

IMPACTS OF VOLTAGE AND CURRENT PROFILE ON GRID INTEGRATION OF ELECTRIC VEHICLES

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ENGINEERING**



Department of Electrical and Electronic Engineering
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MARCH 2021

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A thesis/project
submitted as partial fulfilment of the requirement for the degree of

**BACHELOR OF SCIENCE IN ELECTRICAL AND ELECTRONIC
ENGINEERING**

Department of Electrical and Electronic Engineering
INTERNATIONAL ISLAMIC UNIVERSITY CHITTAGONG

MARCH 2021

CERTIFICATE OF APPROVAL

The thesis entitled as “Impacts of voltage and current profile on grid integration of renewable energy & Electric vehicles” submitted by **Md. Mosaraf Hossain Khan**, bearing Matric **ID. ET 171055** and **Amran Hossain** bearing Matric **ID. ET 171006** of session Autumn 2019, to the Department of Electrical and Electronic Engineering (EEE), International Islamic University Chittagong (IIUC), has been accepted as satisfactory in partial fulfilment of the requirements for the degree of Bachelor of Science in Engineering and approved for the examination held on 25th March, 2021.

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DECLARATION

It is hereby declared that this work has been done by us and no portion of the work contained in this thesis/project has been submitted elsewhere for the award of any degree or diploma.

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Md. Mosaraf Hossain Khan

ACKNOWLEDGMENT

In the name of Allah, the Most Gracious and the Most Merciful.

First of all, we are grateful to almighty Allah for giving us strength and wisdom throughout all our life. We thank our family for their love, their moral and financial support they had given us. This helped us a lot. We would like to give our gratitude for our supervisor Dr. Md. Aasim Ullah, Lecturer, Dept. of EEE, IIUC who has given us significant suggestions and inspections during the whole process of the work. His invaluable help of constructive comments and suggestions throughout the thesis work have contributed to the success of this thesis.

Last but not the least we are really grateful to S M Shahnewaz Siddiquee, our friends and classmates who have given us their unlimited support and help in each and every aspect. We are really fortunate to have nice human being like them beside us.

Authors

ABSTRACT

The entrance of Electric Vehicles inflicts amenities to keep Eco-balance, lowering greenhouse gas emissions, and enhancing ambient air quality. Electric Vehicles add a new relation between transportation and electric power Industries. The use of electric cars provides many benefits, including increased use of renewable electricity, reduced use of non-renewable energy sources, a clean atmosphere and options for storing energy. With the popularity of Electric vehicles for lower carbon emission, another faces it makes a big deal in electric power demand to charging on-peak hours. It seems like it is also important to consider what effect EVs would have on distribution networks nationwide. Increased use of EVs has brought new challenges for the power sector and the grid, after addressing many challenges. This paper investigates the impacts of Electric Vehicles on low voltage distribution network can be ascertained as per the perspective issue of EVs like charging time, vehicles penetration, charging method & characteristics. In this paper, the impact of renewable energy and EVs Integration in the grid in terms of Power Demand, voltage profile, power quality, and system adequacy Investigate based on different EVs charging scenarios.

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LIST OF ABBREVIATIONS

EVs	Electric Vehicles
ICE	Internal combustion engine
IEA	International Energy Agency
PEVs	Plug-in Electric Vehicle
HPEVs	Hybrid Plug-in Electric Vehicle
TSO	Transmission System Operator
DSO	Distribution System Operator
PQ	Power Quality
PV	Photovoltaic
THD	Total Harmonic Distortion
SOC	State Of Charge
OCV	Open Circuit Voltage
THDi	Total Harmonic Distortion of current
THDv	Total Harmonic Distortion of voltage
V2G	Vehicle to grid
RMS	Root mean Square
PLL	Phase Lock Loop
DG	Diesel Generation
DSS	Distribution System Simulator
RES	Renewable Energy Sources
PWM	Pulse Width Modulation
PCU	Power Control Unit

CHAPTER 1 INTRODUCTION

1.1 Introduction

Air pollution in shipping, manufacturing and coal-fired electricity generation exacerbated by fossil fuel combustion has been a critical problem for the global climate in recent years. Climate change, incremental energy prices and reliance on fossil fuels are significant challenges in the world nowadays. All of these complicated issues are intimately associated to the three heavy corporations that use most fossil fuels listed above. Researchers and governments around the globe are making a significant contribution to limiting fossil fuel awakening and substituting it with clean solutions [1]. Increased environmental awareness and the call for renewable energy led as a form of transport to the market for electric vehicles. In the renewable energy environment, numerous countries around the world are already contributing to accomplish those goals [2]. The electric vehicle is an alternative to the renewable source of mobility with reduced emissions and effective compliance in order to eliminate the impacts of higher fuel costs and enforce environmental regulation of stricter performance [3].

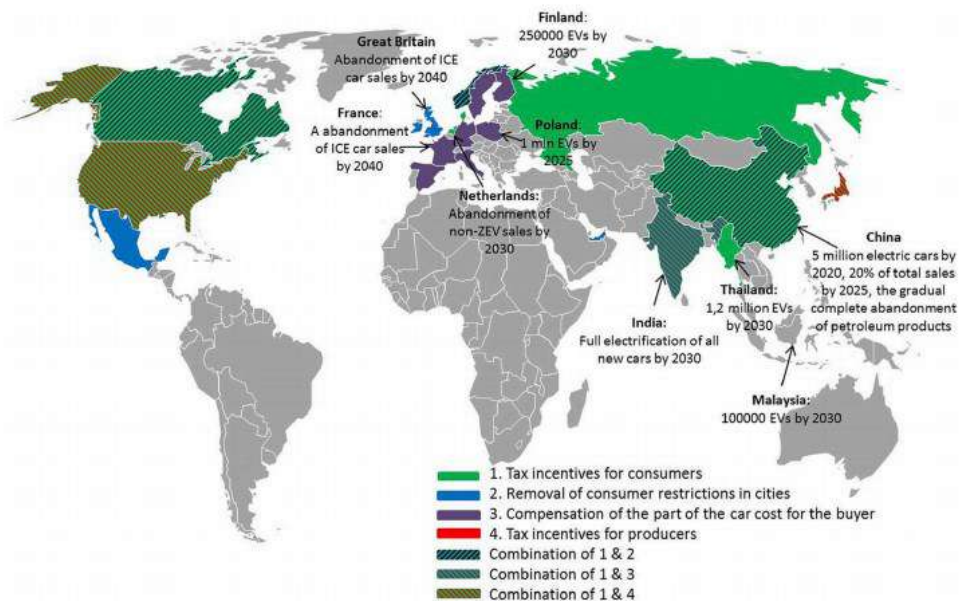


Fig 1.1: Electric vehicles state support mechanisms and national goals across the world [4]

Preference to manufacturers of Electric Vehicles (EVs) (IEA, 2017a). Besides EV30@30 participants, all EU 20 countries, along with Brazil and SAR, are entitled to electric transport preferential taxation. Some towns like Paris and Mexico have declared their plan to prohibit the entry of ICE cars inside city limits. The London administration does

not intend a complete ban on ICE, but has identified charges to use urban roads, which will exclude EVs (OECD/IEA, 2017) **Fig 1.1** [4].

Electric vehicles (EVs) are extensively identified as an effective solution for reducing greenhouse gas emissions, in terms of direction CO₂, and reconfiguring the energy structure in urban areas. The emission level can be significantly influenced by the executives of EVs, and EVs are one of the most effective ways to solve environmental issues. In addition, integration between EVs and distributed generations can further reduce greenhouse gas. As a result, increasing numbers of countries have viewed EVs as one of the most prevalent development legislation [5].

Transport electrification has a considerable potential to improve energy safety by reducing oil and gas dependency, reducing carbon energy consumption and improve quality of the environment. Passenger Plug-in EVs (PEVs) are an important part of most long-term mitigating climate change strategies [6], [7]. Transport to a more prosperous and stable world. For instance, the Renewable Energy Ministerial Electric Vehicle Strategy sets the aim of deploying 20 million PEVs by 2020. Around 90% of the world's renewable energy spending and 75% of global greenhouse gas emissions are made by the Clean Energy Legislative [8].

With its appealing approach to higher pollution ratings, the production and implementation of electric car technology is a solution that emerges for the above-mentioned problems. The importance of global transport also increases with each day the acceptance of EVs with the overall aim of eliminating toxic pollution. The displacement of internal combustion engines by EVs reflects an improved economic solution by electrifying large sections of the electricity and transport industries [9]. Hybrid EVs (HEVs), and Plug-in EVs can be categorized in significant numbers (PEVs). PEVs are also classified into hybrid plug-in EVs (PHEVs) and battery EVs. In HEVs, in comparison to PEVs, the battery cannot be recharged from an external energy source. Plug-in EVs will be used with EVs throughout this issue [2].

The incorporation of renewables into the energy grid in a wide way is hindered. Renewable sources of energy, such as power from wind and solar photovoltaics are also supply variable with little connection to demand adjustments. Whereas natural gas turbines can be extended to accommodate market changes, renewable sources of electricity, such as wind and solar, are available because when the wind blows or the sun shines. Many techniques to handle the volatility variations of various timescales were

created, including packaging, dispatching loads, and alternative volumes. Several of these approaches could be assisted by electric vehicles with the electric grids connection; therefore the large implementation of electric vehicles could play an essential part in incorporating renewable energy in existing power systems [10].

A model aggregator is proposed in this analysis to administer EVs in the parking lot. In **Fig 1.2**, Specifies the relationship between electricity generation, electricity aggregator and grid transmission operator describing the pattern of electricity drivers and the physical characteristics of electricity power transmission batteries and the physical properties of charge infrastructure etc.

