station load on Reliability, Voltage stability and power loss is analysis for all the case as mentioned in the table 3.1.

4.1.1. Impact of EV charging station load on voltage profile

Table 4.1 shows the voltage of all the buses for the base case as well as after placing charging stations for all case mentioned in table 3.1. The voltage at Bus 11 in case 2 is less than the voltage at base case but it is within acceptable range. However, in case 4 the voltage at bus 11 is 0.6898 and bus 15 is 0.6243. These values were not within the tolerance limit.

Figure 4.7 shows after V2G integration Voltage profile of the system increases. Voltage at each Bus increases. Figure 4.7 shows Voltage for case6 is fourth ranking in this profile followed by case 2 and case 4.

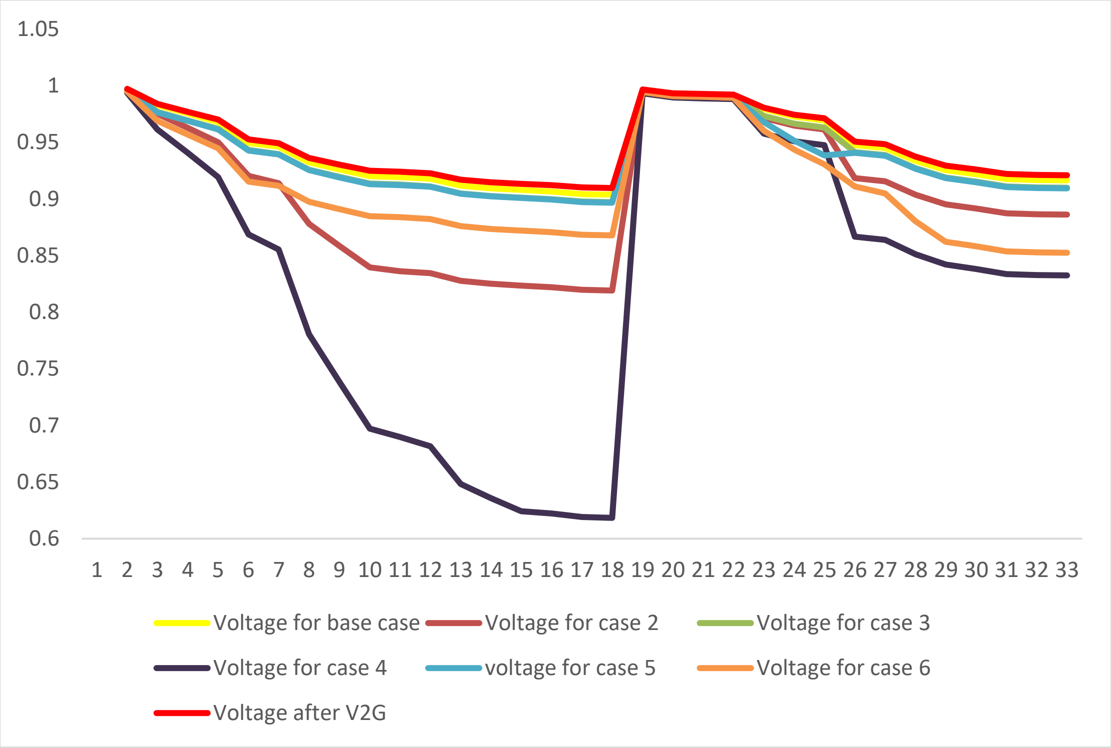

figure 4. 7 impact of charging station and V2G on voltage profile

Table 4. 1. impact of charging station on voltage profile

Bus no	Voltage for base case	Voltage for case 2	Voltage for case 3	Voltage for case 4	voltage for case 5	Voltage for case 6
2	0.997025159	0.995787049	0.996064525	0.993646759	0.996000611	0.994826158
3	0.982892958	0.975036422	0.976797057	0.961459773	0.976391508	0.968945957
4	0.975383394	0.962636964	0.969234327	0.940616397	0.968825211	0.956786134
5	0.967957115	0.950123267	0.961755201	0.919322441	0.961342541	0.944524514
6	0.949479149	0.920282071	0.943145237	0.868757744	0.942723724	0.915360829
7	0.945954385	0.913760486	0.939594912	0.855239789	0.939171684	0.911693657
8	0.932298475	0.877894159	0.925840104	0.780445157	0.925410242	0.89748679
9	0.925965787	0.8584574	0.919461095	0.738393943	0.919028124	0.890895916
10	0.920091682	0.839458379	0.913543918	0.697102983	0.913108058	0.884781712
11	0.919222923	0.836153735	0.912668786	0.689821444	0.912232498	0.883877423
12	0.917708051	0.834484297	0.911142779	0.681563114	0.910705744	0.882300472
13	0.911532324	0.827674923	0.904921436	0.6482115	0.90448134	0.87587037

14	0.909242296	0.825149371	0.902614458	0.635916737	0.902173225	0.87348581
15	0.907815453	0.823575438	0.901177033	0.624316675	0.900735089	0.871999942
16	0.906433448	0.822050824	0.899784769	0.622298504	0.899342137	0.870560714
17	0.904385323	0.819790911	0.897721412	0.619304526	0.897277759	0.868427623
18	0.903771997	0.819114192	0.897103527	0.618408159	0.896659567	0.867788864
19	0.996496791	0.995258018	0.995535643	0.993116579	0.995471695	0.994296612
20	0.992919169	0.991675902	0.991954535	0.989526668	0.991890355	0.990711001
21	0.992214661	0.990970508	0.99124934	0.988819738	0.991185114	0.990004918
22	0.991577237	0.990332283	0.990611295	0.988180122	0.990547027	0.989366069
23	0.979307063	0.971420939	0.973188248	0.957791975	0.967840841	0.960323355
24	0.972635594	0.964694329	0.966474075	0.950967872	0.951318983	0.94366256
25	0.969310448	0.961341616	0.96312758	0.94756641	0.938316133	0.930550608
26	0.947549496	0.918287146	0.941201801	0.866635733	0.940779363	0.91093937
27	0.944985235	0.915635932	0.938619181	0.863815162	0.938195512	0.904891635
28	0.933543353	0.90380592	0.927095351	0.851229144	0.926666185	0.880231297
29	0.925323597	0.895307009	0.918816658	0.842186396	0.918383539	0.862062478
30	0.921765459	0.891627812	0.915232964	0.838271291	0.91479813	0.858239129
31	0.917603446	0.887323463	0.911040908	0.833689361	0.910604059	0.8537652
32	0.916687839	0.886376534	0.91011869	0.832681347	0.909681398	0.852780952
33	0.916404138	0.886083125	0.90983294	0.832369001	0.90939551	0.852475975

4.1.2. Impact of charging station load on VSI

The value of VSI is calculated using equation no 14. Table 4.2 shows the report of the VSI calculated for all the cases. It is observed that VSI at bus 29 in case 6 is 0.5743. This is very low and is unacceptable. The voltage profile for case 4 is better than other cases. Thus, placement of charging station at the weakest bus caused severe degradation of the voltage stability.

Figure 4.8 Shows, VSI for case 5 is very lower than other cases and for case 3 is higher than other cases. After V2G integration, VSI of the overall System increases. As the number of EV increase the voltage profile more will improve. The system does not get collapse in any condition. So, we can add a greater number of charging station. But the best case for placement of charging station is case 3 and worst case is 4.

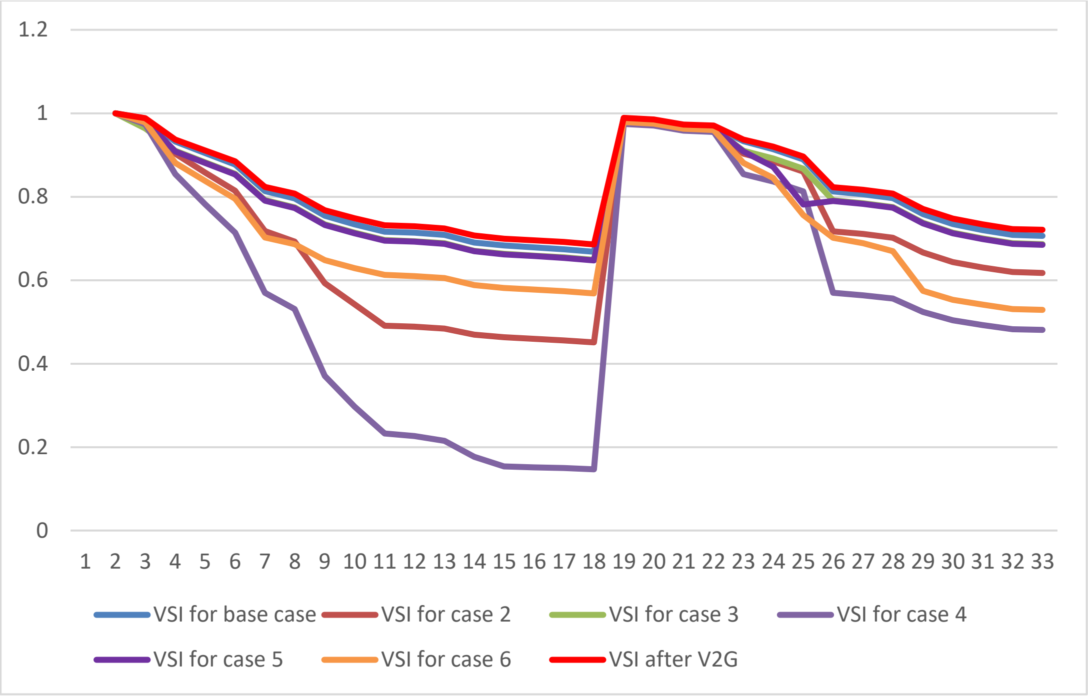

figure 4. 8 impact of charging station and V2G on VSI

Table 4. 2 impact of charging station and on VSI

Bus no	Voltage for base case	Voltage for case 2	Voltage for case 3	Voltage for case 4	voltage for case 5	Voltage for case 6
2	0.999840275	0.999840275	0.999840275	0.999840275	0.999840275	0.999840275
3	0.987302043	0.982404917	0.963943896	0.973982369	0.983248322	0.978616857
4	0.932608393	0.903134664	0.909678057	0.853855176	0.908167692	0.880771398
5	0.90470548	0.858322998	0.882101308	0.782422529	0.880612568	0.837640481
6	0.877039874	0.814140438	0.854767108	0.713546517	0.853300341	0.795110422
7	0.813269619	0.717786806	0.791791905	0.570091128	0.790377854	0.702561371
8	0.795833661	0.6925956	0.774582933	0.531002882	0.773183933	0.686330003
9	0.75445503	0.593071543	0.733751837	0.37028174	0.732389144	0.647857215
10	0.734132645	0.542214027	0.713706422	0.296619916	0.712362096	0.629004885
11	0.71653285	0.490933476	0.696350898	0.232249704	0.69502277	0.612701645
12	0.713593274	0.488498645	0.693452629	0.226221346	0.69212724	0.609981329
13	0.708279054	0.484094626	0.688213357	0.215233995	0.686892939	0.605064936
14	0.69021481	0.46915135	0.670406094	0.176465927	0.669102716	0.588364764
15	0.682845322	0.463072702	0.66314289	0.153566102	0.66184656	0.581559446
16	0.678491594	0.459485486	0.658852274	0.151592077	0.65756013	0.577540725

17	0.674181028	0.455937005	0.654604455	0.149551022	0.653316472	0.57356323
18	0.66810518	0.45094084	0.648617503	0.146690564	0.647335414	0.567959258
19	0.987942746	0.983044029	0.984140307	0.974618738	0.983887709	0.979254737
20	0.984048639	0.979159574	0.980253689	0.970750938	0.980001589	0.975377764
21	0.971540005	0.966682057	0.967769202	0.958327122	0.967518708	0.96292437
22	0.968573529	0.963723006	0.964808488	0.955380883	0.964558377	0.959971075
23	0.932700377	0.903225184	0.909768904	0.853943193	0.908258463	0.88086079
24	0.91412718	0.884946984	0.891424801	0.836169186	0.871932797	0.845072741
25	0.889377486	0.860596083	0.86698481	0.812499886	0.781088526	0.755642505
26	0.812505583	0.717069141	0.791038051	0.569451761	0.789624676	0.701851379
27	0.80583367	0.710789995	0.784452394	0.563835541	0.783044738	0.688307302
28	0.796443712	0.701957433	0.775184843	0.55594387	0.773785304	0.66956367
29	0.758485388	0.666300954	0.737731989	0.524173794	0.736365968	0.574321714
30	0.73425454	0.643584216	0.713833613	0.504014023	0.712489638	0.553258632
31	0.720236997	0.630461875	0.700012635	0.492403578	0.698681696	0.541093308
32	0.708347378	0.619338435	0.688291252	0.482574143	0.686971468	0.530788959
33	0.706147614	0.617281532	0.686122857	0.48075852	0.684805153	0.528884783

4.2.Impact of charging station load and V2G on reliability

The impact of charging station and V2G on reliability is analysis for all the six cases in table 4.3. In order to calculate the reliability, the data of failure rate, outage duration and repair rate of the system for IEEE 33 bus [8]. For case 2, SAIFI is more than the base case but less than the critical value of SAIFI, Similarly for SAIDI, CAIDI and AENS. For case 5 and 6, indices value is very large that cannot be tolerated.

