“Different Charging Methods of EV and it’s Impact on Grid”

Major Project Report

Submitted in Partial Fulfillment of the Requirements for the Degree of

MASTER OF TECHNOLOGY

IN

ELECTRICAL ENGINEERING

(Electrical Power Systems)

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Abstract

Integration and integration of electric vehicles (EVs) has a huge impact on the grid. Uncoordinated charging, i.e. charging EVs without considering the grid or restrictions, can create problems for grid safety and reliability. It can lead to the highest demand, the ability to publish electronic products and local plans. In addition, if payments are made mainly during periods of high carbon emissions, inconsistent payments can result in the unavailability of renewable energy and increased emissions of carbon monoxide gas filled with electricity.

Coordinated charging, on the other hand, includes intelligent management and optimization of EV charging according to grid and user preferences and has many advantages. It allows many electric vehicles to be connected to the grid without major interruptions. Shared payment can eliminate peak demand by incentivizing payment during the missed period when capacity is overloaded. This will help reduce the need for expensive powerline installation and additional infrastructure investment.

In addition, coordinated charging can facilitate the integration of renewable energy by integrating EV charging with the timing of renewable energy. This not only reduces dependence on fossil fuels, but also promotes the use of clean energy and reduces greenhouse gas emissions. The integrated system can also include customer preferences such as desired departure time and battery requirements, making the job easier and more convenient for EV owners.

As a result, uncoordinated EV charging can strain the grid and affect the environment, while co-charging has the opportunity to mitigate these issues. By using technology in conjunction with a grid management plan, integration can improve grid security, improve energy efficiency and promote the integration of renewable energy. Policymakers, utilities and EV owners must collaborate and implement joint solutions to get the most out of EVs while minimizing the impact of grid quality.

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Chapter 1

Introduction

1.1 What is EV?

- An electric motor powers an electric vehicle (EV), compared to an internal combustion power-generating machine that uses fuel and petroleum.A vehicle that appears to have one or more electric motors as a component of its propulsion system is termed to be an electric vehicle (EV). As an outcome, such a vehicle is being taken into account as a possible replacement for current-generation cars in order to address concerns such arising pollution, global warming, the depletion of natural resources, etc. The proposal of electric vehicles has been around for a while, however over the last ten years it has received a lot of attention because of the increasing carbon emissions and other adverse environmental impacts of fuel-powered vehicles.

1.1.1 Impacts of EV

- Vehicles may be used for transportation, but they also have an impact in many other areas. As a result, the change in the automotive industry brought about by EVs has a significant effect on the electrical systems, the environment, and the economy. Due to the advantages, they offer in each of these areas, EVs are becoming more and more popular, but they also have certain drawbacks. On the power grid, the ecology, and the economy, the implications of electric cars are shown in Fig. 1.

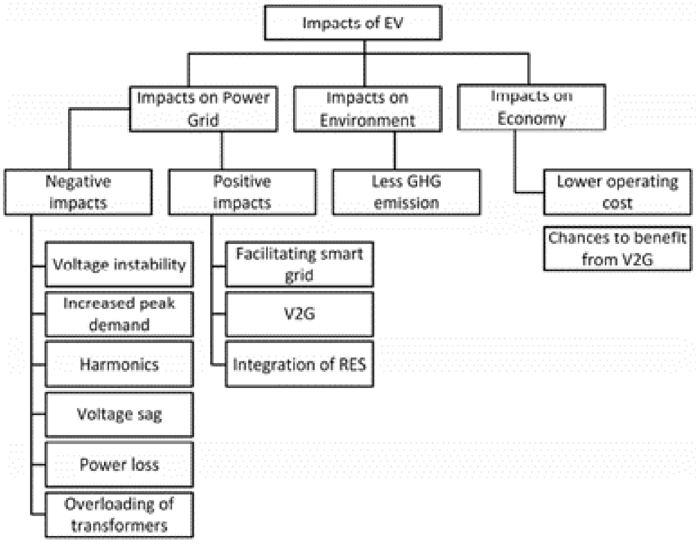


Figure 1.1: Impacts of EV

1.1.2 Impact on Grid

Unfavourable Outcomes

- High-power loads in the power distribution network, in particular the transformers, wires,fuses, are thought to have an effect on EVs. The use a 24-kWh battery combination, a Nissan Leaf may use as much energy as one European home. In a 220 V, 15 A system, a 3.3 kW charger can increase current consumption by 17% to 25%. If charging occurs during peak hours, the situation can become highly dangerous as a result of system overload, equipment damage, tripped protection relays, and a rise in infrastructure costs. Uncoordinated, uncontrolled, or dumb charging are all terms used to describe charging without any consideration for when you will be pulling electricity from the grid. As a result, there could be a spike in the amount of EVs running during peak hours, which could give rise to a load imbalance, a less requirement of power, instability, a decline in acceptable, and a decline in source quality.Due to higher power losses and generation costs, the penetration of EVs can cause voltage variations in the updated standard IEEE-23 kV distribution network below the 0.89 p.u. threshold up to 0.82 p.u.

- The power system is not severely affected by stage-1 charging at a 110-V soket, but issues start to appear when the charging voltage rises. It can be comparable to putting numerous homes to the network to add an EV for quick charging. Although the distribution networks are built with a certain number of households in mind, a sudden addition of such enormous loads can frequently cause issues. The grid is likely to be able to survive it. Manufacturers now routinely reduce charging times to set their vehicles apart in the EV market, but doing so demands greater voltages than ever.

- Therefore, using low charging voltages to mitigate the negative impacts is unlikely. Coordinated charging, also known as regulated or smart charging, must be implemented in order to prevent these consequences and offer effective charging using the current infrastructure. In this plan, the EVs are charged at times when there is less demand, such the hours after midnight. These kinds of strategies might provide a lot of advantages. Additionally, it suddenly surges the load in the load profile valley regions, limiting the summation of additional load during peaktime and enabling a more efficient use of the power plants. Smart charging solutions can lower distribution system investment costs by 60% to 70%. The primary issues with power systems are caused by:

- **Unstable voltage:**

- Typically, power systems are run at or close to their stability limit. Due to the nature of the load, such systems are susceptible to voltage instability, which can result in blackouts. EV loads use a lot of power quickly and have nonlinear characteristics that set them besides If the EVs exhibit constant impedance load characteristics, the grid may be able to handle multiple EVs without experiencing any instability. The addition of several EVs at once may violate distribution limitations since the loads for EVs cannot be predicted in advance, making their power usage unpredictable. Appropriate modelling techniques are necessary to accurately predict these loads. A well-planned charging system, adjusting the tap settings of transformers, and using the issue can be resolved by utilizing control mechanisms such as fuzzy logic controllers to estimate.

- **Harmonics:**

- Harmonics, or high frequency current and voltage components, are created as a result of the nonlinear nature of EV charger characteristics.To assess the number of harmonics in a system, one can utilize the measurements of total current harmonic distortion (THDi) and total voltage harmonic distortion (THDv). Harmonics can reduce the quality of the power by changing the voltage and current waveforms. Additionally, it puts a strain on fuses, cables, and other parts of the power system. When using slow charging, the existing cabling can handle 25% of EV penetration, but only 15% when using quick charging. Current flow in the neutral wire can also be caused by harmonics and voltage imbalance. To ascertain the consequences of harmonics generated on by EV penetration, numerous strategies have been used. Pulse width modulation can be used in EV chargers to decrease, if not completely eliminate, harmonics. With the use of supply system filtering equipment, high THDi can be avoided.

- **Voltage Sag:**

- Voltage sag refers to a decrease in voltage lasting for a duration of half a cycle or one minute. Overloading of electrical equipment or the initial startup of electric machines are common causes of voltage sag. In such circumstances, the implementation of distributed generation becomes advantageous. This involves utilizing energy generated at residential locations through sources like PV cells or CHP plants to charge electric vehicles. The adoption of distributed generation can effectively mitigate losses and offer significant benefits.

- **Overloading of Transformers:**

- Transformers utilised for distribution are directly impacted by EV charging. Transformer ageing rates can be enhanced by the additional heat produced by EV loads, although this also relies on the surrounding temperature. The amount of ageing brought on by temperature is little in parts like Vermont where the weather can frequently be chilly. When determining a transformer's lifetime, the speed of EV level, the start of charge, and the required temperature are all taken into account.