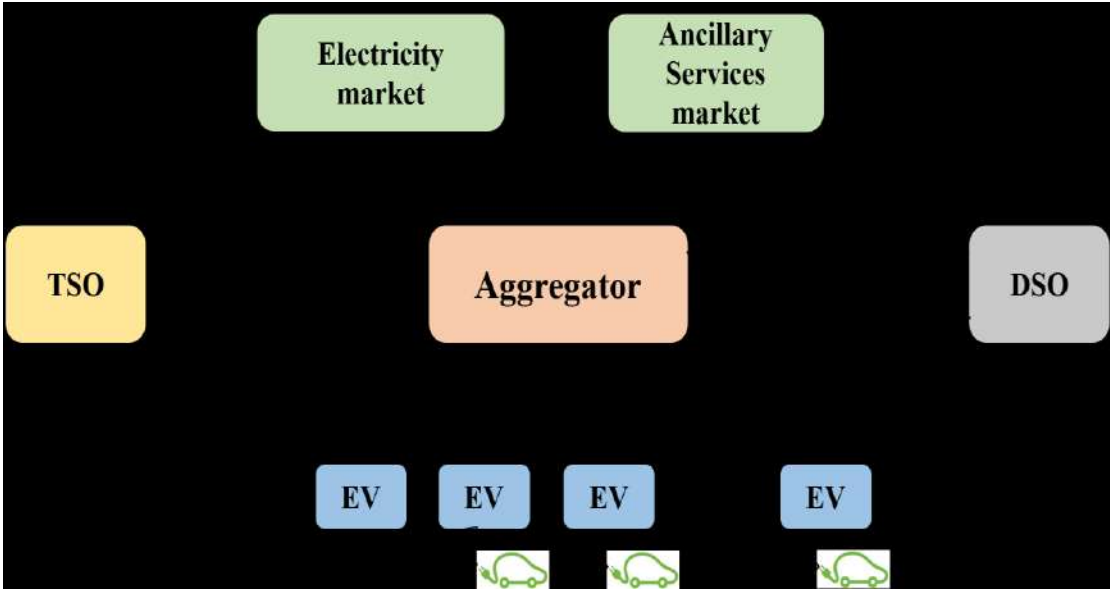


Fig 1.2 The overall structure of centralized charging control method

1.2 EV incorporation continuing Challenge

The rapid growth of Renewable Energy (REs) and EVs, on the other hand, introduces different energy system problems to the charging demand. The impact of EVs and REs on the grid in the worst charging situation also needs to be monitored. Numerous technological research is underway to evaluate the impacts of EVs with specific focus on economic, environmental and electricity grid impact evaluations. In dual viewpoint, like power grid and EV owners, the economic consequences of the EVs can be investigated. In order to analyse the economic and environmental analysis of the EVs, the position of the electricity mix is relevant. When charging is exclusively contingent on fossil-fuel power units, environmental impacts of EVs can indeed be identified. The significant problems involved with incorporating EVs in power networks are based on a detailed investigation of several technological research: increased load profile in peak hour, loading of power system components over, transmission losses, voltage fluctuations, phased unbalance, harmonics and system stability problems, which decrease the performance efficiency and reliability of the power system.

Despite the detrimental effects of charging on the power grid, some researchers have evaluated its key objective, instead of analysing the adverse effect of charge charging on the power grid, to study the collaborative charging technique. The load curve between synchronized loading and general load, for example. The effect demonstrates the spatial and temporal adjustments by coordinated charging methods to change the EV load with the low load time [5]. Proposed an efficient contribution to coordinated charge policies by contrasting the maximum charge plan, the inadequate strategy and uncoordinated charging conditions to minimize charge costs and peak charges. Most notably, an individual review was not considered on the negative impact on the grid of the unordered charging. And several researches have been published into voltage reliability in the power system [11].

In terms of attitude, charging EVs can have two major impacts on the electrical energy grid. First, the extra demand for recharging EVs batteries that are supplied mostly in residential households while parking and charging vehicles mostly during night would affect the total energy requirements and make electricity, transmission and delivery managements more difficult [12]. Second, EVs would either have to be interpreted as a distributed storage system or as versatile loads functioning as a virtual power plant.

Applications of coordinated EV charging and vehicle to grid (V2G) aim in automated smart grids to better incorporate unused renewables and generally improve electricity systems' operation and reliability. An order to predict potential uses, modelling the impacts of charging activity [8]. Several responses to residential demand, from aggregate top-down [13], [14] surveys to comprehensive bottom-up [15], [16], have been suggested.

1.3 Contributions Spectrum

The novelty of this research paper is that a research is carried out in order to determine the consequences on the distribution network of medium-scale EVs in a numerous different charging scenario, taking into account the charging of EVs from the viewpoint of power demand and voltage profile . In consideration of the incorporation of EVs into the transport and power grid it is important to understand not just the charge demand, but also EVs have plug-in planned functionality, contributing to their behaviours and the architecture of a transport network called the vehicle energy network influences mobile energy.

In the literature additional limits were found. First, the limited purpose of MATLAB Simulink is to model practical grid circumstances, since the situation in the real world has a lot of implications for the grid. But Simulink must have been known in MATLAB as the ideal grid. Second, EVs are normally expected to be "smart" (that means "off peak" hour) charged all over the spot, which could not always be the case. Third, most research relies on regular data to estimate the amount of charging capacity of vehicles, which charging time generally calculate on the basis of supposed operational vehicle accessibility . The Methods provide specific information [8].

In order to meet these limitations, use a highly resolved modelling of residential power demand and EV's based on a bottom-up approach to measure consumer behaviour and use of real-world vehicles, in order to determine more accurately the aggregate and local impact of coordinated EV charging. Residential and commercial energy standards, in particular, are structured in a single framework, containing the whole energy footprint of a single home with all appliances, air-conditioning and other electric power demands.

These models create strongly solved power demand profiles for the residential area (24 hours of phasor resolution) and recharge the EV's, simulating real-world use of

automobiles. This research has implemented various charging profile strategies to maximize the recharge of EVs in addition to assessing the impact of EV adoption in different circumstances under which smart grids are not completely deployed. The strongly solved electrical load profiles used in this paper including household consumption and electrical supplies charging suggest that even with a medium-level EV market share of 40% the improvement in aggregate demand in total kilowatt hours may be marginal.

Coordinated charging of electricity could modify the overall residential demand dramatically even at low levels of adoption, potentially affecting electricity infrastructure. On the local level, clustering effects in vehicle adoption could yield high levels of EV, while overall adoption remains low, dramatically raising the need for distribution transformers and requiring adjustments in the power distribution system [8]. The purpose of this paper is therefore to examine, with the power requirement considered in the various charging situations traffic electrical networks, the effects of a large-scale EVs on the distribution network in the worse charge situation.

The novelty in this paper is to analyse the smart grid of the distribution network in a thorough insight into renewable energies, vehicle energy networks, and electric energy networks and the detrimental effect of mobile energy on the power network in the most severe case of charge based on an examination of voltage profile and power demand.

CHAPTER 2 LITERATURE REVIEW

2.1 Introduction

The imminent environmental challenges and increasing issues about global energy challenges are increasing the need for new opportunities and solutions that can satisfy substantially higher demand for safer and more sustainable energy systems. This includes the construction of transport and power generation networks. Electrification of the transport sector is a promising solution to renewable transport networks and to reduce climate change problems. This research explores the current situation, new introduction and difficult problems in the introduction of networks and charging EVs in accordance with many international norms and charging protocols. It also evaluates the impacts and opportunities of EVs in society. The adverse effects of EVs was classified and carefully reviewed. Remedial steps for adverse impacts are identified and the gains gained therefrom are outlined. The existing challenges related to the massive implementation of EVs, as well as potential research developments, are also discussed in this chapter.

2.2 Power Quality issue in a EV integrated Grid with Renewable generation

Integration of renewable energy and a greater number of EVs, careful monitoring of charging situations and adequate communication are required. The deployment of charging facilities with the EVs framework is seen in the **Fig 2.1**.

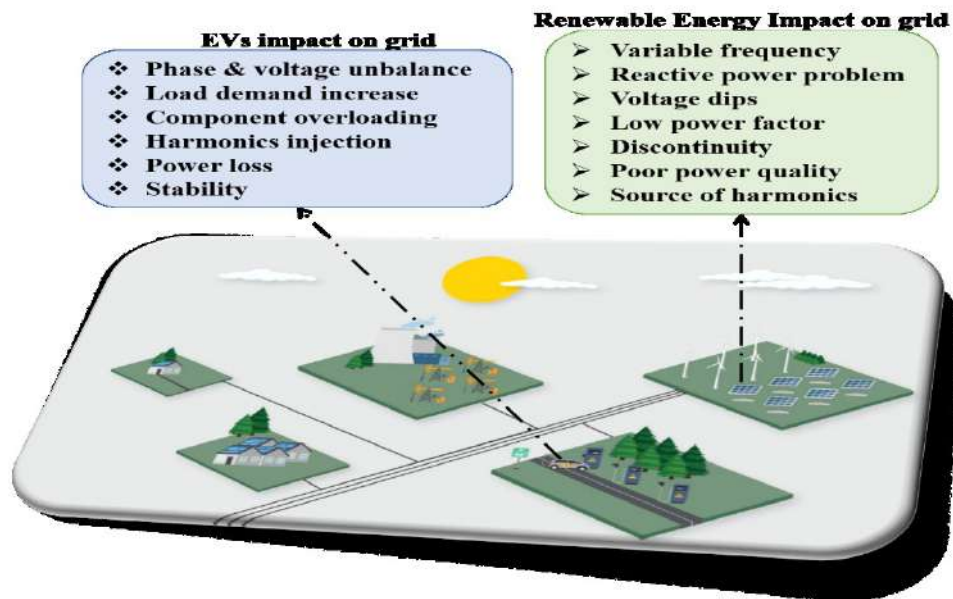


Fig 2.1 Power Quality issue in EV integrated Grid with Renewable generation

2.3 Renewable Generation (PV solar)

As photovoltaic systems incorporate power converters, which are harmonic generating devices, they will have an influence on the power quality of the supply network. The most cited PQ problems that may arise due to grid connected PV generation are:

- Voltage dips,
- Fluctuations,
- Harmonic distortion,
- Transient phenomena &
- Reverse power flow.

These effects can cause possible harm to the sensitive electronics and condenser banks, transformer overheating and neutral conductors and further power system losses. Degraded power quality ensures that the supplier and its customers will also be paid additional costs [17], [18].

Voltage dips:

The voltage sag happens as the root mean square voltage (rms) decreases below 90% nominal voltage causing power disruption. The voltage sag is characterized by various names based on the length of the voltage drop. This is called an instantaneous slope if its length is 0.5-30 cycles, before three seconds it is seen as an instantaneous and temporary slit, which will last for one minute [19].

Power Fluctuation

The irradiance variability could lead to significant energy variations produced by large photovoltaic (PV) grid-connected plants. When PV energy is infiltrated into our infrastructure, those power fluctuations will impact the quality and reliability of power adversely. Short-term variations in power (below 10 minutes) are normally consumed in the grid, which influences the power efficiency.

Total difference between 2(two) normalized outputs the power equation is:

$$\Delta P \Delta t, N(t) = [PN(t+\Delta t) - pN(t)] \times 100 \dots \dots \dots (1)$$

The magnitude, $N(t)$ in the case of number N , $\Delta P \Delta t$ power fluctuation of the PV plants combined at t , and a certain sampling period of time Δt .

Harmonic distortion:

PV devices have electronic power controllers, producing harmonic levels [19], which may lead to distortions in current and voltage. The harmonics of the waveform current or voltage are the aggregation of many higher rate sinusoidal elements, which are the integer multiple of the basic frequency. Harmonics influence the performance and stability of the power grid, loads and defensive relays [20] greatly. Just high frequency occurs with the turn harmonics and PLL induced harmonics. The high-quality harmonics can be diluted with the inverter filter, and hence the power system has very limited effects. As the output power of the inverter reduces, the harmonic amplitude will increase. This is mostly due to the difference of the DC-link voltage [21].