Table 4. 3 Impact of charging station and V2G on reliability

case no	SAIFI	SAIDI	CAIDI
1	0.098237	0.504788	5.13845
2	0.112165	0.551215	4.914306
3	0.116034	0.638266	5.500667
4	0.126094	0.64407	5.10787
5	0.184086	1.001808	5.442061
6	0.426959	1.136738	2.662405
After V2G	0.090463	0.464839	1.737955

4.3.Impact of EV charging load on power Quality

Loss Sensitivity Factor (LSF) in the radial distribution network of IEEE 33 Bus is analysis for all the six case as mentioned in the table 3.1. The LSF is calculated by euation(15). The value of LSF increases after the placement of charging station. From table 4.4, For case 2, the value of LSF is only 0.00546 which is very low. For case 5 and 6 value of LSF is 0.0318 and 0.0494 respectively. These value are very high compared to base case. LSF is directly depends on power loss. Power loss increases as charging stations distance from the origin increases represented by table 4.4. power loss for case 3 is low and case 7 is very high.

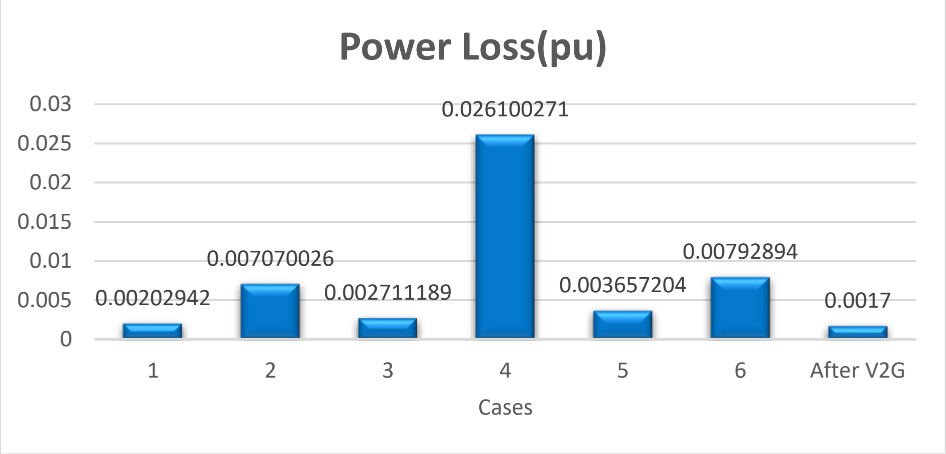

figure 4. 9 Impact of EV Charging station on power loss

Table 4. 4 impact of charging station on LSF

Bus no	Voltage for base case	Voltage for case 2	Voltage for case 3	Voltage for case 4	voltage for case 5	Voltage for case 6
2	0.000115739	0. 00011602	0.000115963	0.000116528	0.000115978	0.000116252
3	0.000573112	0.000582385	0.010896513	0.000598949	0.00058077	0.00058973
4	0.000576069	0.000591425	0.000583401	0.000619441	0.000583894	0.000598681
5	0.000304537	0.000316077	0.000308478	0.000337611	0.000308743	0.000319835
6	0.000680185	0.000724029	0.000689351	0.000812457	0.000689968	0.000731835
7	0.000522105	0.000559543	0.000529197	0.000638738	0.000529674	0.000562083
8	0.004913989	0.005541914	0.004982785	0.007012281	0.004987415	0.005302589
9	0.000899417	0.001046438	0.000912188	0.001414408	0.000913048	0.000971622
10	0.00092332	0.001109216	0.000936603	0.001608498	0.000937497	0.000998486
11	0.000130652	0.005772178	0.000132535	0.008480835	0.000132662	0.000141311

12	0.000332844	0.000402544	0.000337658	0.000603445	0.000337982	0.000360095
13	0.001322805	0.001604428	0.001342203	0.002615811	0.001343509	0.001432716
14	0.000980987	0.001191125	0.000995446	0.002005497	0.00099642	0.001062945
15	0.000536916	0.000652371	0.000544855	0.031408579	0.00054539	0.000581927
16	0.000680073	0.000826856	0.00069016	0.001442878	0.00069084	0.000737274
17	0.00117994	0.00143602	0.001197522	0.002516276	0.001198707	0.001279674
18	0.001006464	0.001225257	0.001021483	0.00214964	0.001022495	0.001091662
19	0.00018548	0.000185942	0.000185838	0.000186745	0.000185862	0.000186302
20	0.001713495	0.001717794	0.001716829	0.001725264	0.001717052	0.001721142
21	0.000467141	0.000468314	0.000468051	0.000470354	0.000468112	0.000469228
22	0.000809724	0.000811761	0.000811304	0.000815301	0.000811409	0.000813347
23	0.000528368	0.000536981	0.000535033	0.000552372	0.000540961	0.000549464
24	0.004974941	0.005057184	0.005038576	0.00520423	0.00520039	0.005285119
25	0.004997975	0.005081178	0.005062351	0.005229987	0.02565214	0.026082065
26	0.00016928	0.000180241	0.000171571	0.000202366	0.000171725	0.00018316
27	0.00023828	0.0002538	0.000241523	0.000285165	0.000241741	0.000259863
28	0.000909789	0.000970643	0.000922489	0.001094251	0.000923343	0.001023331
29	0.001406438	0.001502325	0.001426429	0.001697819	0.001427775	0.023226171
30	0.001490691	0.001593167	0.001512047	0.001802434	0.001513485	0.001719539
31	0.002166113	0.002316473	0.002197432	0.002624113	0.00219954	0.002502155
32	0.000968279	0.001035636	0.000982307	0.001173507	0.000983252	0.001118841
33	0.000304014	0.000325177	0.000308422	0.000368499	0.000308718	0.000351321

4.4.EVPI Evaluation for test cases

EVPI helps in determining for placement of the EVCS in various buses. This index consider all the distribution network parameters. The threshold value for EVPI indicates the severity of buses to check whether charging load can be done or not. The weight assigned to EVPI parameter after EVCS placement in table 4.4. We are going through reliabilty approach. So, weight assigned for reliabilty parameter is higher than VSI and LSF. The value obtained for this index at different test cases shown in fig 4.4. $EVPI_T$, is determined using (19). The result from fig 4.10 shows that the value of EVPI is not beyond the threshold value. $EVPI_T$ that retains the steady operation of the network after the placement of charging loads. Hence , there can add a large penetration of charging stations.

Table 4. 5 Weight of each index

S. N	Weights	value
1	W_{VSI}	0.2
2	W_R	0.7
3	W_{LSF}	0.1
4	W_{COI}	0.5
5	W_{EOI}	0.2

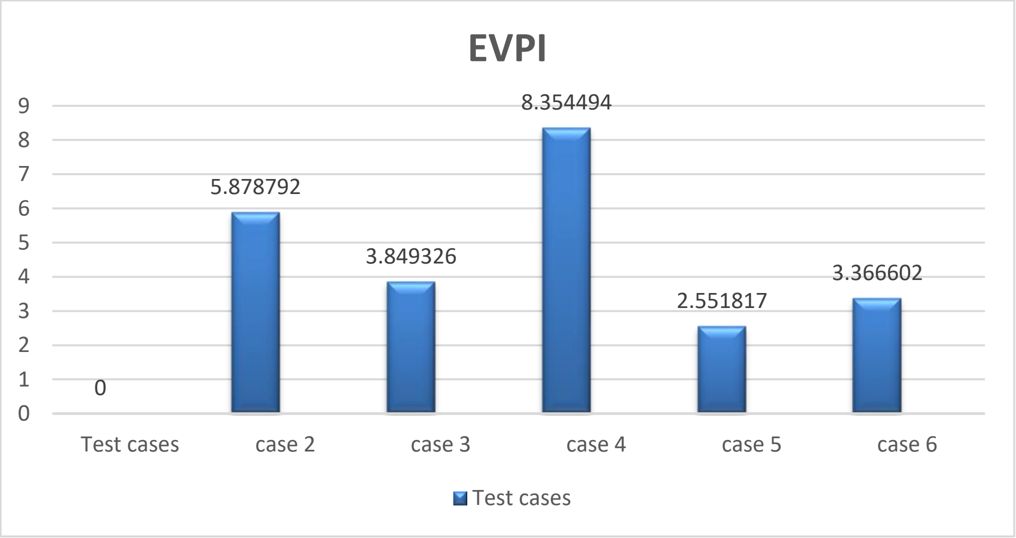

figure 4. 10 EVPI of charging stations

The load in the charging station is not fixed. Then how can we analysis the system considering peak load only although at that time charging station load is very low. Due to lack of time, we have broken the load in three parts of the day. According to NEA it is categorized for TOD meter. It is peak during 5PM- 11 P M. There is no load during night time so called off-peak time between 11 PM- 5 AM. During day time there is neither peak load nor very less load i.e. normal load in between 5 AM- 5 PM.

4.5. Apply load model of CS in the network

The load in the charging station is not fixed. It is peak during 11-1:00 AM and there is no load during night time. Then how can we analysis the system considering peak load only although at that time charging station load is very low. Due to lack of time, we have broken the load in four parts of the day.

Table 4. 6 Load distribution based on time

Time	IEEE load	CS load (KW) In that time
11:00 PM- 5:00 AM	Off peak (60% of peak load_	0.8
5:00 PM- 11:000 PM	Peak load	700
5:00 AM-5:00 AM	Normal (80% of peak load)	1297

Table 4. 7 EVPI of the whole day

time	Case 2	Case 3	case 4	case 5	case 6
00:00-6:00	0.8850049	0.8659811	0.8860355	0.870498	0.8742879
6:00-12:00	2.738558	1.966855	2.752204	1.436978	1.51641
12:00-18:00	4.640993	3.057735	5.555524	2.023221	2.473329
18:00-24:00	1.882748	1.479254	1.803292	1.197548	1.176285

From the above table 3.7 it can be seen that value of EVPI is lowest in bus 3 in all the time of day. So, it is the best placement of charging station.

4.6.Optimal placement of charging stations

Charging stations are placed in the distribution network based on EVPI index. Genetic algorithm (GA) is used for optimally placement of charging station. Table 4.5 shows the optimal locations of the charging stations in the IEEE 33 bus distribution network. For single charging station the optimal location is Bus 24. For two charging station the optimal placement are Bus 29 and Bus 18. For the placement of three CS, the optimal placement are Bus 18, Bus 29 and Bus 11.

4.7.Case study in Baneshwor feeder

Nepal Electricity Authority (NEA) has set up 51 fast charging stations in different parts of country. It has planned more than hundred to be set up till the end of 2080 B.S. This charging station takes 1hr to charge the vehicle fully. The real system data of Baneshwor feeder is considered for the analysis. It also includes 24 distribution transformers. The scheduled and unscheduled outages of this section for the past 1 year (September 2022- September 2023) is taken for the analysis. The diagram of feeder shown in figure 4.6. The yellow dotted spot represents the transformer.

