TRIBHUVAN UNIVERSITY
INSTITUTE OF ENGINEERING
PULCHOWK CAMPUS

THESIS NO: M-377-MSREE-2019-2023

Impact Analysis of Electric Vehicle Charging Station on Bharatpur-2 Feeder

by
Dibyashori Paudel

A THESIS
SUBMITTED TO THE DEPARTMENT OF MECHANICAL AND AEROSPACE ENGINEERING
IN PARTIAL FULLFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTERS OF SCIENCE IN
RENEWABLE ENERGY ENGINEERING

DEPARTMENT OF MECHANICAL AND AEROSPACE ENGINEERING

LALITPUR, NEPAL

OCTOBER, 2023

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ABSTRACT

The rapid proliferation of Electric Vehicles (EVs) in recent years has brought about significant advancements in sustainable transportation. However, this surge in EV adoption has raised pertinent concerns regarding the potential consequences on power distribution networks. This thesis investigates the multifaceted influence of EV charging stations on the Bharatpur-2 feeder, a representative segment of the electrical grid. The research entails a comprehensive analysis that encompasses load profile characterization, voltage stability assessment, power quality evaluation, and an exploration of the dynamic relationship between feeder load and voltage levels.

The findings from load profile analysis unveils temporal patterns and peak demand periods, aiding in grid management and capacity planning. The voltage stability assessment elucidates potential challenges arising from EV charging and offers solutions to mitigate voltage fluctuations. Furthermore, the power quality analysis sheds light on the impact of EV charging on the grid's overall quality and suggests measures for enhancement. The correlation between feeder load and voltage dynamics offers valuable insights into grid resilience and performance optimization strategies. Finally, the simulation results, including THD and power loss calculations, provide quantifiable data for decision-makers to formulate effective strategies for grid modernization and sustainable transportation integration.

ACKNOWLEDGEMENTS

I would like to express special gratitude to my Supervisor **Assoc. Prof. Dr. Surya Prasad Adhikari** and **Assist. Prof. Akhileshwar Mishra**, for their invaluable guidance, encouragement and regular support without which I may not have accomplished this study. I am influenced by their knowledge and attitude which guided me to complete this task and gain my graduate degree.

I would also like to express my deepest sense of gratitude and sincere respect to Head of MSc Program Coordinator **Assoc. Prof. Dr. Hari Bahadur Darlami** for his continuous advice and encouragement throughout this thesis.

I would also like to express my gratitude to **Er. Sujan Wagle, Er. Hari Pandey** for their support and guidance.

At last, I am very much thankful to all staff of NEA, all respondents, my colleagues, Er. Lilamani Poudel, my family and all those people who directly or indirectly contributed their parts in completing this thesis.

Dibyashori Paudel
October, 2023

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ACRONYMS AND ABBREVIATIONS

A	Ampere
AC	Alternating Current
CS	Charging Station
DC	Direct Current
DOD	Depth of Discharge
EMB	Electric minibuses
EVs	Electric Vehicles
EVGI	Electric vehicle grid integration
FCS	Fast Charging Station
GHG	Green House Gas
GON	Government of Nepal
HV	High Voltage
ICE	Internal Combustion Engine
KV	Kilovolt
KVAr	Kilo-volt Ampere Reactive
KW	Kilo watts
MW	Megawatt
NDCs	Nationally Determined Contributors
NEA	Nepal Electricity Authority
Pf	Power factor
SoC	State of Charge
THD	Total Harmonic Distortion

CHAPTER ONE : INTRODUCTION

1.1 Background

Transportation is an indispensable component of the global economy, profoundly affecting the daily lives of people worldwide. In recent decades, there has been a remarkable surge in the movement of goods and passengers globally, with road transport emerging as the predominant mode for both. Historically, conventional vehicles primarily relied on fossil fuels such as petrol and diesel. However, mounting energy scarcity and environmental pressures have intensified the need for energy-efficient, clean, and eco-friendly alternatives, particularly Electric Vehicles (EVs). The escalating concerns surrounding climate change due to greenhouse gas emissions have prompted countries to seek cleaner and more sustainable energy sources. EVs, powered by renewable electricity, have emerged as a promising solution to reduce petroleum consumption and curb emissions, making them increasingly desirable in urban environments.

The landscape of the transportation sector has undergone rapid transformation in recent years, with EVs playing a pivotal role in fostering sustainability by reducing carbon emissions. Battery EVs and plug-in hybrid EVs are recognized as crucial elements in mitigating challenges related to fossil fuel availability and energy security. Governments and utility companies worldwide have offered incentives such as tax credits and rebates to promote the adoption of EVs, further accelerating their growth. (Anon., 2020). EVs not only contribute to reduced air pollution but also offer superior performance, instantaneous acceleration, and advanced technology and safety features. As concerns about climate change related to fossil fuels continue to rise, the shift towards EVs in transportation systems is becoming increasingly encouraged, particularly for their noiselessness, zero exhaust pollutants, and lower overall emissions. (Schey S, 2012)

While the evolution of modern technology and ideas paints a promising future for EVs in transportation, several challenges must be addressed, including charging infrastructure, safety, and power demand. The high energy efficiency, environmental friendliness, zero emissions, and reduced noise of EVs have garnered widespread support from governments worldwide. However, the integration of large-scale EVs into power grids presents novel challenges for the safe and economical operation of these systems (Zhang, et al., 2022). Urban residents' adoption of EVs significantly influences the demand for charging stations, with megacities witnessing higher demand than older cities. The increased popularity of fast-charging stations, while alleviating range anxiety for drivers, imposes substantial charging loads on the power system due to their high power density.

Two distinct categories of electric vehicles, small-capacity, short-range cars, and long-range buses with larger battery capacities, employ varying charging methods and rates. Common charging methods include constant voltage, constant current and constant power, each tailored to the specific characteristics of the batteries they serve. As EV adoption continues to expand within power grids, the impact on these grids becomes a critical consideration. The construction of different charging stations exerts varying effects on voltage and current stability, load balance, and power losses. Analyzing the power system's efficiency and its ability to mitigate the impact of large-scale EV integration necessitates an examination of charging station critical load modeling, given the unpredictability and dispersion of EV users and their charging behaviors. These challenges encompass a heightened demand for power, increased harmonic distortion, and capacity limitations of grid components, as well as network losses.

Considering the evolving landscape of EVs and the challenges they pose to electrical distribution grids, this research aims to assess the potential impact of EVs, which are poised to increase their presence substantially in the near future, on distribution networks. The study unfolds in two stages: firstly, it evaluates the effects of EVs on existing distribution networks, and secondly, it collects crucial data related to uncoordinated charging strategies. Nevertheless, the integration of a substantial EV fleet into the electrical grid presents significant challenges such as overheating distribution transformers, voltage instability, and harmonic distortion. Therefore, there is an urgent need for comprehensive modeling and assessment of the impacts of EV charging on the grid, a critical step in ensuring a seamless and sustainable transition to widespread EV adoption.

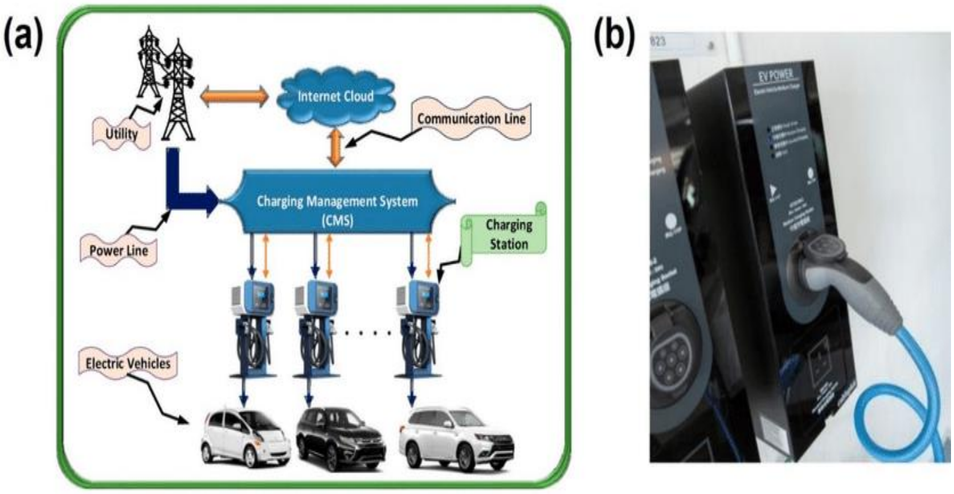

Figure 1-1: EVs power distribution and charging port

1.2 Problem Statement

In recent years, the utilization of Electric Vehicles (EVs) has exhibited a relatively passive trajectory, marked by limited developmental paradigms. While challenges in coordinating various facets of this technology were present, the predominant focus primarily revolved around the deployment and suitability assessment of EVs within the context of Nepal. The advent of Electric Vehicle Charging Stations (EVCS) ushered in a plethora of multifaceted challenges, encompassing concerns such as power factor management, voltage stability preservation, harmonics mitigation, and power filter optimizations (Sun, et al., 2013). Nevertheless, one of the most salient and yet academically underexplored dimensions of EVs pertained to their profound impact on power distribution feeders, a facet predominantly reliant on empirical knowledge derived from engineers' practical experience in the field. It became increasingly apparent that the operation of Charging Stations (CS) had the potential to induce consequential effects on these feeders, thereby prompting a surge in research endeavors aimed at unraveling the intricate web of feeder impact analysis.

While the operational performance of the feeder station remained uneventful during the preceding years, the relentless surge in Electric Vehicles (EVs) and the burgeoning proliferation of Charging Stations (CS) along the same feeder trajectory have engendered the potential for critical disruptions in its seamless functionality. The emerging technical intricacies poised to accompany the escalating deployment of CS necessitate meticulous investigation. Moreover, the forthcoming transformation of the Power Grid into a primary power source driven by the exponential growth of these CS mandates an exhaustive analysis of its resultant impact on power supply dynamics. The impetus for this research project lies in the realm of protection coordination challenges and the exigency to conduct an in-depth grid impact analysis vis-à-vis the evolving feeder landscape, wherein the variable loads imposed by these emergent CS configurations demand astute observation.

The contemporaneous cadence of design and manufacturing advancements within the CS domain, coupled with the relentless pursuit of scientific innovations aimed at optimizing their utility, augments the urgency of delving into their prospective implications. It is this overarching drive towards an enhanced comprehension of the transformative potential, future prospects, and comprehensive impact analysis of CS within the broader context of feeder operations that galvanizes the core motivation underpinning this research endeavor.

1.3 Objective

1.3.1 Main Objective:

To analyze the impact of electric vehicle charging station on Bharatpur-2 Feeder.

1.3.2 Specific objective:

- To analyze the impact of charging station on feeder graphically.
- To Simulate an EV charging station using MATLAB.
- To carry out the load flow analysis of Bharatpur-2 feeder with and without consideration of charging station.

1.4 Limitation

- This is specific to only one site Bharatpur-2 feeder due to which actual impact on other CS may not be found.
- Charging station is in initial phase, thus impact of load observed isn’t sufficient due to unware of location by users.

- Charging load contributes minority of total load because of which dominant impacted may not be seen on the feeder.

2.1 History of Electric Vehicle

The inception of electric buses can be traced back to the mid-19th century, commencing with Ányos Jedlik's pioneering work in 1828, when the Hungarian inventor devised an early iteration of the electric motor, propelling a diminutive automobile model with this groundbreaking technology. Subsequently, in 1834, on American soil in Vermont, Thomas Davenport etched history by crafting the inaugural American direct current (DC) electric motor. However, it wasn't until 1840 that the emergence of rechargeable batteries provided a viable mechanism for storing electricity within vehicles. The late 1890s and early 1900s witnessed a burgeoning interest in motor vehicles. Nonetheless, as the 20th century dawned, the electric automobile faced a decline in its market prominence, attributed to its sluggish pace, limited range, the widespread availability of economical gasoline, and its costly operational demands (contributors, n.d.).

However, a resurgence of interest in electric vehicles materialized during the 1970s, driven by mounting concerns over global warming and greenhouse gas emissions, heralding a renewed era of exploration and development in this eco-conscious domain.

2.1.1 Electric Vehicle in Nepal

The inception of electric vehicles (EVs) in Nepal traces back to the establishment of trolley machine services. Despite their initial introduction, the widespread adoption of EVs failed to materialize as expected. It wasn't until 1993 when EVs made their debut in the Kathmandu Valley, gradually gaining prominence across the nation with the introduction of new variants boasting superior features. The primary motivation behind launching these vehicles was to combat the escalating pollution levels in urban areas. Notably, the promising dawn of the EV industry was fostered by positive government intervention, the progress of non-governmental organizations, and international support. Nevertheless, in recent times, the EV sector has faced challenges and failed to gain momentum as initially anticipated. (Tamrakar, 2021).

Prior initiatives and budgetary allocations aimed to incentivize EV usage through tax breaks, although a persistent lack of charging infrastructure remained a major concern. The potential for significantly increased EV adoption in the Kathmandu Valley existed, given reduced purchase and operating costs, coupled with faster charging times. However, the significant surge in duty rates in the 2077/2078 budget adversely affected EV sales. Yet, there is optimism that the substantial reduction in levies anticipated in 2078/79 will rekindle interest in EVs in Nepal. Notably, the price of an electric vehicle can now be as low as one-third of a comparable gasoline or diesel vehicle, enhancing affordability. The recent selection of a contractor by the Nepal Electricity Authority to install 50 electric vehicle charging stations across the country is set to address the charging infrastructure gap, thereby boosting EV adoption. Furthermore, the addition of 1000 MW of electricity to the public grid by the end of the fiscal year 2078/79 from various hydroelectric projects under construction is expected to ensure continuous power supply, further bolstering the prospects for EVs in Nepal. Consequently, the future of electric vehicles in Nepal appears promising, supported by the current fiscal framework and improved electricity supply. Nepal is poised to lay the foundation for a significant transportation transition, contingent upon the establishment of the requisite robust infrastructure. (Meromotor, 2021)

The transport sector in Nepal significantly contributes to greenhouse gas emissions from the energy sector, accounting for 36% of the total. Recognizing the pivotal role of EVs, the Government of Nepal (GON) has accorded them a high priority within the transport sector. Nepal's enhanced Nationally Determined Contributions (NDCs) ambitiously target electrifying 20% of public transport vehicles by 2025. The GON anticipates a net periodic surplus of hydropower by 2022, further enhancing the feasibility of these electrification efforts. (Meromotor, 2021)

.Approach to Transformational Change:

The "Nepal – Electric Transportation" initiative is devised with the overarching goal of eliminating the existing barriers impeding the electrification of the transportation sector while concurrently promoting electric transport technologies. This comprehensive design entails a strategic amalgamation of fiscal incentives and targeted support measures, with a particular emphasis on the minibus segment, both within the

Kathmandu Valley and extending beyond its borders. The primary objective of this initiative is to provide financial assistance to public transport operators for the procurement and deployment of 3,020 electric minibuses (EMB) and the requisite charging infrastructure nationwide. Simultaneously, it seeks to stimulate and fortify the widespread adoption of electric vehicles (EVs) by instituting reforms in policy, regulatory frameworks, permitting processes, and capacity-building initiatives. Furthermore, a dedicated Electric Mobility Unit will be established within the government apparatus, which will be fully operationalized. Collectively, this comprehensive design endeavors to facilitate a green recovery by generating employment opportunities in the green sector, nurturing entrepreneurship in clean transport, and enhancing overall mobility options, all of which are imperative for a sustainable and economically viable recovery.

Envisioned as an outcome of this initiative, it is anticipated that by 2030, a remarkable 85% of all newly procured minibuses in Nepal will be electric, marking a substantial shift towards sustainable transportation practices. The estimated financial investment required for the successful implementation of this mobility initiative amounts to EUR 299 million, with a predominant focus on forward-looking mobility solutions (fore-mobility).

Mitigation potential:

The project will directly mitigate 1.78 million tons CO_2e over the lifetime of the vehicles.

2.2 Electric Vehicles Technology

Electric vehicles (EVs) utilize a battery pack as an energy storage system to power their electric motors. Recharging of battery is done by connecting the vehicle to the CS. This charging process replenishes the electrical energy within the batteries, allowing the vehicle to operate. Additionally, EVs employ a regenerative braking system, where the electric motor functions as a generator during braking. This regenerative braking process converts kinetic energy into electrical energy, which is then fed back into the batteries, further contributing to their charge and enhancing the overall energy efficiency of the vehicle.

2.2.1 Working of EVs

EVs are equipped with an electric motor in lieu of an internal combustion engine (ICEs). This electric motor is powered by a sizable battery pack. It is charged by connecting the vehicle to a charging station (Energy, n.d.).

Since EVs operate exclusively on electricity, they do not emit any exhaust through a tailpipe, in stark contrast to conventional gasoline or diesel vehicles. Furthermore, EVs lack the typical components associated with fuel systems as they do not rely on liquid fuels for propulsion.