Transient phenomena:

The consequences on the system of fast-varying (transient) phenomena triggered by or initiated by PV-DG (e.g. generation intermittency due to cloud movements, faults and subsequent switching). The time frame of interest will range from sub-minute to several hours with rather fine time measures that will catch the feeder equipment's complex activity and reaction time, including PV inverters (usually sub-second steps), automatic voltage control equipment (sub-minute or minute steps), and loads. Fast disconnection (tripping) of a large portion PV-DG plant fluctuations in the performance of the PV-DG due to intermittency and accidental insulation of a feeder section downstream of an electronic switching system (a recloser or remote-controlled switch)[22].

Reverse Power Flow:

The voltage rise issue is a typical voltage quality problem due to the reverse power flow from the distributed generators in a distribution system[23],[24].Whenever large numbers of solar panels (PV cells) are connected to the distribution grid, the effect could be that the volume of locally produced electricity will surpass the local load at some times of the day, resulting in the flow of power back to the substation. With rising voltage on the distribution network and increasing in the opposite direction the sum of Active Current reduces the voltage setting of the sub-station transformer. At that condition transformer taps down to remain within the bandwidth of the reduced setup point, the PV

cells would have to bear greater load and therefore retain an appropriate delivery voltage[25].

2.4 Electric Vehicles

The increase in large EVs penetration contributes to substantial increased demand for charging, which may have some unexpected impacts on the power grid. In this circumstance, the power grid faces an increase in the load profile in maximum hours, over loading of the power components, loss of transmission, voltage regulation, unbalance of phase, harmonics and system stability problems, which degrade power quality and the power system reliability. The EVs impact evaluation is based on many significant conditions for example:

- Various Levels of EVs Penetration
- Strategies of Charging
- Different Characteristics of EVs Battery
- Location of Charging
- Charging Patterns
- Charging Time
- Battery State of Charge
- Profiles for Fleet Charging
- Driving Patterns for EVs
- Driving Distances
- Tariffs
- Demand Response Techniques [26], [27].

2.1.1 Issues of voltage instability and phase unbalance

Voltage instability is one of the major causes of significant electricity network power shortages. The explanation for this is that the power grid is normally run up to the system's reliability constraints and has significant load demands. Different properties of different loads can also leading to instability issues [28]. The secure power grids are therefore capable of imperatively conducting and certifying a reliable power transmission for consumers. Conventional residential and industrial load concentration varies from EVs load characteristics. The battery load of EV requires more power and is nonlinear in

order to completely regenerate in a limited timeframe. The grid voltage stability is considerably influenced by the characteristics of the load. The problems of voltage fluctuations and decreases will emerge either in the transmission grids as well as in the link point for EV, as the demand for EV from the distribution network is greater [29],[30]. The Monte Carlo simulation approach for two scenarios, namely the uncoordinated charging system and the V2G technology, is proposed for research on the effect of EVs charges to Grid Tolerance deviation below the tolerance level of 7% Chinese standard for 10KVA distribution Network. The study demonstrated that voltage values of up to 90% of EVs integration in Chinese standard are regulated in the V2G charging mode. The penetration rate of 60% or above with coordinated charging systems, exceeds operating conditions and significantly changes the voltages of the network [31]. The V2G charge system can balance loads and continues to maintain the minimal voltage difference between high and low demands. Smart charging technique for retaining a reasonable tolerance range of network voltage, which otherwise breaches the 50% EVs acceptance rate [32].

Due to unequal distribution of charging by EV across all three phases, level 1 slow charging in residential areas can suffering the phase imbalance issue. In an experiment all EVs are connected to the single phase 'a' an extreme phase unbalance phenomenon is seen [33].The findings recommended that there should be a significant phase unbalance in the network and that the potential EV integration should have additional emphasis. Due to EVs incorporation in the electricity grid, a minor effect on voltage and current disbalance is observed. The problem of phase unbalance is however, regulated by different experimental conditions [34]. In [35], The EVs charging model has been built with constant power and negative exponential load components in the Simulink configuration. Model simulation is conducted in the IEEE-43 bus distribution network and voltage stability for several variables including power factor, location and number of charging stations is investigated based on load margin. The outcomes demonstrating that accelerated charging of EVs is commonly regarded for decreasing a distribution network's voltage stability. The IEEE-39 bus feeder network serves for simulation and modelling in Open-DSS applications of the power grid. Comprehensive patterns of travel are used for that function. In the case of voltage stabilization situations in the electricity grid, higher charge levels with wide EV integration are mainly responsible [36].Although optimized charging methods help increase the distribution network's reliability. EVs should be used as a steady impedance load by the electricity grid before voltage stability.

The problem of voltage instability because of different degrees of penetration in EVs is enhanced by a wide area management technique that overcomes differences in the charge as well as the discharge of the EV battery [37].

Method for reducing the voltage instability problem is suggested using a tap-changing transformer voltage control technology. The authors proposed that effective planning strategies could be used to charge EV networks to reduce the voltage volatility effect on the grid. The planning strategies for charging stations rely fundamentally on criteria such as: optimum charging station dimensioning, time charging scenarios and a related venue [38]. Several scientific research has been undertaken to examine the effect evaluation on voltage stability, voltage drop, voltage deviations and phase imbalance for EVs charging scenarios. The characteristics of the EVs are different from regular loads because it is not possible to predict the power requirements of EVs earlier. As a consequence, if a sufficient number of EVs are incorporated into an electrical grid, the risk of a contravention of distribution component parameters may increase. Therefore, load control in all three phases should be used, voltage control devices, voltage assist strategies, and sufficient charge engineering of electrical vehicles in future to support a grid voltage profile without infringing.

2.1.2 Impact analysis of peak demand and load profile

The research into substantial high demand was carried out as a result of increasing usage of EVs. The authors find that 100% penetration of coordinated charge system EVs place peak demands that surpass the required electricity generating capability on average days of load. Consequently the transmission grid must be filled with up to 93% EVs over peak hours, if no additional generation services are incorporated into the distribution network [39]. With a penetration level of 30% in the EVs, the effect of coordinated charging increased demand to 53% [40]. Uncontrolled charging in residential areas led to a considerable rise in EV's penetration level up to 10%. Also under the standard EV charge case, the large improvement in peak demand is observed. Appropriate charging status is then necessary [41]. Described that only the time-of-use tariff plans and structured charge conditions will considerably ease the peak demand, even without additional generation capacity [42]. Without any substantial grid impact, the distribution network in Ontario, Canada will incorporate about 500,000 EV for charge [43]. In study [44], The authors have shown that the current US grid network capability can accommodate penetration

levels of up to 73 % of EVs. In order to determine the effect on the load profile, a scientific study [45] is undertaken on the German Power system in 2030. However, 42 million ICE cars are supplemented by electric vehicles. It is doubled. The study also showed that a 16% lower peak load can be accomplished using 1 million EVs as a storage grid stabilizer. In [46], There is an hourly overview of the Korean grid, featuring criteria such as EVs charge position, EV charging speeds and EV requirements for 2020. The parameters include EV charging location. The paper emphasize the stability of the delivery grid as a result of additional charging scenarios for EVs. The dilemma of the peak load profile is therefore addressed with time-of-use tariff arrangements. In study [47], The Estonian grid conducts up to 30% of available passenger vehicles with EVs. The results showed that coordinated charging increased by 5% at peak charging and that coordinated charging increased by 4%. In study [48], In comparison, the night time controlled charging approach will level the load profile. In order to avoid peak residential and EV load duplication, the researchers proposed an intelligent charging technique. The offering includes various charging options, including fast charging, AC charging, easy DC charging and the possibility of battery swaps. Queuing model serves to predict delays in various charging plants and a principle of partial charging is employed to avoid duplication of EV and residential maximum load. The ideal challenge is to find a minimal charge time, expense and travel time to provide an efficient charging station with an optimized solution. An improved meta-heuristic optimization of the colony is carried out, and the proposed findings suggest a decrease in the charge cost of 15% and a waiting period of 25%.

The EVs are an extra burden to the delivery grid, so the large integration of the EVs impacts a system load profile. The spontaneous charging activity of electricity proprietors increases the risk of picking high charging times [49]. Consequently, large EV penetration under various charging conditions greatly increases the maximum delivery grid load. Time-of-use plans and RES integration can be utilized for the streamlined charge approach to address power network peak demand and load profile problems [50].

2.1.3 Harmonics impact analysis

The use of power electronic devices to load EVs which cause problems in power quality in distribution networks as a result of the appearance of a switching phenomenon. The harmonic problem is important to look at since harmonic distortion plays an important role for the derivation of distribution components. Owing to the large convergence of EVs, the transmission efficiency of the power network can be impacted. The arbitrary amount of energy required EV batteries will lead to a demand-side management problem when charging EVs [51]. The spectrums of current and voltage depict harmonics. In a power network, for example, non-linear loads, the undesirable values of such spectrums would be predicted. Due to EV loading scenarios, no major harmonic problem is found in [52]. In a study [53] the THD voltage value has been raised to a level, i.e. the authors investigated an increase of the THDv level by 11.4% due to EVs with quick and random charging which contravene the EN 50160 standard limit of 8 %. A proposed approach to reduce the problem of harmonics is the control of the PV inverter as an active filter. There was an increase in THDv values above the agreed limit [54,55] in the outcomes of related harmonic tests. The random charge of 18 EVs during the peak hours is reported in [56] for THDv of up to 45 %. By using uniform charging systems the increase in device efficiency can be noticed. High THDi in [57] of 12%-24% attributable to fast charging scenarios is, in comparison, observed. The higher THDi range may have a serious effect on the power grid efficiency. In [58], the authors used fluke-scale power quality analysers to investigate power quality problems and to harmonically calculate current and voltage harmonics in real-time scenarios. The authors found that charging EVs can produce harmonics with THDi and THDv. The analysis also showed that THD is not a linear multiple factor that integrates EVs massively into the power grid.

In general, a distributing grid endures a range of nonlinear load types to provide customers with the essential power. In this way, different harmonic patterns can be seen in a power network. Even then, harmonics cancellation in a grid can be achieved through different load patterns [59]. A high number of EVs can increase the probability of harmonic cancellation. In [60]. The authors analysed four conventional EVs, including single and 3-stage rectifier, square wave and pulse width modulation on four conventional EVs (PWM).