- The amount of harmonics and voltage imbalances will increase in the case of a significant penetration of EVs into the grid, which will worsen power quality. Positive Results Positively, there are numerous ways that EVs can help the electrical grid.
- **Smart Grid:**
- The grid design is combined with smart communication and decision-doing in the grid system. The smart grid widely recognised the power grid of the future and offers a wide range of benefits to provide dependable power supply and sophisticated control. With such a system, it is simple to achieve the highly desired coordinated charging because user interaction with the grid system is made very simple.Opportunities like V2G and more renewable energy integration may be made possible by the connection between EVs and the smart grid. In fact, EV is one of the eight objectives for creating a successful smart grid.
- **Car2G:**
- Car to grid, is a way by which an EV can supply the grid with energy. When they are drawing energy, the vehicles in this system function as loads. However, when they are providing energy back into the grid, they can transform into dynamic energy storage.During coordination of charging (V2G), EV packs are put in the valley score points of the load profile; Electric cars can provide electricity during peak hours. The implementation of V2G is made possible by the smart network technology. By leveraging the capabilities of the smart network, Electric vehicles can serve as stationary loads or dynamic energy storage systems, enabling the possibility of unidirectional or bidirectional power flow.Similar to the coordination of charging arrangements, in a unidirectional system, electric vehicles are charged during periods of low load, but in a network-managed approach, the system autonomously determines the optimal time to charge the vehicles. This technology allows vehicles to be plugged in at any time, while the system takes charge of deciding when it is most advantageous to initiate the charging process. Smart metres are necessary to make this system functional. The grid can receive power from moving vehicles thanks to the bidirectional mechanism. In this case, vehicles that employ this system will draw energy from storage and send it to the grid as needed. There are several

compelling features of this approach. Energy storages are becoming increasingly necessary to deal with the intermittent role of renewable power sources (RES) on the grid, but they are quite expensive. EVs have energy storage systems, and they frequently go unused for extended periods of time. This concept can be illustrated by the cars parked at office buildings' parking lots, where they remain idle until the end of the workday, or by seasonal vehicles, such beach buggies. Studies have also shown that parked cars remain there two-way charging needs chargers that must provide electricity flow in two directions. To gain deeper insights into real-time unit charging and assess the impact of the actual cost associated with charging or discharging at specific times of the day, it is essential to track the utilization and sale of units through the implementation of smart meters.

- **Including Renewable Energy Sources in your Approach:**

- With EVs in the mix, renewable energy utilisation will become more succesfull.Owners of EVs can generate power to boost(charge) vehicles using RES. Parking lot rooftops offer for the installation of solar panels that can power the grid in the event of excess generation while also charging the cars parked below. This will support the expansion of commercial local installations.This structure also makes it possible togive excess power to the network, such when cars is in hault position and the system anticipates the owner won't require the until after a specific period. This helps incorporate RES for EV charging as well as to the grid. Increased wind energy penetration may be made possible through V2G.

1.1.3 Merits and Demerits

- **Merits:**

- **B**etter to Run: Compared to a petrol or diesel vehicle, the cost of operating an EV is substantially lower. Your car runs more efficiently on electricity than on petrol. Therefore, even if many EVs currently cost more to purchase than their petrol or diesel counterparts, annual fuel expenditures will be lower. The price of maintenance is likewise lower. Electric cars often have fewer moving items. This implies:

- Changeable components like brake, pads required less maintenance.

- The car will remain off the road for a shorter period of time because services or repairs are frequently straightforward.

- The expense of servicing shouldn't exceed a straightforward checkup.

- **Environmental Advantages of Electric Vehicles:** Since EVs have less of an adverse effect on the environment, many people are drawn to them.

- **Better Driving:** Driving an electric vehicle is safer and more comfortable. This is due to two key factors:

- EVs are responsive when you put your foot down and incredibly silent on the road thanks to their electric powertrain.

- The capacity and distribution of the battery produce a less mid of gravity, which improves comfort & handling.

- **Solid Re-Sale Value (SRV):** Once you leave the showroom, the major of new car lose any of the value. Amazingly, some electric vehicles do not have problem. Their asset decreases gradually than that of gasoline-powered cars, and in very rare circumstances, it may even increase1! Additionally, Electric cars are not likely to cost less than a original price due to the high value of their batteries. No concern on how much old or how far miles it has driven, you won't be able to find a Nissan for not more of £5,000.

- **Cut Down on Noise Voice:**Who hasn't been irritated by an annoying car or motorbike? Electric cars must help to lessen this anti-social component because they are naturally less producing sound than petrol and diesel cars. In fact, they are so quiet that a new law requiring EVs to have an Acoustic Vehicle Alert System (AVAS) has been passed. These emit an artificial noise to draw attention from onlookers when reversing or travelling at less than 12 mph. EVs' moderate hum, which is good news to both rural areas and inner areas, is extremely helpful for reducing both noise and air calamities.

- **Accessable and Practical Charge:** With an Electric car, the world is your group—or it soon will be, as numerous municipal governments begin to increase their public charging infrastructure.It implies that you can put in charge an electric car wherever there is a compatible area or outlet, saving you the trip to the petrol station.

- **Demerits:**

- Although the government's charge-in allowance lowers the prize of many Electric car to levels comparable to those of their oil or diesel counterparts, the fees can frequently still be higher.

- Selection of Electric car is now limited and might be wider. But as the 2030 prohibition on the sale of new oil and diesel cars draws closer, solutions will only get better and more numerous.

- They can be challenging to charge. When it goes to an Electric cars range, individuals who frequently travel great distances are still very cautious. This has to do with the charging infrastructure that exists in the UK today, as was already mentioned. The good news is that more and more charging stations are popping up around the world.

1.2 Market Scenario

Table 1.1: Market Scenario

Estimates put the number of electrified vehicles produced in 2019 at 6 million, with that number expected to rise to 16 million in 2023.
Most places have inadequate facilities for charging devices.
Between 2018 and 2026, the production of new EV charging equipment will grow at a compound annual growth rate of 22%.
The majority of charging takes happen across several hours at home or at work (AC charging)
Customers want charging times that correspond to the duration of long-distance gasoline stops (DC charging).
To facilitate rapid charging, DC chargers' voltage and power output are rising.
Business models are shifting; increase the value of property

Chapter 2

Literature Survey

- In paper [1] In mentioned paper, a level two cork-in hybrid electric car (PHEV) battery socket charging is presented with a unique power factor correction scheme.To do less overall size of charger, the amount of time PHEVs need to charge,cost of energy consumed by the system, a topology with high efficiency is required. For this design, a complete analytical model is also provided that enables guessing of the topology power losses and performance.Testing,modelling outcomes are investigated for a dc-dc converter that can change any given ac initial voltage (85-264 V) to 400 V dc output up to 3.5 kW load. The study results suggested a peak efficiency at switching frequency of 75 kHz, 265 V, and capacity of 1.3 kW. They also suggested a pf more than 0.98 between 745 W and 3.5 kW, a THD not more than than 5% from only half capacity to peak capacity, and a THD not more than than 5% overall.

- In paper [2],The single-phase on-board two way plug-in electric car (PEV) charger showed in current study may help the utility grid's reactive power requirements in addition to charging the car's battery. Two phases of the topology are full-bridge ac-dc boost topology and a half-bridge two way dc-dc converter. The battery can work in two parts of the apparent power plane and has five operating slots: charging-only, charging-capacitor, charging-inductive, capacitive-only, and inductor-only.Additionally, this research presents a controller for adhering to utility apparent power requirements in a smart network scenario.

- In [3],In order to account for active electrical consumption, the author suggests an electric vehicle (EV) battery charging station that injects active electricity from a multi directional car to grid (V2G) charger into the network.As a result, it is possible to reduce transformer overloading and raise voltage levels. Using a unique control strategy, bidirectional electric car chargers are handled.The charger has a two-level bidirectional power converter with a buck-boost converter in the second stage and an AC-DC topology in the first level for keeping a constant DC link voltage. The dc-dc converter handles the grid to car (G2V) charging and the grid to car (V2G) discharging processes. The switching of the charging station's bidirectional DC-DC converter modules controls the constant current charging and variable current draining of the EV battery. The effectiveness of the dual controller prototype with the current ling approach is confirmed by simulation in the software under various load circumstances. The in charge method considers both steady charging and discharge.

- In paper[4], The popularity of various cars is rising, including plug-in hybrid electric automobiles. Batteries for this plug-in hybrid cars must be charging at household using a regular electrical case or on a parking lot belonging to a business. The effect of this increased electrical loads on the network is measured in terms of power misplacement and swing of voltage. When plugged in, the vehicles begin to charge instantly, or if the charging is not coordinated, after putting start delay. This inefficient usage of power at the regional level could cause problems for the grid. So, in order to decrease power misplacement and raise original source load factor, coordinated charge would be advantageous. By preventing power loss, the best charging profile for plug-in hybrid electric cars is calculated.

- In[5],Electric cars power converter and fast charging network designs are presented. Presenting and contrasting the results of simulations for various power converter topologies. When charging the battery of an electric car, safety precautions and the amount of time the battery requires to charge must be considered. Power quality problems, such as a poor power factor, may occur due to voltage harmonics and current harmonics. Applying power factor correction technology is one potential cure for the low power factor problem.

- The suggested method in [6], can now model various EV charging flow as well as the output source of various solar panels with various methods and inclinations. The suggested approach can be used in extensive distribution networks and is simple to implement. Without incorporating the issues with time-series research, the PV production and load consumption uncertainties were modelled. The maximum solar panel penetration that will not force the voltage outside of the typical type without the installation of EESS was 34 percent, or 1.8 kWp per customer. To calculate the EESS capacity necessary to stop network overvoltage, simulations were run.

- In [7] according to the author, there are many power quality concerns as electric car inclusion into the distribution network has been growing progressively. The current study examines the effect of inclusion of electric cars into distribution systems and shows potential poor operational outcome, such as overloading of feeders & transformers, poor voltage profiles, large system losses, and operational expenses. Two synchronised and uncoordinated charging systems are employed to achieve electric car inclusion for two EV penetration levels—20% and 100%.