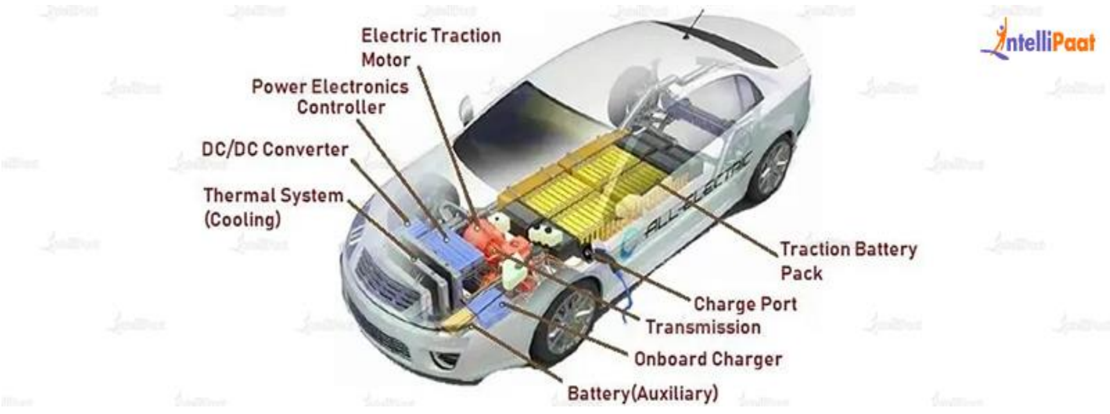

Figure 1-2: Components of EVs

2.2.2 Components of EVs

Battery: At the heart of EVs lies the battery, serving as the epicenter of energy storage and delivery. This pivotal component stores electrical energy, driving not only the electric traction motor but also powering an array of vehicle accessories.

Charge Port: The charge port, a pivotal interface, establishes the vital connection between the EV and an external power source, facilitating the essential charging process that replenishes the battery pack.

Direct Current (DC) Converter: The DC converter assumes a critical role in the energy ecosystem, transforming the high-voltage DC power stored within the traction battery pack into the lower-voltage DC power requisite for the operation of vehicle accessories and the auxiliary battery.

Electric Traction Motor: Serving as the prime mover it propels the vehicle's wheels through the judicious utilization of power drawn from the traction battery pack. Furthermore, during deceleration and braking, the motor ingeniously transitions into a generator, recapturing and harnessing kinetic energy.

On-Board Charger: A key player in the charging infrastructure, the on-board charger is entrusted with the pivotal task of converting Alternating Current (AC) electricity sourced through the charge port into the requisite DC power format to recharge the traction battery. Throughout this process, the on-board charger diligently monitors crucial battery parameters like temperature, current and voltage.

Power Electronics Controller: It presides over orchestration of electrical energy flows within EVs. This indispensable component exercises precise control over both the electric motor's speed and the torque it generates, ensuring the seamless and efficient operation of the vehicle.

Thermal System: The thermal system, an engineering marvel, is charged with the responsibility of meticulously maintaining the optimal operating temperature range for critical components such as the engine, electric motor, power electronics, and associated subsystems. This temperature control regimen is instrumental in safeguarding performance efficiency and component longevity.

Transmission: Completing the powertrain ensemble, the transmission stands as the mechanical linchpin that transfers the mechanical power generated by the electric motor to the vehicle's wheels. It serves as the conduit for the translation of motor-generated power into vehicle movement, encompassing both forward and reverse motion.

2.2.3 Batteries in EVs

In the realm of engineering, rechargeable elements are essential for charging electric vehicles (EVs), which encompass Battery Electric Vehicles (BEVs) and Hybrid Electric Vehicles (HEVs). The choice of batteries is contingent on several critical factors, including weight, power density, energy density, and cost considerations. Traditionally, lead-acid batteries were preferred due to their affordability and established technology. However, the battery landscape has undergone significant advancements, leading to the emergence of various innovative battery types. Presently, battery storage solutions, employing diverse combinations and iterations of lithium-ion (Li-ion) technology, have gained widespread acceptance. This preference is driven by their reduced weight, enhanced power density, rapid response times, shorter charging intervals, and extended lifespan. Notably, Li-ion batteries excel in retaining a higher specific energy capacity compared to alternative variants (Mission, n.d.).Understanding these battery dynamics is integral to advancing engineering practices and promoting sustainable mobility solutions.

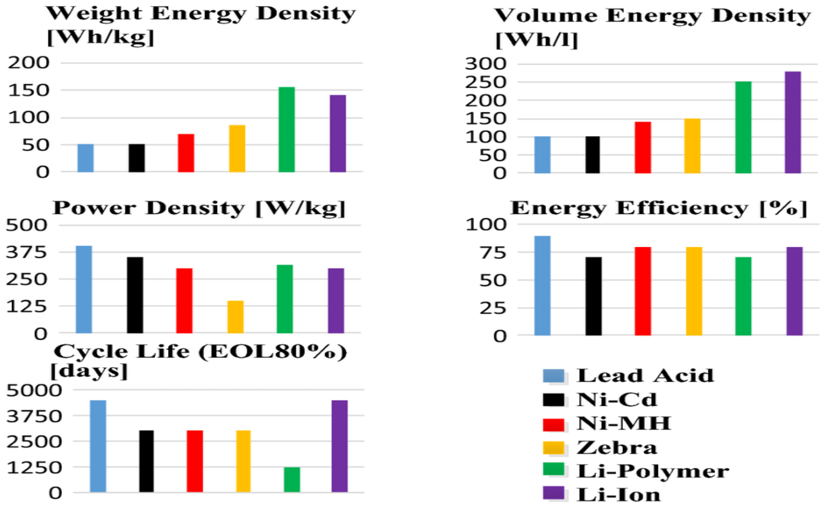

Figure 1-3: Comparison of Batteries ((Micari, 2022)

2.2.3.1 State of Charge (SoC)

SoC denotes amount of energy that is available in the battery at a specific time. It is expressed in percentage.

2.2.3.2 Depth of Discharge (DoD)

It denotes how much energy is cycled into and out of the battery. DoD is expressed in percentage of capacity of battery.

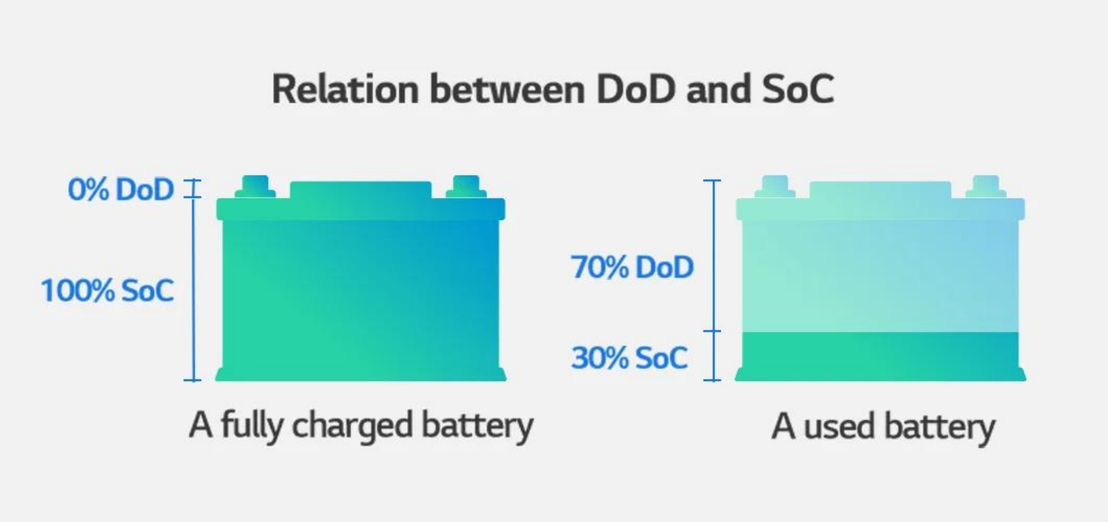

Figure 1-4: Relation between DoD and SoC (Anon., n.d.)

2.3 Charging Station

For recharging of vehicles we need EVs charging station that supplies power. The charge of vehicles takes place in different CS such as home, workplace, public places.

2.3.1 Charging Time

The power output and battery capacity of electric vehicles (EVs) are contingent upon the duration of the charging process. The charging level signifies the quantity of charge stored within the EVs. The charging time is influenced by the utilization of conventional charging stations (CS) or fast-charging stations (FCS) accessible in public locations.

2.3.2 Charging Infrastructure

Fast charging plays a pivotal role in the widespread adoption and success of electric vehicles (EVs). The charging infrastructure encompasses both AC (Alternating Current) and DC (Direct Current) charging methods. In the case of AC charging, electric power is supplied to an onboard charging device, which subsequently charges the Battery Energy Storage (BES) of the EV by converting AC to DC. Conversely, DC charging delivers electric power directly to the battery management system within the BES, eliminating the need for an additional onboard charging system. It's important to note that fast charging, which is essential for rapid EV charging, is exclusively achievable with DC technology (Sagar K. Rastogi, 2019).

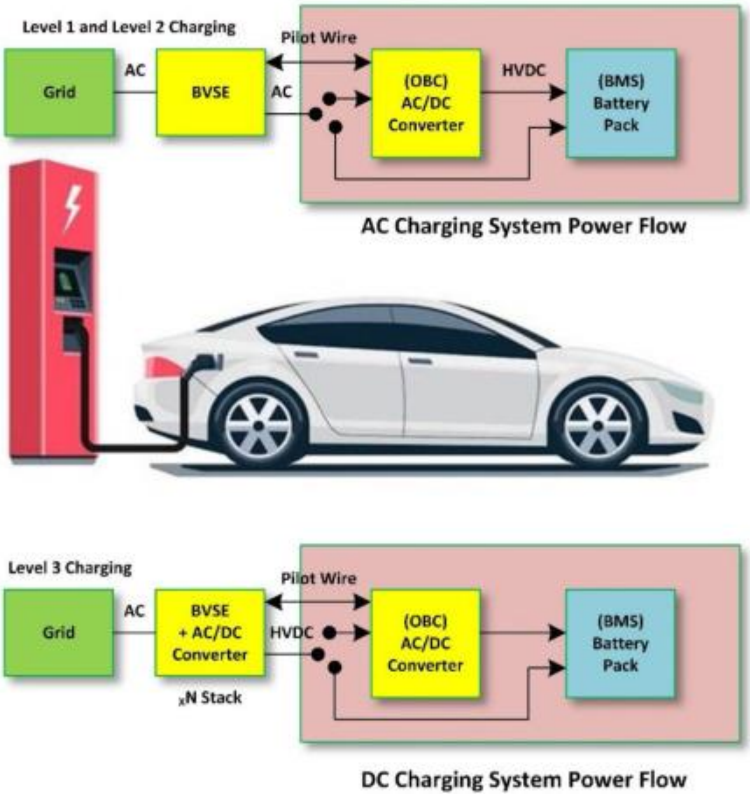

Figure 1-5: Modes of Charging

EV charging is categorized into three levels (Forbes, n.d.):

Level 1: This level employs a standard 120-volt household outlet, making it accessible for all electric vehicles and plug-in hybrids. Level 1 charging involves plugging the charging equipment into a regular wall outlet, albeit it is the slowest method, adding roughly 3 to 5 miles of range per hour. Connectors commonly used include J1772 and Tesla.

Level 2: Level 2 charging is the most prevalent choice for daily EV charging. Charging equipment for Level 2 can be installed at various locations, including homes, workplaces, and public areas such as shopping centers and train stations. Level 2 charging can replenish the EV's range by approximately 12 to 80 miles per hour, contingent on the charger's power output and the vehicle's maximum charge rate.

Level 3: Level 3 charging, also known as fast charging, is the swiftest charging option available, capable of recharging an EV at a rate ranging from 3 to 20 miles of range per minute. Unlike Level 1 and Level 2, Level 3 charging employs DC technology, offering higher voltage levels. Due to the substantial power requirements, Level 3 chargers are not typically found in residential settings and are instead located in specific public charging stations. Connector types utilized for Level 3 charging include Combined Charging System, CHAdeMO, and Tesla.

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2.3.3 Charging Equipment’s

Charging equipment’s are categorized on the basis of rate of charge of battery. The charging time differs from 20 minutes to 20 hours based on different factors that affect the plug in EVs. Charger itself is built on EVs and battery stores the charge.

The charging ports available is J1772 charge Port that is found on all EVs except Tesla that is best suitable for charging Level I or Level II. EVs cord fits into the J1772 port at an end and outlet of 240V is placed at other end.

In context of Asia, EVs that can fast charge the batteries are available with two ports J1772 and CHAdeMO.

2.4 Chargeable EVs

2.4.1 Market for Charging EVs

The potential to replace all types of transportation, including both two-wheeled and four-wheeled private vehicles, as well as public motorcars, with electric vehicles powered by renewable energy sources is a feasible prospect. Additionally, Nepal's advantageous position in hydroelectricity production presents a significant opportunity to substitute traditional energy sources with sustainable alternatives in the near future.

Electric vehicles (EVs) currently comprise a small portion of the total vehicle sales in Nepal; however, their demand is steadily increasing. This growth can largely be attributed to the declining costs of batteries, which have made EVs more affordable. Domestic automobile dealers have noticed a growing preference among consumers for electric vehicles, driven by the cost savings they offer compared to vehicles reliant on fossil fuels.

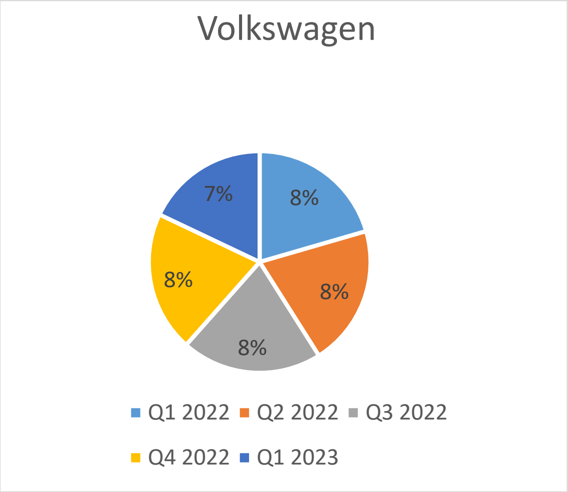
Data also highlights the rapid acceleration of EV adoption within Nepal. A majority of these EVs are imported from countries like China, India, South Korea, and Thailand. It is evident that global trends in the automotive industry are influencing the growth of EVs in Nepal, underlining their potential to become a prominent feature of the country's transportation landscape.

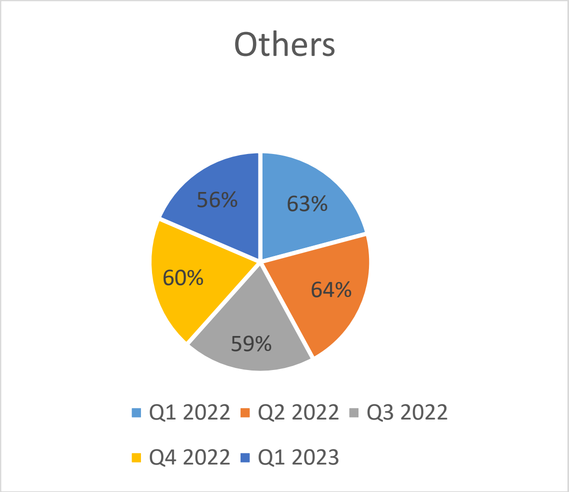
2.4.2 Market Share of EVs

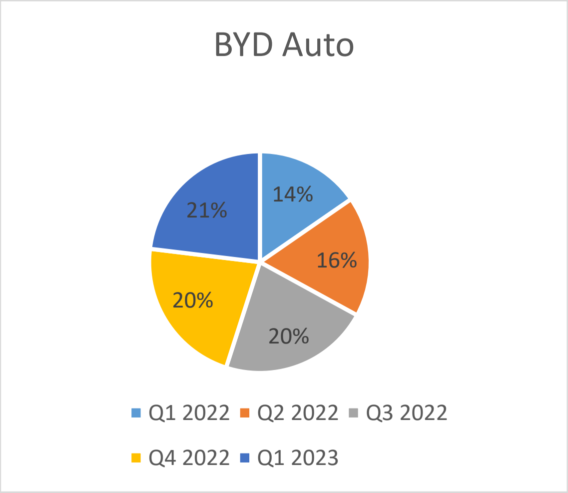
Electric vehicles (EVs) have experienced a remarkable surge in popularity within Nepal, capturing a substantial 30% market share in 2022, a significant contrast to the global average of 10%. This notable growth can be attributed to a paradigm shift among manufacturers, as they redirect their focus away from traditional petroleum-based vehicles and toward the burgeoning EV market. Globally, the market share of EVs exhibited substantial growth, rising from 8.3% in 2021 to surpass the 10% mark in 2022. During the same year, a staggering 7.8 million units of EVs were sold worldwide. Nevertheless, there linger concerns regarding the future trajectory of EVs, prompting concerted efforts to enhance charging infrastructure and bolster consumer confidence in this transformative technology. In the United States, EV sales experienced a commendable increase of 2.6% in 2022, while sales of combustion engine vehicles declined by 8%. Projections indicate that the worldwide sales share of EVs is poised to reach an estimated 14% by 2023 (Anon., 2023).