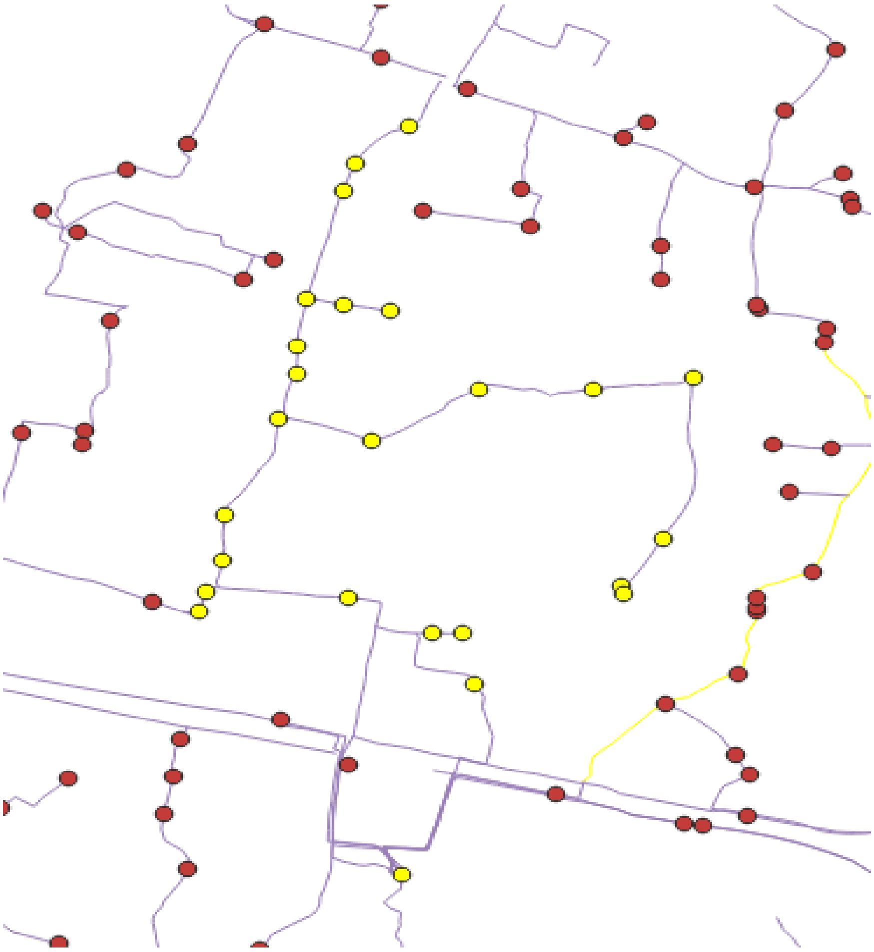

figure 4. 11 Map of Baneshwor feeder diagram

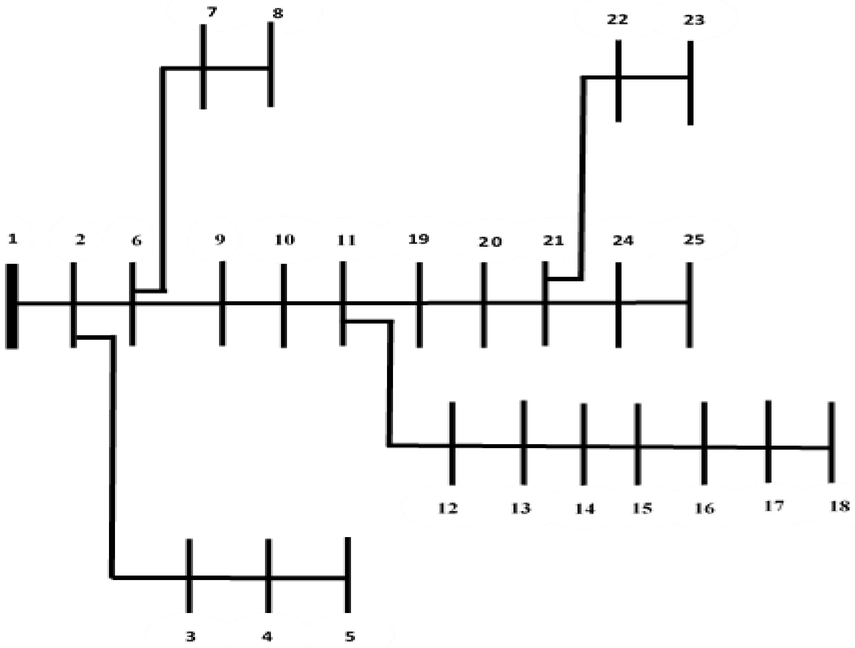

figure 4. 12 Single line diagram of Baneshwor feeder diagram

Load flow analysis is carried out in Matlab. The result of Bus voltage, Power loss, LSF, BRI and VSI is shown in fig 4.61. Bus 17 is the weakest bus as its voltage is 0.9891. Bus 2 is the strongest bus as its voltage 0.9994. Bus 5 is the second strongest bus with bus voltage 0.9947. bus 25 is the second weakest bus with bus voltage 0.9899. The test case is developed by placement of charging station. As looking from the BRI perspective shown in table 4.6 Bus 3 has the least value of BRI and maximal for bus 22. Thus bus 3 represents strongest bus and bus 22 is the weakest bus.

EV chargers consume 60KW power in charging station. Case 1 is the base load without CS in the system. Consider case 2, fast CS is placed at bus 3, represents strongest bus that serve only 2 vehicles. Consider case 3, CS is placed at bus 8, represents strong or weak bus. Also, consider case 4, two charging station (240KW) placed at bus 3 and bus 6 represents strongest and second strongest bus in the system. In case 5, only one charging station serving two EV are allocating at bus 12 represents weakest bus of the system. And In case 6, consider Two fast charging station located at bus 12 and bus 23, indicates weakest and second weakest bus of the system. Table 3.2 shows conditions for test cases.

Table 4. 8 BRI index of Baneshwor feeder

Bus No.	2	3	4	5	6	7	8	9	10	11	12	13
BRI	0.237	0.111	0.444	0.689	0.111	0.444	0.452	0.444	0.459	0.111	0.833	0.689

Bus No.	14	15	16	17	18	19	20	21	22	23	24	25
BRI	0.444	0.222	0.444	0.111	0.444	0.111	0.111	0.444	1	0.689	0.111	0.111

Table 4. 9 Test case condition for Baneshwor feeder

Case no.	Description	Increase in load (KW)	No of charging column
1	Base load	---	--
2	EVCS at Bus 3	120	2
3	EVCS at Bus 8	120	2
4	EVCS at Bus 3 and Bus 6	240(120 KW each)	4
5	EVCS at Bus 12	120	2
6	EVCS at Bus 12 and Bus 23	240(120 KW each)	4

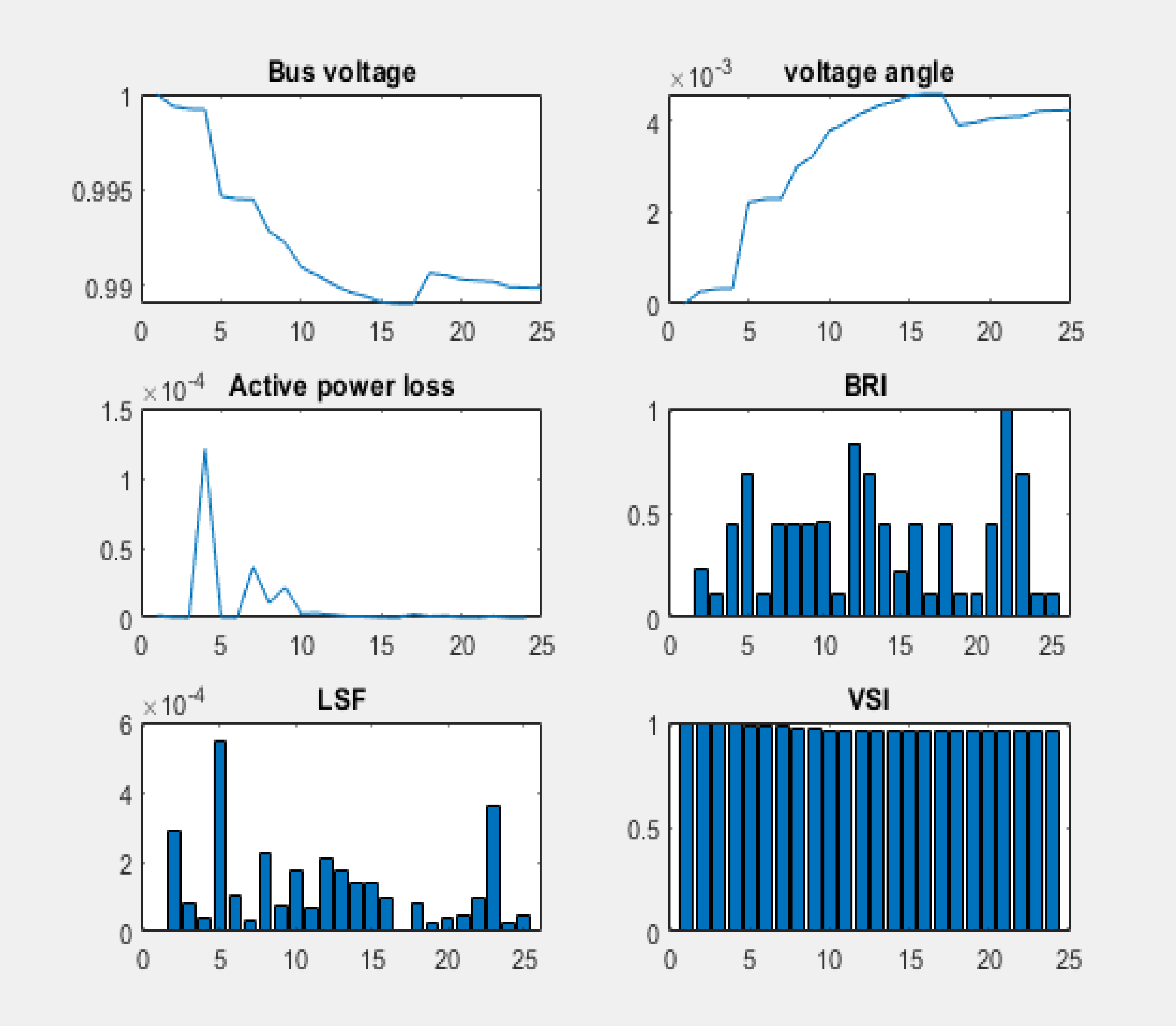

figure 4 13 Base case value for Bus voltage, voltage angle., power loss, BRI , LSF and VSI for baneshwor feeder

4.7. 1. Impact of charging station load and V2G on voltage profile of Baneshwor feeder.

Table 4.10 shows lists of the voltage profile of all the cases before and after placing CS cases mentioned in table 4.9. The voltage of bus 3 for case 2 is 0.998968. The magnitude of the voltage for bus 3 in base case 2 is 0.9989 less than the base case voltage, but still within the threshold value. The lowest voltage occurs at bus16 in case 6.

Figure 4.14 shows case 2 is the best case for voltage profile and case 6 is the worst case. Case 2 is followed by case 3, case 5 and case 4 in descending order respectively. After V2G applied voltage profile of the whole system improved. This is the voltage profile during peak load only. But during Off-peak condition voltage profile decrease because of charging.

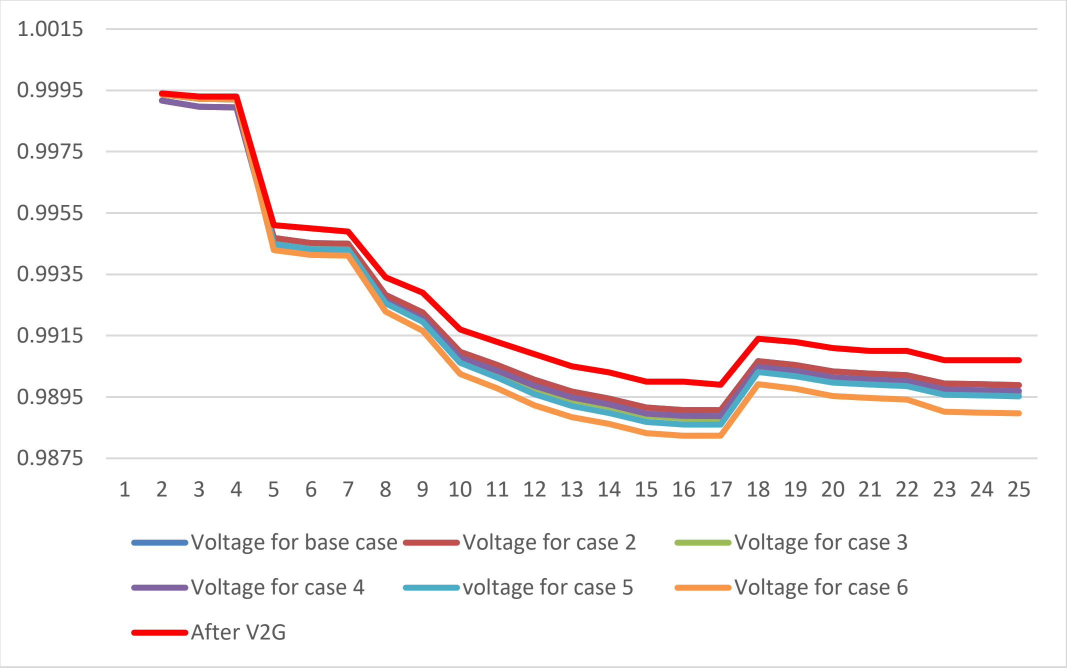

figure 4 14 Impact of charging station load and V2G on voltage profile of Baneshwor feeder

Table 4 10 Impact of charging station load on voltage profile of Baneshwor feeder

Bus no	Voltage for base case	Voltage for case 2	Voltage for case 3	Voltage for case 4	voltage for case 5	Voltage for case 6
2	0.999368909	0.999166077	0.999368909	0.999166077	0.999368909	0.999368909
3	0.999230745	0.998968711	0.999230745	0.998968711	0.999230745	0.999230745
4	0.999209367	0.998947327	0.999209367	0.998947327	0.999209367	0.999209367
5	0.994682192	0.994682192	0.994489031	0.994489648	0.994487979	0.994293556
6	0.994517804	0.994517804	0.99432461	0.99425482	0.994323558	0.994129103
7	0.994500823	0.994500823	0.994307627	0.994237835	0.994306574	0.994112116
8	0.992828718	0.992828718	0.992557224	0.992635812	0.992555746	0.99228248
9	0.992253856	0.992253856	0.991982204	0.992060837	0.991954749	0.99165532
10	0.990973548	0.990973548	0.990701544	0.990780279	0.990611865	0.990249793
11	0.990548376	0.990548376	0.990276254	0.990355023	0.99013902	0.989776775
12	0.990060945	0.990060945	0.98978869	0.989867497	0.98959175	0.989229304
13	0.989679151	0.989679151	0.98940679	0.989485628	0.989209774	0.988847188

14	0.989451261	0.989451261	0.989178837	0.989257693	0.988981775	0.988619106
15	0.989151995	0.989151995	0.988879489	0.988958369	0.988682368	0.988319588
16	0.989073108	0.989073108	0.988800579	0.988879466	0.988603443	0.988240634
17	0.989070087	0.989070087	0.988797558	0.988876445	0.98860042	0.988237611
18	0.990673369	0.990673369	0.990401282	0.990480041	0.990311575	0.989919675
19	0.990544072	0.990544072	0.990271949	0.990350718	0.990182231	0.989775156
20	0.990330939	0.990330939	0.990058757	0.990137544	0.98996902	0.989534438
21	0.990264389	0.990264389	0.98999219	0.990070981	0.989902446	0.989467835
22	0.990212929	0.990212929	0.989940715	0.990019511	0.989850967	0.989416333
23	0.989939045	0.989939045	0.989666756	0.989745573	0.989576983	0.989016234
24	0.989914116	0.989914116	0.98964182	0.989720639	0.989552045	0.988991282
25	0.989887792	0.989887792	0.989615488	0.98969431	0.989525711	0.988964933

4.7. 2. Impact of charging station load on VSI for Baneshwor feeder

Table 4.11 shows the VSI of all the buses of Baneshwor feeder for the base cases as well as after placement of charging station for all the cases mentioned in table 4.9.