The THD supply or specified harmonics from PWM EVs loading systems can be decreased automatically [61]. In [62] the authors suggested a solution to the problems of

consistency of power. The concept is based on the construction of a PCU that enables only the controlled charge scenario of electrical transmission units. To achieve the required power management, the PCU is compatible with the smart grid. Experiments on PCUs are based on the mode of battery charge and discharge, inductive and capacitive conditions. The results from the project showed that the suggestions of a PCU will reduce the problems with energy quality in the power grid by solving the voltage degradation issue, reducing the THD value and trying to compensate EV batteries for reactive power. By using filter devices in the supply system, the higher THDi value can be minimized. Finally, numerous research experiments [51], [62] undertaken for the evaluation of the harmonic effect achieved various results. The results of studies showed that the distribution network had minor harmonic effects. However, certain technical reports explored negative impacts due to charging situations for EVs. The variation in results from numerous harmonic effects experiments was mainly focused on methods of machine analysis and EVs charger modelling. Many different approaches to the harmonic problems, such as filters, are obtained from several implemented experimental methods in order to integrate power charging circuits.

2.1.4 Impact analysis on distribution components and system losses

The large integration of EVs will conflict with the stability of the power grid and increase the risk of errors in network components. There are significant issues about power losses for infrastructure due to additional power network losses from additional EV loads. The power losses of the feeder can be determined as [63]:

$$P_i = \sum_{i=1}^{N_B} i^2 R_i \dots \dots \dots (2)$$

Where,

I = Current

R_i = Resistance of feeder i

N_B = Number of distribution network feeders

As shown in education [64], additional power losses may be caused by various charging conditions of EVs.

$$AP_L = TPL_{EV} - TPL_{Origin}$$

Where,

TPL_{EV} = Total losses during EVs charging/Connected to grid,

TPL_{Origin} = Total losses with no EV connected to grid.

There have been many technical experiments to analyse the effect of EVs on system losses. The authors in [65] investigate the impact of EV charging on the Danish distribution network. The study found that device losses rose by up to 50 percent in uncontrolled charging scenarios by 40% and a coordinated charge reduced grid losses to 10% compared to a base case of no EV integration. There is a probabilistic method to calculate network losses in relation to mass penetration of EVs in [66] depending on the charging period, charging rates and overall charging duration. The simulated findings revealed that huge integration of EVs increased distribution network power losses. In [67], the simulation of power losses is implemented on a large distribution model. In case of 85% EV charging during off-peak time and the remaining of EV charging during peak time the date of arrival and charging patterns will not be proposed in this research. Also when 60% EVs are integrated into the power network, the findings of one scenario revealed a 40 percent rise in power loss during off-peak charging. With a widespread EV-penetration the coordinated charging technique will result in increased system losses. The authors therefore proposed in [68] that a coordinated charging goal be optimized to minimize losses of power. The research used stochastic programming to obtain an ideal solution with decreased network power loss owing to the unavailability of sufficient load prediction. In a 1200-node radial test network with Australian residential houses load profile, a large rise in delivery transformer losses is assessed [69]. In 415V busses, the penetration rate of EVs up to 42% increase the losses of the transformer by 300% for higher EV penetration.

Finally, the findings of numerous technological studies show that due to the EV charging scenario the power flow will be improved. This increases losses in the system. The coordinated charge strategy can be used to mitigate network losses from EV charging. Furthermore, the nearest distributed generation can accommodate EV loads to mitigate the power loss of the grid [70].

CHAPTER 3 METHODOLOGY

3.1 Introduction

This chapter illustrates the work flow of the study with block diagram of the proposal, UML diagram proper explanation for better understanding and characterization in the section 3.2 and 3.3 respectively.

3.2 The Proposed block diagram of Grid Infrastructure

As EVs are powered by power devices, smart grid connections and proper loader control equipment, they are both the energy resource stored and reserves for unforeseen breakdowns. Grid connectivity, intelligent EV and network operator contact and intelligent metering are important for the advantage of V2G service . **Fig 3.1** displays the overall G2V framework implementation, its specifications and G2V power flow.

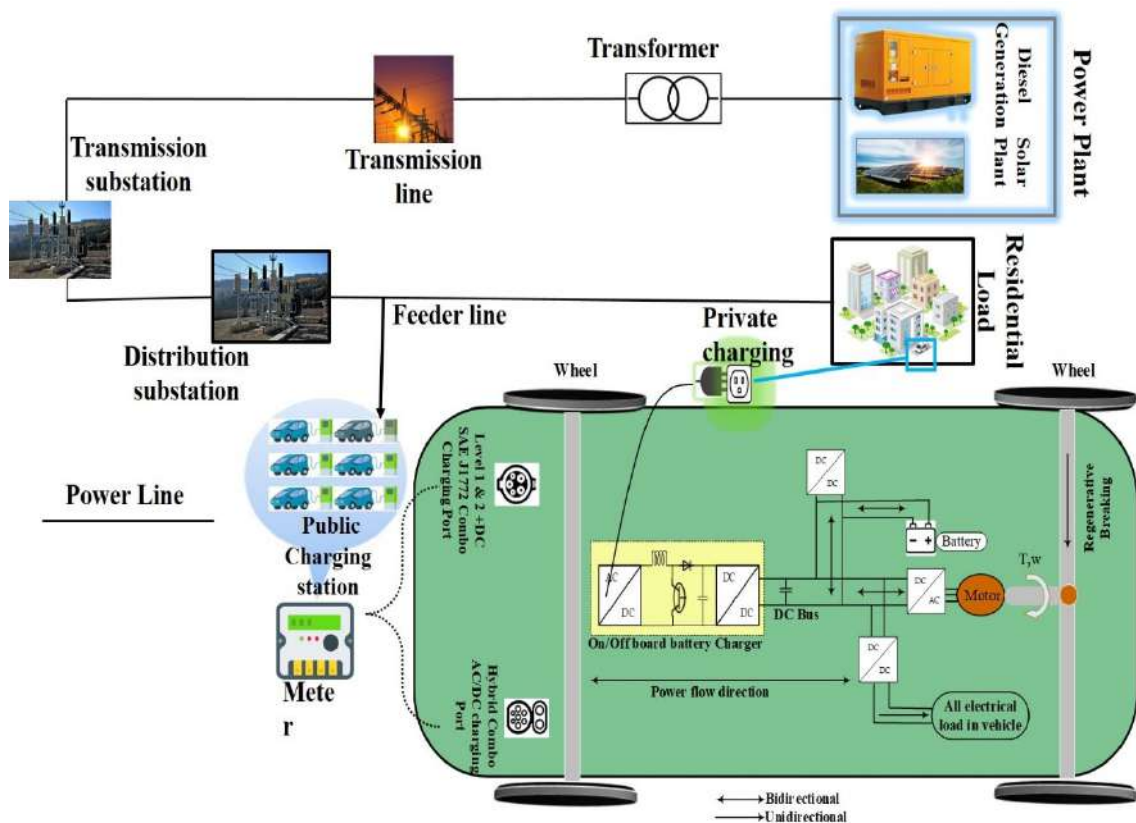


Fig 3.1 Architecture of grid model and Electric Vehicles charging infrastructure

Considering the total amount of V2G infrastructure distributed storage capacities has many impacts on grid operation. Electric vehicles have the energy back-up ability to build and use their energy storage devices for energy supply in low-voltage grids EVs are able to contribute to the collection and distribution of grid resources. They will lead to the injection of electricity into the distribution grid as required and function as a reservoir of distributed storage capacity. EVs will serve as a power source on the delivery side for emergency generators. As EV is attached to a power supply, it can be used in two separate modes: 1) Charging mode, known as G2V mode.

2) Discharge Mode known as Vehicle-to-Grid Mode (V2G). EV is a grid load in the first mode but in the second mode EV supplies grid electricity. Thus, EV is known as load or generation in terms of the utilities grid. When vehicles are in charge mode, they can store energy when releasing energy during discharge. EVs can serve as quick response load, but they can be a generator/power source for DN, even with its intended intent for transportation, while in parking mode i.e. they are plug-in to the grid and V2G technology enabled.

3.3 Methodology

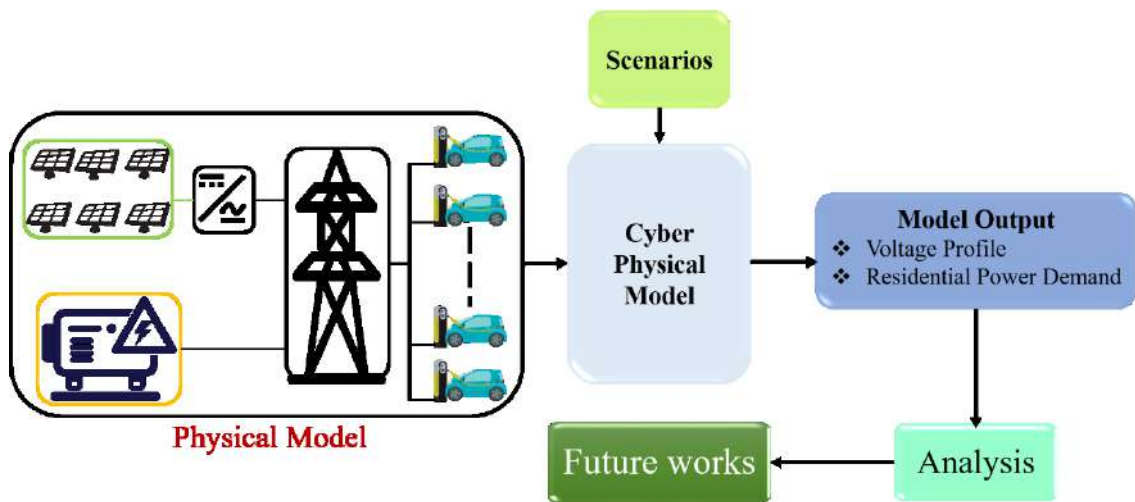


Fig 3.2 Flow diagram of methodology

Strategies The impact on the power system of EVs charging. Several studies have analysed the impacts of EVs on the electric power grid, which usually can be summed up in two Power demand profile, Power Flow. The impact analysis for EV integration involves of MATLAB Phasor 24-hour numerical simulations on grid models, eligibility regulations as well as EVs charging requirements to examine the effects of EVs integration on the loading of electrical components and voltage drops within distribution networks.

Power consumption increases (i.e. additional kilowatts of energy consumed hours), given an excess load and adjustments in the form of the demand for power (for example, changes in peak demand). Effects may eventually impact the production of electricity and transmission and distribution infrastructures.

Initial and extensive research suggest that a significant use of energy by charging electricity would have minor negative impacts on electricity generation infrastructure if any and that the impact on distribution networks is considered the most critical problem. In the MATLAB simulation, for example, the 40 % rise in overall energy demand for integration of 100 EVs is taken into account when studying different charging and integration scenarios.

However one major drawback of these study studies is that EVs are charged in a "smart" way which means that electric power suppliers control the charging and charge EVs for the off-peak" hours and different charging scenario for an ideal situation. Alternatively,

direct monitoring of demand for residential power in grid simulation may be the case in future.