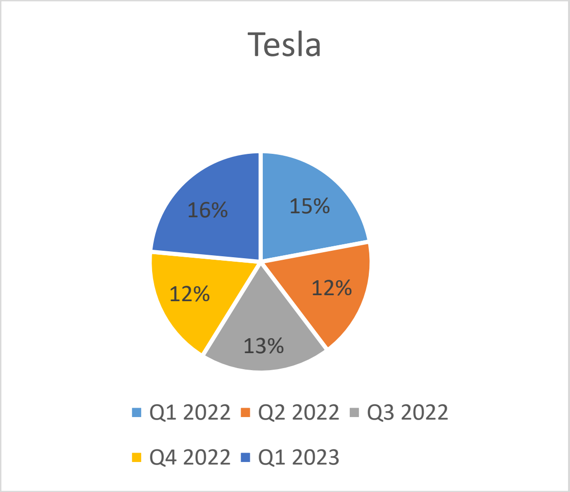
Table 1-1: Global Passenger EVs Market Share

Brands	Q1 2022	Q2 2022	Q3 2022	Q4 2022	Q1 2023
BYD Auto	14%	16%	20%	20%	21%
Tesla	15%	12%	13%	12%	16%
Volkswagen	8%	8%	8%	8%	7%
Others	63%	64%	59%	60%	56%









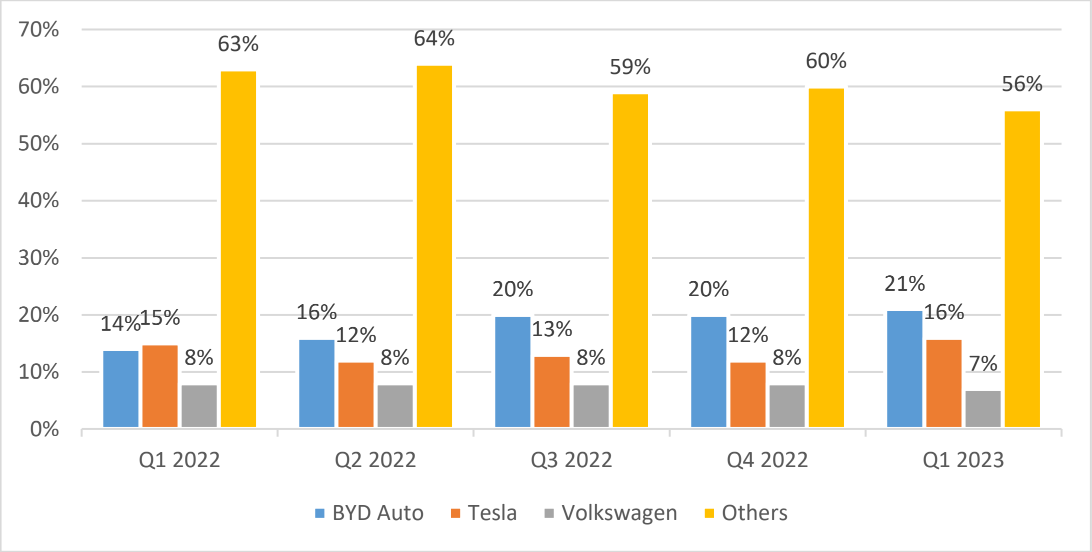


Figure 1-6: Global Passenger EVs Market Share

2.4.3 Market share of EVs in Nepal

According to data from the customs department, Nepal has witnessed a substantial increase in the import of electric vehicles (EVs) during the first seven months of the current fiscal year, which concluded in mid-February. A total of 2,009 EV units, valued at Rs5.62 billion, were imported during this period. This represents a significant upswing from the 1,191 units of EVs, with a cumulative worth of Rs3.49 billion, imported during the corresponding period in the previous fiscal year. The statistics further reveal that, of the EVs imported in the first seven months of the current fiscal year, 1,435 units, valued at Rs3.89 billion, originated from India. Additionally, Nepal imported 294 EVs, worth Rs643.59 million, from China, and 227 EVs, with a total worth of Rs861.41 million, from South Korea during this period. The burgeoning demand for electric vehicles can be attributed to evolving mobility needs, changing lifestyles, favorable tax policies, and the availability of liberal banking finance services (Post, 2023).

Table 1-2: Import of EVs in Nepal

Fiscal Year	Price(Millions)	EVs Imports
2020/21	2560	792
2021/22	5000	1807
2022/23	6840	2704
2023/24	5620	2009

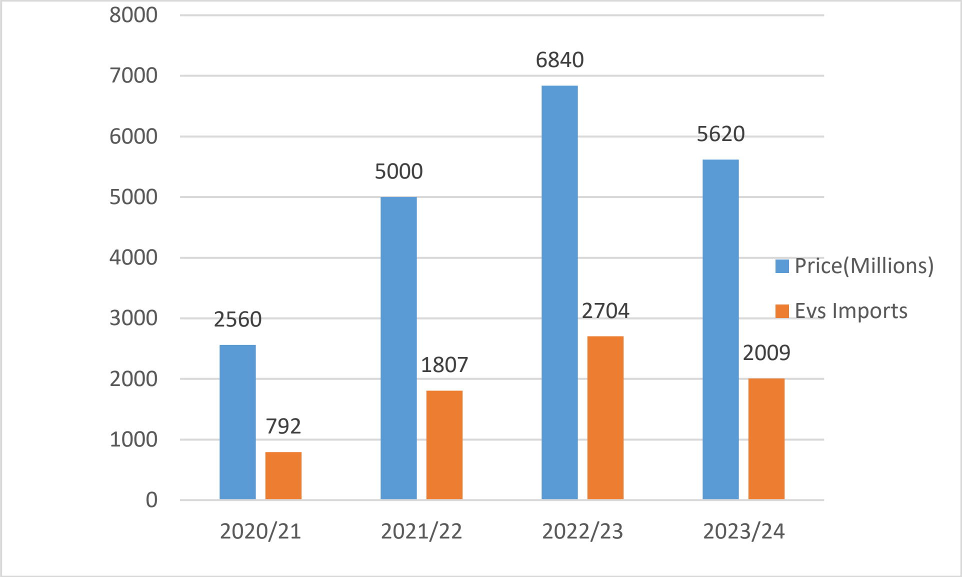


Figure 1-7: Import of EVs in Nepal

2.4.4 Budget Subsidy

In the current fiscal year's budget, the government unveiled ambitious plans to transition both private and public petroleum-based vehicles to electric vehicles within the Kathmandu Valley. Simultaneously, the government also set its sights on elevating the annual per capita electricity consumption to 400 kilowatts (kW) per hour as part of its broader energy objectives.

Table 1-3: Budget Subsidy comparison

Motor Capacity	**Budget 2080/81**	**Budget 2079/80**
50 kW to 100 kW	10% Excise Duty – 15% Customs Duty	0% Excise Duty – 10% Customs Duty
101 kW to 200 kW	20% Excise Duty – 20% Customs Duty	30% Excise Duty – 30% Customs Duty
201 kW to 300 kW	45% Excise Duty – 40% Customs Duty	45% Excise Duty – 45% Customs Duty
Above 301 kW	Same as Before	60% Excise Duty – 60% Customs Duty

2.4.3 Charging of EVs distribution

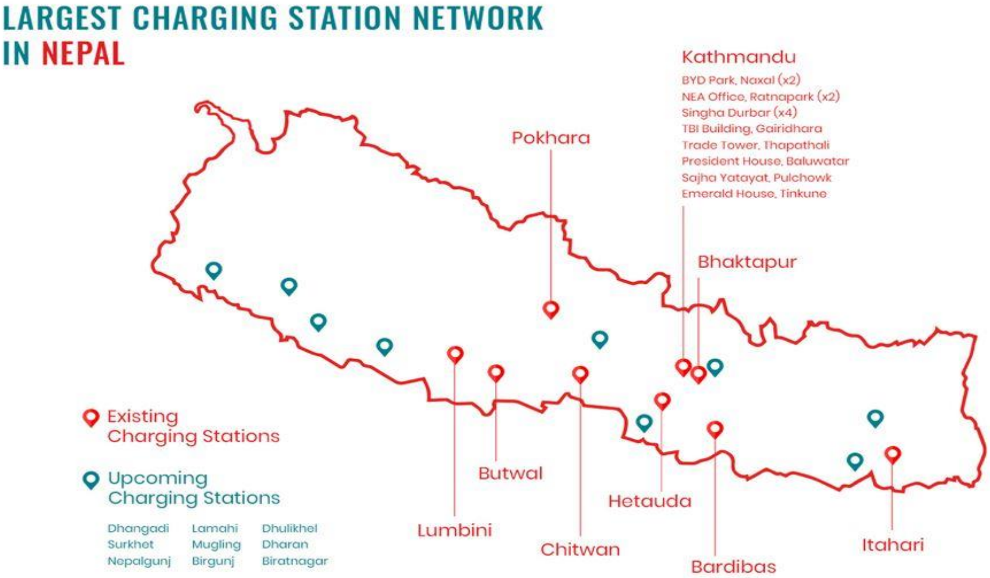


Figure 1-8: Charging stations in Nepal (trading, n.d.)

2.5 The integration of electric vehicles with the power grid

The intersection of the transportation and electric power sectors is a relatively recent development, resulting in significant interplay between the two. This convergence has brought about substantial disruptions for electric utilities due to the widespread adoption of electric transport. While electric vehicles (EVs) present notable challenges for the power grid, they also offer substantial advantages. Traditionally, one of the most critical aspects of EVs is their integration into the electric vehicle grid (EVGI). There is potential for EVs to play a significant role in feeding electricity back into the grid and providing services such as harmonious reduction, reactive power support, peak demand management, and more within an intelligent energy management framework. However, achieving this requires a robust EVGI system in terms of both technical capabilities and business operations to meet these evolving demands. As technology advances, communities are taking an active role in managing the distribution, generation, and control of electricity. Additionally, specialized processes, including low-position operational methods, are emerging to effectively align electricity operations and dispatch networks (Muhammad Shahid Mastoi, 2022).

2.6 Need for renewable energy sources

Carbon dioxide emissions primarily stem from electricity generation facilities and the transportation sector, leading to heightened health and environmental risks that have reached a critical juncture. The adoption of renewable energy practices can play a pivotal role in mitigating global warming while concurrently championing environmental preservation. Nonetheless, renewable energy sources often rely heavily on unpredictable natural conditions for their energy production, posing a substantial drawback. The integration of electric vehicles (EVs) into the power grid offers a viable solution to address these challenges. By harnessing EVs as a means to balance the intermittent generation of renewable energy, a remedy is provided for the inconsistent utilization of clean energy sources.

Furthermore, EVs serve as a reservoir to store surplus electricity generated by renewable sources, effectively preventing wastage of these resources. This approach enables the customization of the power system to optimize the use of clean energy, EV energy storage, and interconnected grids. It is anticipated that the incorporation of electric vehicles will stimulate economic growth within the clean energy sector. To enhance the efficiency and safety of both EVs and the potential power grid, it will be imperative to establish adequate electrical storage mechanisms that bridge the gap between renewable energy sources and electric vehicles.

2.7 The effects of electric vehicle integration on the grid

The impact of integrating electric vehicles (EVs) into the grid can be categorized into both adverse and favorable effects. Electric vehicles pose notable challenges to power utilities, particularly in the context of distribution networks. The extensive integration of EVs into these networks can disrupt their stability. This unfavorable outcome arises from shifts in load profiles, imbalances in voltage and frequency, an overabundance of harmonics introduced into the system, and increased power losses. Furthermore, the excessive penetration of EVs into the grid may lead to a deterioration in power quality, heightened peak loads, and complications in power regulation.

2.7.1 EVs load impacts on Electricity Generation

A critical necessity lies in the assessment of generation capacity to address the demands imposed by electric vehicles (EVs). Charging EVs during off-peak load hours can obviate the need for new power plants dedicated solely to meet EV charging demands. By controlling and shifting the charging of EVs to off-peak hours, there is no incremental burden on the system's peak load demand. Consequently, this approach safeguards the adequacy of power generation without adverse effects. However, in the absence of controlled charging, large-scale deployment of EVs has the potential to diminish supply adequacy, necessitating the construction of additional power plants to bridge the gap (Dubey, 2015).

2.7.2 EVs load impacts on transformer loading

More use of electric vehicles (EVs) leads to increase in load demand, and voltage fluctuations and elevated system losses within the grid. This demand has the potential to overload service transformers, shorten their operational lifespan, and amplify system losses. Furthermore, the rated capacity of service transformers may be surpassed thus increasing the aging process of the equipment. Nevertheless, charging EVs on off peak hours has the potential to reduce the daily expansion and contraction cycles experienced by the transformers, resulting in a favorable impact on the transformers' longevity and overall performance (Dubey, 2015).

2.7.3 EVs load impacts on Power Quality

The process of electric vehicle (EV) charging can introduce power quality issues into the grid, including conditions such as harmonics, imbalance in power, voltage drop. As rate of growth of EVs on the road rises, there is a corresponding increase in electricity demand to charge their batteries. For instance, Level-II chargers consume twice as much power as Level-I chargers when charging a EVs. This demand in load helps in contributing additional voltage drops within the secondary service voltages, thereby impacting overall quality.

2.7.4 Time-of-Use (TOU) pricing to mitigate EV load impacts

Analysis of electric vehicle impacts indicates that during peak load hours EVs charging results in increase of Peak load demand that results in occurrence of under voltage conditions, necessitating enhancements and expansions of grid infrastructure. The extent of EV load penetration into the distribution grid is contingent on the unregulated charging practices of EV owners. To mitigate this issue, utility companies have implemented a Time-of-Use (TOU) pricing structure with rate different for peak and off peak hours. This helps to reduce the load demand profile and decrease strain on the grid during peak hours.

2.8 Challenges and future trends

Electric vehicles (EVs) have emerged as a promising solution to the multifaceted challenges plaguing conventional transportation, encompassing the reduction of fossil fuel dependency, the amelioration of greenhouse gas emissions, and the combatting of global warming. However, it is imperative to recognize that the widespread embrace of EVs encounters a myriad of impediments. These obstacles encompass issues such as grid congestion stemming from the proliferating presence of EVs, the constrained longevity of batteries, reservations surrounding driving range, and the comparatively exorbitant price tags attached to EVs when juxtaposed with their internal combustion engine counterparts. Collectively, these challenges serve as a deterrent to the mass adoption of EVs and necessitate concerted efforts on the part of governmental and private stakeholders to facilitate their ubiquitous integration.

The escalated costs associated with EVs, entwined with factors like charging infrastructure and battery installation, persist as a conspicuous concern. For instance, lithium-ion batteries exhibit a finite lifecycle, precipitating recurrent replacements and contributing to the overall cost burden of the vehicle. Effectively addressing this challenge entails the advancement of battery technology and materials to protract their durability and enhance their performance. Furthermore, it is pivotal to acknowledge that EVs are not entirely exempt from environmental repercussions. The ecological footprint of an EV hinges upon the provenance of electricity generation. In cases where a substantial proportion of electricity derives from coal and gasoline sources, EVs can emit greenhouse gases at levels akin to internal combustion engines. To genuinely curtail pollution and foster a cleaner, more efficient environment, it becomes imperative to integrate renewable energy sources such as solar and wind, facilitated through the auspices of a smart grid infrastructure.

CHAPTER THREE : METHODOLOGY

3.1 Basic

The flow chart shown in the figure 3.1 expresses the basic methodology of this thesis.