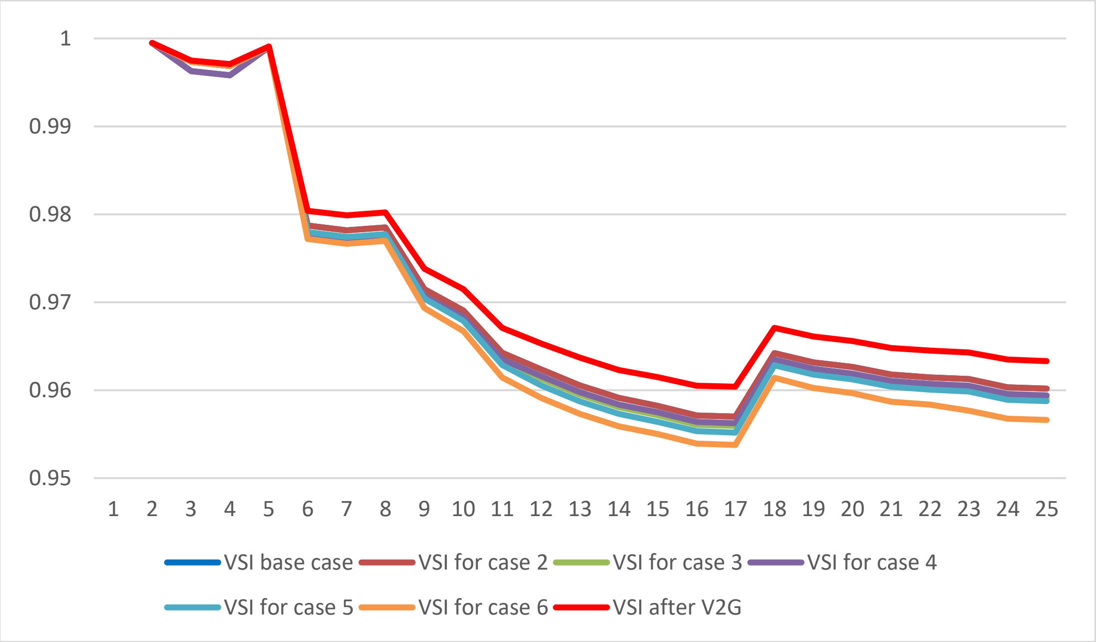

figure 4. 15 Impact of CS load and V2G on VSI for Bnawshwor feeder in all test cases

Table 4. 11 Impact of CS load on VSI for Baneshwor feeder.

Bus no	VSI for base case	VSI for case 2	VSI for case 3	VSI for case 4	VSI for case 5	VSI for case 6
2	0.999483181	0.999483181	0.999483181	0.999483181	0.999483181	0.999483181
3	0.997327353	0.996281842	0.997327353	0.996281842	0.997327353	0.997327353
4	0.996856607	0.995811337	0.996856607	0.995811337	0.996856607	0.996856607
5	0.999027766	0.999027766	0.999027766	0.999027766	0.999027766	0.999027766
6	0.978721087	0.978721087	0.977960993	0.977686529	0.977956854	0.977192247
7	0.978196127	0.978196127	0.977436237	0.977161836	0.977432099	0.976667697
8	0.978507658	0.978507658	0.977442036	0.977750074	0.977743508	0.976978984
9	0.971492938	0.971492938	0.970430665	0.970738063	0.970424882	0.969356561
10	0.969064897	0.969064897	0.96800395	0.968310965	0.967896771	0.966728448
11	0.964262355	0.964262355	0.963204035	0.963510289	0.962855301	0.961448281
12	0.96235679	0.96235679	0.961299516	0.961605467	0.960535324	0.959129999
13	0.960529149	0.960529149	0.959472879	0.95977854	0.958709354	0.957305365
14	0.959110062	0.959110062	0.958054572	0.958360007	0.957291612	0.95588866
15	0.958230516	0.958230516	0.95717551	0.957480805	0.9564129	0.955010593
16	0.957142115	0.957142115	0.956087708	0.95639283	0.955325532	0.953924022
17	0.956994026	0.956994026	0.9559397	0.956244799	0.955177583	0.953776181
18	0.964232908	0.964232908	0.963174604	0.963480854	0.962825876	0.961418878
19	0.96317471	0.96317471	0.962116987	0.962423068	0.96176845	0.960246904
20	0.962641525	0.962641525	0.961584095	0.961890092	0.961235654	0.959655874
21	0.96179634	0.96179634	0.960739374	0.961045237	0.960391087	0.958705733
22	0.961458752	0.961458752	0.960401972	0.96070778	0.960053745	0.958368687
23	0.961257431	0.961257431	0.960200761	0.960506537	0.959852571	0.957679818
24	0.960319813	0.960319813	0.959263659	0.959569286	0.958915639	0.956743944
25	0.960179008	0.960179008	0.959122931	0.959428536	0.958774937	0.956603401

4.7. 3. Impact of charging station load on reliability for Baneshwor feeder

Table 4.12 shows the impact of placement of charging station on different reliability indices. The value of SAIFI for case 2 is 2.126025. This value is more than the base case but less than the critical value. Similarly for other indices SAIDI, CAIDI, AENS. It is noticed that for case 5 and case 6 indices value is lowest but can be tolerated. For the placement of charging station bus with good reliability indices should choose.

Table 4. 12 Impact of charging station in Baneshwor feeder on different reliability indices.

case no	SAIFI	SAIDI	CAIDI
Base case	2.090352	0.936256	0.447894
2	2.126025	0.954092	0.448768
3	2.161697	0.972523	0.449889
4	2.161697	0.971928	0.449614
5	2.200613	0.973043	0.442169
6	2.30763	1.019059	0.441604
After V2G	1.90731	0.854272	0.447894

4.7. 4. Impact of charging station load on power quality in Baneshwor feeder

Table 4.13 shows results of the power loss of the Baneshwor Feeder distribution network for all the test cases mentioned in the table 4.9. The power loss increased after placing the charging station. The power loss for case 5 is less than that of case 6 shows the advantage of placing charging station. For case 6, the loss is maximum because charging stations are placed at weak bus. Table 4.66 shows the LSF of all the buses of Baneshwor feeder which helps to calculate the EVPI.

Table 4. 13 Impact of EV charging load on power loss

case	Ploss(Pu)
Base case	0.000208
2	0.000211
3	0.000226
4	0.000224
5	0.000233
6	0.000259

Table 4. 14 Impact of charging station load on LSF in Baneshwor distribution network

Bus no	Voltage for base case	Voltage for case 2	Voltage for case 3	Voltage for case 4	voltage for case 5	Voltage for case 6
2	0.000287206	0.000287323	2.87E-04	0.000287323	2.87E-04	2.87E-04
3	8.39E-05	2.02E-04	8.39E-05	2.02E-04	8.39E-05	8.39E-05
4	3.89E-05	3.90E-05	3.89E-05	3.90E-05	3.89E-05	3.89E-05
5	0.000545376	0.000545376	0.000545588	0.000545588	0.000545589	0.000545803
6	1.00E-04	1.00E-04	1.00E-04	2.42E-04	1.00E-04	1.00E-04
7	3.11E-05	3.11E-05	3.11E-05	3.11E-05	3.11E-05	3.11E-05
8	2.22E-04	2.22E-04	3.79E-04	2.22E-04	2.22E-04	2.22E-04
9	7.38E-05	7.38E-05	7.38E-05	7.38E-05	7.38E-05	7.39E-05
10	1.77E-04	1.77E-04	1.77E-04	1.77E-04	1.77E-04	1.77E-04
11	6.78E-05	6.78E-05	6.79E-05	6.79E-05	6.79E-05	6.79E-05
12	0.00021314	0.00021314	0.000213257	0.000213223	0.000333817	0.000334062
13	0.000175408	0.000175408	0.000175505	0.000175477	0.000175575	0.000175703
14	0.000139652	0.000139652	0.000139729	0.000139707	0.000139785	0.000139887
15	1.38E-04	1.38E-04	1.38E-04	1.38E-04	1.38E-04	1.38E-04
16	9.68E-05	9.68E-05	9.68E-05	9.68E-05	9.68E-05	9.69E-05
17	5.56E-06	5.56E-06	5.56E-06	5.56E-06	5.56E-06	5.57E-06
18	8.48E-05	8.48E-05	8.48E-05	8.48E-05	8.48E-05	8.49E-05
19	2.16E-05	2.16E-05	2.16E-05	2.16E-05	2.16E-05	2.16E-05
20	3.91E-05	3.91E-05	3.92E-05	3.92E-05	3.92E-05	3.92E-05
21	4.89E-05	4.89E-05	4.89E-05	4.89E-05	4.89E-05	4.90E-05
22	9.46E-05	9.46E-05	9.46E-05	9.46E-05	9.46E-05	9.47E-05
23	3.60E-04	3.60E-04	3.60E-04	3.60E-04	3.60E-04	6.16E-04
24	2.29E-05	2.29E-05	2.29E-05	2.29E-05	2.29E-05	2.30E-05
25	4.84E-05	4.84E-05	4.84E-05	4.84E-05	4.84E-05	4.85E-05

4.7. 5. EVPI Evaluation of Baneshwor feeder after placement of Charging station

Figure 4.16 shows graph of EVPI of Baneshwor feeder after placement of charging station with all the test cases in the table 4.61. Figure below shows that the EVPI for all test cases is within the acceptable value that means the network has steady operation even after the establishment of EV charging loads. Hence, Large number of charging station can be penetrated at strong buses.

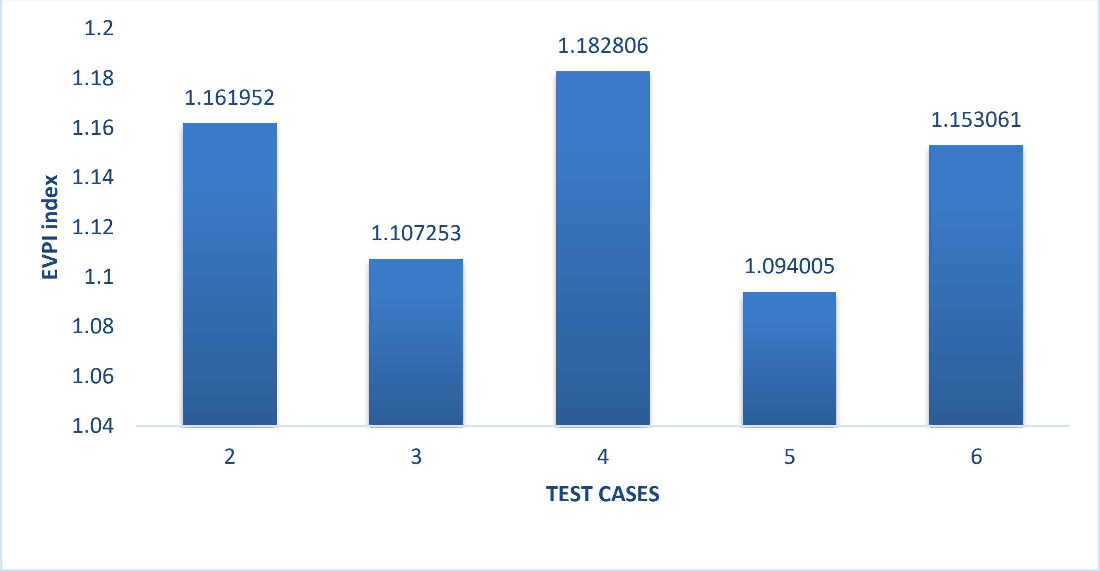

figure 4. 16 EVPI for Baneshwor distribution feeder

Thus, system will operate smoothly by placing the charging station. It is good to place the charging station at strong buses. Such that all the operating parameter of distribution will be in operating range. Distributing charging station at many strong buses rather than focusing on the weak buses. Hence reliability index approach is the best way for proper planning of charging station without restructuring the distribution network.