The research examined the impact on distribution infrastructure of the EVs charging. The study identifies: charging features, charging time, and approval of EVs the core principles deciding the impacts of EVs on the distribution network. Combines bottom-up EVs and residential charging models to demonstrate that coordinated EVs charging in a low-voltage distribution network can cause voltage unbalances. An additional study[71] suggests the use of synchronized charging for the purposes of optimizing the main grid charge factor in terms of transformer and feed overloads, power losses and power efficiency.

For coordinated charging of EVs the power losses and voltage differences are registered, provided hourly distributions, and provided the vehicle is charged for set time windows. Residential properties loads are also estimated. Detailed charge demand data are used to estimate the effect of EVs charge on transformers of overhead delivery and infer that coordinated charging rate increases considerably transformer elderly rates, especially for first charging. The EVs charging rate and scheduling are indicated to have a major impact on the loading system curve, with mild tension deviations [n] being documented. The residential load curve is average to model each household's residential load. EVs shall supposedly be batteries with a capacity of 40 kW which are charged to 90% per day. Load profiles of 24 Hour EVs have been expected for numerous load handling situations including coordinated charging.

An analysis of this vast literature illustrates the second limitation: the research relies on specific distribution networks or rely on average figures for the calculation of residential demand or charging loads of electricity electrical vehicles rather than comprehensive models. For example, the average daily power usage also estimates the overall demand for charging EVs. Charging times are normally calculated from the planned supply of vehicles (for example, all vehicles charge during a predetermined time period). These conclusions are typically based on average sample or hypothesis based on multiple proposed studies. Although this method can be helpful for determining general patterns, more comprehensive data helps the impact of electricity charges on the electrical grid to be estimated better.

Pay attention to resolve the two limitations through the use of comprehensive bottom-up models on all modules to simulate different charging scenarios and to determine the impact of the coordinated charging on residential power demand, using the medium

statistical data and using omnipresent 'smart' EVs charging. For the potential use of EVs and the development of residential charging facilities, various possibilities are considered.

It is important to note that some studies involve V2G applications that enable vehicle batteries to be charged and discharged for grid service and system stability. Various grid-to-vehicle setups were predicted [45] well in advance of the introduction of V2G. The use of V2G remains problematic, as charge and update cycles affect battery life and performance. V2G delivers a service to electric utility providers and likely to PEV owners using the resources that are responsible for vehicle manufacturers (e.g., automotive manufacturers guarantee the battery life), using the V2G complex. The current research does not take into account V2G connections, including energy from the EV battery to the grid [8].

CHAPTER 4 CASE STUDY

4.1 Introduction

This chapter demonstrated the grid modelling as well as discuss EVs charging profile in section 4.2, model specification and used components parameter and profile in section 4.3, reason of phasor simulation in section 4.4, Design of EVs charging profile in section 4.5, essential parameters of driving pattern in section 4.6, local residential power demand impact on the grid section 4.8, behaviour of power quality of the electrical network section 4.9

4.2 Grid Modelling

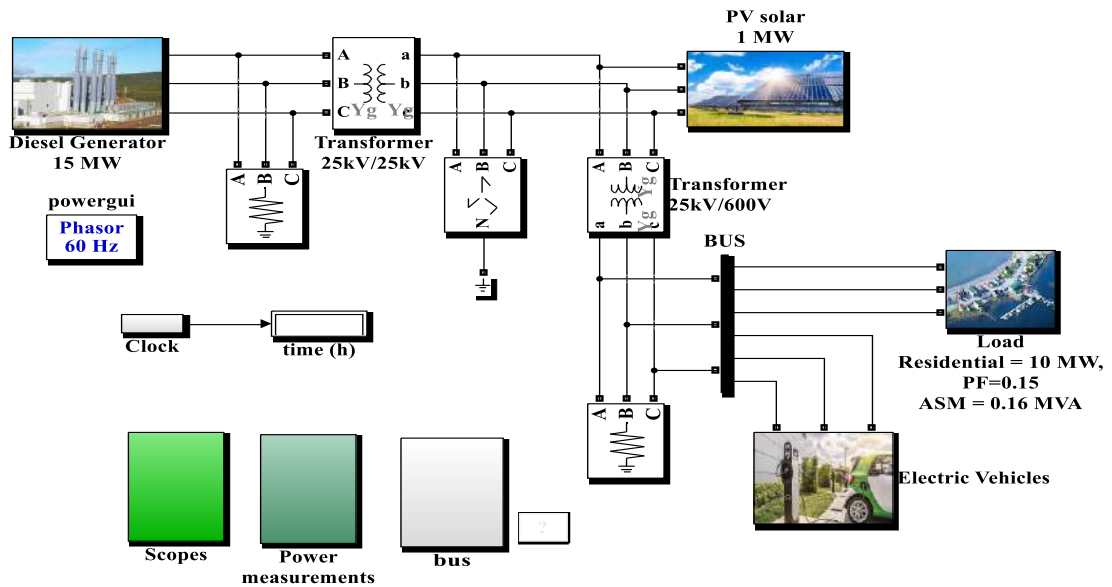


Fig 4.1 Architecture of MATLAB simulation model

The microgrid consists of four major parts: a diesel generator, functioning as the foundation power generator; a photovoltaic farm for renewable energy production; an electricity generator, set up near the last portion of the grid load system and utility grid. During the low demand day in spring or fall, the population of the microgrid represented a community of about one thousand residences. In the simple model, there are 100 electric vehicles, which ensures that the vehicles and residences have a 1:10 ratio. In the immediate future, this is a reasonable solution, it show in **Fig 4.1** [72].

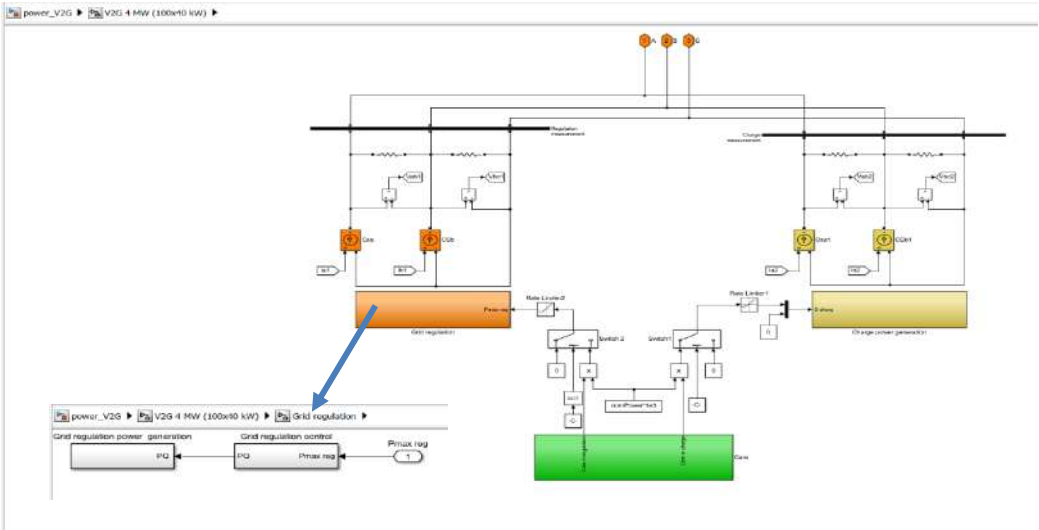


Fig 4.2 Grid Integration of EVs Simulink

The diesel generator combines the energy used and the energy produced. By looking at the rotor speed of the synchronous unit, we will calculate the frequency shift of the grid. This microgrid has renewable energy. PV farm generates energy proportional to three factors: the size of the area protected by the PV farm, the performance of the solar panels and the solar radiation statistics. The load consists of a residential load and an asynchronous machine which reflects the impact of an industrial inductive load on the microgrid (as is the case with a ventilation system). The residential load fits an energy factor utilization profile. A square relationship between the rotor velocity and the mechanical torque governs the asynchronous system.

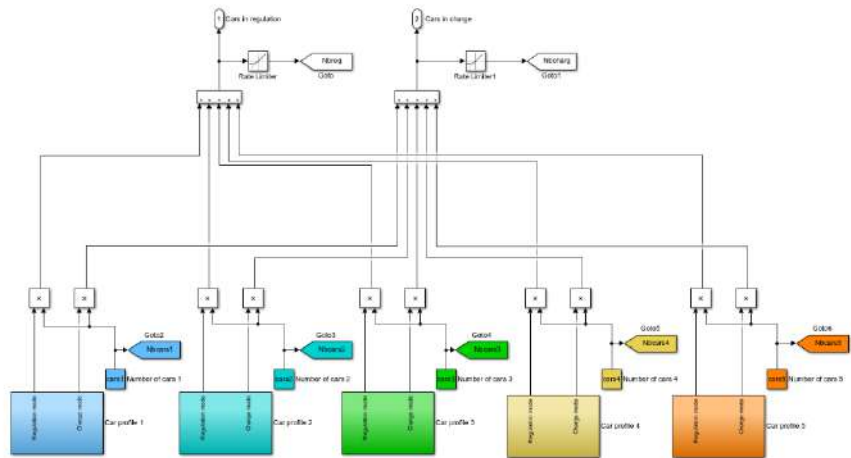


Fig 4.4 EV user profiles Simulink

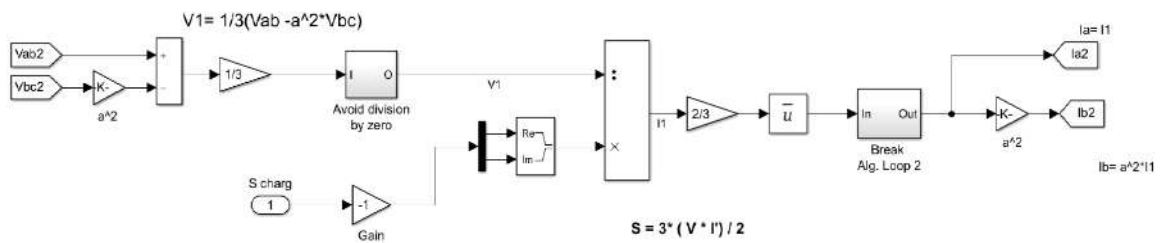
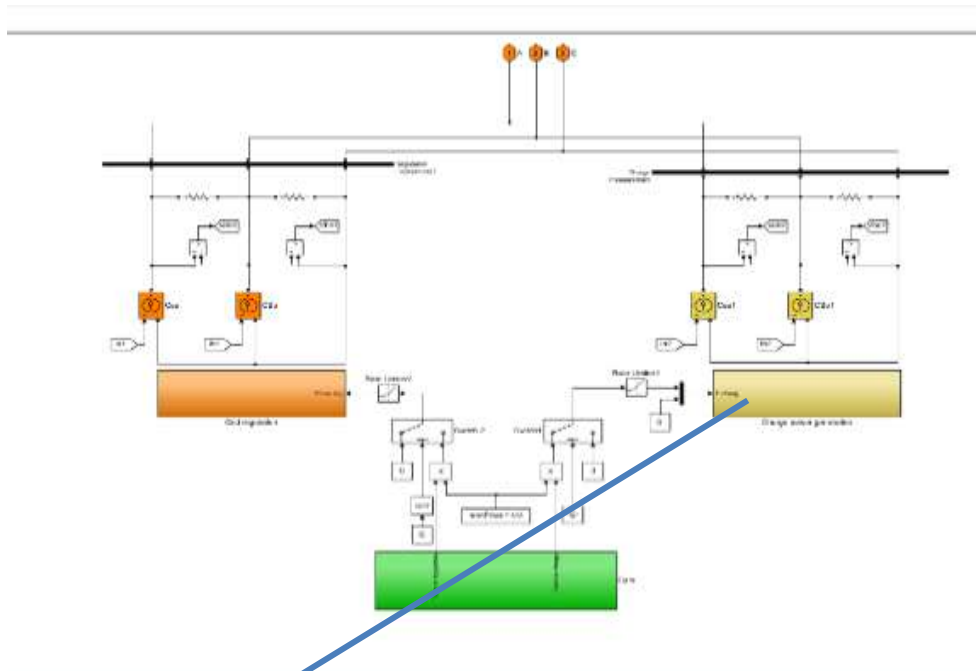