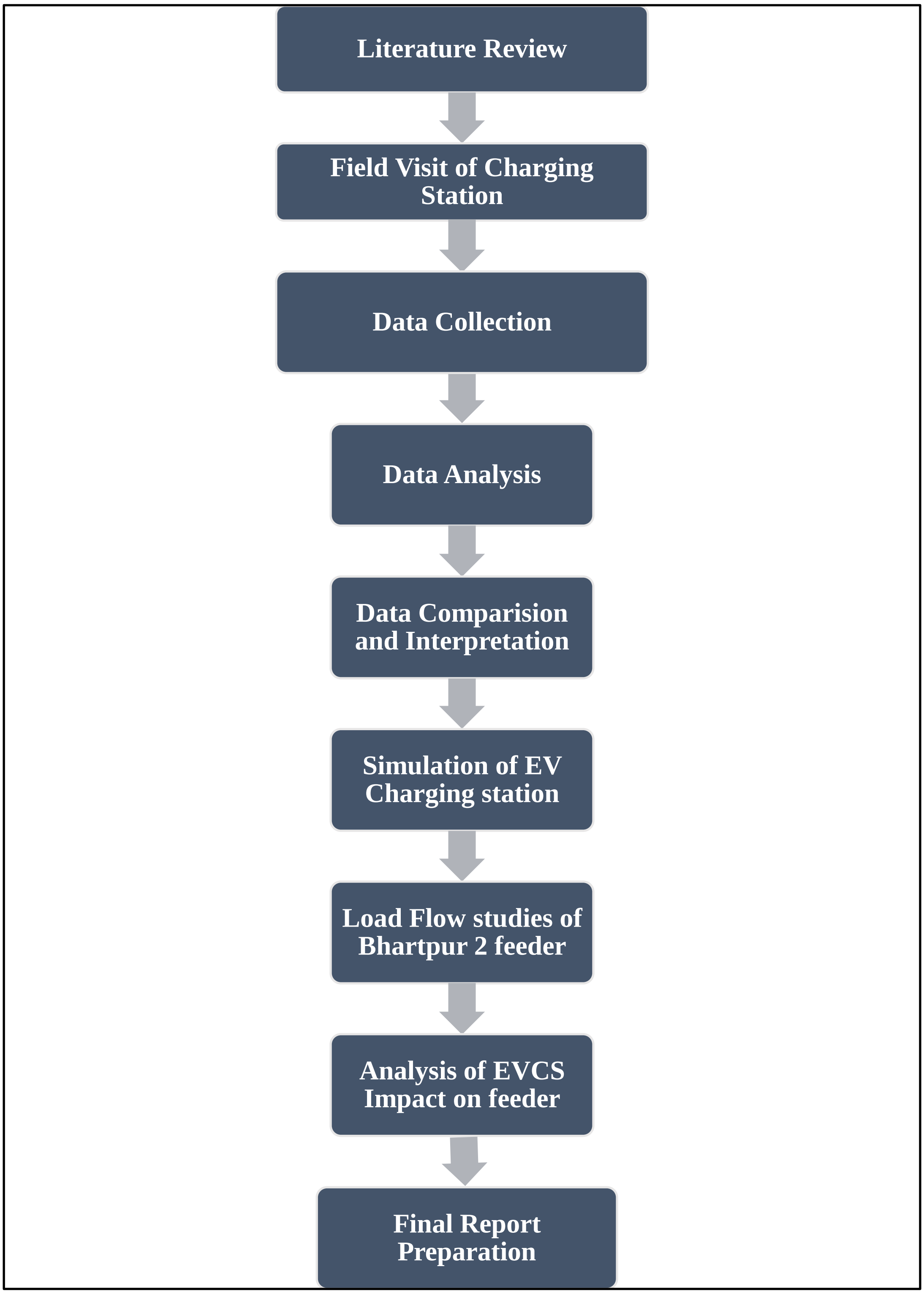


Figure 3-1: Flow chart of Research Project

3.2 Literature review

The research for this thesis began with an extensive review of existing literature related to the impact of EV charging stations on power distribution feeders. This encompassed a thorough examination of studies addressing load profiles, voltage stability, and power quality, while also considering the interactions between these factors and the integration of EV charging infrastructure. This review served as the foundation for developing a comprehensive understanding of the subject matter.

In addition to the literature review, the research involved an in-depth analysis of global trends and best practices in the deployment of EV charging infrastructure. This analysis spanned various regions and jurisdictions, providing insights into successful strategies and implementations worldwide. These insights were instrumental in shaping the subsequent recommendations and potential solutions for optimizing the integration of EV charging stations within the local power distribution network.

In summary, the research approach combined a rigorous review of existing knowledge with a practical examination of real-world practices, enabling a holistic perspective on the subject matter and facilitating the generation of valuable recommendations and insights for the thesis.

3.3 Field visit and survey

3.3.1 Charging Station Location

Within the jurisdiction of Bharatpur-2 Feeder, there are two EV Charging stations situated at Paras Buspark. These charging stations are equipped with both DC fast chargers and Level 2 Chargers. In total, there are six charging units available at this location, comprising four DC fast chargers compatible with CCS 2.0 and GB/T standards, along with two Level 2 chargers. The Level 2 chargers have an output power capacity of 22kW, while the DC fast chargers can deliver an output power of 120kW. To gain a comprehensive understanding of the distribution network, a single-line diagram of the Bharatpur-2 Feeder is provided below for reference.

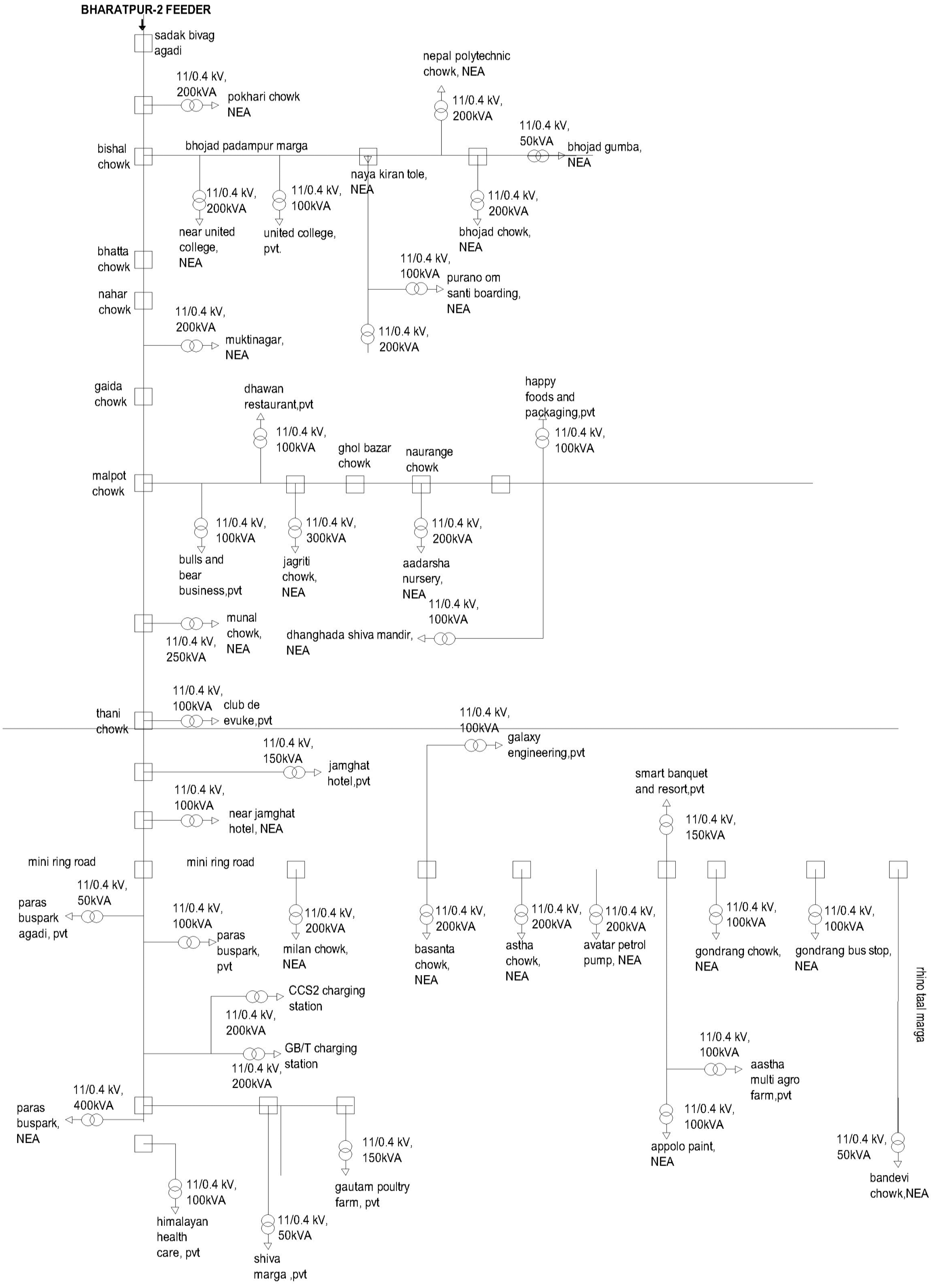


Figure 3-2 Single Line Diagram of Bharatpur-2 Feeder

3.3.2 Data Collection

Data pertaining to feeder load and voltage was acquired from the Old Bharatpur Substation. Additionally, direct interactions were conducted with members of the Nepal Electricity Authority to gather relevant information. Records of EV charging sessions including load profiles, voltage levels, and power factor measurements and charging energy consumption, were meticulously collected from Electric Vehicle Charging Stations (EVCs).

Real-time data was meticulously gathered from the respective charging stations and feeders. This encompassed data on power consumption, voltage variations, and power quality metrics both before and after the installation of the EV charging stations.

To ensure a comprehensive dataset, historical data spanning one year was procured from the charging station's Time-of-Day (TOD) meter and the substation log sheet, which are appended for reference. These datasets offer real-time, actual information concerning feeder voltage, current, and load at the charging station. Furthermore, through meticulous analysis of this data, peak and off-peak periods were identified, facilitating a graphical examination of the impact of Charging Stations (CS) on the feeder.

3.4 Data Analysis

3.4.1 Load Profile Analysis

The data obtained from the charging station and feeder was analyzed to create comprehensive load profiles for the Bharatpur-2 feeder, taking into account various time periods, notably peak hours and charging intervals.

3.4.1.1 Parameter for load flow studies

The single-line diagram of the feeder was acquired from the substation and can be found in the following section. To determine the line parameters between each bus, we computed the distance and utilized the resistance per kilometer data from the technical specifications of the ACSR Dog conductor employed on the Bharatpur-2 feeder.

Table 3-1: Specification of ACSR conductor (Lumino, n.d.)

Data for Aluminium Conductors Steel Reinforced (ACSR) As per IS 398 (Part-II): 1996																
Code Words	**Aluminium Area (Sq.mm)**		**Total Sectional Area (Sq.mm)**	**Stranding & Wire Diameter**				**Overall Dia (mm) (Approximate)**	**Weight Mass**			**Resistance at 20°C (ohm/ km) (Max)**	**Ultimate Breaking Load (N)**	**Current Carrying Capacity**		
	Sectional Area	**Nominal Area**		**Conductor (Al)**		**Conductor (Steel)**			**Al kg/ km**	**Steel kg/ km**	**Total kg/ km**			**90°C**	**75°C**	**65°C**
				No.	**Dia (mm)**	**No.**	**Dia (mm)**							**Amp**	**Amp**	**Amp**
Kundah	404.1	400	425.2	42	1.96	7	1.96	26.88	1119	163	1282	0.07311	88790	-	705	566
Zebra	428.9	420	484.5	54	3.18	7	3.18	28.62	1182	439	1621	0.06868	130320	-	737	590
Moose	528.5	520	597	54	3.53	7	3.53	31.77	1463	535	1998	0.05595	159600	-	836	667
Racoon	78.83	80	91.97	6	4.09	1	4.09	12.27	215	103	318	0.3712	26910	-	244	200
Panther	212.1	200	261.5	30	3	7	3	21	588.5	387.5	976	0.139	89670	-	487	395
Squirrel	20.98	20	24.48	6	2.11	1	2.11	6.33	58	27	85	1.394	7610	-	107	89
Weasel	31.61	30	36.88	6	2.59	1	2.59	7.77	87	41	128	0.9289	11120	-	138	114
Mole	10.6	10	12.37	6	1.5	1	1.5	4.5	29	14	43	2.78	3970	-	70	58
Dog	**105**	**100**	**118.5**	**6**	**4.72**	**7**	**1.57**	**14.15**	**288.3**	**105.7**	**394**	**0.2792**	**32410**	**-**	**291**	**239**
Rabbit	52.88	50	61.7	6	3.35	1	3.35	10.05	145	69	214	0.5524	18250	-	190	157
Wolf	158.1	150	194.9	30	2.59	7	2.59	18.13	438	289	727	0.1871	67340	-	405	329

ACSR Code Number	**Type of ACSR**	**Calculated Resistance at 20°C (ohms/km) (Max)**	**Current Rating Max. (Amps)**	**Nominal Aluminium Area (sq. mm)**	**Inductive Reactance (ohm/km)**	**Weight (kg/km)**
1	Squirrel	1.374	76	20	0.355	80
2	Gopher	1.098	85	25	0.349	106
3	Weasel	0.9116	95	30	0.345	128
4	Rabbit	0.5449	135	50	0.335	214
5	Otter	0.3434	185	80	0.328	339
6	**Dog**	**0.2792**	**205**	**100**	**0.315**	**394**

Table 3-2: Line Parameter between bus

S.N.			**Distance (km)**	**Resistance (ohm)**	**Inductance (mH)**
1	Sadak Bivag Agadi	Bishal Chowk	0.45	0.12	0.05
2	Bishal Chowk	United College	0.4	0.11	0.04
3	United College	Purano Om shanti boarding	0.8	0.22	0.08
4	United College	Nepal Poly-technic Chowk	0.9	0.25	0.09
5	Nepal Poly-technic Chowk	Bhojad Chowk	0.55	0.15	0.06
6	Bhojad Chowk	Bhojad Gumba	1	0.27	0.10
7	Purano Om shanti boarding	Naya kiran tole	0.28	0.08	0.03
8	Bishal Chowk	Bhatta Chowk	1.6	0.44	0.16
9	Bhatta Chowk	Nahar Chowk	2.1	0.57	0.21
10	Nahar Chowk	Malpot Chowk	0.85	0.23	0.09
11	Malpot Chowk	Bulls And Bear Business	0.22	0.06	0.02
12	Malpot Chowk	Dhawan Restraunt	1	0.27	0.10
13	Jagriti chowk	Adarsha Nursery	1.3	0.36	0.13
14	Adarsha Nursery	Dhanghada shiv Mandir	1.7	0.46	0.17
15	Dhanghada shiv Mandir	Happy Foods And Packaging	0.4	0.11	0.04
16	Bulls And Bear Business	Munal Chowk	1	0.27	0.10
17	Munal Chowk	Club De Evuke	0.8	0.22	0.08
18	Club De Evuke	Jamghat Hotel	0.65	0.18	0.07
19	Jamghat Hotel	Paras Bus Park	0.14	0.04	0.01
20	Paras Bus Park	Milan Chowk	0.5	0.14	0.05
21	Milan Chowk	Galaxy Engineering	0.85	0.23	0.09
22	Galaxy Engineering	Astha Chowk	0.85	0.23	0.09
23	Astha Chowk	Avatar Petrol Pump	0.3	0.08	0.03
24	Avatar Petrol Pump	Smart Banquet and Resort	0.55	0.15	0.06
25	Smart Banquet	Gondrang Chowk	0.8	0.22	0.08
26	Gondrang Chowk	Ban devi chowk	1	0.27	0.10
27	Avatar Petrol Pump	Appolo Paint	1	0.27	0.10
28	Paras Bus Park	Gautam Poultry Form	2.7	0.74	0.27
29	Paras Bus Park	Himalayan Health Care	1	0.27	0.10

3.4.1.2 Load factor

Additionally, all transformers connected to the feeder have been loaded based on the load factor of the feeder, which was obtained on the peak day.

The data we have utilized is from Ashadh 14, 2080.

Table 3-3: Load factor (Peak load)

Time(hr)	Feeder Load (MW)
1	5.01
2	4.91
3	4.79
4	4.66
5	4.50
6	4.44
7	4.47
8	5.16
9	5.35
10	5.51
11	7.46
12	7.24
13	7.68
14	7.59
15	6.55
16	6.55
17	6.36
18	6.74
19	6.89
20	**9.19**
21	8.63
22	8.44
23	7.90
24	6.80

Where Total load of 24 hr is 152.81MW and Peak load at that time is 9.19MW.

$$\text{Load factor} = \frac{\boldsymbol{Average\ Load}}{\boldsymbol{Peak\ Load}}\ \boldsymbol{X\ 100}$$

$$= \frac{152.81}{24\ X\ 9.19}\ X\ 100$$

$$= 69.28\%$$

3.4.2 Voltage Stability Analysis

The recorded voltage levels from the logbook of the Bharatpur-2 feeder were subjected to a thorough evaluation and analysis. This comprehensive assessment aimed to determine the feeder's voltage stability while considering various scenarios related to the charging of electric vehicles (EVs). In essence, the study sought to understand how different EV charging conditions and loads impacted the stability of the feeder's voltage levels. This analysis was crucial in assessing the feeder's capacity to maintain consistent and reliable voltage supply, especially in the presence of increasing EV charging demands.

3.4.3 Power Quality Analysis

The power quality data, encompassing factors such as harmonic content and voltage fluctuations, will be subjected to a comprehensive analysis. This analysis is essential for evaluating the influence of the EV charging station on the overall power quality of the feeder. By examining harmonic content and voltage fluctuations, the study aims to assess whether the presence of the charging station has any adverse effects on the feeder's power quality. This assessment is crucial for ensuring that the electrical system maintains high-quality power delivery, even in the context of increasing EV charging loads.

3.5 Software and Tools

Some of the software that will be used for the implementation of this thesis are:

3.5.1 EXCEL

This software is used to analyze the graphical representation of data's.

3.5.2 Mat lab Simulink

A straightforward MATLAB simulation model of the Bharatpur-2 feeder has been constructed, and it will undergo a load flow analysis. Additionally, the model will be utilized to simulate various EV charging scenarios. These simulations are designed to provide insights into how EV charging impacts the feeder's performance, load distribution, voltage levels, and power quality. By conducting these simulations, we can gain a deeper understanding of how the integration of electric vehicle charging stations influences the overall behavior of the feeder, helping us make informed decisions regarding grid stability and power quality management.

3.5.2.1 Simulation parameter for charging station

Table 3-4: Simulation Parameter for CS

Feeder Voltage	11 kV
Frequency	50 Hz
Transformer Rating	200 KVA, 11/0.4 KV
Charging Load	120 kW

The charging load of 120 kW was selected based on the highest charging load observed over the past year, while the other parameters used in the current feeder simulation remain consistent with standard settings. This approach allows us to assess the impact of charging stations under real-world conditions and evaluate their effects on the feeder's performance and stability, considering the variability in charging loads that may occur over time.