The optimal placement of charging station in Baneshwor distribution network using Genetic algorithm (GA) is bus no 3 and 5.

4.7. 6. Impact of V2G integration in Baneshwor feeder.

According to Nea booklet fiscal year 080/081, there are 70,000 consumers in Baneshwor DCs. In this DCs there is 26 feeders. On dividing consumer there is only around 2000 consumer in this feeder. So, we consider 100 vehicles only in this area. The area is more dense than other. More number of EV user lives in this area. Three case scenario is developed. 10% charging, 70% charging and after V2G integration. Let’s see how ENS and other parameter if reliability gets effected. Total power in the system is divided equally to all the bus proportionally to their capacities.

From the table 4.20. reliability of the system decreases ac EV in the system increases. But with integration of V2G the reliability is not only increase but it is better than base case.

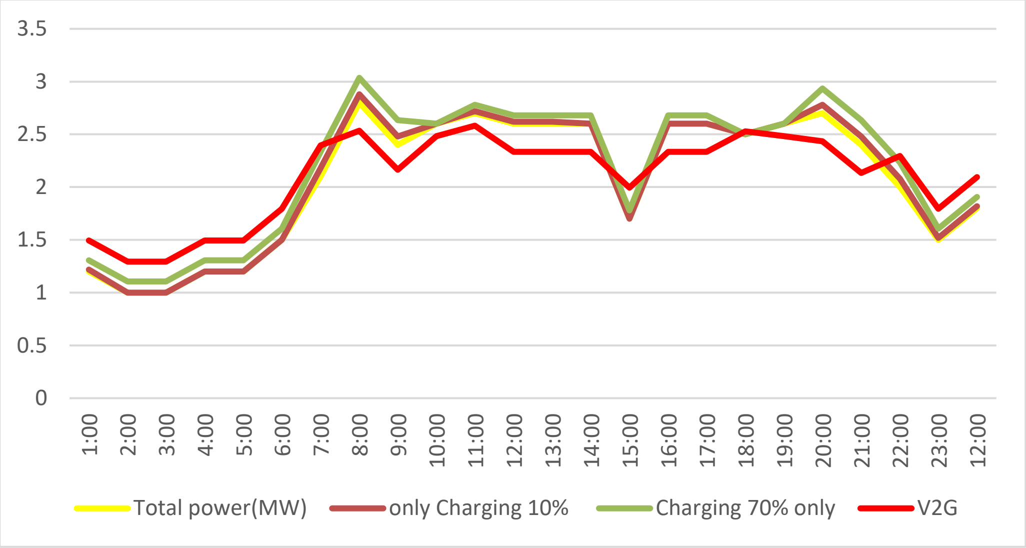

figure 4. 17 24 hour load flow of baneshwor feeder with all condition.

Table 4. 15 Reliability evaluation for all the cases

Reliability indices	Base load	10% Charging only	70% charging only	After V2G
SAIFI	2.0906	2.15	2.26685	1.893
SAIDI	0.9364476	0.9632	1.01537	0.84795
CAIDI	0.4479	0.448	0.447921124	0.447939778
ENS(MWH/Yr)	46.68913502	47.25053	49.340217	47.2117914
AENS	0.017343661	0.017552203	0.018328461	0.017537813

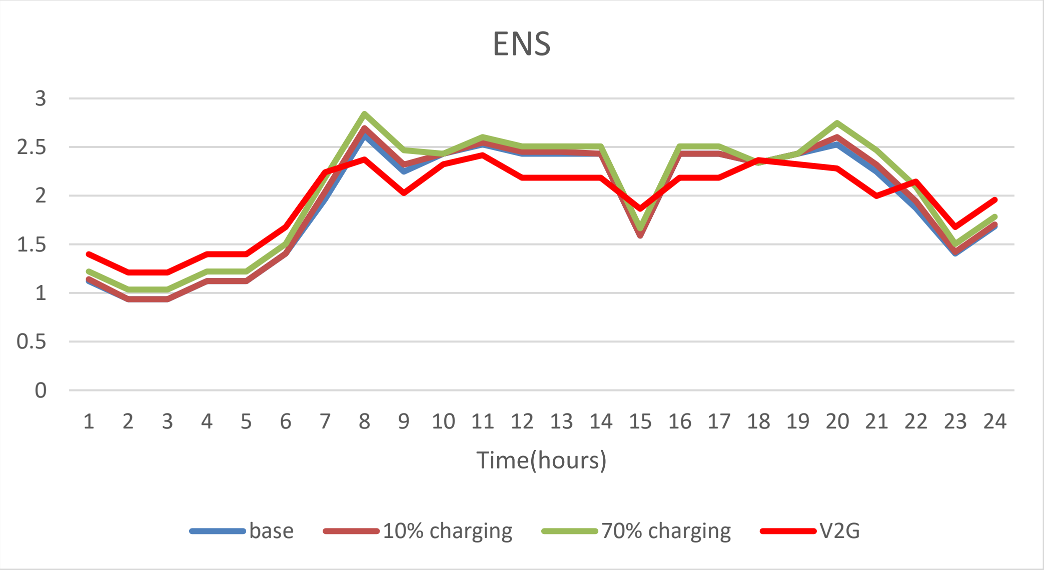

figure 4. 18 ENS graph of Baneshwor distribution system

In the Table 4.20 ENS for the base case is 46.689Mwh/Yr. when charging station is added in the system by 10 % it increases to 47.25053Mwh/Yr. and 49.3402Mwh/Yr. when charging by 70% EV. With integration of V2G ENS decreases to 47.2118Mwh/yr. it is lesser than 10% and 70% charging but higher than base case. Figure 4.18 shows ENS of the system increases after adding EV in the system. But with proper coordinating of V2G ENS during peak hour decreases and during off-peak hour increases. Hence resultant ENS decreases than charging case but higher than the base case.

Table 4. 16. Base load of Feeder distributes in each bus for each hour

	Time											
bus no.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
1	0	0	0	0	0	0	0	0	0	0	0	0
2	0.0304	0.0253	0.0253	0.0304	0.0304	0.038	0.0532	0.0709	0.0608	0.0658	0.0684	0.0658
3	0.0304	0.0253	0.0253	0.0304	0.0304	0.038	0.0532	0.0709	0.0608	0.0658	0.0684	0.0658
4	0.0608	0.0506	0.0506	0.0608	0.0608	0.0759	0.1063	0.1418	0.1215	0.1316	0.1367	0.1316
5	0.0608	0.0506	0.0506	0.0608	0.0608	0.0759	0.1063	0.1418	0.1215	0.1316	0.1367	0.1316
6	0.0304	0.0253	0.0253	0.0304	0.0304	0.038	0.0532	0.0709	0.0608	0.0658	0.0684	0.0658
7	0.0608	0.0506	0.0506	0.0608	0.0608	0.0759	0.1063	0.1418	0.1215	0.1316	0.1367	0.1316
8	0.0608	0.0506	0.0506	0.0608	0.0608	0.0759	0.1063	0.1418	0.1215	0.1316	0.1367	0.1316
9	0.0608	0.0506	0.0506	0.0608	0.0608	0.0759	0.1063	0.1418	0.1215	0.1316	0.1367	0.1316
10	0.0608	0.0506	0.0506	0.0608	0.0608	0.0759	0.1063	0.1418	0.1215	0.1316	0.1367	0.1316
11	0.0304	0.0253	0.0253	0.0304	0.0304	0.038	0.0532	0.0709	0.0608	0.0658	0.0684	0.0658
12	0.0759	0.0633	0.0633	0.0759	0.0759	0.0949	0.1329	0.1772	0.1519	0.1646	0.1709	0.1646
13	0.0608	0.0506	0.0506	0.0608	0.0608	0.0759	0.1063	0.1418	0.1215	0.1316	0.1367	0.1316
14	0.0608	0.0506	0.0506	0.0608	0.0608	0.0759	0.1063	0.1418	0.1215	0.1316	0.1367	0.1316
15	0.0304	0.0253	0.0253	0.0304	0.0304	0.038	0.0532	0.0709	0.0608	0.0658	0.0684	0.0658
16	0.0608	0.0506	0.0506	0.0608	0.0608	0.0759	0.1063	0.1418	0.1215	0.1316	0.1367	0.1316
17	0.0304	0.0253	0.0253	0.0304	0.0304	0.038	0.0532	0.0709	0.0608	0.0658	0.0684	0.0658
18	0.0608	0.0506	0.0506	0.0608	0.0608	0.0759	0.1063	0.1418	0.1215	0.1316	0.1367	0.1316
19	0.0304	0.0253	0.0253	0.0304	0.0304	0.038	0.0532	0.0709	0.0608	0.0658	0.0684	0.0658
20	0.0304	0.0253	0.0253	0.0304	0.0304	0.038	0.0532	0.0709	0.0608	0.0658	0.0684	0.0658
21	0.0608	0.0506	0.0506	0.0608	0.0608	0.0759	0.1063	0.1418	0.1215	0.1316	0.1367	0.1316
22	0.0911	0.0759	0.0759	0.0911	0.0911	0.1139	0.1595	0.2127	0.1823	0.1975	0.2051	0.1975
23	0.0608	0.0506	0.0506	0.0608	0.0608	0.0759	0.1063	0.1418	0.1215	0.1316	0.1367	0.1316
24	0.0304	0.0253	0.0253	0.0304	0.0304	0.038	0.0532	0.0709	0.0608	0.0658	0.0684	0.0658
25	0.0304	0.0253	0.0253	0.0304	0.0304	0.038	0.0532	0.0709	0.0608	0.0658	0.0684	0.0658
Total	1.2	1	1	1.2	1.2	1.5	2.1	2.8	2.4	2.6	2.7	2.6

13	14	15	16	17	18	19	20	21	22	23	24	outage duration
0	0	0	0	0	0	0	0	0	0	0	0	0
0.0658	0.0658	0.043	0.0658	0.0658	0.0633	0.0658	0.0684	0.0608	0.0506	0.038	0.0456	0.533333333
0.0658	0.0658	0.043	0.0658	0.0658	0.0633	0.0658	0.0684	0.0608	0.0506	0.038	0.0456	0.5
0.1316	0.1316	0.0861	0.1316	0.1316	0.1266	0.1316	0.1367	0.1215	0.1013	0.0759	0.0911	1
0.1316	0.1316	0.0861	0.1316	0.1316	0.1266	0.1316	0.1367	0.1215	0.1013	0.0759	0.0911	1.033333333
0.0658	0.0658	0.043	0.0658	0.0658	0.0633	0.0658	0.0684	0.0608	0.0506	0.038	0.0456	0.5
0.1316	0.1316	0.0861	0.1316	0.1316	0.1266	0.1316	0.1367	0.1215	0.1013	0.0759	0.0911	1
0.1316	0.1316	0.0861	0.1316	0.1316	0.1266	0.1316	0.1367	0.1215	0.1013	0.0759	0.0911	1.016666667
0.1316	0.1316	0.0861	0.1316	0.1316	0.1266	0.1316	0.1367	0.1215	0.1013	0.0759	0.0911	1
0.1316	0.1316	0.0861	0.1316	0.1316	0.1266	0.1316	0.1367	0.1215	0.1013	0.0759	0.0911	1.033333333
0.0658	0.0658	0.043	0.0658	0.0658	0.0633	0.0658	0.0684	0.0608	0.0506	0.038	0.0456	0.5
0.1646	0.1646	0.1076	0.1646	0.1646	0.1582	0.1646	0.1709	0.1519	0.1266	0.0949	0.1139	1.25
0.1316	0.1316	0.0861	0.1316	0.1316	0.1266	0.1316	0.1367	0.1215	0.1013	0.0759	0.0911	1.033333333
0.1316	0.1316	0.0861	0.1316	0.1316	0.1266	0.1316	0.1367	0.1215	0.1013	0.0759	0.0911	1
0.0658	0.0658	0.043	0.0658	0.0658	0.0633	0.0658	0.0684	0.0608	0.0506	0.038	0.0456	0.5
0.1316	0.1316	0.0861	0.1316	0.1316	0.1266	0.1316	0.1367	0.1215	0.1013	0.0759	0.0911	1
0.0658	0.0658	0.043	0.0658	0.0658	0.0633	0.0658	0.0684	0.0608	0.0506	0.038	0.0456	0.5
0.1316	0.1316	0.0861	0.1316	0.1316	0.1266	0.1316	0.1367	0.1215	0.1013	0.0759	0.0911	1
0.0658	0.0658	0.043	0.0658	0.0658	0.0633	0.0658	0.0684	0.0608	0.0506	0.038	0.0456	0.5
0.0658	0.0658	0.043	0.0658	0.0658	0.0633	0.0658	0.0684	0.0608	0.0506	0.038	0.0456	0.5
0.1316	0.1316	0.0861	0.1316	0.1316	0.1266	0.1316	0.1367	0.1215	0.1013	0.0759	0.0911	1
0.1975	0.1975	0.1291	0.1975	0.1975	0.1899	0.1975	0.2051	0.1823	0.1519	0.1139	0.1367	1.5
0.1316	0.1316	0.0861	0.1316	0.1316	0.1266	0.1316	0.1367	0.1215	0.1013	0.0759	0.0911	1.033333333
0.0658	0.0658	0.043	0.0658	0.0658	0.0633	0.0658	0.0684	0.0608	0.0506	0.038	0.0456	0.5
0.0658	0.0658	0.043	0.0658	0.0658	0.0633	0.0658	0.0684	0.0608	0.0506	0.038	0.0456	0.5