- in [8],The creation of plug-in hybrids has been a very attractive area of study. Most PHEV-related studies that have been published in the past focused on analysing generational effects. The other facets of PHEV research are assessing how well the residential distribution system can accommodate PHEVs. This study covers this topic since it is crucial to comprehend the effects of integrating PHEVs into the distribution system of the electrical grid. The way that local distribution grids are used will alter depending on where and when the vehicles are hooked in. This study's goal is to assess how different charging procedures for PHEVs affect the residential distribution network.

- In [9],This study's objective is to determine the effects of quick charging stations in their current operational configurations, especially in grid-to-car (G2V) mode, if or not they are run in coordinated mode. On the other hand, to decide which tokk out is best for a given application, the effects of the vehicle-to-grid (V2G) mode are examined at various dispatch levels. A crucial component of infrastructure for the requirement of the electric car sector is battery charging facilities.

- in [10],The author talks about a thorough model to examine how PHEVs affect residential distribution systems. As a result, the fundamental characteristics of PHEVs, including battery withstand,percentage of charge (SOC), and energy requirement during everyday travel, are correctly predicted. From linked public sources, the all over number of cars in a home distribution scheme, the anticipated degree of PHEV levels, the distribution of PHEVs within the network, and the anticipated growth in household load are all obtained. The proposed PHEV model takes into account the activities and interests of the car owner because some of these useful characteristics depend on their behaviour.

- In paper [11],The current study lays out the battery charge program for electric cars. When charging an EV's original battery bank,safe operations and time for must be taken into account. The battery socket charger must also be able to handle high power capabilities. Consequently, a three-phase AC-DC boost topology may be supplied as the battery charger for EVs. For applications requiring systems with higher power than a few kW, LCL-filter is preferable over L-filter. For the battery charger to be developed, the battery charging algorithm needs to be properly chosen, taking into account all of the battery kinds, capacities, and applications. (CC-CV) facility charging has traditionally been used to ensure the operation safety of the battery.

- In paper[12], contrast to earlier proposed solutions, the acceptable voltage-feedback controller for a on-board car socket charger is investigated in this study. It does not necessitate actual-time communication for the car and the system. The mentioned controller makes a comparison between the network voltage at the charging location and a predetermined estimated voltage. As the network voltage move towards this standard, EV charging decreases. The low charging flow takes into account both the user's preferred end-of-time charge (ETC) and the percentage of charge of the car battery. Full simulations are performed on a distribution network with& without voltage controlling technologies to test the proposed control structure. According to simulation data, this approach can prevent network voltage breaches that will else wise be brought on by car charging.

- In paper[13] in requirement to calculate the effects of PEV charging on circuits, a realistic load flow scheme related on simulations is given. A probable simulation of plug-in-cars driving and charging is combined with a probabilistic customer demand model. Investigated are three showing circuits. Presented are the effects on the circuits highest demand, energy consumption, secondary transformer extra loading, and bus voltage downfall. PEV penetration will be higher when smart grid technologies are integrated since charging might be moved to when there is less demand. Even on overloaded networks, this can be performed without significantly expanding the network infrastructure.

- In paper [14],the number of cork-in electric cars worldwide is estimated to grow dramatically in the near time. Despite the benefits indicated above, electric utilities face a number of brand-new difficulties as a result of the integration of PEV with the power grid. This study offers a thorough method for assessing the effect of various Plug-in-cars penetration levels on distribution scheme investment& additional power losses. The suggested scheme is on analysis of two actual distribution areas using a large-scale distribution planning model. The obtained results demonstrate that, in the absence of PEVs, the necessary network reinforcements can amount to up to 19% of the overall actual network expenses, depending on the projected levels of driving and charging during peak hours.

- in paper[15,tThe rising use of EVs has raised the demand for electricity, which is projected to have an impact on how well energy distribution systems function. The effects of uncoordinated vehicle charging in (LV) schematic are investigated in this paper, and a fuzzification power management strategy for coordinating vehicle charging in Less Voltage networks is shown. This is the first time that the distance between vehicles and transformers has been factored into fuzzy management systems.The initial approach investigates the maximum permissible capacity for EV charging in a case study network, taking into account the impact of household loads on the grid. In a series of simulation situations, the second method looks at the quantity of network under voltages and line ampacity violations. The output of the given approach demonstrate that the maximum number of charging EVs is significantly influenced by the distance of the EVs from the network substation.

- In [16],To enhance the duration of EV charging and reduce limitations such as voltage magnitude, three-phase voltage distortion, and transformer capacity violations, efforts are made to optimize the charging process, this study offers adaptive car charging scheduling framework. Convenience for EV users is taken into account, and EV charging costs are minimised. For vehicle charging scheduling approximation, DC power flow based optimisations are provided, and Parallel AC power flow verification is utilized to validate the scheduling results. The schedule gap of dc and ac model is further proposed to be fixed using an incremental feasibility improvement technique.

- This study examines the effects of integrating EVs into distribution systems and emphasises potential poor operational performance, including overloading of feeders and transformers, decreased voltage profiles, increased system losses, and operational costs. For two vehicles case levels 25% and 100% two charge methods—coordinated and uncoordinated—are used to achieve EV integration.To find out how EV case and coordinated affect voltage output, feeder and transformer loads, network losses, operating costs, voltage output, and regular load graphs, simulations are run. According to the simulation's findings, the penetration levels of EVs have a significant impact on network, uncoordination charging has a not positive impact on system activity, and coordinated charging lessens those not positive effects.

Chapter 3

Different Charging Methods

3.1 Different Methods

- **Constant Voltage:**

- Transformer which steps-down from the mains and rectifier, which provides the DC voltage required to boost the battery, make up a similar voltage charger, a DC power generator. It's common for inexpensive car battery chargers to feature such plain designs. In vehicles and source backup power systems, constant voltage charging are frequently utilised with lead-acid batteries.Furthermore, constant voltage systems, which are often more complicated and contain additional circuitry to preserve the batteries and the user's safety, are routinely used with lithium-ion cells.

- **Constant Current:**

- When the battery voltage reaches the level of a full charge, constant current chargers turn off in order to maintain a constant current flow. For nickel-cadmium and nickel-metal hydrate cells or batteries, this architecture is typically employed.

- **Trickle Charge:**

- The purpose of trickle charging is to offset the battery's natural self-discharge. perpetual charging. For standby use, long-term constant current charging. The frequency of discharge affects the charge rate. Not appropriate for some battery chemistries, such as NiMH and Lithium, which can be harmed by overcharging. When the battery is fully charged, certain chargers are built to switch to trickle charging.

- **Pulsed Charge:**

- Pulsed chargers deliver the battery charge current to the battery in a pulsed manner. By adjusting the pulse width, usually set at one second, the charging rate can be precisely controlled based on the average current. To stabilize the chemical reactions within the battery, shorter rest intervals of 10 to 30 milliseconds are incorporated between the pulses during the charging process. This helps in achieving a balanced reaction throughout the majority of the electrode before resuming the charging.

3.2 Different Methods

- **Case 1: Residence charging**

- Currently, homes account for 80% of all EV charging. Customers almost always have their batteries fully charged while they are sleeping, enabling them to awaken the following morning with a battery that usually gives very much than enough vehicle range of the majority of people's regular routine requirements.

- The 2 methods of residence charging available are AC Household Charging with a wall box installed and Trickle Charge using household current. The following are the major variations:

- **Trickle Charge:**
- Allows charging using the factory-installed (three-prong) 220V plug for your electric vehicle. The opposite end is only straight-hooked into your Electric Vehicle.
- Does not require the installation of extra charging equipment, may charge at a rate of 13 to 16 kilometers per hour. The range may be charged to about 65 km in 5 hours or the range may be charged to about 200 km in 14 hours.
- Only in dire situations, such as when your battery is nearly dead and you are unable to use an AC wall box at home or travel to a public station, should you resort to trickle charging. This is because to the potential for problems with energy bills and electrical loads resulting from utilizing domestic electricity, therefore use this charge solution with caution and consult your power provider before using it for the first time.
- **AC Household Charging:**
- This option permits charging over a 230V outlet at a rate that is three to four times quicker than Trickle Charge, depending on the particular mode and the charger.
- Because it takes a 40-kWh battery car roughly 6 hours to fully charge, it is especially advantageous if you utilize time put your electric car overnight.
- It necessitates hiring a licensed electrician to install a particular wall box for EV charging.
- If you have a garage or driveway where it may be placed, that's ideal.
- Your city or country may have financial incentives to lower installation and buying costs.

- **Case 2: Public charging stations**
- These stations, which are increasingly available due to the network's continual expansion and are frequently spread across urban centres in particular, can recharge your battery while you are moving if required to travel longer.
- First and Second solutions will be faster then charging at residence: AC local Charging could be 4 to 10 times quicker than AC Residence Charging, depend on watt of the charging loaction and your EV's ability to accept AC Charging. The data below demonstrates how quickly all DC charger stations charge devices:
- **DC Fast Chargers**
- This is now the rapid way of charging an electric vehicle.
- Produces more than 50kW of charging power at 450V and up to 125A of current.
- Can charge from 20 to 80 percentage of its initial battery in about 2400 seconds.
- DC Charging should be used sparingly to help high-voltage batteries last longer.
- DC Fast Charging allows for a 30-minute charge of an EV.