CHAPTER FOUR: RESULTS AND DISCUSSION

In this chapter, we will delve into the outcomes of the study and engage in a comprehensive discussion. We will commence by presenting the findings derived from the analysis of load profiles, followed by an exploration of the results obtained from the voltage stability analysis and power quality assessment. Furthermore, we will scrutinize the impact of the EV charging station on the Bharatpur-2 feeder and establish comparisons with the existing body of literature in order to provide a well-rounded understanding of the implications and significance of our research findings.

4.1 Graphical Analysis

Table 4-1: Data of Bharatpur-2 Feeder (2079 Ashad 28)

2079 Ashad 28 (Peak Load)						
Time (hr)	**Bharatpur-2 Feeder**				**Feeder Load (MW)**	**CS Load**
	Current (A)			**Voltage (kV)**		
	R	**Y**	**B**			
1	151	151	151	11.36	4.75	0
2	150	150	150	11.3	4.72	0
3	148	148	148	11.2	4.66	0
4	146	146	146	11.3	4.60	0
5	144	144	144	11.4	4.53	0
6	160	160	160	11.5	5.04	0
7	181	181	181	11.5	5.70	0
8	189	189	189	11.5	5.95	0
9	220	220	220	11.5	6.93	0
10	221	221	221	11.5	6.96	0
11	223	223	223	10.8	7.02	0
12	223	223	223	10.9	7.02	0
13	225	225	225	10.8	7.08	0
14	228	228	228	10.8	7.18	0
15	**235**	**235**	**235**	**10.7**	**7.40**	0
16	202	202	202	11	6.36	0
17	199	199	199	11.09	6.26	0

18	183	183	183	11.12	5.76	0
19	190	190	190	11.2	5.98	0
20	213	213	213	11.2	6.71	0
21	211	211	211	11.12	6.64	0
22	198	198	198	11.2	6.23	0
23	176	176	176	11.3	5.54	0
24	171	171	171	11.2	5.38	0

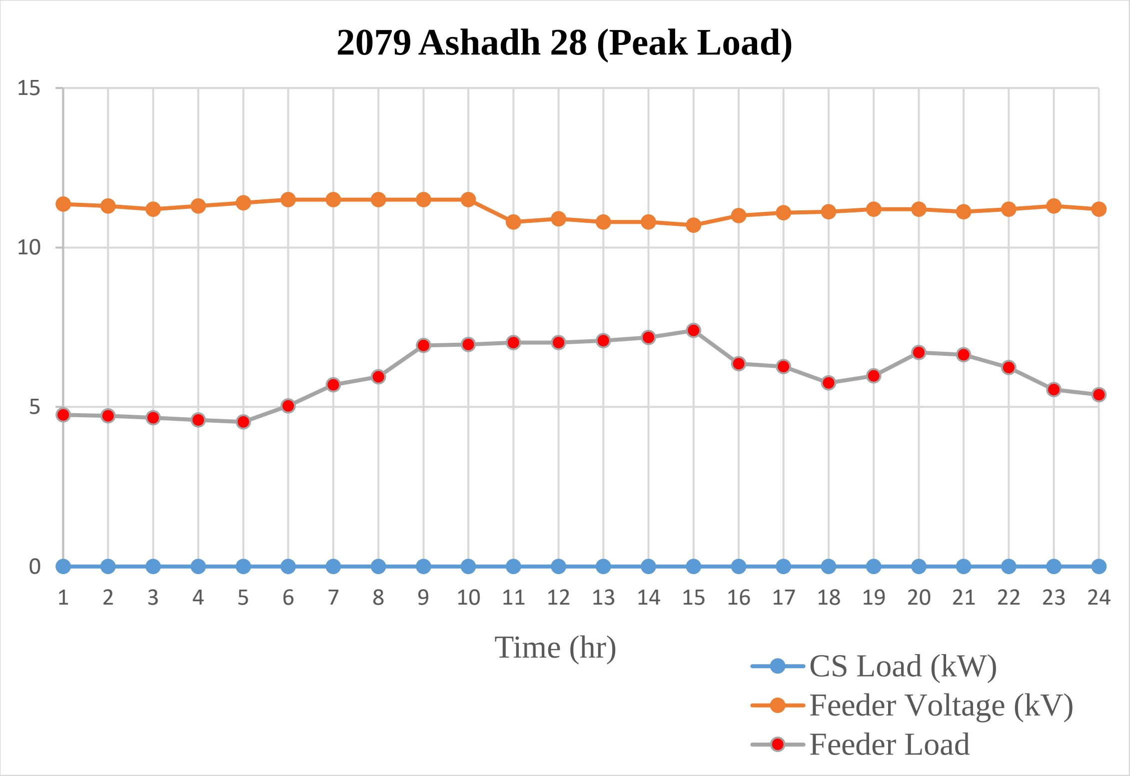


Figure 4-1: Load Versus (Vs) Voltage Curve (2079 Ashadh)

The graph of 2079 Ashad showcases significant fluctuations in voltage levels, ranging from a minimum of 10.7 kV to a maximum of 11.5 kV, and variable feeder load levels, spanning from 4.53 MW to 7.40 MW, within the power distribution system over a 24-hour cycle. Furthermore, the consistent CS Load at 0 MW throughout the observation period suggests the absence of charging load during that period. All the voltage drops were seen because of feeder load only.

Table 4-2: Data of Bharatpur-2 Feeder (2079 Mangsir 27)

2079 Mangsir 27 (Peak Load)						
Time	**Bharatpur-2 Feeder**				**Feeder Load (MW)**	**CS Load (kW)**
	Current (A)			**Voltage (kV)**		
	R	**Y**	**B**			
1	80	80	80	11.2	2.52	0.30
2	80	80	80	11.1	2.52	0.30
3	78	78	78	11.1	2.46	0.30
4	80	80	80	11.1	2.52	0.30
5	112	112	112	11.1	3.53	0.30
6	152	152	152	11.1	4.79	0.30
7	204	204	204	10.9	6.42	0.12
8	**209**	**209**	**209**	**10.9**	**6.58**	**15.00**
9	176	176	176	10.7	5.54	0.11
10	167	167	167	10.8	5.26	0.11
11	130	130	130	11	4.09	0.12
12	110	110	110	10.9	3.46	0.12
13	112	112	112	11	3.53	0.12
14	111	111	111	10.8	3.49	0.12
15	120	120	120	11.02	3.78	0.12
16	114	114	114	11.02	3.59	0.12
17	142	142	142	11.03	4.47	0.12
18	188	188	188	10.9	5.92	0.30
19	157	157	157	11.1	4.94	22.80
20	138	138	138	11.1	4.34	15.89
21	100	100	100	11.2	3.15	0.34
22	89	89	89	11.3	2.80	0.30
23	74	74	74	11.3	2.33	0.30
24	69	69	69	11.1	2.17	0.30

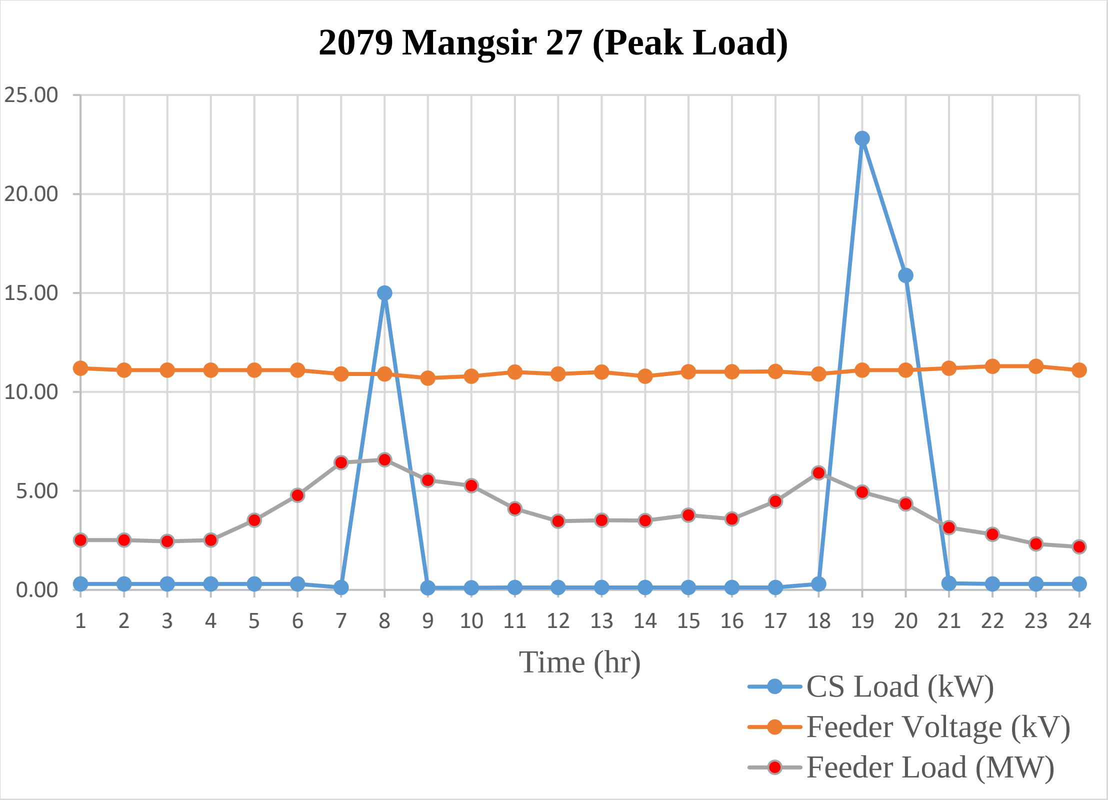


Figure 4-2: Load Vs Voltage Curve (2079 Mangsir)

In Mangsir 2079, a notable effect on voltage levels when the CS (Charging Station) Load is connected to the power distribution system. Initially, voltage levels remained relatively stable, fluctuating within a narrow range between 11.1 kV and 11.3 kV. However, a distinct deviation occurred at 8 AM when the CS Load was introduced at a significant 15.00 kW. This introduction resulted in a sudden drop in voltage to 10.9 kV. Subsequently, at 7 PM and 8 PM, when the CS Load reached 22.80 kW and 15.89 kW, respectively, another decline in voltage was observed. These fluctuations underline the substantial impact of CS Load variations on voltage stability within the distribution system, signifying the need for careful consideration and management of control system-related loads to ensure consistent and reliable voltage levels for consumers and equipment.

Table 4-3: Data of Bharatpur-2 Feeder (2079 Falgun 19)

2079 Falgun 19 (Peak Load)						
Time	**Bharatpur-2 Feeder**				**Feeder Load (MW)**	**CS Load (kW)**
	Current (A)			**Feeder Voltage (kV)**		
	R	**Y**	**B**			
1	68	68	68	11.4	2.14	0.13
2	70	70	70	11.4	2.20	0.13
3	69	69	69	11.4	2.17	0.13
4	69	69	69	11.3	2.17	0.13
5	98	98	98	11.1	3.09	25.53
6	111	111	111	11.1	3.49	18.01
7	155	155	155	11	4.88	0.07
8	153	153	153	10.9	4.82	0.06
9	139	139	139	11	4.38	0.06
10	123	123	123	10.8	3.87	0.07
11	115	115	115	10.9	3.62	23.06
12	108	108	108	10.8	3.40	0.08
13	108	108	108	10.9	3.40	0.07
14	155	155	155	10.7	4.88	0.07
15	163	163	163	10.7	5.13	0.07
16	166	166	166	10.9	5.23	0.08
17	179	179	179	10.8	5.64	0.07
18	197	197	197	11.2	6.20	0.07
19	**221**	**221**	**221**	**10.9**	**6.96**	**18.01**
20	190	190	190	11.1	5.98	0.13
21	156	156	156	11.2	4.91	0.13
22	123	123	123	11.2	3.87	0.13
23	119	119	119	11.1	3.75	23.04
24	100	100	100	11.1	3.15	0.15

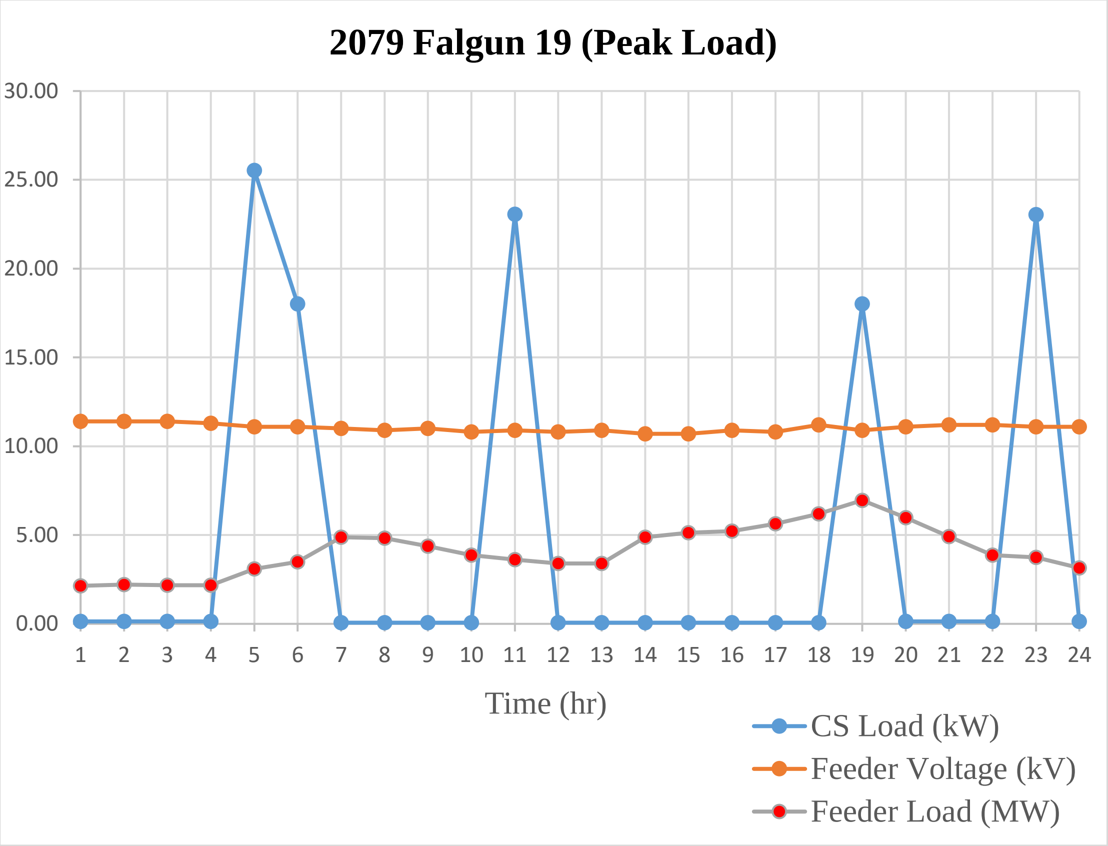


Figure 4-3: Load Vs Voltage Curve (2079 Falgun)

The analysis of the graph for Falgun 2079 reveals a dynamic interplay between the Charging Station (CS) load and feeder load on voltage levels within the power distribution system. Initially, voltage levels remained relatively stable at around 11.4 kV, corresponding to a feeder load of approximately 2.17 MW. However, significant fluctuations in voltage became evident as the CS Load was introduced and varied throughout the 24-hour period. Notably, at 5 AM, when the CS Load surged to 25.53 kW, voltage levels dropped to 11.1 kV, and the feeder load increased to 3.09 MW. This observed decline in voltage is indicative of the substantial impact of the CS Load on voltage stability. Conversely, during moments of reduced CS Load, such as 8 AM when it decreased to 0.06 kW, voltage levels saw a marginal improvement to 10.9 kV, despite a feeder load of 4.82 MW. These dynamics underscore the intricate relationship between CS Load variations and feeder load in influencing voltage levels.