Fig 4.5 Charge power generation

The EVs have one mechanism: to monitor the battery charge. Four separate EV user profiles are implemented:

1. Profile 1: People would have the possibility of charging their car at work.
2. Profile 2: People will have the opportunity to charge their car at work, but they will have a longer ride.
3. Profile 3: People going to work with no possibility to charge their car at work.
4. Profile 4: People working on a night shift

It takes 24 hours to simulate (phasor). The intensity of the solar is natural, with the maximum intensity at midday. The residential load is comparable to a standard household intake in a traditional pattern. The daily intake is low and in the evening it rises to a high and in the night it declines steadily. The grid frequency of the day is influenced by two events:

1. A partial shading at noon affecting the production of solar power.
2. The kick-off of the asynchronous machine early at the third hour.

4.2.1 Diesel Generation

A system with a resistive and motor load is installed at 2400 V via a transformer 6 MVA 25/2 kV Wye-Delta and an emergency sync generator/diesel engine set from 25 kV distribution network. An R-L equivalent source with a short-run level of 1000 MVA and 5 MW load is used in the 25 kV network, it show in **Fig 4.2** [73].

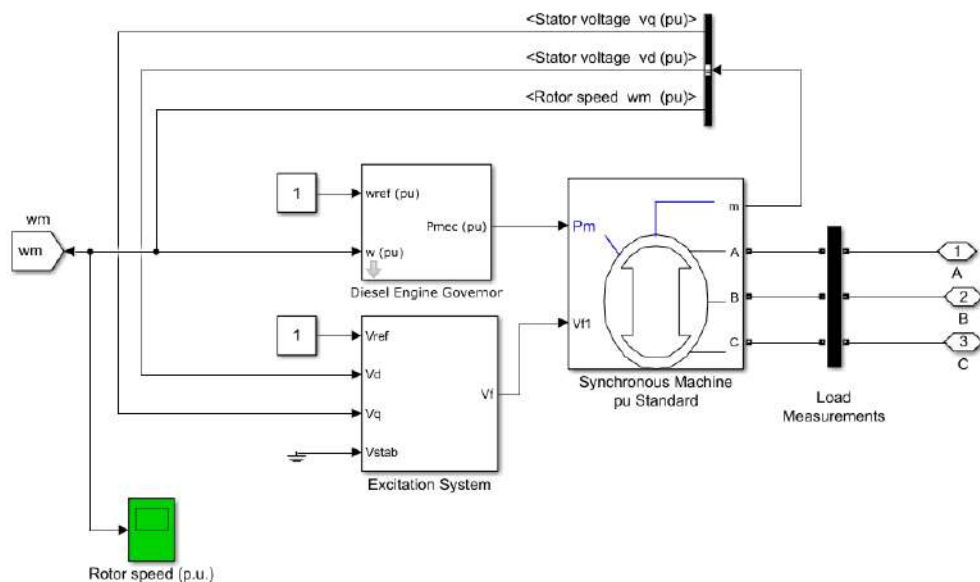


Fig 4.2 MATLAB block diagram of Diesel Generation

Demonstration

1. The asynchronous motor and synchronous machine must initialize the load flow tool of powergui to launch the simulation in steady state. In the Load Flow tab of the two blocks, the load flow parameters for the machine and motor are determined:
 - a. "PV" is the parameter of the "Generator type", which mean the load flow takes place by regulation of the terminal voltage and active power of the system. The parameter "Active power generation P" is set to 0.
 - b. For the synchronous machine: The parameter "Mechanical Power" is $22e+006$ W (2000 HP).
2. To solve the load flow, press the "Compute" button. Now the table displays the active and reactive power of the actual devices.
3. To add the load flow solution to the model, press the 'Apply' button.
4. Have to open the block governor of the diesel engine. The initial mechanical power value of the load flow tool is set at 0.00027 pu (844 W).

5. In the initial values tab, open the “EXCITATION” block, field voltages and terminal voltage values are 1.4273 and 1.0 pu respectively.
6. To pick the kind of simulate excitation system, right-click the EXCITATION block. Notice that the initial values of both versions have the same initial values already recommended. The additional line of is set for the ST2A model, representing the initial terminal current 0 pu to 0.2739 pu.
7. Start the simulation, to check in the scopes that the simulation is starting in steady state.

4.2.1.1 Diesel Engine Governor

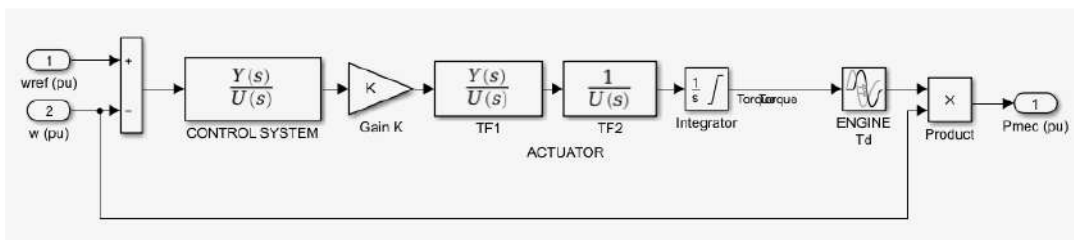


Fig 4.3: MATLAB block diagram of Diesel Engine Governor

In **Fig 4.3** , The Block Governor of type 3 model IEEE3 hydro turbo-Governors has a more detailed governor model than the Block 1 Governor model and employs a linearized model of a turbine, water, column and penstock model [74]. This Block has a much more detailed governor model than the Block 1 Governor [75].

Governor block implements a double input diesel engine and control system. The engine power and actual performance of this block diesel engine. Engine inertia with generator should be combined.

Controller transfer function:

$$H_c = \frac{K.(1+T_3.s)}{1+T_1.s+T_1.T_2.s^2} \dots \dots \dots (3)$$

Actuator transfer function:

$$H_a = \frac{(1+T_4.s)}{[s(1+T_5.s)(1+T_6.s)]} \dots \dots \dots (4)$$

The Sample Time (-1 for inherited) parameter can be used to change between continuous to discrete implementation of the block. Set sample time (-1 for inherited) property to 0. To configure the governor for continuous time. Set the Sample time (-1 for inherited)

property to positive, non-zero value or to -1 to set the sample time to an upstream block in order to configure the governor for a discrete period of time.

4.2.1.2 Excitation System

Provided a synchronous machine excitation system and controlled the terminal voltage in generating mode. The Excitation System Block is a Simulink system that uses a DC exciter described [76,77], without the saturation function of the exciter. The voltage regulator and exciter are the key elements of the excitation system block, it show in **Fig 4.4** .

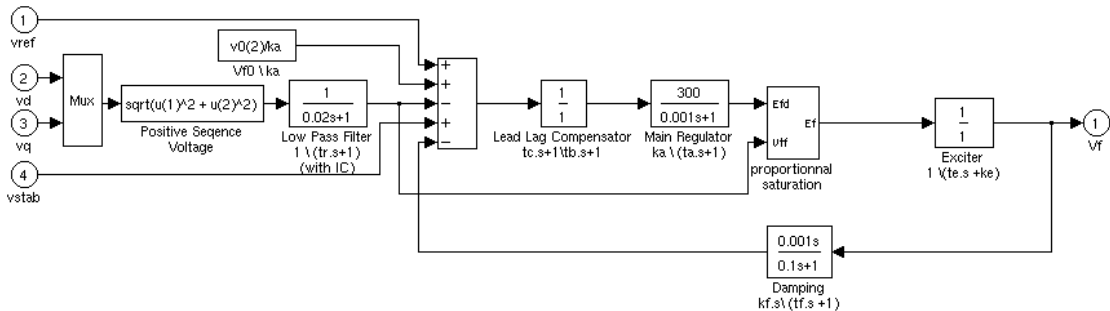


Fig 4.4 MATLAB block diagram of Excitation System

The exciter is shown by the following transfer function between the Vfd voltage excitation and the output of the regulators ef:

$$\frac{Vdf}{ef} = \frac{1}{Ke+sTe} \dots\dots\dots (5)$$

Low-pass filter time constant:

The time constant T_R for the first-order system representing the stator terminal voltage transducer, in seconds (s), 20×10^{-3} is the default.

Regulator gain and time constant:

In seconds (s), the gain K_A and T_a is the main regulator of the first-order system, [300, and 0.001] define as default.

Exciter:

The first order system representing the exciter gains K_e and time, T_e constant, in seconds (s) & [1, 0] by default.

Transient gain reduction:

The time constant is T_b and T_c both are in seconds (s), the first-order compensator system, [0, 0] as the default.

Damping filter gain and time constant:

In seconds (seconds) of the first order method, the K_f and time constant T_f reflect a derivative feedback and [0.001, 0.1] as the default value.

Regulator output limits and gain:

The voltage regulator outputs are subject to $E_{f_{min}}$ and $E_{f_{max}}$ limits. The upper limit may be constant and equal to $E_{f_{max}}$ or variable, with proportional gain K_p being equivalent to the V_{tf} rectified stator terminal voltage. The former applies if K_p is set to 0. The above applies if K_p is set to a positive value and [-11.5, 11.5,0] as default value.

Initial values of terminal voltage and field voltage:

V_{t0} (pu) and V_{f0} are the initial terminal voltage values (pu). They allows to begin the simulation continuously when set correctly. Ordinary 1 pu should be set to first terminal voltage. The load flow utilities of the Powergui block change both V_{t0} and V_{f0} values automatically. The [1.0 1.26] as default.