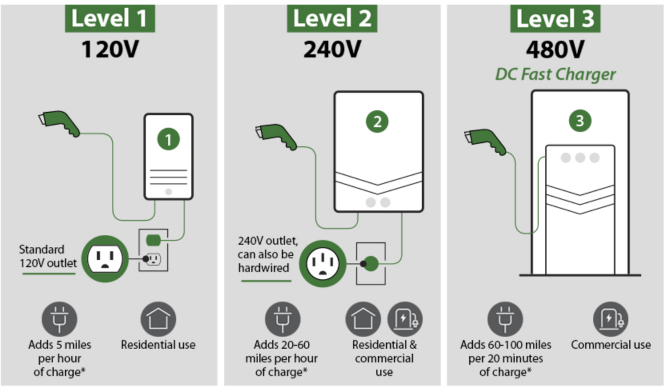


Figure 3.1: Level 1,2,3 Charging

3.3 Electric Vehicle Onboard Charging Module

- The onboard charging module is a critical component of electric vehicles (EVs) that is responsible for managing the charging process and converting the alternating current (AC) from an external power source into direct current (DC) to charge the vehicle's battery.

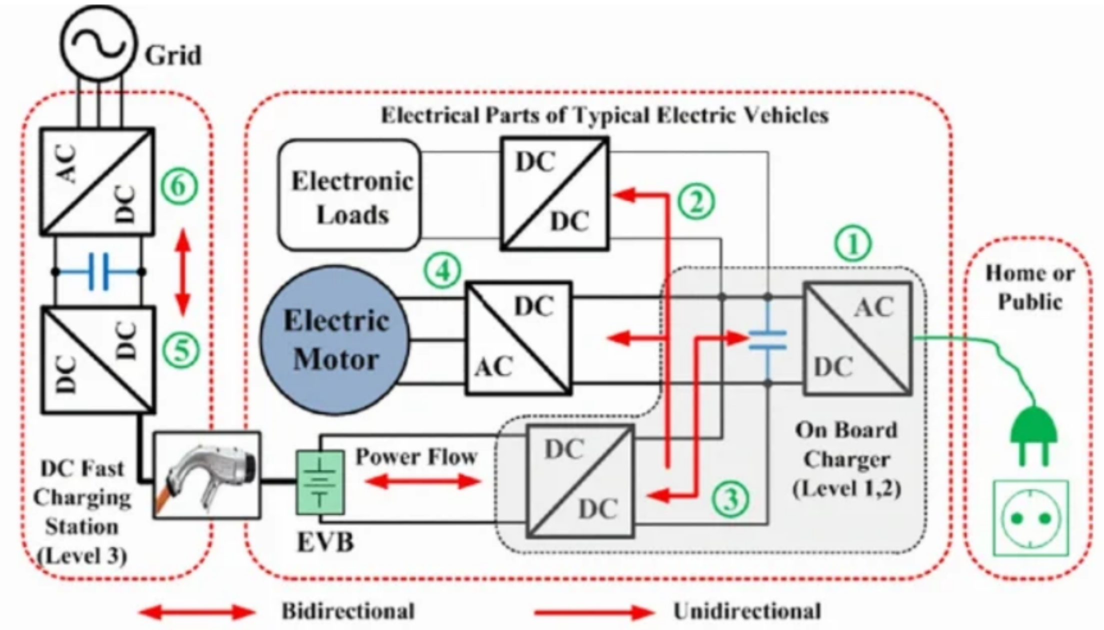


Figure 3.2: Onboard Charging Module

- The primary function of the onboard charging module is to ensure the safe and efficient transfer of electrical energy from the charging infrastructure to the EV's battery pack. It performs several key tasks during the charging process:

1. **AC/DC Conversion:** The onboard charging module incorporates power electronics and converters to convert the incoming AC power from the charging station into the required DC voltage and current levels suitable for charging the EV battery.

2. **Power Regulation:** The module regulates the power flow and manages the charging rate to prevent overcharging or undercharging of the battery. It monitors the battery's state of charge, voltage, and temperature to optimize the charging process and ensure the battery's health and longevity.

3. **Communication and Control:** The onboard charging module communicates with the charging station or external power source to negotiate and establish the appropriate charging parameters, such as voltage, current, and charging protocols. It manages the charging process based on these parameters and may also incorporate safety features, such as ground fault detection and isolation.

4. **Thermal Management:** Charging generates heat, and the onboard charging module is responsible for monitoring and managing the temperature of the charging system. It may include cooling mechanisms, such as fans or liquid cooling, to dissipate heat and maintain optimal operating conditions.

- The onboard charging module is typically integrated into the vehicle's power electronics system, working in conjunction with other components like the battery management system (BMS) and vehicle control unit (VCU). It ensures efficient charging, protects the battery from overcharging or damage, and facilitates compatibility with various charging infrastructure standards, such as AC Level 1, AC Level 2, or DC fast charging.

- Furthermore, advancements in onboard charging technology have led to the development of bidirectional charging capabilities, enabling EVs to serve as energy storage units and participate in vehicle-to-grid (V2G) applications. In such cases, the onboard charging module can also facilitate power flow from the EV's battery back to the grid or other energy consumers, providing grid stabilization and energy management capabilities.

- In summary, the onboard charging module is a critical component in electric vehicles, responsible for converting AC power from the charging infrastructure to DC power for charging the EV's battery. It regulates power flow, communicates with the charging station, and ensures the safe and efficient charging of the battery pack.

3.4 Combined Charging Methods

- The CC-CV charging method first uses CC charging before switching to CV charging when the voltage goes the peak operable threshold value.

- The CC-CV plug-in method is a hybrid strategy that combines the two previously mentioned charging techniques. It starts with the CC (constant current) charging method in the initial stage, but when the voltage reaches the highest operable threshold, it switches to the CV (constant voltage) charging method. The charging process concludes either when the current stops increasing or when the battery reaches its maximum capacity. The sustainable utilization of the battery is often driven by the CV mode, while the charging time is primarily determined by the CC mode.

- Lead-acid batteries were first charged via CC-CV charging, and thereafter Li-ion batteries. Li-ion batteries need a CC mode that lasts a lot longer.

- Because it is more efficient than either the CC or CV procedures alone, the CC-CV charging method serves as a standard for comparison with more modern charging methods.

- CC-CV charging's key difficulty is choosing appropriate constant values for each mode. The ideal current value will strike a compromise between battery safety and charging efficiency.

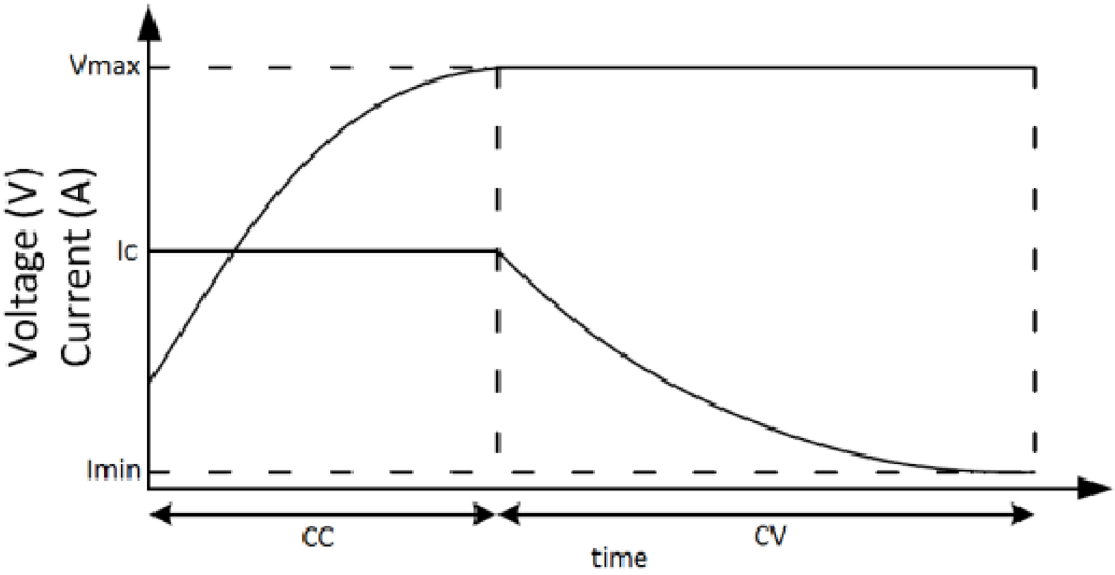
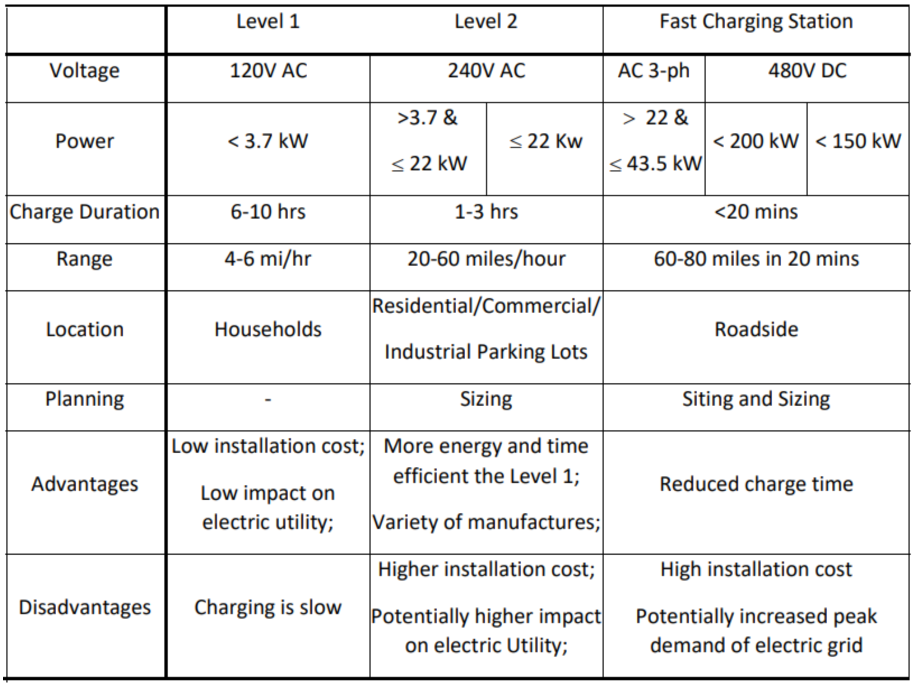