Table 4-4: Data of Bharatpur-2 Feeder (2080 Ashad 14)

2080 Ashad 14 (Peak Load)						
Time	**Bharatpur-2 Feeder**				**Feeder Load (MW)**	**CS Load (kW)**
	Current (A)			**Voltage (kV)**		
	R	**Y**	**B**			
1	159	159	159	11.3	5.01	17.48
2	156	156	156	11.2	4.91	0.29
3	152	152	152	11.3	4.79	0.29
4	148	148	148	11.4	4.66	0.29
5	143	143	143	11.2	4.50	0.29
6	141	141	141	11.2	4.44	0.15
7	142	142	142	11.2	4.47	34.88
8	164	164	164	11.2	5.16	64.84
9	170	170	170	11.4	5.35	0.11
10	175	175	175	11	5.51	70.31
11	237	237	237	11.12	7.46	94.67
12	230	230	230	11.1	7.24	0.11
13	244	244	244	11.01	7.68	17.08
14	241	241	241	11.1	7.59	0.10
15	208	208	208	10.4	6.55	23.32
16	208	208	208	11.2	6.55	20.57
17	202	202	202	11.4	6.36	61.56
18	214	214	214	11.2	6.74	51.49
19	219	219	219	11.2	6.89	20.82
20	**292**	**292**	**292**	**11**	**9.19**	**107.21**
21	274	274	274	11.2	8.63	94.99
22	268	268	268	11.3	8.44	65.79
23	251	251	251	11.3	7.90	22.42
24	216	216	216	11.3	6.80	0.29

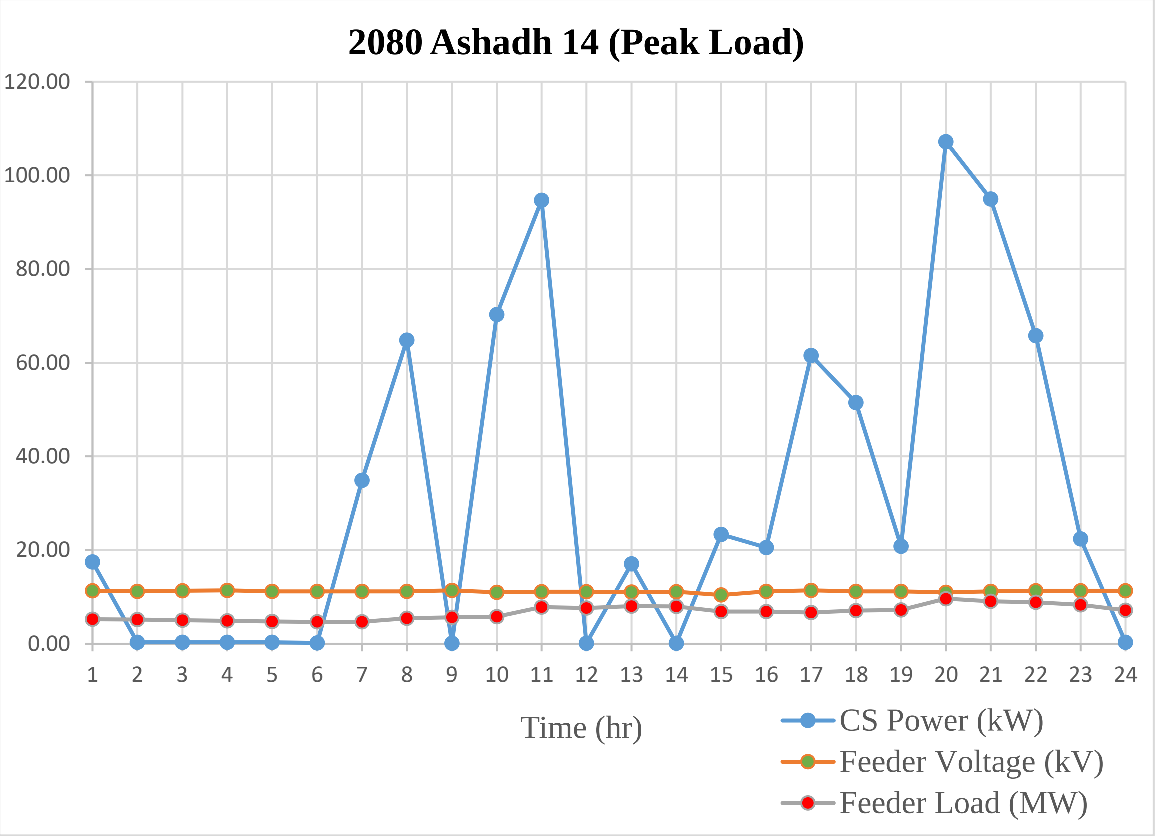


Figure 4-4: Load Vs Voltage Curve (2080 Ashad)

Similarly from the graph of Ashad 2080 a complex interplay between voltage levels, feeder load, and Charging Station (CS) Load with feeder over a 24-hour cycle has been observed. Initially, voltage levels started at 11.3 kV, coinciding with a feeder load of approximately 5.01 MW and a significant CS Load of 17.48 kW. As time progressed, voltage levels showed minor variations, reflecting the relatively stable feeder load. However, at critical junctures, particularly at 7, 8, 10, and 11 AM, when the CS Load experienced substantial surges, voltage levels exhibited noticeable fluctuations. For instance, at 8 AM, when the CS Load spiked to 64.84 kW, voltage dropped to 11.2 kV, and the feeder load increased to 5.16 MW. These observations underscore the substantial impact of CS Load variations on voltage stability, especially during periods of elevated load demands. Conversely, moments of reduced CS Load, such as 3 PM, saw voltage levels drop to 10.4 kV despite a feeder load of 6.55 MW, emphasizing the intricate relationship between CS Load, feeder load, and voltage in the power distribution system.

Result summary:

- From Ashad 2079 to Ashoj 2079 no any load was connected on the charging station (i.e., Charging station is not operated) so voltage fluctuation on the grid was because of existing household load only.
- It is clear from the whole graph that when charging station was loaded voltage has been fallen down. The effect of charging station load was seen with respect to the percentage contribution on the total load.

4.2 Impact analysis of Charging Station only on feeder (Simulation of Charger)

To evaluate the influence of the charging station on the feeder, we connected the charging station, complete with its load, to the feeder and conducted simulations using the MATLAB Simulink platform. These simulations were executed within the MATLAB Simulink environment, allowing us to obtain valuable insights into the system's behavior.

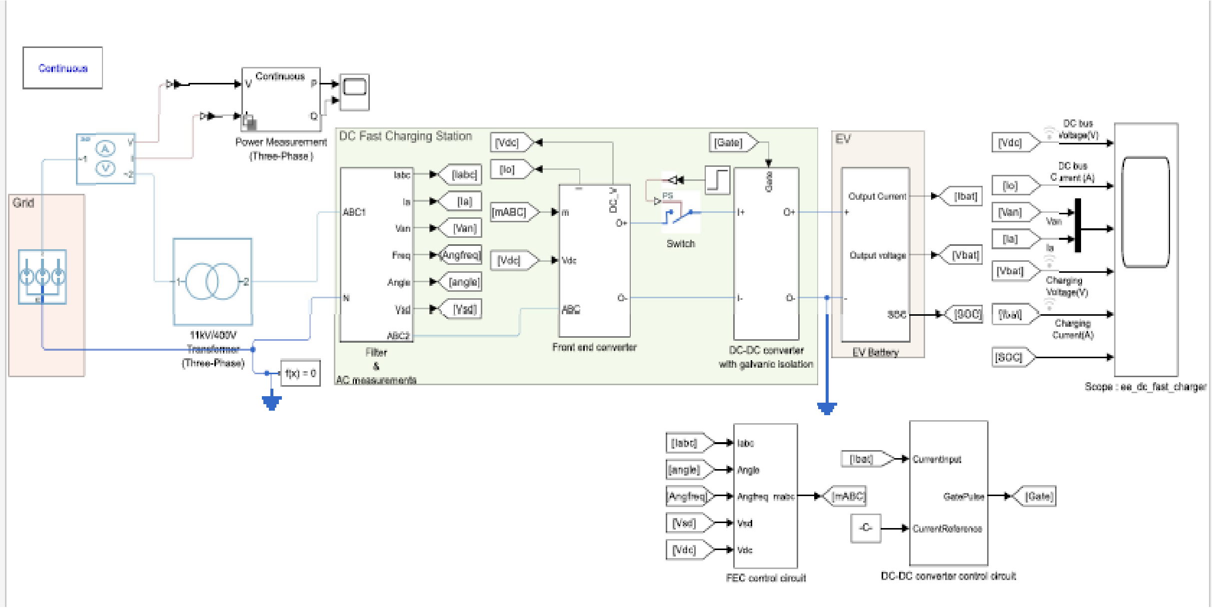


Figure 4-5: Charging station and feeder

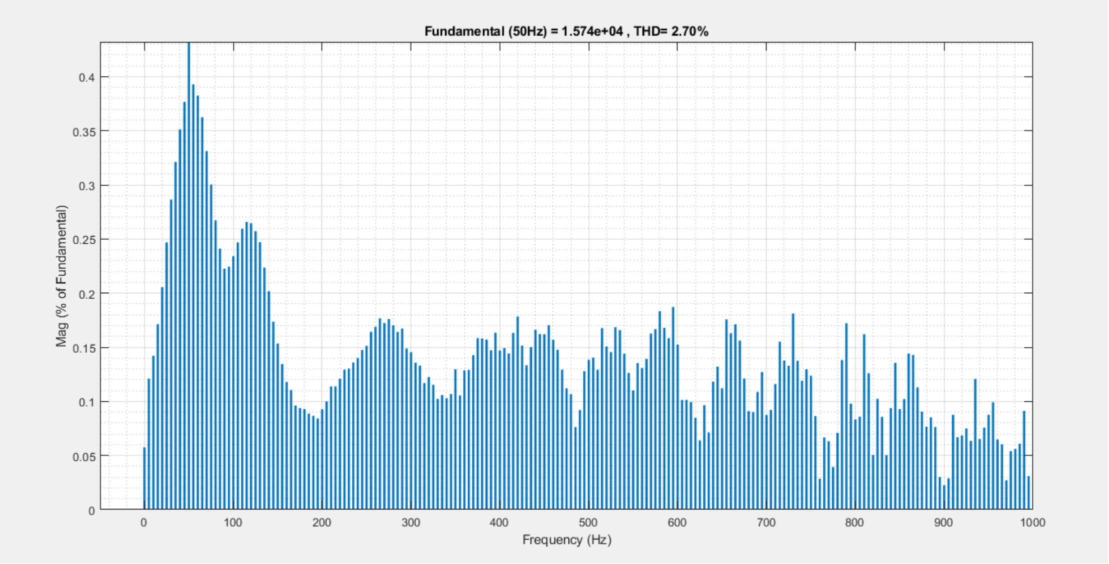


Figure 4-6: THD on grid voltage when CS only in operation

Our simulation results revealed that the Total Harmonic Distortion (THD) of the voltage signal amounted to 2.70%. This discrepancy is primarily attributed to the presence of non-linear loads within the charger situated at the charging station.

4.3 Load flow analysis of Bharatpur 2 Feeder with CS

To conduct the load flow analysis in Bharatpur-2 feeder, which encompasses a total of 29 buses, we designated the feeder as the Slack bus. Furthermore, we assumed that all the transformers connected to the buses were loaded at 69% of their capacity, a value obtained from the load factor of a typical day. Our load flow studies yielded the following results.

	P(MW)	**Q(MVAr)**
Total generation	7.8529	0.2463
Total PQ load	7.6543	0
Total losses	0.1986	0.2463

BUS_1 V= 1 pu/11kV 0 deg; Slack bus

	P(MW)	Q(MVAr)
Generation	7.8529	0.2463

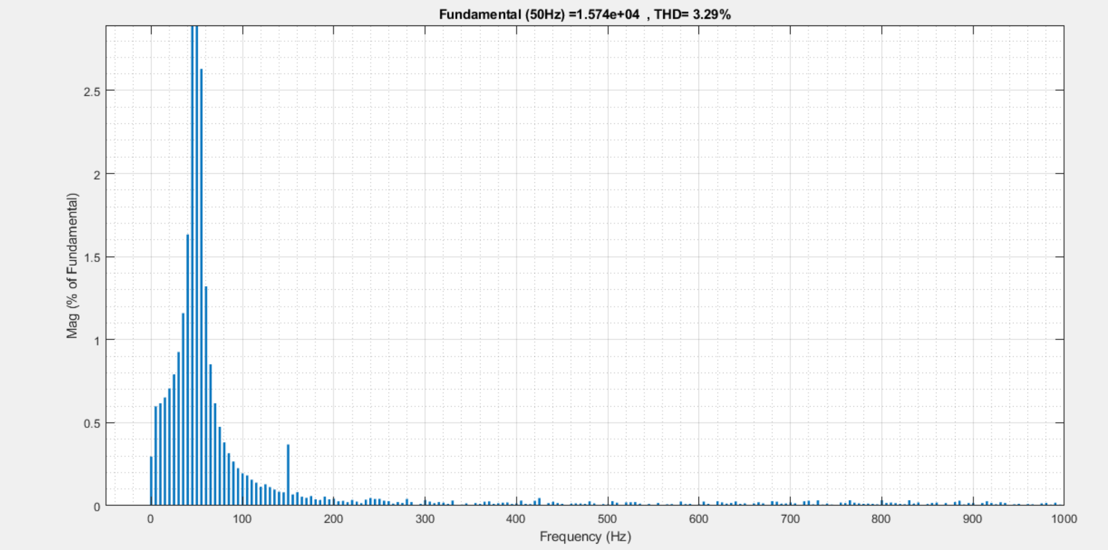


Figure 4-7: THD on grid voltage during load flow with CS

4.4 Load flow analysis of Bharatpur 2 Feeder without CS

Load flow analysis was conducted in Bharatpur-2 feeder, which comprises 29 buses, without the inclusion of the Charging Station. In this analysis, we designated the feeder as the Slack bus, and we assumed that all the transformers connected to the buses were loaded at 69.28% of their capacity, a value derived from the load factor of a typical day. The load flow studies produced the following results.

	P(MW)	Q(MVAr)
Total generation	7.7234	0.2013
Total PQ load	7.5325	0
Total losses	0.1909	0.2013

BUS_1 V= 1 pu/11kV 0 deg; Slack bus

	P(MW)	Q(MVAr)
Generation	7.7234	0.2013

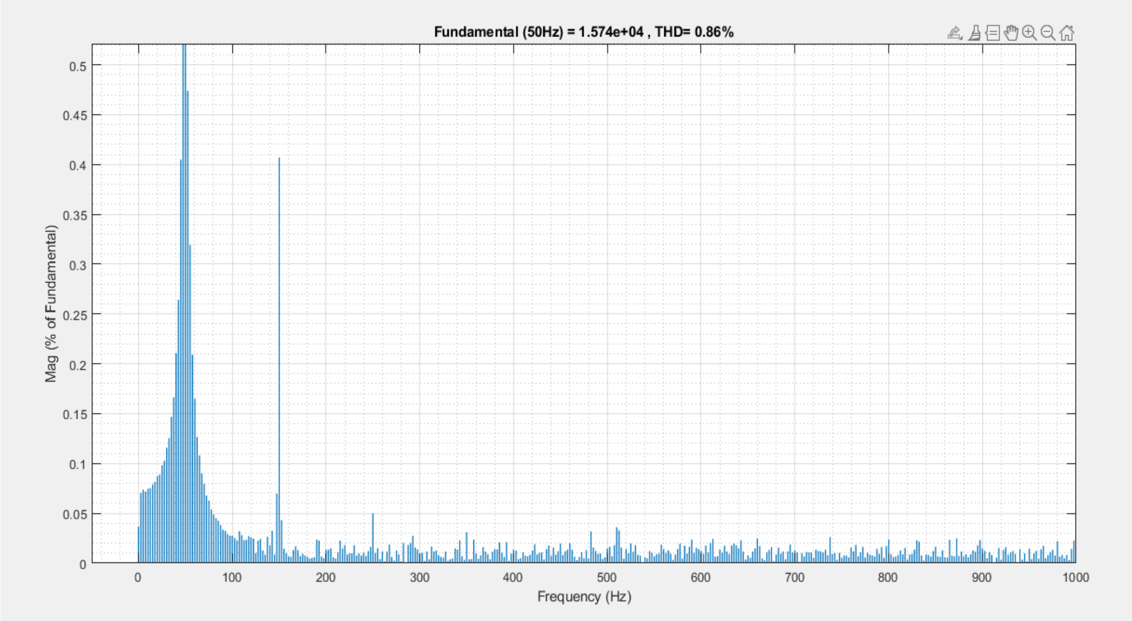


Figure 4-8: THD on grid voltage during load flow without CS

4.5 Load flow analysis of Bharatpur 2 Feeder with assumption of 3 times CS in future

Given the anticipated increase in Electric Vehicle (EV) adoption, we carefully constructed a scenario that involved tripling the load demands. Subsequently, we conducted a thorough load flow analysis simulation, resulting in a comprehensive set of findings.

	P(MW)	Q(MVAr)
Total generation	8.1345	0.3879
Total PQ load	7.9134	0
Total losses	0.2211	0.3879

BUS_1 V= 1 pu/11kV, 0 deg; Slack bus

	P(MW)	Q(MVAr)
Generation	8.1345	0.3879

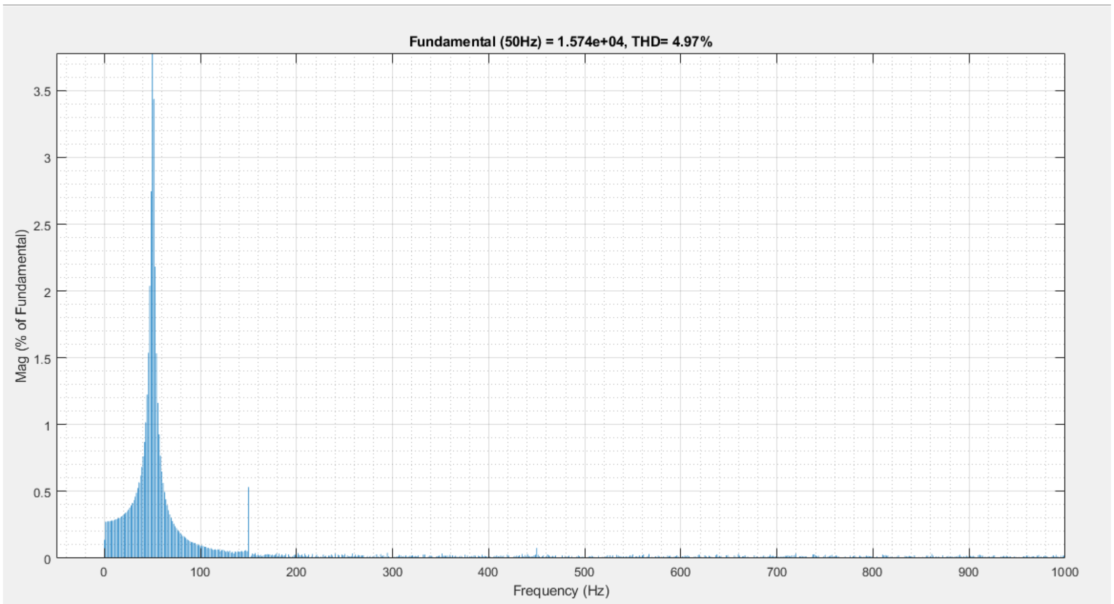


Figure 4-9 THD on grid voltage during load flow with 3 times CS

The results derived from our simulation brought to light a Total Harmonic Distortion (THD) in the voltage signal, measuring at 4.97%. Concurrently, we observed power losses totaling 0.2211 MW and 0.3897 MVAr. The fundamental source of this incongruity can be traced back to the presence of non-linear loads embedded within the charging station's charger infrastructure.