Table 4. 17 After adding 10% charging on the network load in each bus in each hour

	Time											
bus no.	1	2	3	4	5	6	7	8	9	10	11	12
1	0	0	0	0	0	0	0	0	0	0	0	0
2	0.030886	0.0253165	0.02532	0.0304	0.0303797	0.037975	0.0552	0.072911	0.0628	0.0658	0.0689	0.0663
3	0.030886	0.0253165	0.02532	0.0304	0.0303797	0.037975	0.0552	0.072911	0.0628	0.0658	0.0689	0.0663
4	0.061772	0.0506329	0.05063	0.0608	0.0607595	0.075949	0.1104	0.145823	0.1256	0.1316	0.1377	0.1327
5	0.061772	0.0506329	0.05063	0.0608	0.0607595	0.075949	0.1104	0.145823	0.1256	0.1316	0.1377	0.1327
6	0.030886	0.0253165	0.02532	0.0304	0.0303797	0.037975	0.0552	0.072911	0.0628	0.0658	0.0689	0.0663
7	0.061772	0.0506329	0.05063	0.0608	0.0607595	0.075949	0.1104	0.145823	0.1256	0.1316	0.1377	0.1327
8	0.061772	0.0506329	0.05063	0.0608	0.0607595	0.075949	0.1104	0.145823	0.1256	0.1316	0.1377	0.1327
9	0.061772	0.0506329	0.05063	0.0608	0.0607595	0.075949	0.1104	0.145823	0.1256	0.1316	0.1377	0.1327
10	0.061772	0.0506329	0.05063	0.0608	0.0607595	0.075949	0.1104	0.145823	0.1256	0.1316	0.1377	0.1327
11	0.030886	0.0253165	0.02532	0.0304	0.0303797	0.037975	0.0552	0.072911	0.0628	0.0658	0.0689	0.0663
12	0.077215	0.0632911	0.06329	0.0759	0.0759494	0.094937	0.138	0.182278	0.157	0.1646	0.1722	0.1658
13	0.061772	0.0506329	0.05063	0.0608	0.0607595	0.075949	0.1104	0.145823	0.1256	0.1316	0.1377	0.1327
14	0.061772	0.0506329	0.05063	0.0608	0.0607595	0.075949	0.1104	0.145823	0.1256	0.1316	0.1377	0.1327
15	0.030886	0.0253165	0.02532	0.0304	0.0303797	0.037975	0.0552	0.072911	0.0628	0.0658	0.0689	0.0663
16	0.061772	0.0506329	0.05063	0.0608	0.0607595	0.075949	0.1104	0.145823	0.1256	0.1316	0.1377	0.1327
17	0.030886	0.0253165	0.02532	0.0304	0.0303797	0.037975	0.0552	0.072911	0.0628	0.0658	0.0689	0.0663
18	0.061772	0.0506329	0.05063	0.0608	0.0607595	0.075949	0.1104	0.145823	0.1256	0.1316	0.1377	0.1327
19	0.030886	0.0253165	0.02532	0.0304	0.0303797	0.037975	0.0552	0.072911	0.0628	0.0658	0.0689	0.0663
20	0.030886	0.0253165	0.02532	0.0304	0.0303797	0.037975	0.0552	0.072911	0.0628	0.0658	0.0689	0.0663
21	0.061772	0.0506329	0.05063	0.0608	0.0607595	0.075949	0.1104	0.145823	0.1256	0.1316	0.1377	0.1327
22	0.092658	0.0759494	0.07595	0.0911	0.0911392	0.113924	0.1656	0.218734	0.1884	0.1975	0.2066	0.199
23	0.061772	0.0506329	0.05063	0.0608	0.0607595	0.075949	0.1104	0.145823	0.1256	0.1316	0.1377	0.1327
24	0.030886	0.0253165	0.02532	0.0304	0.0303797	0.037975	0.0552	0.072911	0.0628	0.0658	0.0689	0.0663
25	0.030886	0.0253165	0.02532	0.0304	0.0303797	0.037975	0.0552	0.072911	0.0628	0.0658	0.0689	0.0663
Total	1.22	1	1	1.2	1.2	1.5	2.18	2.88	2.48	2.6	2.72	2.62

13	14	15	16	17	18	19	20	21	22	23	24
0	0	0	0	0	0	0	0	0	0	0	0
0.0663	0.0658	0.043	0.0658	0.0658	0.0633	0.0658	0.0704	0.0628	0.0527	0.0385	0.0461
0.0663	0.0658	0.043	0.0658	0.0658	0.0633	0.0658	0.0704	0.0628	0.0527	0.0385	0.0461
0.1327	0.1316	0.0861	0.1316	0.1316	0.1266	0.1316	0.1408	0.1256	0.1053	0.077	0.0922
0.1327	0.1316	0.0861	0.1316	0.1316	0.1266	0.1316	0.1408	0.1256	0.1053	0.077	0.0922
0.0663	0.0658	0.043	0.0658	0.0658	0.0633	0.0658	0.0704	0.0628	0.0527	0.0385	0.0461
0.1327	0.1316	0.0861	0.1316	0.1316	0.1266	0.1316	0.1408	0.1256	0.1053	0.077	0.0922
0.1327	0.1316	0.0861	0.1316	0.1316	0.1266	0.1316	0.1408	0.1256	0.1053	0.077	0.0922
0.1327	0.1316	0.0861	0.1316	0.1316	0.1266	0.1316	0.1408	0.1256	0.1053	0.077	0.0922
0.1327	0.1316	0.0861	0.1316	0.1316	0.1266	0.1316	0.1408	0.1256	0.1053	0.077	0.0922
0.0663	0.0658	0.043	0.0658	0.0658	0.0633	0.0658	0.0704	0.0628	0.0527	0.0385	0.0461
0.1658	0.1646	0.1076	0.1646	0.1646	0.1582	0.1646	0.1759	0.157	0.1316	0.0962	0.1152
0.1327	0.1316	0.0861	0.1316	0.1316	0.1266	0.1316	0.1408	0.1256	0.1053	0.077	0.0922
0.1327	0.1316	0.0861	0.1316	0.1316	0.1266	0.1316	0.1408	0.1256	0.1053	0.077	0.0922
0.0663	0.0658	0.043	0.0658	0.0658	0.0633	0.0658	0.0704	0.0628	0.0527	0.0385	0.0461
0.1327	0.1316	0.0861	0.1316	0.1316	0.1266	0.1316	0.1408	0.1256	0.1053	0.077	0.0922
0.0663	0.0658	0.043	0.0658	0.0658	0.0633	0.0658	0.0704	0.0628	0.0527	0.0385	0.0461
0.1327	0.1316	0.0861	0.1316	0.1316	0.1266	0.1316	0.1408	0.1256	0.1053	0.077	0.0922
0.0663	0.0658	0.043	0.0658	0.0658	0.0633	0.0658	0.0704	0.0628	0.0527	0.0385	0.0461
0.0663	0.0658	0.043	0.0658	0.0658	0.0633	0.0658	0.0704	0.0628	0.0527	0.0385	0.0461
0.1327	0.1316	0.0861	0.1316	0.1316	0.1266	0.1316	0.1408	0.1256	0.1053	0.077	0.0922
0.199	0.1975	0.1291	0.1975	0.1975	0.1899	0.1975	0.2111	0.1884	0.158	0.1154	0.1382
0.1327	0.1316	0.0861	0.1316	0.1316	0.1266	0.1316	0.1408	0.1256	0.1053	0.077	0.0922
0.0663	0.0658	0.043	0.0658	0.0658	0.0633	0.0658	0.0704	0.0628	0.0527	0.0385	0.0461
0.0663	0.0658	0.043	0.0658	0.0658	0.0633	0.0658	0.0704	0.0628	0.0527	0.0385	0.0461
2.62	2.6	1.7	2.6	2.6	2.5	2.6	2.78	2.48	2.08	1.52	1.82

Table 4. 18 Adding 70% charging, load distributed in each bus for 24 hours

	TIME											
bus no.	1	2	3	4	5	6	7	8	9	10	11	12
1	0	0	0	0	0	0	0	0	0	0	0	0
2	0.0331	0.028	0.028	0.0331	0.0331	0.0407	0.0591	0.0769	0.0667	0.0658	0.0704	0.0679
3	0.0331	0.028	0.028	0.0331	0.0331	0.0407	0.0591	0.0769	0.0667	0.0658	0.0704	0.0679
4	0.0661	0.056	0.056	0.0661	0.0661	0.0813	0.1183	0.1537	0.1335	0.1316	0.1408	0.1357
5	0.0661	0.056	0.056	0.0661	0.0661	0.0813	0.1183	0.1537	0.1335	0.1316	0.1408	0.1357
6	0.0331	0.028	0.028	0.0331	0.0331	0.0407	0.0591	0.0769	0.0667	0.0658	0.0704	0.0679
7	0.0661	0.056	0.056	0.0661	0.0661	0.0813	0.1183	0.1537	0.1335	0.1316	0.1408	0.1357
8	0.0661	0.056	0.056	0.0661	0.0661	0.0813	0.1183	0.1537	0.1335	0.1316	0.1408	0.1357
9	0.0661	0.056	0.056	0.0661	0.0661	0.0813	0.1183	0.1537	0.1335	0.1316	0.1408	0.1357
10	0.0661	0.056	0.056	0.0661	0.0661	0.0813	0.1183	0.1537	0.1335	0.1316	0.1408	0.1357
11	0.0331	0.028	0.028	0.0331	0.0331	0.0407	0.0591	0.0769	0.0667	0.0658	0.0704	0.0679
12	0.0827	0.07	0.07	0.0827	0.0827	0.1017	0.1478	0.1922	0.1668	0.1646	0.176	0.1697
13	0.0661	0.056	0.056	0.0661	0.0661	0.0813	0.1183	0.1537	0.1335	0.1316	0.1408	0.1357
14	0.0661	0.056	0.056	0.0661	0.0661	0.0813	0.1183	0.1537	0.1335	0.1316	0.1408	0.1357
15	0.0331	0.028	0.028	0.0331	0.0331	0.0407	0.0591	0.0769	0.0667	0.0658	0.0704	0.0679
16	0.0661	0.056	0.056	0.0661	0.0661	0.0813	0.1183	0.1537	0.1335	0.1316	0.1408	0.1357
17	0.0331	0.028	0.028	0.0331	0.0331	0.0407	0.0591	0.0769	0.0667	0.0658	0.0704	0.0679
18	0.0661	0.056	0.056	0.0661	0.0661	0.0813	0.1183	0.1537	0.1335	0.1316	0.1408	0.1357
19	0.0331	0.028	0.028	0.0331	0.0331	0.0407	0.0591	0.0769	0.0667	0.0658	0.0704	0.0679
20	0.0331	0.028	0.028	0.0331	0.0331	0.0407	0.0591	0.0769	0.0667	0.0658	0.0704	0.0679
21	0.0661	0.056	0.056	0.0661	0.0661	0.0813	0.1183	0.1537	0.1335	0.1316	0.1408	0.1357
22	0.0992	0.084	0.084	0.0992	0.0992	0.122	0.1774	0.2306	0.2002	0.1975	0.2112	0.2036
23	0.0661	0.056	0.056	0.0661	0.0661	0.0813	0.1183	0.1537	0.1335	0.1316	0.1408	0.1357
24	0.0331	0.028	0.028	0.0331	0.0331	0.0407	0.0591	0.0769	0.0667	0.0658	0.0704	0.0679
25	0.0331	0.028	0.028	0.0331	0.0331	0.0407	0.0591	0.0769	0.0667	0.0658	0.0704	0.0679