Figure 3.3: Characteristics of CC-CV Charging



	Level 1	Level 2		Fast Charging Station		
Voltage	120V AC	240V AC		AC 3-ph	480V DC	
Power	< 3.7 kW	>3.7 & ≤ 22 kW	≤ 22 Kw	> 22 & ≤ 43.5 kW	< 200 kW	< 150 kW
Charge Duration	6-10 hrs	1-3 hrs		<20 mins		
Range	4-6 mi/hr	20-60 miles/hour		60-80 miles in 20 mins		
Location	Households	Residential/Commercial/ Industrial Parking Lots		Roadside		
Planning	-	Sizing		Siting and Sizing		
Advantages	Low installation cost; Low impact on electric utility;	More energy and time efficient the Level 1; Variety of manufactures;		Reduced charge time		
Disadvantages	Charging is slow	Higher installation cost; Potentially higher impact on electric Utility;		High installation cost Potentially increased peak demand of electric grid		

Figure 3.4: Charging Facilities

3.5 Uncoordinated & Coordinated Charging

- **Uncoordinated Charging**

- When the batteries of the EVs are plugged in at home with an ad hoc charging technique (particularly at peak time), or sometime after an owner-adjustable imposed start time delay, the batteries of the vehicle are capable of charging instantly.The majority of EVs comes at habitations during busiest hour of the day. Therefore, overloading concerns for system transformers and cables arise if the EVs were on charge as they arrived. This charging could create an immense load at the same time as the peak. Uncoordinated charging has adverse impacts including overloading, greater losses, higher voltage skew, and higher prices.

- **Coordinated Charging**

- When EVs charge at times other than peak hours, that is commonly referred to as coordinated charging, the integration of EVs into the distribution system is improved.Coordinated integration's may substantially decrease the adverse impact of uncoordinated integration on system performance.

3.6 Role of Buck-Boost Converter

- The buck-boost converter plays a crucial role in the electrical system of electric vehicles (EVs). It serves as a vital component for managing the voltage levels and efficiently transferring power between different parts of the vehicle.

- The primary function of a buck-boost converter is to regulate the DC voltage supplied to various components within the EV. This is particularly important because the battery voltage of an EV can vary, depending on factors such as charge level and load demand. The buck-boost converter adjusts the voltage level to match the requirements of different components, ensuring stable and optimal operation.

- In an EV, the buck-boost converter is typically used in two main scenarios:

1. **Battery Charging:** When an EV is being charged, the buck-boost converter allows for the conversion of AC power from the charging station to the appropriate DC voltage level required for battery charging. It ensures efficient power transfer, monitors the charging process, and maintains a safe and controlled charging environment.

2. **Power Distribution:** The electrical system of an EV consists of various components that require different voltage levels for operation. The buck-boost converter plays a crucial role in regulating and converting the voltage to meet the specific requirements of components such as the traction motor, onboard electronics, and auxiliary systems.

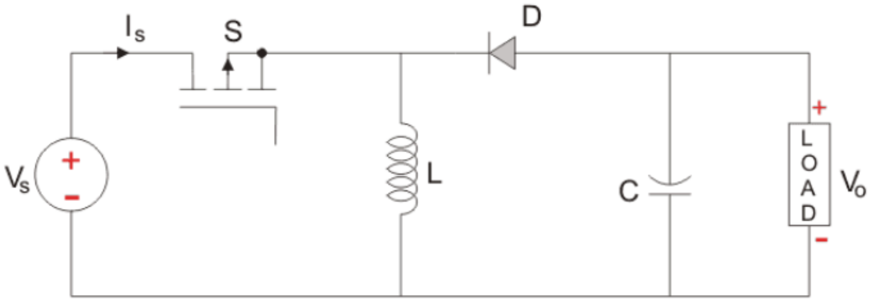


Figure 3.5: Buck-Boost Converter Diagram

- The buck-boost converter operates by utilizing switching elements (such as transistors) and inductors to convert the voltage. It can step up (boost) or step down (buck) the voltage, depending on the requirements of the system. By controlling the switching frequency and duty cycle, the buck-boost converter can efficiently manage the voltage conversion process and minimize power losses.

- Overall, the buck-boost converter is essential in maintaining stable voltage levels, efficient power transfer, and optimal performance of various components within an electric vehicle. Its role in regulating and converting voltage ensures reliable operation and maximizes the overall energy efficiency of the EV system.

Chapter 4

Proposed System

4.1 Test Feeder for IEEE 13 Node

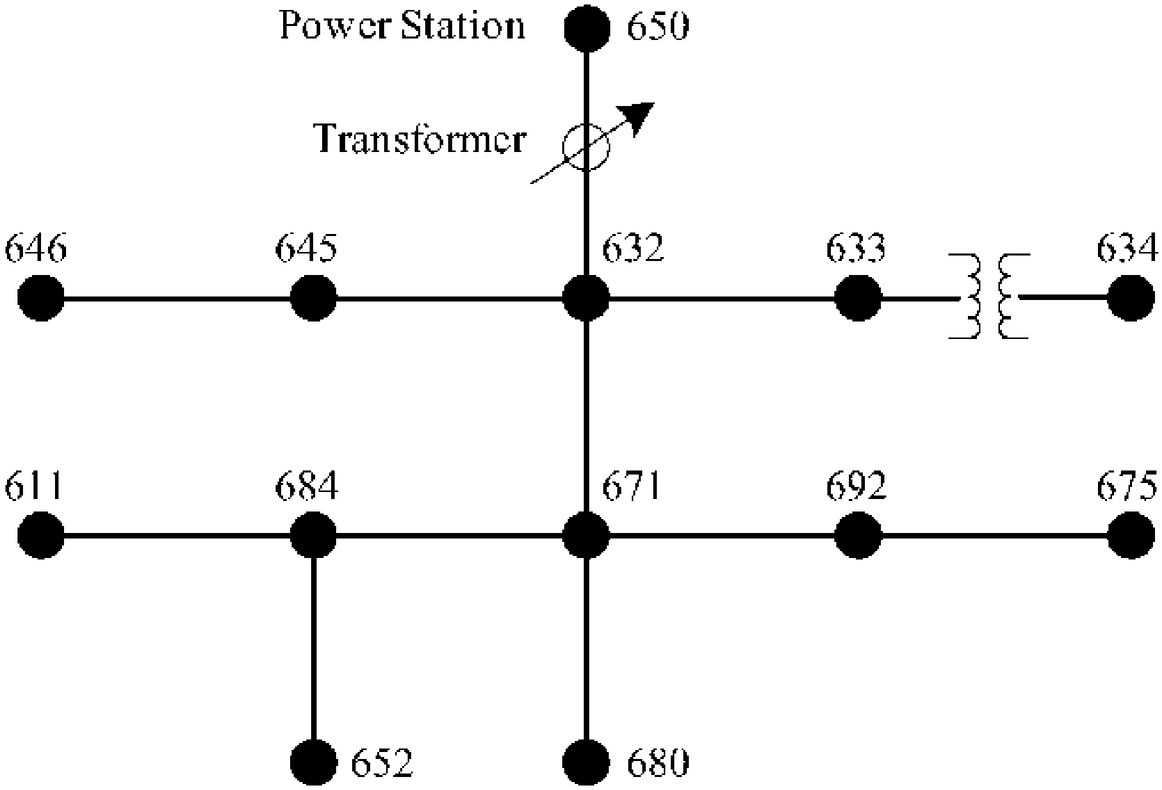


Figure 4.1: Single Line Diagram of the System

- This insignificant feeder demonstrates some extremely intriguing qualities despite its size..
- For a 4.16 kV feeder, it is brief and relatively heavily loaded.
- Three single-phase electronics linked in a wye form a single substation voltage regulator.
- Lines both above and below ground with various phasing.
- Banks of shunt capacitors.
- A transformer in-line.
- Spot and dispersed loads that are unbalanced.
- This will serve as an excellent test for the most prevalent elements of distribution analysis software for a small feeder.
- Below is a list of all the data for this system:

Config.	Phasing	Phase	Neutral	Spacing
		ACSR	ACSR	ID
601	B A C N	556,550,26/7	4/0,6/0	500
602	C A B N	4/0,6/0	1/0	500
603	C B N	1/0	1/0	505
604	A C N	1/0	1/0	505
605	C N	1/0	1/0	510

Table 4.1: Overhead Line Configuration Data

Node A	Node B	Lengtht(ft.)	Config.
632	645	500	603
632	633	500	602
633	634	0	XFM-1
645	646	300	603
650	632	2000	601
684	652	800	607
632	671	2000	601
671	684	300	604
671	690	1000	601
671	692	0	Switch
684	611	300	605
692	675	500	606

Table 4.2: Line Segment Data

Node	Phase-A	Phase-B	Phase-C
	kVAr	kVAr	kVAr
675	200	200	200
611			100
Total	200	200	300

Table 4.3: Capacitor Data

Regulator Data:	1		
Line Segment:	650-632		
Locoation:	650		
Phases:	A-B-C		
Connection:	3-Pase,LG		
Monitoring Phase:	A-B-C		
Bandwidth:	2.0 volts		
PT Ratio:	200		
Primary CT Ratio:	700		
Compensator Settings:	Ph-A	Ph-B	Ph-C
R-Setting:	3	3	3
X-Setting:	9	9	9
Voltage Level:	122	122	122

Table 4.4: Regulator Data

	kVA	kV-high	kV-low	R-%	X-%
Substation	5000	115-D	4.16 Gr. Y	1	8
XFM-1	500	4.16 Gr. W	0.48 Gr. W	1.1	2

Table 4.5: Transformer Data

Node	Load	Ph-1	Ph-1	Ph-2	Ph-2	Ph-3	Ph-3
	Model	kW	kVAr	kW	kVAr	kW	kVAr
634	Y-PQ	160	110	120	90	120	90
645	Y-PQ	0	0	170	125	0	0
646	D-Z	0	0	230	132	0	0
652	Y-Z	128	86	0	0	0	0
671	D-PQ	385	220	385	220	385	220
675	Y-PQ	485	190	68	60	290	212
692	D-I	0	0	0	0	170	150
611	Y-I	0	0	0	0	170	80
	Total	1158	606	973	627	1135	753

Table 4.6: Spot Load Data

Node A	Node B	Load	Ph-1	Ph-1	Ph-2	Ph-2	Ph-3	Ph-3
		Mode	kW	kVAr	kW	kVAr	kW	kVAr
632	671	Y-PQ	17	10	66	38	117	68

Table 4.7: Distributed Load Data

4.2 Calculation for Buck Converter

- **The value of Inductor L can be designed by**

$$\mathrm{L} = \frac{\mathrm{V_{OUT}} \times (\mathrm{V_{IN}} - \mathrm{V_{OUT}})}{\Delta \mathrm{I_L} \times f_\mathrm{S} \times \mathrm{V_{IN}}}$$

$\mathrm{V_{IN}}$ = an average input voltage

$\mathrm{V_{Out}}$ = appealing output voltage

$\mathrm{f_s}$ = minimum converter switching frequency

$\Delta\mathrm{I_L}$ = probable inductor ripple current

- **The value of capacitor C can be designed by**

$$\mathrm{C_{OUT(min)}} = \frac{\Delta \mathrm{I_L}}{8 \times f_\mathrm{S} \times \Delta \mathrm{V_{OUT}}}$$

$\mathrm{C_{Out(min)}}$ = output capacitance at a minimum

$\Delta\mathrm{I_L}$ = probableinductor ripple current

$\mathrm{f_s}$ = minimum converter switching frequency

$\Delta\mathrm{V_{OUT}}$ = an average output voltage ripple

4.3 Calculation for Boost Converter

- **The value of inductor L can be designed by**

$$\mathrm{L} = \frac{\mathrm{V_{IN}} \times (\mathrm{V_{OUT}} - \mathrm{V_{IN}})}{\Delta \mathrm{I_L} \times f_\mathrm{S} \times \mathrm{V_{OUT}}}$$

$\mathrm{V_{IN}}$ = an average input voltage

$\mathrm{V_{Out}}$ = probable output voltage

$\mathrm{f_s}$ = minimum converter switching frequency

$\Delta \mathrm{I_L}$ = probable inductor ripple current

- **The value of capacitor C can be designed by**

$$\mathrm{C_{OUT(min)}} = \mathrm{I_{OUT(max)}} \times \frac{D}{f_\mathrm{S} \times \Delta \mathrm{V_{OUT}}}$$

$\mathrm{C_{Out(min)}}$ = minimum output capacitance

$\mathrm{I_{Out(max)}}$ = maximum current output

D = Duty cycle

$\mathrm{f_s}$ = minimum converter switching frequency

$\Delta \mathrm{V_{OUT}}$ = probable output voltage ripple

4.4 Simulation of IEEE 13 Bus System

- To test distribution systems, a small setup termed the IEEE 13 bus feeder is implemented. It has just one source, a regulator, several short unbalanced transmission lines, shunt capacitors, and a 4.16 kV operating voltage.

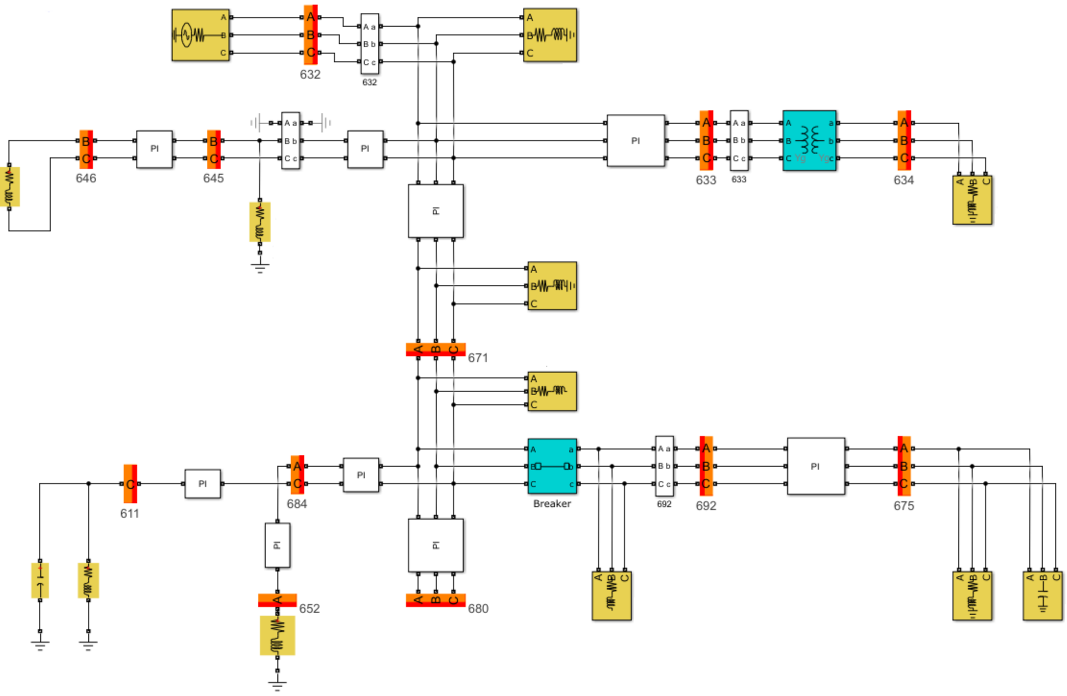


Figure 4.2: Test Feeder for IEEE 13 Node

- Figure 4.1 shows Test Feeder for IEEE 13 Node and the results of the same are shown in below table.

Bus No.	Va	Vb	Vc
632	1.021	1.042	1.017
634	1.018	1.04	1.015

Table 4.8: Voltages at Bus no. 632 & 634

4.5 Simulation of IEEE 13 Bus System with EV connected (Uncoordinated Charging)

- The below figure shows the simulation of Test Feeder for IEEE 13 Node with EV connected at Bus no. 632 & 634.