4.2.2 Residential Load Profile

The load consists of a residential load and an asynchronous machine, which describes the effect of industrial inductive loads on the micro grid (such as a ventilation system). The residential load has the same power factor as the demand profile, it show in **Fig 4.5** . A square relationship is regulated between the rotor speed and the mechanical torque by the asynchronous machine.

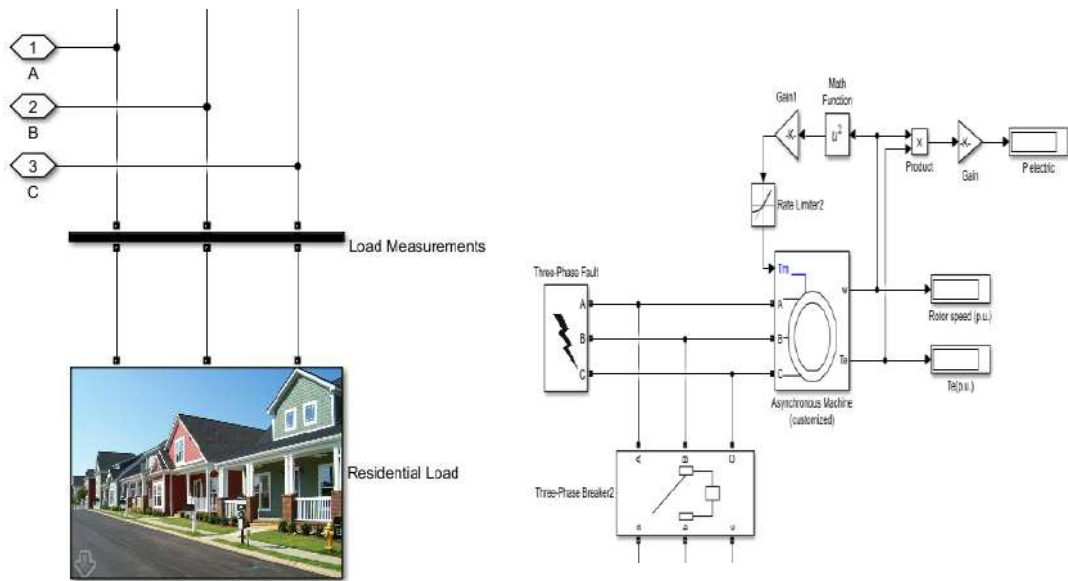


Fig 4.5 MATLAB block diagram of Residential load and Asynchronous Machine model

The load profile requires a nominal power and a power factor to be fixed. The time step used for the consumption profile also needs to be defined. It must be specified in each unit. Important fact that, the vector length must match with the timestep used.

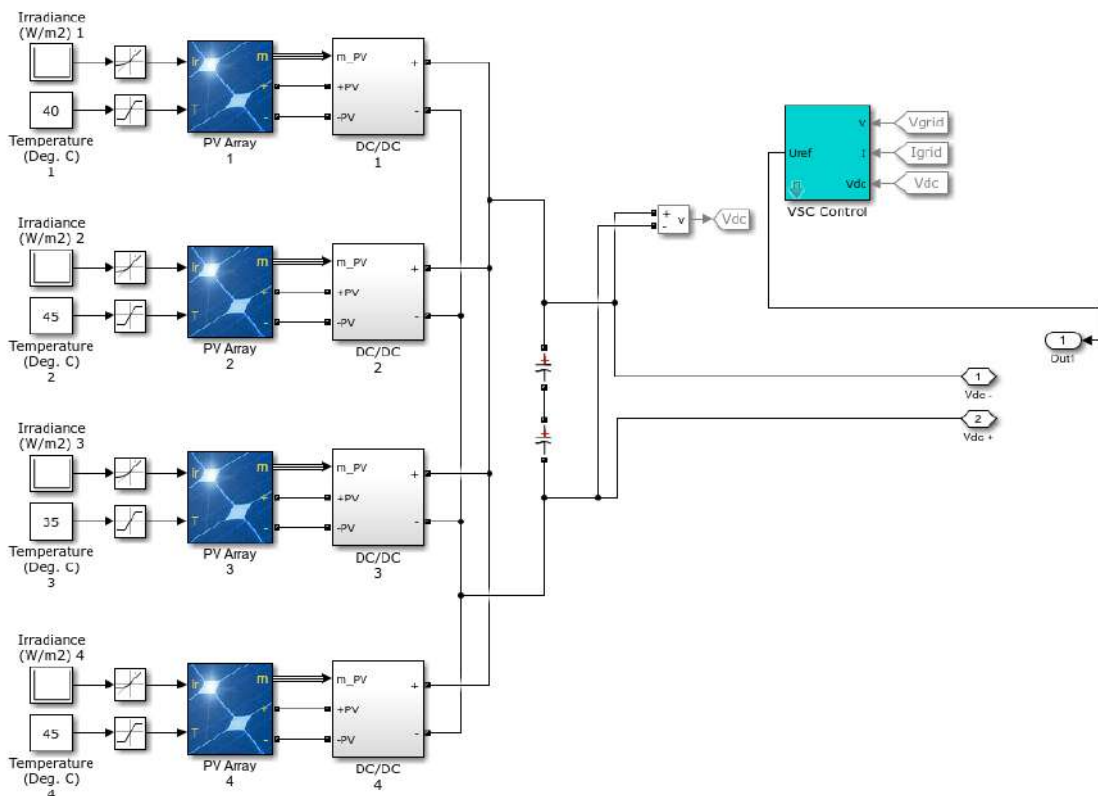


Fig 4.6 : Solar cell simulation

Load Profile

The load profile allows to fix a nominal power and a power factor. It is also needed to specify the timestep used for the consumption data's. A vector expresses the consumption profile. It has to be expressed in per unit. It is imperative that the length of vector fits with the timestep used.

Table 1 Load profile of residential Grid

Nominal Power (MW)	10
Power factor	0.95
Timestep (minutes)	60

Asynchronous Machine

Implements a three-phase Asynchronous Machine modelled in a selectable dq reference frame. Stator and rotor windings are connected in wye to an internal neutral point.

Table 2 Specification of Asynchronous Machine

Nominal power	$1.5 \cdot 10^5$ VA
Voltage (line-line)	600 V
Frequency	60 Hz
Rotor Resistance (Rs)	0.01117 pu
Rotor Inductance (Llr)	0.04832 pu
Mutual inductance	2.424 pu
Inertia constant	0.3096 H
Friction factor	0.01511 pu
Pole pairs	2

Grounding Transformer

In the distribution networks and in some power electronic converters grounding transformers are used to provide a neutral point in a 3-wire system. It is a three-phase two winding transformer connected in zig zag with winding 1 and winding 2, as seen in **Fig 4.7**.

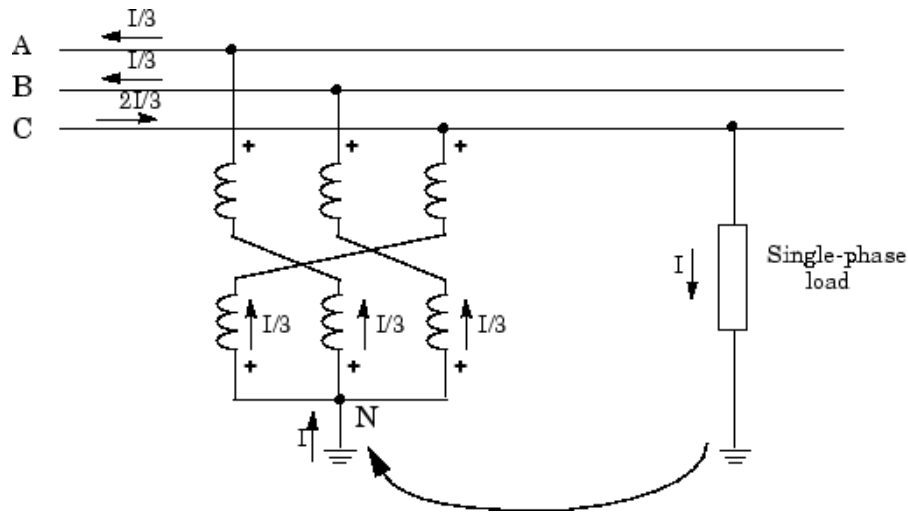


Fig 4.7 One line diagram of Grounding Transformer

The figure indicates a one-phase load connected with a three-wire device between Phase C and the ground. By ground and the neutral transformers, the current I absorbed by the load returns to the source. The zig zag relation and the opposite winding polarities of the top and bottom windings make the grounding transformers a low zero impedance while retaining a very high positive-sequence impedance. That is to say, the three windings can only pass through a zero-sequence current. A zero sequence current is by definition a set of three phase currents of the same magnitude and phase. As a consequence, neutral current I is split into three equal currents $I/3$. Because all three currents are equal, the neutral point remains constant and the line-to-neutral voltages are balanced.

4.3 Phasor Simulation

The phasor solution approach is valuable in particular in the analysis of power network oscillations that requires massive motors and generators. The simulation of a multi-machine system in three-phase structures and devices is an example of this process. This approach is not limited to the study of temporary machinery stability. It is ideal for all linear systems.

Since the phasor solution approach utilizes a steady-state model made up of slow-state machineries, turbines and regulators, the required simulation time is reduced significantly. In solving this type of problem, continuous variable-phase solvers are very efficient. The authors suggested solver is **ode23tb** with single fundamental frequency loop maximum duration ($1/60$ s or $1/50$ s). This easy solution technology provides only in the vicinity of the specific frequency. If interested to changing the magnitude and phase

of all voltages and currents in a linear circuit as switches are closed or opened, no need to solve all differential equations (state-space model) dynamic interplay of R, L, and C components. Instead, you can solve a much simplified series of algebraic equations relating to voltage and current phasors. This is precisely what the phasor solution approach does. As its name suggests, this approach measures voltages and currents as phasors. Phasors are complex numbers describing sinusoidal currents and voltages at a given frequency. They can be represented in Cartesian (real and imaginary) coordinates or in polar coordinates (amplitude and phase). The phasor solution mechanism would not need a special solver to solve the electrical component of your system because of ignorance of electrical conditions. The simulation is also much faster to run but bear in mind, this quicker solution strategy only offers a solution at one specific frequency.

4.4 Design of Electric Vehicles Charging Profile

The state of charge (SOC) is amongst the most significant battery concepts, but there are several issues with its specification. The SOC of a battery is generally specified as the ratio between its current capacity (Qt) and its nominal capacity (Qn).

$$SOC = \frac{Qt}{Qn} \dots\dots\dots (6)$$

SOC is a key indicator for the measurement of EV battery storage systems. SOC forecasts of batteries have also been intensively mentioned due to their fast charge, long life cycle and high density of capacity. However, due to various their diverse properties in varying working conditions, the exact SOC examination of batteries remains difficult. Alternative techniques were used to develop an innovative method of SOC estimation without details on battery chemical reactors, battery models, internal features and extra filters.