13	14	15	16	17	18	19	20	21	22	23	24
0	0	0	0	0	0	0	0	0	0	0	0
0.0679	0.0679	0.0451	0.0679	0.0679	0.0633	0.0658	0.0743	0.0667	0.0566	0.0407	0.0483
0.0679	0.0679	0.0451	0.0679	0.0679	0.0633	0.0658	0.0743	0.0667	0.0566	0.0407	0.0483
0.1357	0.1357	0.0902	0.1357	0.1357	0.1266	0.1316	0.1487	0.1335	0.1132	0.0813	0.0965
0.1357	0.1357	0.0902	0.1357	0.1357	0.1266	0.1316	0.1487	0.1335	0.1132	0.0813	0.0965
0.0679	0.0679	0.0451	0.0679	0.0679	0.0633	0.0658	0.0743	0.0667	0.0566	0.0407	0.0483
0.1357	0.1357	0.0902	0.1357	0.1357	0.1266	0.1316	0.1487	0.1335	0.1132	0.0813	0.0965
0.1357	0.1357	0.0902	0.1357	0.1357	0.1266	0.1316	0.1487	0.1335	0.1132	0.0813	0.0965
0.1357	0.1357	0.0902	0.1357	0.1357	0.1266	0.1316	0.1487	0.1335	0.1132	0.0813	0.0965
0.1357	0.1357	0.0902	0.1357	0.1357	0.1266	0.1316	0.1487	0.1335	0.1132	0.0813	0.0965
0.0679	0.0679	0.0451	0.0679	0.0679	0.0633	0.0658	0.0743	0.0667	0.0566	0.0407	0.0483
0.1697	0.1697	0.1127	0.1697	0.1697	0.1582	0.1646	0.1858	0.1668	0.1415	0.1017	0.1207
0.1357	0.1357	0.0902	0.1357	0.1357	0.1266	0.1316	0.1487	0.1335	0.1132	0.0813	0.0965
0.1357	0.1357	0.0902	0.1357	0.1357	0.1266	0.1316	0.1487	0.1335	0.1132	0.0813	0.0965
0.0679	0.0679	0.0451	0.0679	0.0679	0.0633	0.0658	0.0743	0.0667	0.0566	0.0407	0.0483
0.1357	0.1357	0.0902	0.1357	0.1357	0.1266	0.1316	0.1487	0.1335	0.1132	0.0813	0.0965
0.0679	0.0679	0.0451	0.0679	0.0679	0.0633	0.0658	0.0743	0.0667	0.0566	0.0407	0.0483
0.1357	0.1357	0.0902	0.1357	0.1357	0.1266	0.1316	0.1487	0.1335	0.1132	0.0813	0.0965
0.0679	0.0679	0.0451	0.0679	0.0679	0.0633	0.0658	0.0743	0.0667	0.0566	0.0407	0.0483
0.0679	0.0679	0.0451	0.0679	0.0679	0.0633	0.0658	0.0743	0.0667	0.0566	0.0407	0.0483
0.1357	0.1357	0.0902	0.1357	0.1357	0.1266	0.1316	0.1487	0.1335	0.1132	0.0813	0.0965
0.2036	0.2036	0.1353	0.2036	0.2036	0.1899	0.1975	0.223	0.2002	0.1698	0.122	0.1448
0.1357	0.1357	0.0902	0.1357	0.1357	0.1266	0.1316	0.1487	0.1335	0.1132	0.0813	0.0965
0.0679	0.0679	0.0451	0.0679	0.0679	0.0633	0.0658	0.0743	0.0667	0.0566	0.0407	0.0483
0.0679	0.0679	0.0451	0.0679	0.0679	0.0633	0.0658	0.0743	0.0667	0.0566	0.0407	0.0483

Table 4. 19 After implementing V2G load in each bus with time

	Time											
bus no.	1	2	3	4	5	6	7	8	9	10	11	12
1	0	0	0	0	0	0	0	0	0	0	0	0
2	0.0378	0.0328	0.0328	0.0378	0.0378	0.0454	0.0606	0.0642	0.0548	0.0628	0.0654	0.0591
3	0.0378	0.0328	0.0328	0.0378	0.0378	0.0454	0.0606	0.0642	0.0548	0.0628	0.0654	0.0591
4	0.0756	0.0655	0.0655	0.0756	0.0756	0.0908	0.1212	0.1284	0.1096	0.1257	0.1308	0.1182
5	0.0756	0.0655	0.0655	0.0756	0.0756	0.0908	0.1212	0.1284	0.1096	0.1257	0.1308	0.1182
6	0.0378	0.0328	0.0328	0.0378	0.0378	0.0454	0.0606	0.0642	0.0548	0.0628	0.0654	0.0591
7	0.0756	0.0655	0.0655	0.0756	0.0756	0.0908	0.1212	0.1284	0.1096	0.1257	0.1308	0.1182
8	0.0756	0.0655	0.0655	0.0756	0.0756	0.0908	0.1212	0.1284	0.1096	0.1257	0.1308	0.1182
9	0.0756	0.0655	0.0655	0.0756	0.0756	0.0908	0.1212	0.1284	0.1096	0.1257	0.1308	0.1182
10	0.0756	0.0655	0.0655	0.0756	0.0756	0.0908	0.1212	0.1284	0.1096	0.1257	0.1308	0.1182
11	0.0378	0.0328	0.0328	0.0378	0.0378	0.0454	0.0606	0.0642	0.0548	0.0628	0.0654	0.0591
12	0.0946	0.0819	0.0819	0.0946	0.0946	0.1135	0.1515	0.1605	0.137	0.1571	0.1634	0.1478
13	0.0756	0.0655	0.0655	0.0756	0.0756	0.0908	0.1212	0.1284	0.1096	0.1257	0.1308	0.1182
14	0.0756	0.0655	0.0655	0.0756	0.0756	0.0908	0.1212	0.1284	0.1096	0.1257	0.1308	0.1182
15	0.0378	0.0328	0.0328	0.0378	0.0378	0.0454	0.0606	0.0642	0.0548	0.0628	0.0654	0.0591
16	0.0756	0.0655	0.0655	0.0756	0.0756	0.0908	0.1212	0.1284	0.1096	0.1257	0.1308	0.1182
17	0.0378	0.0328	0.0328	0.0378	0.0378	0.0454	0.0606	0.0642	0.0548	0.0628	0.0654	0.0591
18	0.0756	0.0655	0.0655	0.0756	0.0756	0.0908	0.1212	0.1284	0.1096	0.1257	0.1308	0.1182
19	0.0378	0.0328	0.0328	0.0378	0.0378	0.0454	0.0606	0.0642	0.0548	0.0628	0.0654	0.0591
20	0.0378	0.0328	0.0328	0.0378	0.0378	0.0454	0.0606	0.0642	0.0548	0.0628	0.0654	0.0591
21	0.0756	0.0655	0.0655	0.0756	0.0756	0.0908	0.1212	0.1284	0.1096	0.1257	0.1308	0.1182
22	0.1135	0.0983	0.0983	0.1135	0.1135	0.1363	0.1818	0.1926	0.1644	0.1885	0.1961	0.1774
23	0.0756	0.0655	0.0655	0.0756	0.0756	0.0908	0.1212	0.1284	0.1096	0.1257	0.1308	0.1182
24	0.0378	0.0328	0.0328	0.0378	0.0378	0.0454	0.0606	0.0642	0.0548	0.0628	0.0654	0.0591
25	0.0378	0.0328	0.0328	0.0378	0.0378	0.0454	0.0606	0.0642	0.0548	0.0628	0.0654	0.0591

13	14	15	16	17	18	19	20	21	22	23	24
0	0	0	0	0	0	0	0	0	0	0	0
0.0591	0.0591	0.0505	0.0591	0.0591	0.064	0.0628	0.0617	0.0541	0.0581	0.0454	0.053
0.0591	0.0591	0.0505	0.0591	0.0591	0.064	0.0628	0.0617	0.0541	0.0581	0.0454	0.053
0.1182	0.1182	0.101	0.1182	0.1182	0.1281	0.1257	0.1233	0.1081	0.1162	0.0908	0.106
0.1182	0.1182	0.101	0.1182	0.1182	0.1281	0.1257	0.1233	0.1081	0.1162	0.0908	0.106
0.0591	0.0591	0.0505	0.0591	0.0591	0.064	0.0628	0.0617	0.0541	0.0581	0.0454	0.053
0.1182	0.1182	0.101	0.1182	0.1182	0.1281	0.1257	0.1233	0.1081	0.1162	0.0908	0.106
0.1182	0.1182	0.101	0.1182	0.1182	0.1281	0.1257	0.1233	0.1081	0.1162	0.0908	0.106
0.1182	0.1182	0.101	0.1182	0.1182	0.1281	0.1257	0.1233	0.1081	0.1162	0.0908	0.106
0.1182	0.1182	0.101	0.1182	0.1182	0.1281	0.1257	0.1233	0.1081	0.1162	0.0908	0.106
0.0591	0.0591	0.0505	0.0591	0.0591	0.064	0.0628	0.0617	0.0541	0.0581	0.0454	0.053
0.1478	0.1478	0.1262	0.1478	0.1478	0.1601	0.1571	0.1541	0.1352	0.1452	0.1135	0.1325
0.1182	0.1182	0.101	0.1182	0.1182	0.1281	0.1257	0.1233	0.1081	0.1162	0.0908	0.106
0.1182	0.1182	0.101	0.1182	0.1182	0.1281	0.1257	0.1233	0.1081	0.1162	0.0908	0.106
0.0591	0.0591	0.0505	0.0591	0.0591	0.064	0.0628	0.0617	0.0541	0.0581	0.0454	0.053
0.1182	0.1182	0.101	0.1182	0.1182	0.1281	0.1257	0.1233	0.1081	0.1162	0.0908	0.106
0.0591	0.0591	0.0505	0.0591	0.0591	0.064	0.0628	0.0617	0.0541	0.0581	0.0454	0.053
0.1182	0.1182	0.101	0.1182	0.1182	0.1281	0.1257	0.1233	0.1081	0.1162	0.0908	0.106
0.0591	0.0591	0.0505	0.0591	0.0591	0.064	0.0628	0.0617	0.0541	0.0581	0.0454	0.053
0.0591	0.0591	0.0505	0.0591	0.0591	0.064	0.0628	0.0617	0.0541	0.0581	0.0454	0.053
0.1182	0.1182	0.101	0.1182	0.1182	0.1281	0.1257	0.1233	0.1081	0.1162	0.0908	0.106
0.1774	0.1774	0.1514	0.1774	0.1774	0.1921	0.1885	0.185	0.1622	0.1742	0.1363	0.159
0.1182	0.1182	0.101	0.1182	0.1182	0.1281	0.1257	0.1233	0.1081	0.1162	0.0908	0.106
0.0591	0.0591	0.0505	0.0591	0.0591	0.064	0.0628	0.0617	0.0541	0.0581	0.0454	0.053
0.0591	0.0591	0.0505	0.0591	0.0591	0.064	0.0628	0.0617	0.0541	0.0581	0.0454	0.053

Table 4. 20 failure rate and repair rate of three cases for all the buses

			Peak Load				Failure rate		
Bus no:	Failure rate	Repair hour	Base peak load	10% charging only	70% charging only	After V2G integration	10% charging only	70% charging only	After V2G integration
1	0	0	0	0	0	0	0	0	0
2	2	0.53333333	0.070886	0.07291139	0.076860759	0.064187342	2.057142857	2.168571429	1.811
3	1	0.5	0.070886	0.07291139	0.076860759	0.064187342	1.028571429	1.084285714	0.9055
4	2	1	0.141772	0.14582278	0.153721519	0.128374684	2.057142857	2.168571429	1.811
5	3	1.03333333	0.141772	0.14582278	0.153721519	0.128374684	3.085714286	3.252857143	2.7165
6	1	0.5	0.070886	0.07291139	0.076860759	0.064187342	1.028571429	1.084285714	0.9055
7	2	1	0.141772	0.14582278	0.153721519	0.128374684	2.057142857	2.168571429	1.811
8	2	1.01666667	0.141772	0.14582278	0.153721519	0.128374684	2.057142857	2.168571429	1.811
9	2	1	0.141772	0.14582278	0.153721519	0.128374684	2.057142857	2.168571429	1.811
10	2	1.03333333	0.141772	0.14582278	0.153721519	0.128374684	2.057142857	2.168571429	1.811
11	1	0.5	0.070886	0.07291139	0.076860759	0.064187342	1.028571429	1.084285714	0.9055
12	3	1.25	0.177215	0.18227848	0.192151899	0.160468354	3.085714286	3.252857143	2.7165
13	3	1.03333333	0.141772	0.14582278	0.153721519	0.128374684	3.085714286	3.252857143	2.7165
14	2	1	0.141772	0.14582278	0.153721519	0.128374684	2.057142857	2.168571429	1.811
15	2	0.5	0.070886	0.07291139	0.076860759	0.064187342	2.057142857	2.168571429	1.811
16	2	1	0.141772	0.14582278	0.153721519	0.128374684	2.057142857	2.168571429	1.811
17	1	0.5	0.070886	0.07291139	0.076860759	0.064187342	1.028571429	1.084285714	0.9055
18	2	1	0.141772	0.14582278	0.153721519	0.128374684	2.057142857	2.168571429	1.811
19	1	0.5	0.070886	0.07291139	0.076860759	0.064187342	1.028571429	1.084285714	0.9055
20	1	0.5	0.070886	0.07291139	0.076860759	0.064187342	1.028571429	1.084285714	0.9055
21	2	1	0.141772	0.14582278	0.153721519	0.128374684	2.057142857	2.168571429	1.811
22	3	1.5	0.212658	0.21873418	0.230582278	0.192562025	3.085714286	3.252857143	2.7165
23	3	1.03333333	0.141772	0.14582278	0.153721519	0.128374684	3.085714286	3.252857143	2.7165
24	1	0.5	0.070886	0.07291139	0.076860759	0.064187342	1.028571429	1.084285714	0.9055
25	1	0.5	0.070886	0.07291139	0.076860759	0.064187342	1.028571429	1.084285714	0.9055