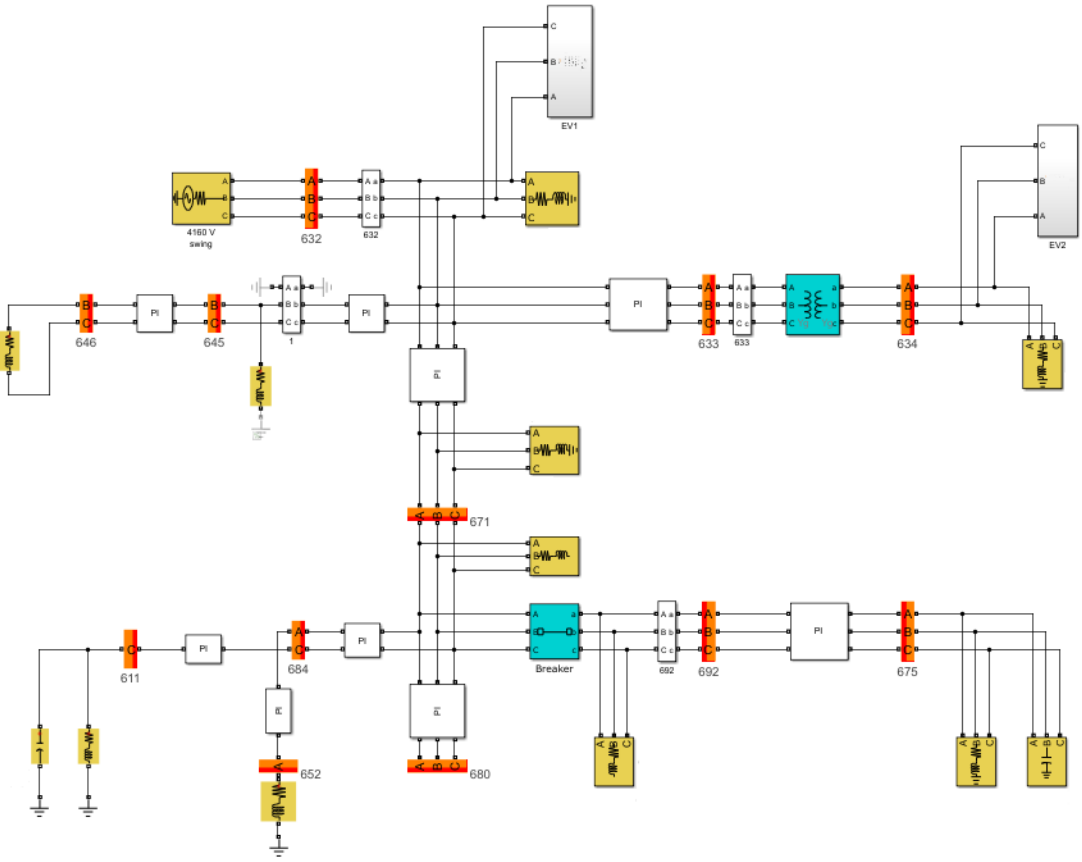


Figure 4.3: Simulation of 13 Node Test Feeder with EV (Uncoordinated Charging)

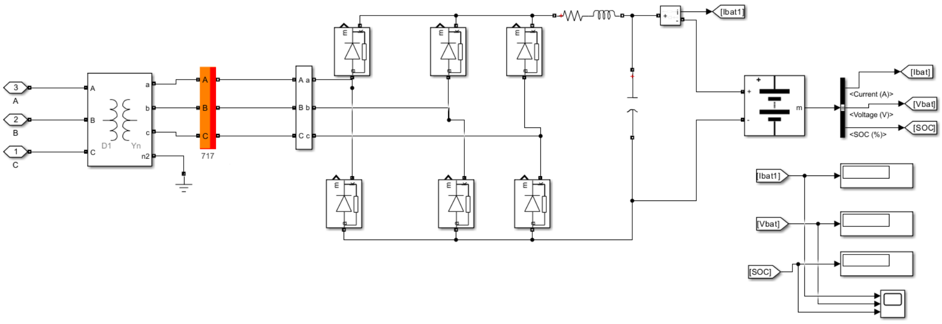


Figure 4.4: Controller 1

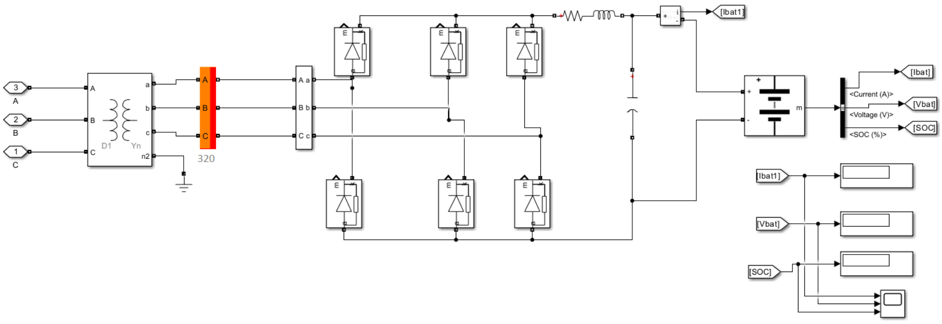


Figure 4.5: Controller 2

- The below table shows the result os standard IEEE 13 Node Test Feeder voltages at bus no. 632 & 634.

Bus No.	Va	Vb	Vc
632	1.021	1.042	1.017
634	1.018	1.04	1.015

Table 4.9: Voltages at Bus no. 632 & 634

- The below table shows the result of Test Feeder for IEEE 13 Node voltages with EV connected (Uncoordinated Charging) at bus no. 632 & 634.

Bus No.	Va	Vb	Vc
632	0.7122	0.7548	0.7936
634	0.7197	0.7599	0.7984

Table 4.10: Voltages at Bus no. 632 & 634 (Uncoordinated Charging)

- Upon comparing the standard result with the obtained result, it is evident that the voltage magnitudes at bus 632 & 634 significantly differ when the EV is connected.
- The presence of the EV connection introduces additional factors that could impact the voltage levels at bus number 632 & 634. Some possible considerations for this discrepancy include: EV Charging Load and Voltage Regulation.

4.6 Simulation of Test Feeder for IEEE 13 Node with EV connected (Coordinated Charging)

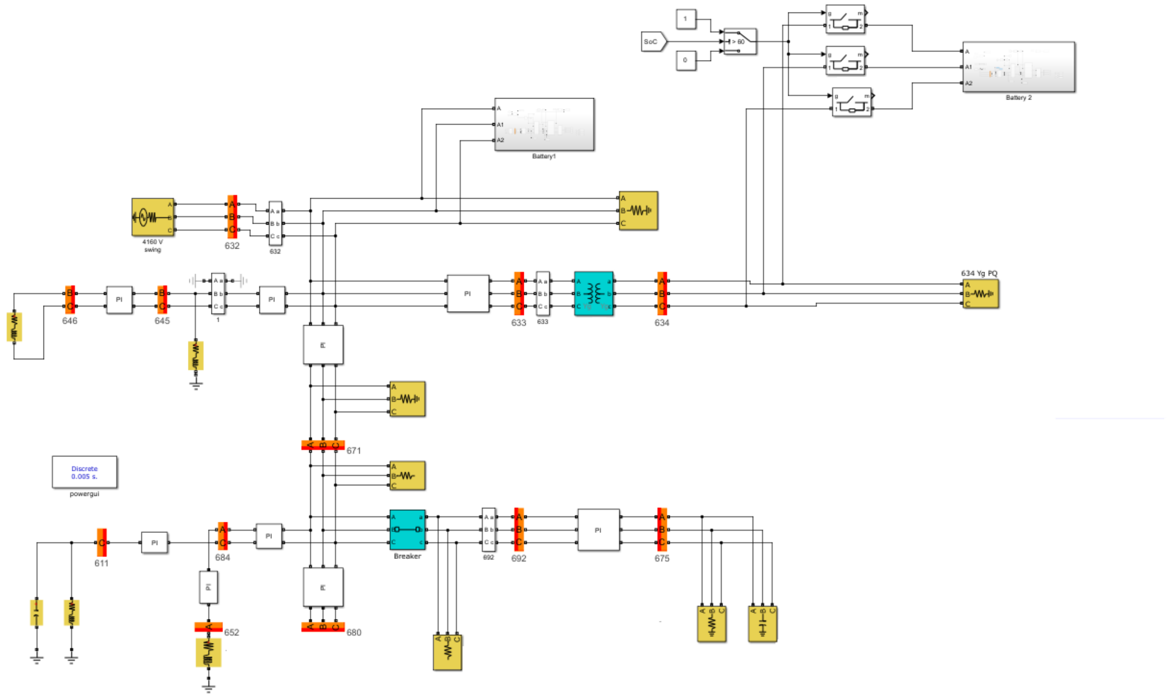


Figure 4.6: Simulation of 13 Node Test Feeder with EV (Coordinated Charging)