CHAPTER FIVE: CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

- In summary, the study's results and conclusions are based on both graphical and simulation analyses. The graphical analysis focused on the impact of increased load on voltage levels. The findings clearly show that when the charging station was loaded, there was a significant decrease in voltage.
- Furthermore, the effect of the charging station load was assessed in terms of its percentage contribution to the total load. Using MATLAB, we conducted a simulation of EV charging stations integrated into the Bharatpur-2 feeder, and the total harmonic distortion (THD) was determined to be 2.70%.
- Additionally, we conducted a load flow analysis of the Bharatpur-2 feeder without the charging station, resulting in a THD of 0.86% and a power loss of 0.1909 MW.
- Finally, a load flow analysis of the Bharatpur-2 feeder, including the charging station, was performed, yielding a THD of 3.29% and a calculated power loss of 0.1986 MW. These findings provide valuable insights into the impact of the EV charging station on the feeder's voltage stability, harmonic content, and power losses.

5.2 Recommendations

This several important considerations and recommendations can be made based on the study's findings:

- This study focused exclusively on the Bharatpur-2 feeder, and the results may not be generalized to other charging stations.
- To achieve higher accuracy and a more comprehensive analysis, it is advisable to study additional charging stations across various locations.
- Future studies should include charging stations located in peak traffic areas and under different traffic conditions to provide a more effective analysis. This would assist the Nepal Electricity Authority (NEA) in optimizing distribution patterns more efficiently.

- To assess the potential future impacts accurately, it is recommended to analyze the load from multiple charging stations on the same feeder, as this may result in fluctuations in load demand in the near future.

By addressing these considerations and expanding the scope of the study to include more charging stations and varied operating conditions, NEA can better understand and manage the impact of electric vehicle charging stations on its distribution feeders. This knowledge will be essential for planning and optimizing the integration of electric vehicles into the grid.

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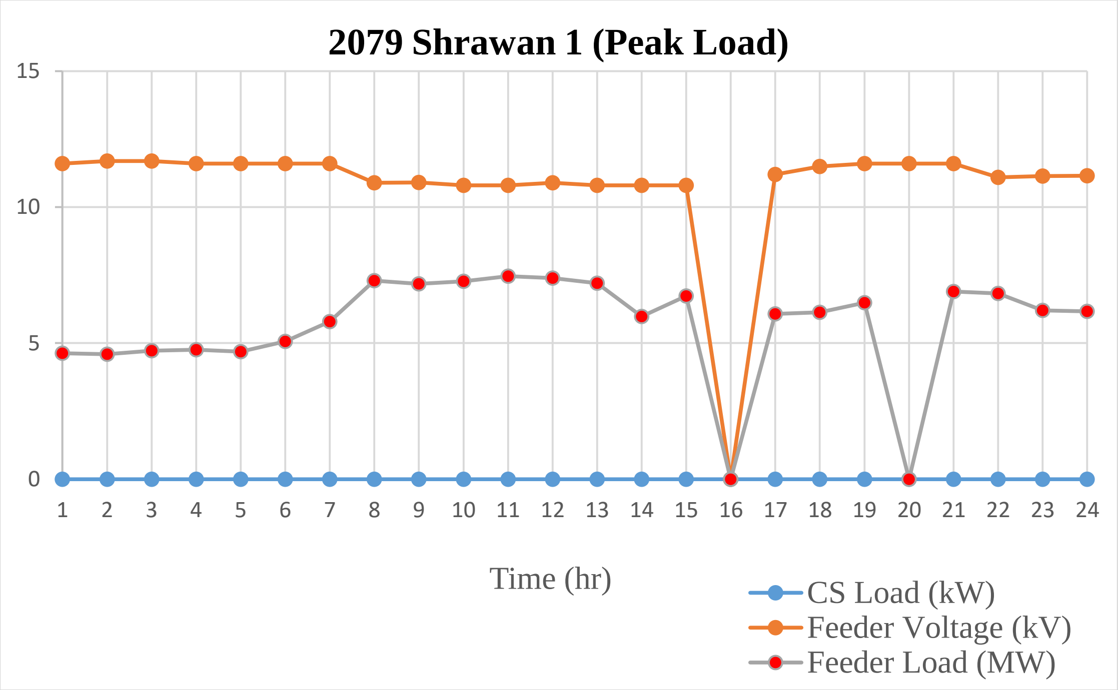
APPENDIX A: Charging Station

APPENDIX B: Data of Bharatpur-2 Feeder and CS

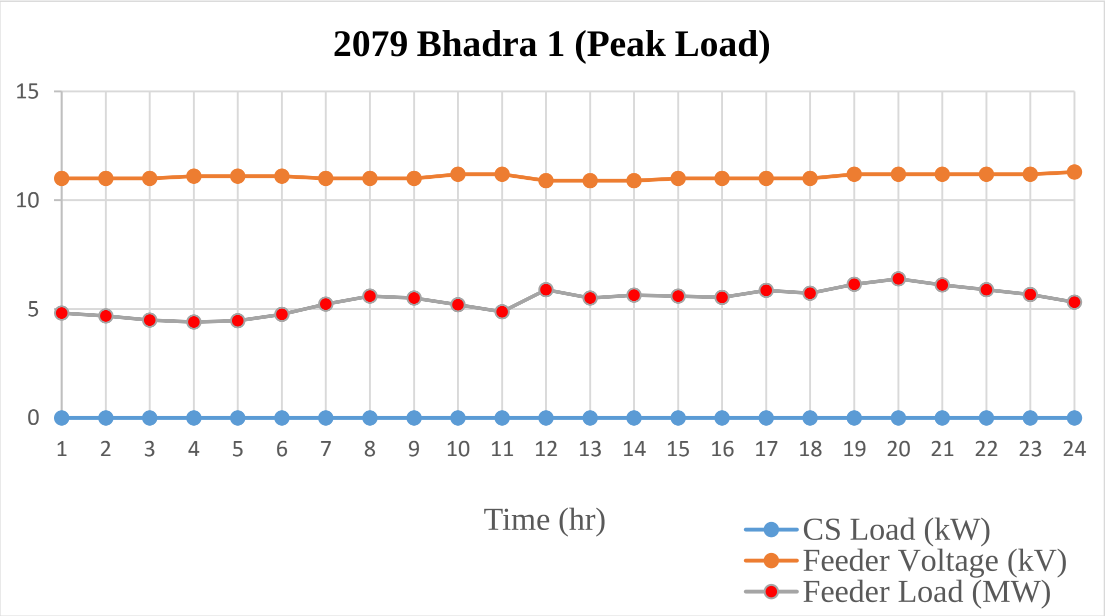
2079 Shrawan 1 (Peak Load)						
Time	**Bharatpur-2 Feeder**				**Feeder Load (MW)**	**CS Load**
	Current (A)			**Voltage (kV)**		
	R	**Y**	**B**			
1	147	147	147	11.6	4.63	0
2	146	146	146	11.7	4.60	0
3	150	150	150	11.7	4.72	0
4	151	151	151	11.6	4.75	0
5	149	149	149	11.6	4.69	0
6	161	161	161	11.6	5.07	0
7	184	184	184	11.6	5.79	0
8	232	232	232	10.9	7.30	0
9	228	228	228	10.91	7.18	0
10	231	231	231	10.8	7.27	0
11	**237**	**237**	**237**	**10.8**	**7.46**	0
12	235	235	235	10.9	7.40	0
13	229	229	229	10.8	7.21	0
14	190	190	190	10.8	5.98	0
15	214	214	214	10.8	6.74	0
16	0	0	0	0	0.00	0
17	193	193	193	11.2	6.08	0
18	195	195	195	11.5	6.14	0
19	206	206	206	11.6	6.49	0
20	0	0	0	11.6	0.00	0
21	219	219	219	11.6	6.89	0
22	217	217	217	11.1	6.83	0
23	197	197	197	11.15	6.20	0
24	196	196	196	11.16	6.17	0



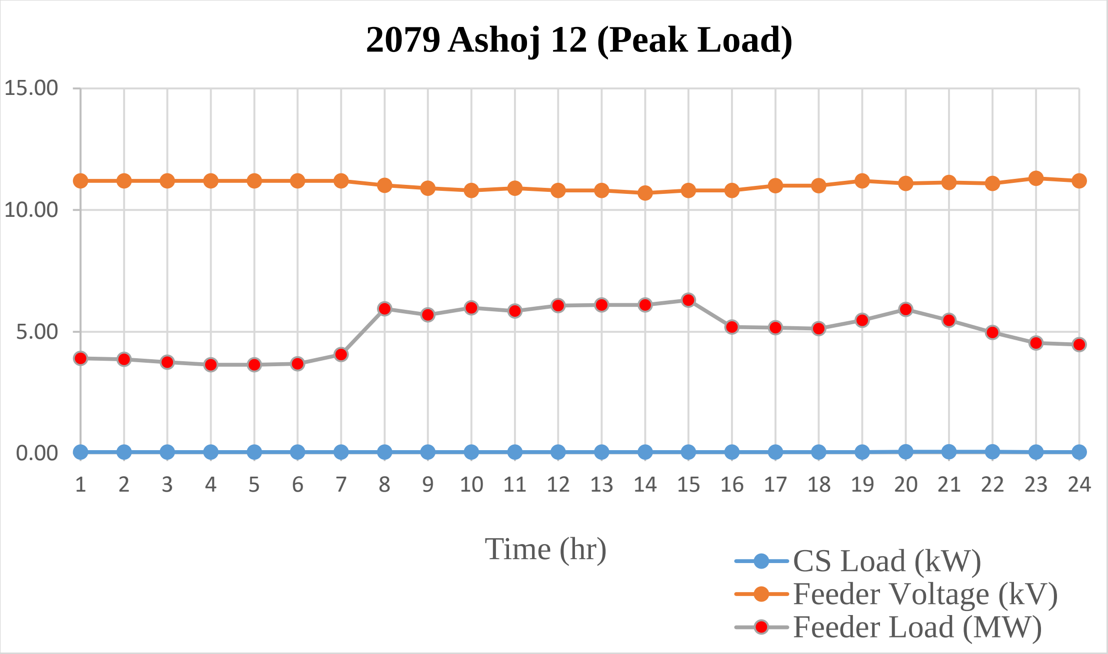
2079 Bhadra 1 (Peak Load)

Time	**Bharatpur-2 Feeder**				**Feeder Load (MW)**	**CS Load**
	Current (A)			**Voltage (kV)**		
	R	**Y**	**B**			
1	153	153	153	11	4.82	0
2	149	149	149	11	4.69	0
3	143	143	143	11	4.50	0
4	140	140	140	11.1	4.41	0
5	142	142	142	11.1	4.47	0
6	151	151	151	11.1	4.75	0
7	166	166	166	11	5.23	0
8	178	178	178	11	5.60	0
9	175	175	175	11	5.51	0
10	165	165	165	11.2	5.19	0
11	155	155	155	11.2	4.88	0

12	187	187	187	10.9	5.89	0
13	175	175	175	10.9	5.51	0
14	179	179	179	10.9	5.64	0
15	178	178	178	11	5.60	0
16	176	176	176	11	5.54	0
17	186	186	186	11	5.86	0
18	182	182	182	11	5.73	0
19	195	195	195	11.2	6.14	0
20	**203**	**203**	**203**	**11.2**	**6.39**	**0**
21	194	194	194	11.2	6.11	0
22	187	187	187	11.2	5.89	0
23	180	180	180	11.2	5.67	0
24	169	169	169	11.3	5.32	0



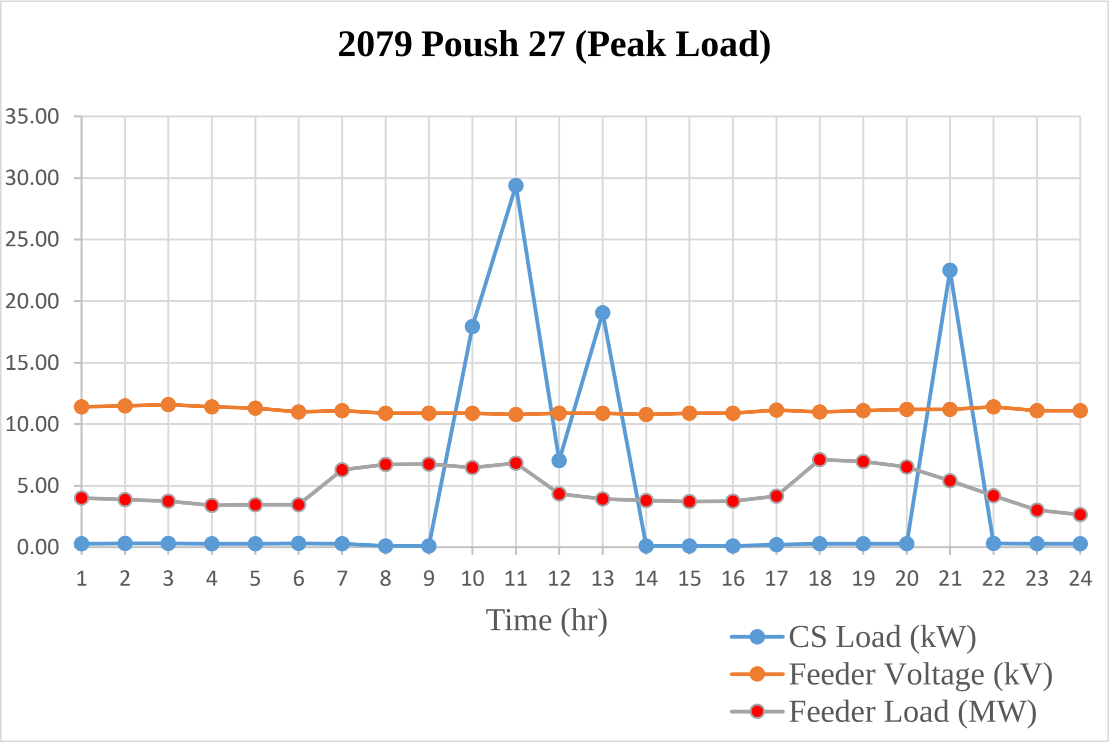
2079 Ashwin 12 (Peak Load)						
Time	**Bharatpur-2 Feeder**				**Feeder Load (MW)**	**CS Load**
	Current (A)			**Voltage (kV)**		
	R	**Y**	**B**			
1	124	124	124	11.2	3.90	0.07
2	123	123	123	11.2	3.87	0.06
3	119	119	119	11.2	3.75	0.06
4	116	116	116	11.2	3.65	0.06
5	116	116	116	11.2	3.65	0.06
6	117	117	117	11.2	3.68	0.06
7	129	129	129	11.2	4.06	0.05
8	189	189	189	11.02	5.95	0.05
9	181	181	181	10.9	5.70	0.06
10	190	190	190	10.8	5.98	0.06
11	186	186	186	10.9	5.86	0.06
12	193	193	193	10.8	6.08	0.06
13	194	194	194	10.8	6.11	0.06
14	194	194	194	10.7	6.11	0.06
15	**200**	**200**	**200**	**10.8**	**6.30**	**0.06**
16	165	165	165	10.8	5.19	0.06
17	164	164	164	11	5.16	0.06
18	163	163	163	11	5.13	0.06
19	174	174	174	11.2	5.48	0.06
20	188	188	188	11.1	5.92	0.07
21	174	174	174	11.13	5.48	0.07
22	158	158	158	11.1	4.97	0.07
23	144	144	144	11.3	4.53	0.07
24	142	142	142	11.2	4.47	0.06