Repair rate				Failure rate * Nc			Repair rate * Nc		
10% charging only	70% charging only	After V2G integration	No of consumer	10 % charging	70% charging	After V2G integration	10 % charging	70% charging	After V2G integration
0	0	0		0	0	0			
0.54857143	0.57828571	0.48293333	68	139.885714	147.462857	123.148	37.3028571	39.3234286	32.8394667
0.51428571	0.54214286	0.45275	68	69.9428571	73.7314286	61.574	34.9714286	36.8657143	30.787
1.02857143	1.08428571	0.9055	136	279.771429	294.925714	246.296	139.885714	147.462857	123.148
1.06285714	1.12042857	0.93568333	136	419.657143	442.388571	369.444	144.548571	152.378286	127.252933
0.51428571	0.54214286	0.45275	68	69.9428571	73.7314286	61.574	34.9714286	36.8657143	30.787
1.02857143	1.08428571	0.9055	136	279.771429	294.925714	246.296	139.885714	147.462857	123.148
1.04571429	1.10235714	0.92059167	136	279.771429	294.925714	246.296	142.217143	149.920571	125.200467
1.02857143	1.08428571	0.9055	136	279.771429	294.925714	246.296	139.885714	147.462857	123.148
1.06285714	1.12042857	0.93568333	136	279.771429	294.925714	246.296	144.548571	152.378286	127.252933
0.51428571	0.54214286	0.45275	68	69.9428571	73.7314286	61.574	34.9714286	36.8657143	30.787
1.28571429	1.35535714	1.131875	175	540	569.25	475.3875	225	237.1875	198.078125
1.06285714	1.12042857	0.93568333	136	419.657143	442.388571	369.444	144.548571	152.378286	127.252933
1.02857143	1.08428571	0.9055	136	279.771429	294.925714	246.296	139.885714	147.462857	123.148
0.51428571	0.54214286	0.45275	68	139.885714	147.462857	123.148	34.9714286	36.8657143	30.787
1.02857143	1.08428571	0.9055	136	279.771429	294.925714	246.296	139.885714	147.462857	123.148
0.51428571	0.54214286	0.45275	68	69.9428571	73.7314286	61.574	34.9714286	36.8657143	30.787
1.02857143	1.08428571	0.9055	136	279.771429	294.925714	246.296	139.885714	147.462857	123.148
0.51428571	0.54214286	0.45275	68	69.9428571	73.7314286	61.574	34.9714286	36.8657143	30.787
0.51428571	0.54214286	0.45275	68	69.9428571	73.7314286	61.574	34.9714286	36.8657143	30.787
1.02857143	1.08428571	0.9055	136	279.771429	294.925714	246.296	139.885714	147.462857	123.148
1.54285714	1.62642857	1.35825	205	632.571429	666.835714	556.8825	316.285714	333.417857	278.44125
1.06285714	1.12042857	0.93568333	136	419.657143	442.388571	369.444	144.548571	152.378286	127.252933
0.51428571	0.54214286	0.45275	68	69.9428571	73.7314286	61.574	34.9714286	36.8657143	30.787
0.51428571	0.54214286	0.45275	68	69.9428571	73.7314286	61.574	34.9714286	36.8657143	30.787

5. CHAPTER FIVE CONCLUSION

The expected contribution of this thesis is twofold. Firstly, it provided valuable insights into the impact of electric vehicles charging stations on distribution system parameters, addressing the specific challenges and risks associated with their integration. The research on the optimal placement of charging stations employing the (EVPI) index-based approach has provided valuable insights into the identification of strategic locations for charging stations, minimizing costs while maximizing the overall benefit to the network.

Secondly, it proposed V2G techniques and recommendations for distribution system operators and policymakers to enhance reliability in the presence of electric vehicles. These contributions will aid in making informed decisions regarding infrastructure planning, grid management, EV integration strategies. In the face of EV era, the integration of V2G technology emerges as a promising solution to enhance the resilience, efficiency, and sustainability of urban distribution systems.

As the demand for electric vehicles continues to grow, the findings of this thesis contribute to the ongoing discourse on the optimal placement of charging stations and integration of V2G into existing power systems

6. CHAPTER SIX. FUTURE RECOMMENDATION

The Future works are

- EV charging load profile of different charging station.
- Commercial and residential load both have different load profile. Analysis carried considering both types of loads.
- Forecasting the impact on the grid with rise in number of vehicles.
- Maximum number of CS that can be placed with increasing number of vehicles.
- Reliability evaluation using other optimization technique.

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ANNEX

Table 6. 1 Conductor size of Baneshwor feeder.

Line No.	Starting Bus	End Bus	segment length (m)	conductor type
1	1	2	837.617	Dog
2	2	3	244.51	Dog
3	3	4	56.75	Dog
4	1	5	787.835	Dog
5	5	6	289.548	Dog
6	6	7	44.864	Dog
7	5	8	319.582	Dog
8	8	9	106.076	Dog
9	9	10	254.072	Dog
10	10	11	194.359	Dog
11	11	12	244.033	Dog
12	12	13	250.847	Dog
13	13	14	199.621	Dog
14	14	15	393.176	Dog
15	15	16	138.192	Dog
16	16	17	15.875	Dog
17	10	18	121.479	Dog
18	18	19	61.835	Dog
19	19	20	112.12	Dog
20	20	21	70.029	Dog
21	21	22	90.25	Dog
22	20	23	515.302	Dog
23	23	24	65.56	Dog
24	24	25	138.455	Dog

Table 6. 2 Resistance and reactance of Baneshwor feeder

Line No.	Starting Bus	End Bus	R(pu)	X(pu)
1	1	2	0.270435	0.04327
2	2	3	0.078943	0.012631
3	3	4	0.018322	0.002932
4	1	5	0.254363	0.040698
5	5	6	0.093484	0.014957
6	6	7	0.014485	0.002318

7	5	8	0.103181	0.016509
8	8	9	0.034248	0.00548
9	9	10	0.08203	0.013125
10	10	11	0.062751	0.01004
11	11	12	0.078789	0.012606
12	12	13	0.080989	0.012958
13	13	14	0.06445	0.010312
14	14	15	0.126942	0.020311
15	15	16	0.044617	0.007139
16	16	17	0.005125	0.00082
17	10	18	0.039221	0.006275
18	18	19	0.019964	0.003194
19	19	20	0.036199	0.005792
20	20	21	0.02261	0.003618
21	21	22	0.029138	0.004662
22	20	23	0.166372	0.02662
23	23	24	0.021167	0.003387
24	24	25	0.044702	0.007152

Table 6. 3 Transformer rating, failure rate, repair rate and number of consumer in each bus of Baneshwor feeder

Bus no.	Tr size kVA	P (pu)	Q (pu)	Failure rate (failure/yr)	Outage rate (Hour/yr)	No. of Customer
1	0	0	0			
2	100	0.00085	0.00052678	2	32	33
3	100	0.00085	0.00052678	1	30	33
4	200	0.0017	0.00105356	2	60	66
5	200	0.0017	0.00105356	3	62	66
6	100	0.00085	0.00052678	1	30	33
7	200	0.0017	0.00105356	2	60	66
8	200	0.0017	0.00105356	2	61	66
9	200	0.0017	0.00105356	2	60	66
10	200	0.0017	0.00105356	2	62	66
11	100	0.00085	0.00052678	1	30	33
12	250	0.00213	0.00131695	3	75	85
13	200	0.0017	0.00105356	3	62	66
14	200	0.0017	0.00105356	2	60	66
15	100	0.00085	0.00052678	2	30	33
16	200	0.0017	0.00105356	2	60	66
17	100	0.00085	0.00052678	1	30	33

18	200	0.0017	0.00105356	2	60	66
19	100	0.00085	0.00052678	1	30	33
20	100	0.00085	0.00052678	1	30	33
21	200	0.0017	0.00105356	2	60	66
22	300	0.00255	0.00158034	3	90	99
23	200	0.0017	0.00105356	3	62	66
24	100	0.00085	0.00052678	1	30	33
25	100	0.00085	0.00052678	1	30	33
Total	3950			45	1196	1306

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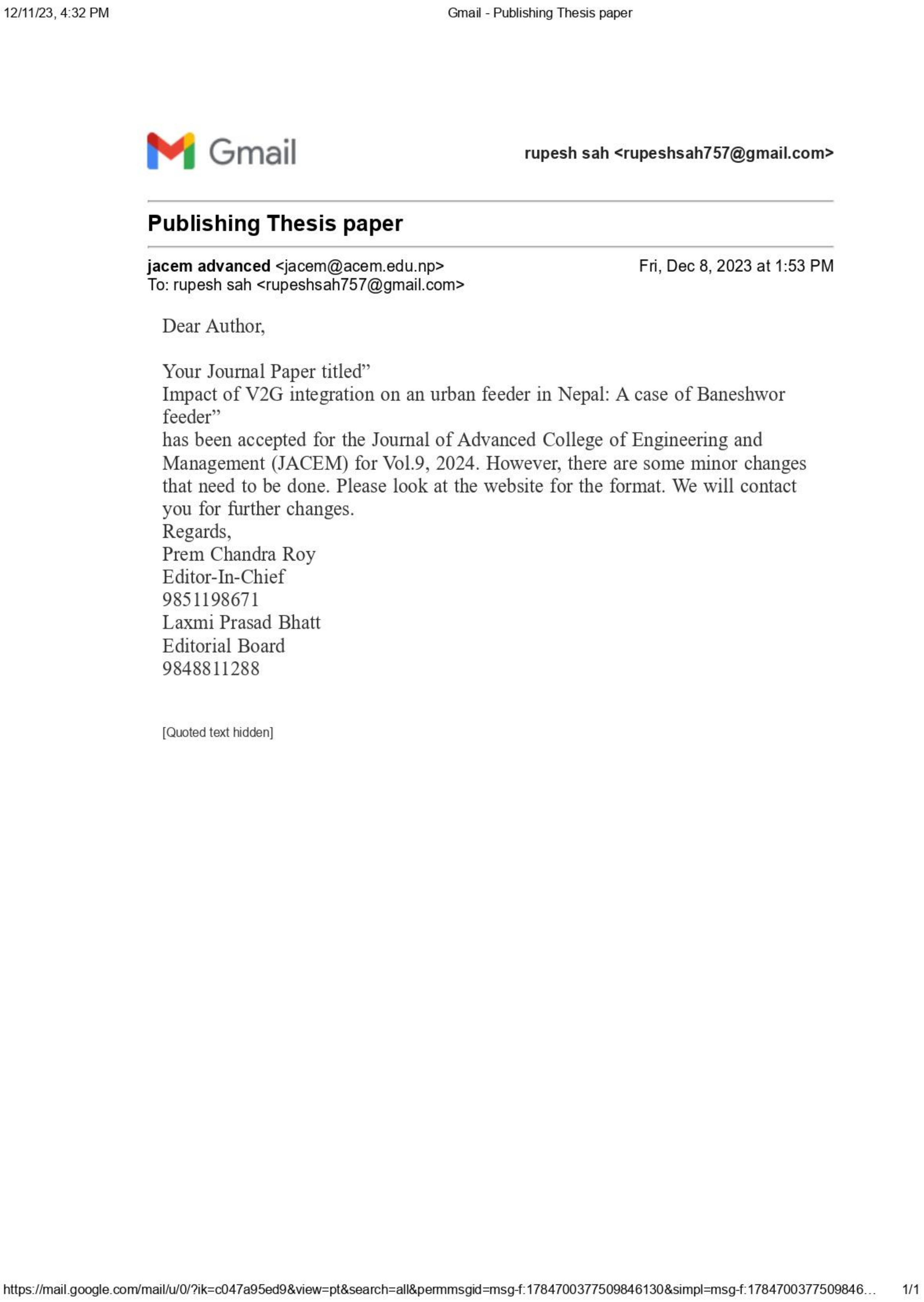

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