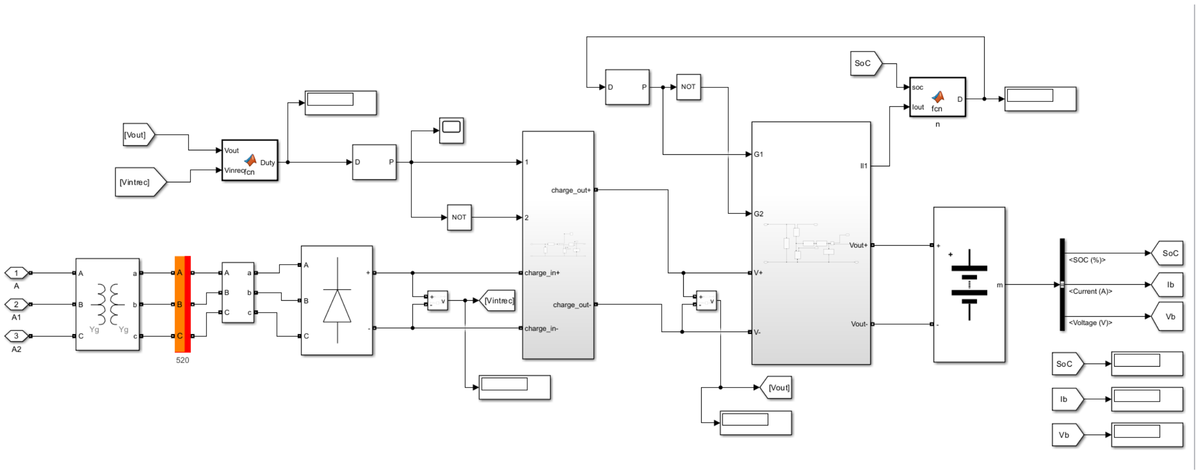


Figure 4.7: Controller 1

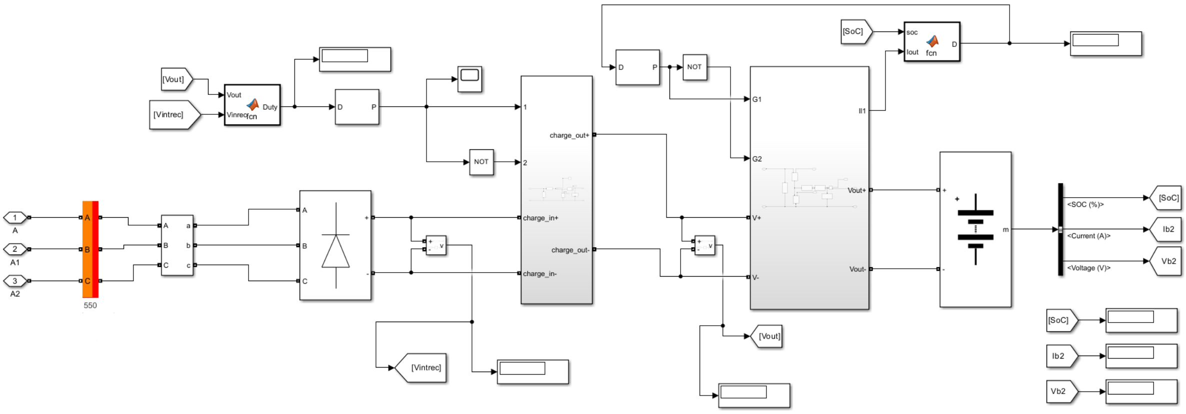


Figure 4.8: Controller 2

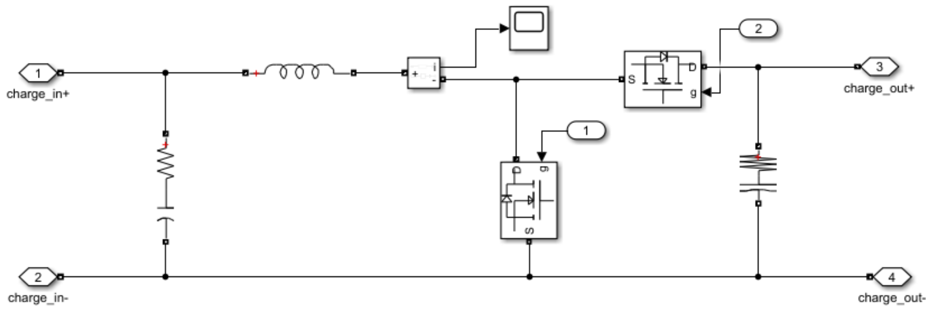


Figure 4.9: Boost Converter

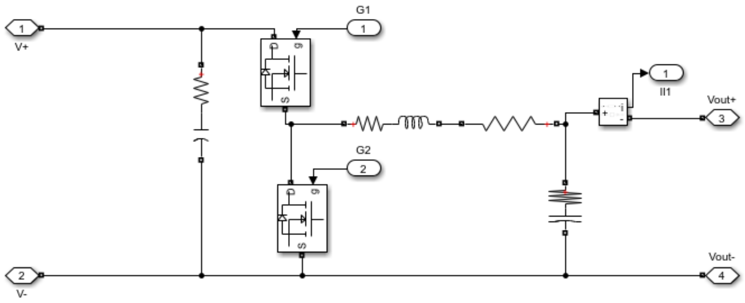


Figure 4.10: Buck Converter

- The below table shows the result of standard Test Feeder for IEEE 13 Node voltages at bus no. 632 & 634.

Bus No.	Va	Vb	Vc
632	1.021	1.042	1.017
634	1.018	1.04	1.015

Table 4.11: Voltages at Bus no. 632 & 634

- The below table shows the result of standard IEEE 13 Node Test Feeder voltages with EV connected (Uncoordinated Charging) at bus no. 632 & 634.

Bus No.	Va	Vb	Vc
632	0.7122	0.7548	0.7936
634	0.7197	0.7599	0.7984

Table 4.12: Voltages at Bus no. 632 & 634 (Uncoordinated Charging)

- The below table shows the result of standard Test Feeder for IEEE 13 Node voltages with EV connected (Coordinated Charging) at bus no. 632 & 634.

Bus No.	Va	Vb	Vc
632	0.910	0.915	0.915
634	0.907	0.914	0.916

Table 4.13: Voltages at Bus no. 632 & 634 (Coordinated Charging)

- Upon comparing the standard result with the obtained results,In the uncoordinated charging scenario, the obtained voltages are significantly lower than the standard voltages, indicating a more pronounced voltage drop and potential voltage instability.On the other hand, in the coordinated charging scenario, the obtained voltages show an improvement compared to the uncoordinated charging scenario. Although they are still lower than the standard voltages, the coordinated charging approach has effectively mitigated the voltage drop and improved voltage stability.

- The below table shows the result of feeder loading at bus no. 632 & 634.

Bus No.	kW(Without EV)	kW(Uncoordinated)	kW(Coordinated)
632	100	266	244
634	50	158	136

Table 4.14: Feeder Loading at Bus no. 632 & 634

- The below table shows the result of transformer loading at bus no.634.

Bus No.	kW(Without EV)	kW(Uncoordinated)	kW(Coordinated)
634	50	158	136

Table 4.15: Transformer Loading at Bus no. 634

- Upon comparing the standard result with the obtained results, it is evident that both the uncoordinated and coordinated charging scenarios result in increased feeder loading at bus number 632 & 634 compared to the standard value.In the uncoordinated charging scenario, the obtained feeder loading of 266 kW is significantly higher than the standard loading of 100 kW. This suggests that without coordination, multiple EVs charging simultaneously impose a substantial additional demand on the feeder at bus number 632, potentially leading to overloading and compromising the overall system reliability.On the other hand, in the coordinated charging scenario, the obtained feeder loading of 244 kW shows a slight improvement compared to the uncoordinated charging scenario. Although still higher than the standard loading, the coordinated charging approach has effectively mitigated the excessive demand by optimizing the charging schedule, load management, or other control strategies. This helps to reduce the strain on the feeder and ensure more reliable and balanced operation of the electrical system.

- The below table shows the result of current loading at bus no. 632 & 634.

Bus No.	Current Loading	Current Loading(Uncoordinated)	Current Loading(Coordinated)
632	27.07	39.07	34.07
634	12	22	19

Table 4.16: Current Loading at Bus no. 632 & 634

- The below table shows the result of current loading at bus no.634.

Bus No.	Current Loading(Without EV)	(Uncoordinated)	(Coordinated)
634	12	22	19

Table 4.17: Current Loading at Bus no. 634

- Upon comparing the standard result with the obtained results, it is evident that both the uncoordinated and coordinated charging scenarios result in significantly increased current loading at bus number 632 & 634 compared to the standard value.In the uncoordinated charging scenario, the obtained current loading of 39.07A is higher than the standard loading of 27.07A. This suggests that without coordination, the simultaneous charging of multiple EVs introduces an additional electrical load on the bus, leading to increased current flow and potentially overloading the electrical infrastructure. However, there seems to be an anomaly in the obtained result for the coordinated charging scenario, with a value of 34.07A.

Chapter 5

Conclusion and Future Scope

5.1 Conclusion

- This thesis analyses the impact of EV integration into standard IEEE-13 Node Test Feeder through simulation in MATLAB/SIMULINK environment. Two charging schemes (Uncoordinated and Coordinated) has been considered for the project. The behavior of EVs has a significant impact on safety and efficiency, even without coordination or cooperation. The uncoordinated charging of electric vehicles (EVs) leads to an increased current loading compared to the standard result. This suggests that simultaneous charging of multiple EVs without proper coordination can impose an additional electrical load on the bus, potentially leading to overloading and compromising the overall system reliability.Proper coordination of EV charging is essential to optimize the charging schedule, manage the load, and prevent excessive current loading. By implementing coordinated charging strategies, such as load management techniques or smart charging algorithms, it is possible to balance the load and ensure more reliable and efficient operation of the electrical system.Coordinated charging strategies can help optimize the charging schedule, distribute the load evenly, and prevent overloading of the electrical infrastructure.

5.2 FutureScope

- Based on the simulation results, several future scopes for the project can be identified. Firstly, the implementation of the coordinated charging system in a real-world setting would provide valuable insights into its practical feasibility and scalability. Field trials involving a diverse set of EV users, grid operators, and charging infrastructure providers could validate the effectiveness of the simulation findings and identify any potential challenges or limitations.

- Secondly, exploring the synergy between integration and energy storage would be a great avenue for future research. Combining electric vehicles with sustainable electronic equipment could make the grid more resilient and more resilient.Finding the right coordination between EV charging, energy storage, and grid management plans can unlock additional benefits such as peak shaving, load balancing, and endurance improvements.

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