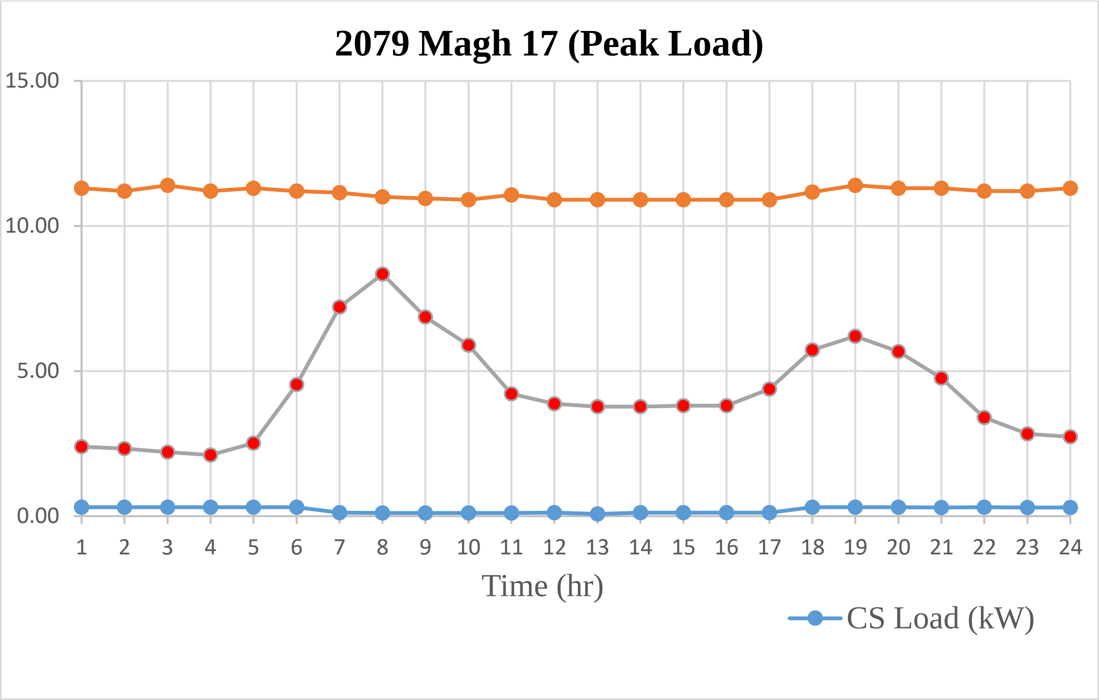
2079 Poush 27 (Peak Load)

Time	**Bharatpur-2 Feeder**				**Feeder Load (MW)**	**CS Load (kW)**
	Current (A)			**Voltage (kV)**		
	R	**Y**	**B**			
1	127	127	127	11.4	4.00	0.30
2	123	123	123	11.5	3.87	0.32
3	119	119	119	11.6	3.75	0.31
4	108	108	108	11.4	3.40	0.30
5	110	110	110	11.3	3.46	0.30
6	110	110	110	11	3.46	0.32
7	200	200	200	11.1	6.30	0.30
8	214	214	214	10.9	6.74	0.11
9	215	215	215	10.9	6.77	0.11
10	206	206	206	10.9	6.49	17.94
11	217	217	217	10.8	6.83	29.38

12	138	138	138	10.9	4.34	7.04
13	125	125	125	10.9	3.94	19.04
14	121	121	121	10.8	3.81	0.11
15	118	118	118	10.9	3.71	0.12
16	119	119	119	10.9	3.75	0.12
17	132	132	132	11.15	4.16	0.21
18	226	226	226	11	7.11	0.30
19	**221**	**221**	**221**	**11.1**	**6.96**	**0.30**
20	207	207	207	11.2	6.52	0.30
21	172	172	172	11.2	5.41	22.51
22	133	133	133	11.4	4.19	0.30
23	96	96	96	11.1	3.02	0.30
24	84	84	84	11.1	2.64	0.30



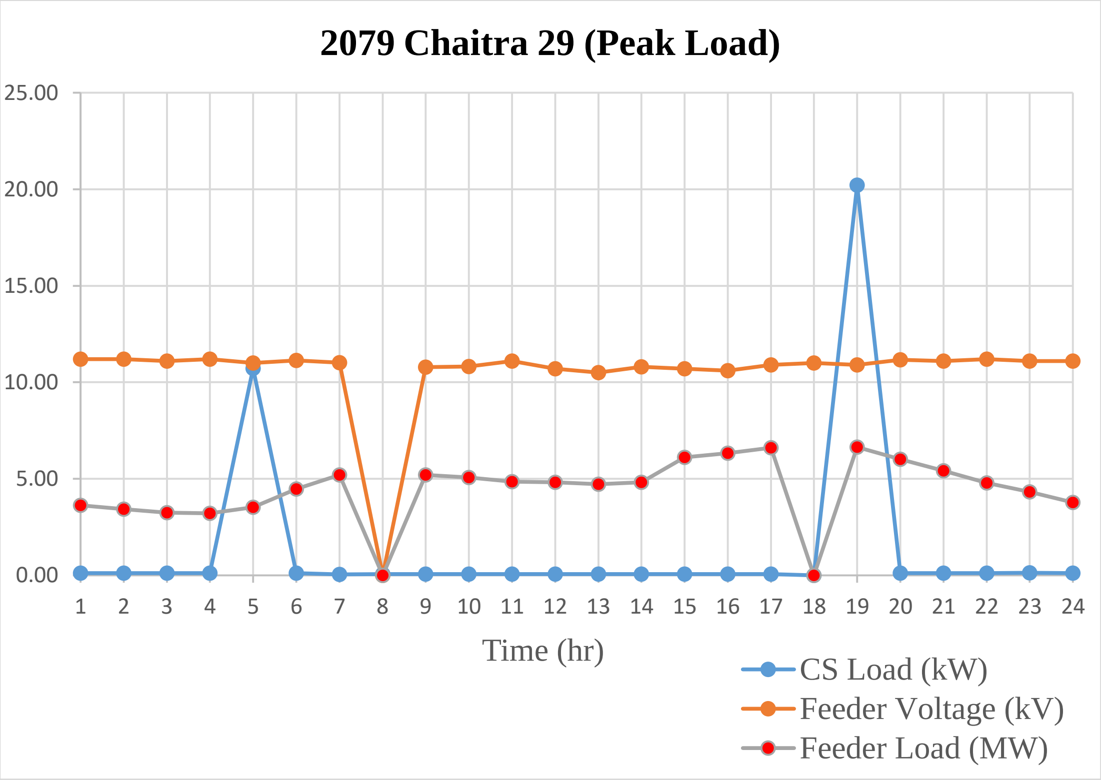
2079 Magh 17 (Peak Load)						
Time	**Bharatpur-2 Feeder**				**Feeder Load (MW)**	**CS Load**
	Current (A)			**Voltage (kV)**		
	R	**Y**	**B**			
1	76	76	76	11.3	2.39	0.30
2	74	74	74	11.2	2.33	0.30
3	70	70	70	11.4	2.20	0.30
4	67	67	67	11.2	2.11	0.30
5	80	80	80	11.3	2.52	0.30
6	144	144	144	11.2	4.53	0.30
7	229	229	229	11.15	7.21	0.12
8	**265**	**265**	**265**	**11**	**8.34**	**0.11**
9	218	218	218	10.95	6.86	0.11
10	187	187	187	10.9	5.89	0.11
11	134	134	134	11.07	4.22	0.11
12	123	123	123	10.9	3.87	0.12
13	120	120	120	10.9	3.78	0.08
14	120	120	120	10.9	3.78	0.12
15	121	121	121	10.9	3.81	0.12
16	121	121	121	10.9	3.81	0.12
17	139	139	139	10.9	4.38	0.12
18	182	182	182	11.17	5.73	0.31
19	197	197	197	11.4	6.20	0.30
20	180	180	180	11.3	5.67	0.30
21	151	151	151	11.3	4.75	0.30
22	108	108	108	11.2	3.40	0.30
23	90	90	90	11.2	2.83	0.30
24	87	87	87	11.3	2.74	0.30



2079 Chaitra 29 (Peak Load)

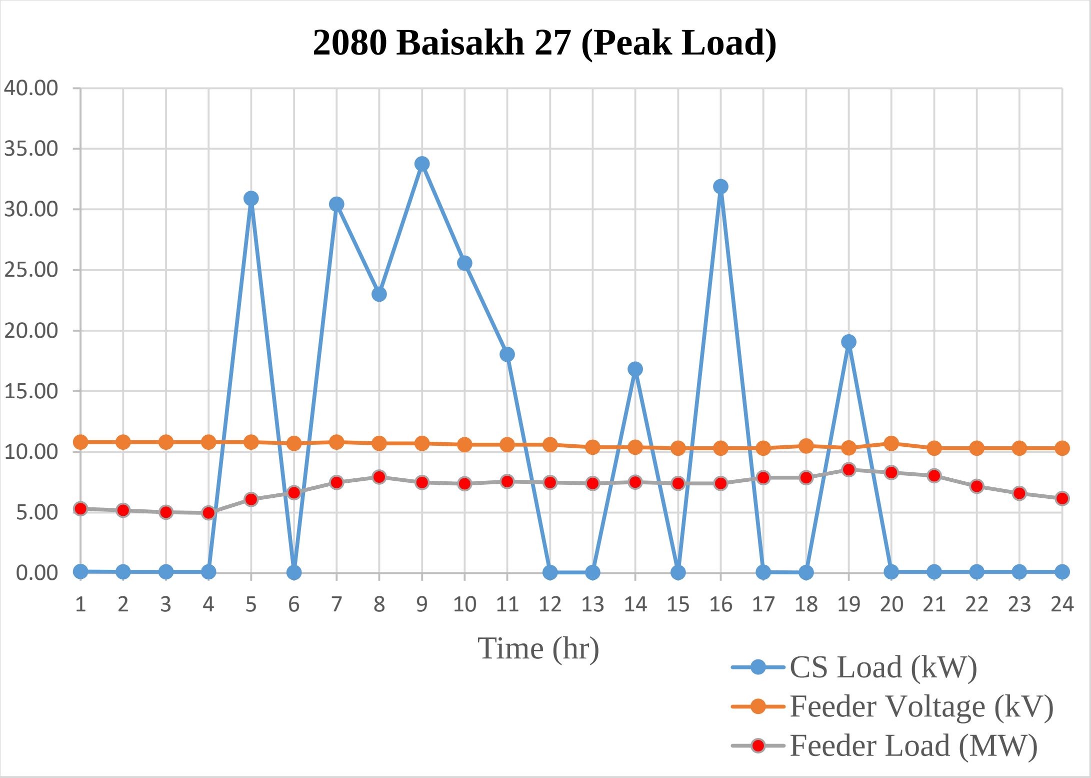
Time	Bharatpur-2 Feeder				Feeder Load (MW)	CS Load (kW)
	Current (A)			Voltage (kV)		
	R	Y	B			
1	115	115	115	11.2	3.62	0.11
2	109	109	109	11.2	3.43	0.11
3	103	103	103	11.1	3.24	0.11
4	102	102	102	11.2	3.21	0.11
5	112	112	112	11	3.53	10.72
6	142	142	142	11.13	4.47	0.11
7	165	165	165	11.01	5.19	0.05
8	0	0	0	0	0.00	0.05
9	165	165	165	10.78	5.19	0.05
10	161	161	161	10.81	5.07	0.05
11	154	154	154	11.1	4.85	0.05

12	153	153	153	10.7	4.82	0.05
13	150	150	150	10.5	4.72	0.05
14	153	153	153	10.8	4.82	0.05
15	194	194	194	10.7	6.11	0.05
16	201	201	201	10.6	6.33	0.05
17	210	210	210	10.9	6.61	0.05
18	0	0	0	11	0.00	0.00
19	**211**	**211**	**211**	**10.9**	**6.64**	**20.21**
20	191	191	191	11.16	6.01	0.11
21	172	172	172	11.1	5.41	0.11
22	152	152	152	11.2	4.79	0.11
23	137	137	137	11.1	4.31	0.12
24	120	120	120	11.1	3.78	0.11



2080 Baisakh 27 (Peak Load)

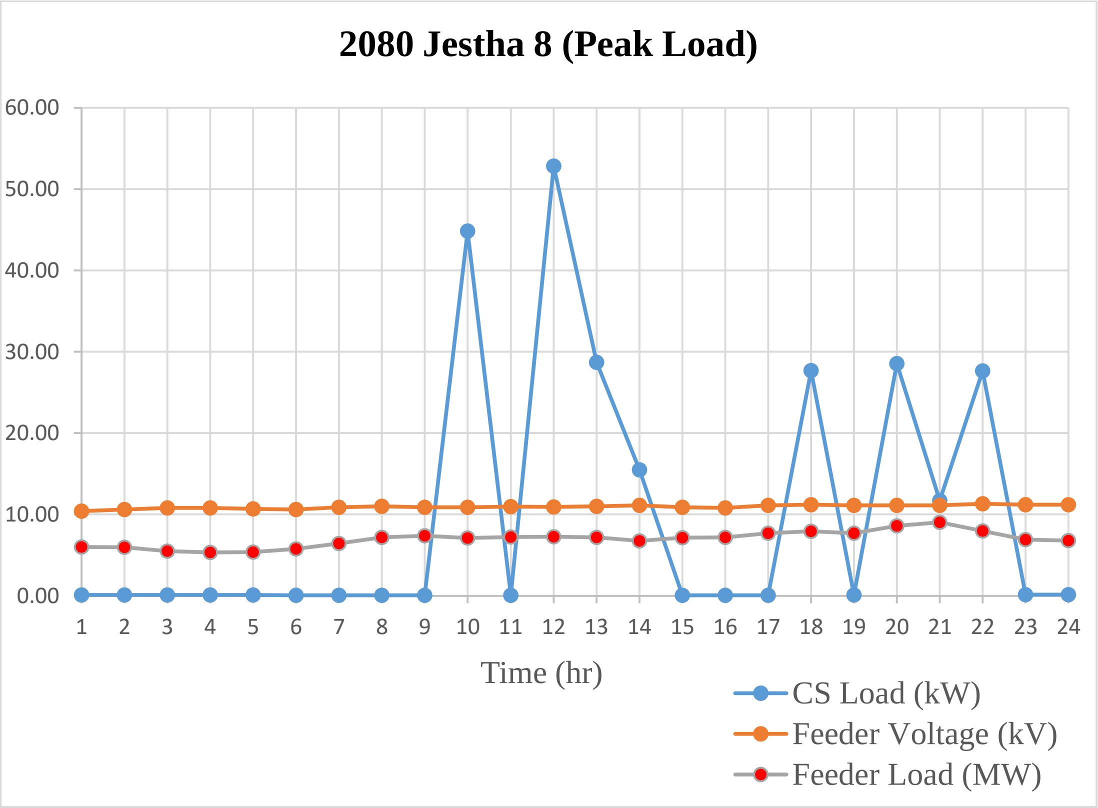
Time (hr)	**Bharatpur-2 Feeder**				**Feeder Load (MW)**	**CS Load (kW)**
	Current (A)			**Voltage (kV)**		
	R	**Y**	**B**			
1	169	169	169	10.8	5.32	0.14
2	165	165	165	10.8	5.19	0.13
3	160	160	160	10.8	5.04	0.13
4	158	158	158	10.8	4.97	0.12
5	193	193	193	10.8	6.08	30.90
6	211	211	211	10.7	6.64	0.05
7	238	238	238	10.8	7.49	30.42
8	252	252	252	10.7	7.93	23.01
9	238	238	238	10.7	7.49	33.76
10	234	234	234	10.6	7.37	25.57
11	240	240	240	10.6	7.56	18.05
12	238	238	238	10.6	7.49	0.05
13	235	235	235	10.4	7.40	0.05
14	239	239	239	10.4	7.52	16.84
15	235	235	235	10.3	7.40	0.05
16	235	235	235	10.31	7.40	31.88
17	250	250	250	10.3	7.87	0.09
18	250	250	250	10.5	7.87	0.05
19	**271**	**271**	**271**	**10.35**	**8.53**	**19.08**
20	264	264	264	10.7	8.31	0.11
21	255	255	255	10.3	8.03	0.12
22	228	228	228	10.3	7.18	0.11
23	209	209	209	10.3	6.58	0.12
24	196	196	196	10.3	6.17	0.11



2080 Jestha 8 (Peak Load)

Time	**Bharatpur-2 Feeder**				**Feeder Load (MW)**	**CS Load (kW)**
	Current (A)			**Voltage (kV)**		
	R	**Y**	**B**			
1	191	191	191	10.4	6.01	0.12
2	190	190	190	10.6	5.98	0.12
3	175	175	175	10.8	5.51	0.12
4	170	170	170	10.8	5.35	0.12
5	171	171	171	10.7	5.38	0.11
6	183	183	183	10.6	5.76	0.05
7	205	205	205	10.9	6.45	0.05
8	228	228	228	11	7.18	0.05
9	234	234	234	10.9	7.37	0.05
10	226	226	226	10.9	7.11	44.84
11	229	229	229	10.96	7.21	0.05

12	231	231	231	10.92	7.27	52.81
13	228	228	228	11.02	7.18	28.71
14	214	214	214	11.1	6.74	15.51
15	227	227	227	10.9	7.15	0.05
16	228	228	228	10.8	7.18	0.05
17	244	244	244	11.1	7.68	0.05
18	252	252	252	11.2	7.93	27.68
19	244	244	244	11.1	7.68	0.11
20	273	273	273	11.1	8.59	28.54
21	**287**	**287**	**287**	**11.1**	**9.04**	**11.70**
22	253	253	253	11.3	7.96	27.66
23	219	219	219	11.2	6.89	0.12
24	216	216	216	11.2	6.80	0.12



APPENDIX C: Load Flow Analysis of Feeder

Impact Analysis of Electric Vehicle Charging Station on Bharatpur-2 Feeder

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