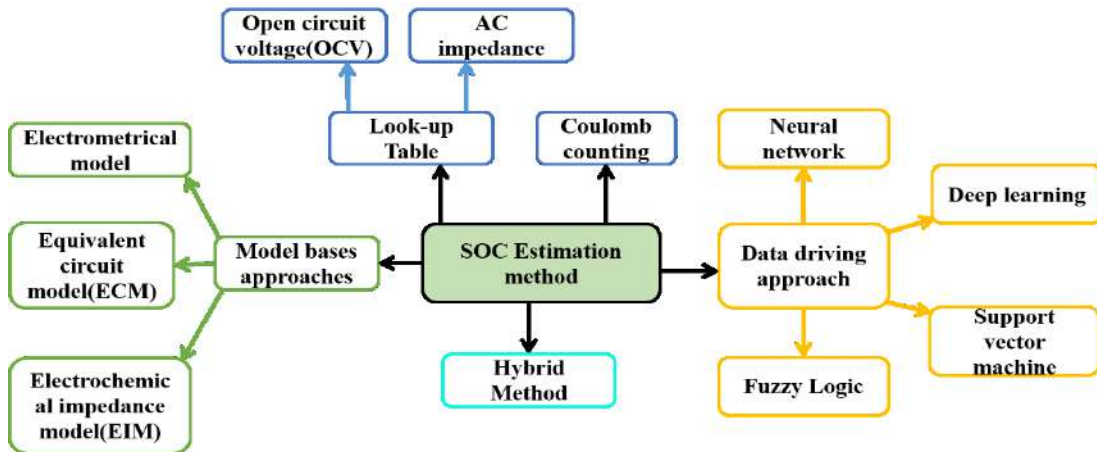


Fig 4.7 Classification of SOC estimation method

This analysis separates the methods of SOC estimate into five categories, including the lookup table technique, the coulomb counting approach, model based estimate techniques, data-driving measurement methods and the hybrid methodology, as seen in this **Fig 4.7**. The conclusions are illustrated in several research on SOC estimation.

4.4.1 LOOK-UP TABLE METHOD

The lookup table approach uses the direct mapping association between SOC and external parameters including an Open-Circuit Voltage (OCV), impedance, respectively. This approach consists of tabulating relationships by performing intense physical examinations to characterize battery behavior [78]. The approach of the OCV look-up table is clear in principle and very descriptive [79].

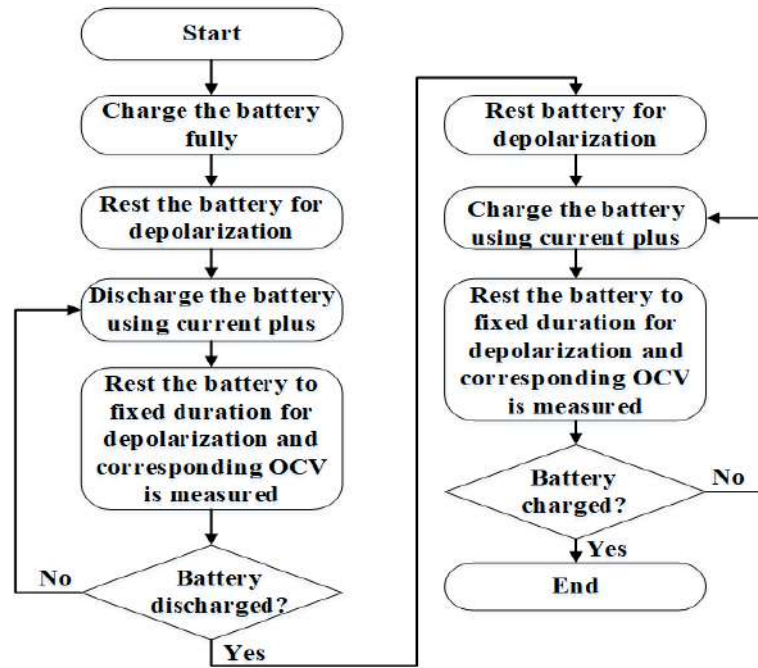


Fig 4.8 Flowchart of OCV-based SOC estimation process

The OCV-based SOC estimation process flow chart is shown in **Fig 4.8**. For a set interval to enter the depolarization stage, the LIB is totally charged. After that, using current pulses, the LIB is completely discharged. Then, the battery is kept in rest for a set time and subsequent OCV of LIB is measured. The association between the OCV and the SOC is then mapped. During the charging period, the OCV display is accompanied by a similar process. When the look-up table is developed, the SOC level is given by evaluating the LIB's simultaneous OCV. The main downside of look-up table strategies is that they are only valid when the battery is in the static state i.e. not exposed to any load and permitted sufficient rest time to reach an overall balance. The LIB is typically run on an ongoing basis in real-world implementations outside the laboratory setting. Therefore, to estimate the online SOC calculation, this method might not be very practicable.

4.5 Design of Charging Infrastructure in MATLAB/Simulink

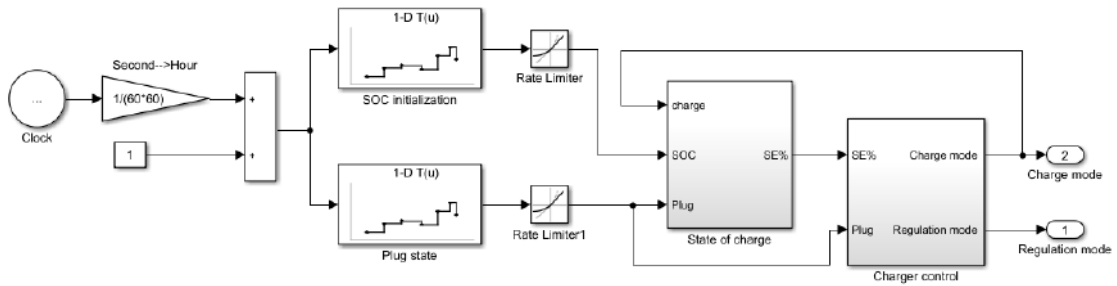


Fig 4.9 Block Diagram of develop charging infrastructure using lookup-table method

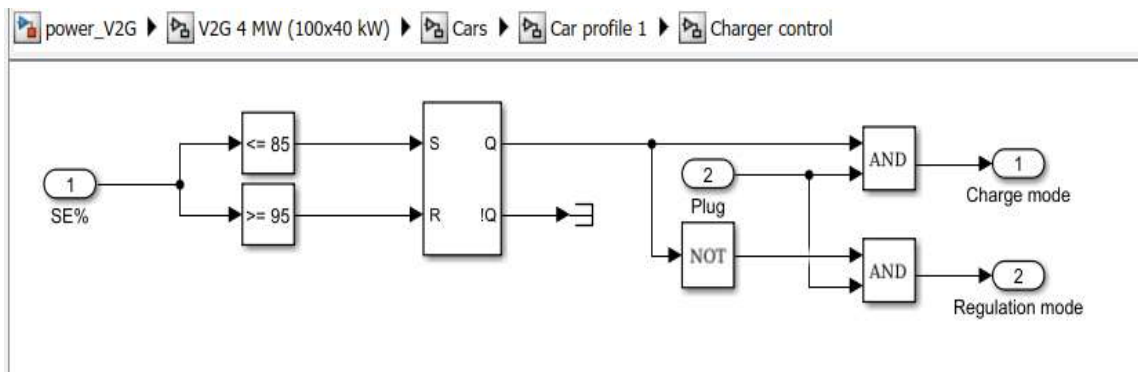


Fig 4.6 Charge controller Simulink for Profile

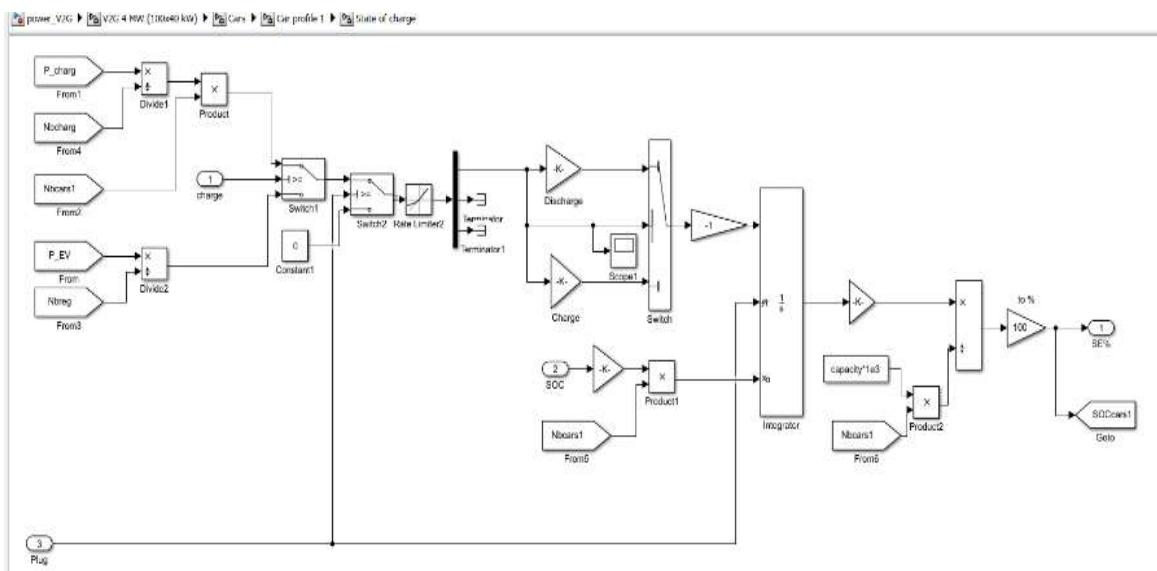


Fig 4.7 State of charge Simulink for Profile

In this study, to simulate the charging profile use look-up table strategies in terms of learning efficiency, reliability, generalized efficiency and speed towards improved SOC evaluations. Through experiments in the batteries, EV drive cycles, temperature, noise and aging impact, we apply the theoretical process. Present a variety of state-of-the-art

approaches to precision, adaptability and robustness across a range of operational situations under the proposed system. The system architecture of the MATLAB simulation demonstrates in **Fig 4.9**.

In order to evaluate SOC and battery end voltages at the next simulation, the battery method includes the battery current and the original SOC value. The SOC is part of the battery current split between the overall battery capacities (Cbat) as shown in Equation.

$$SOC_{(t+1)} = SOC(t) + \frac{1}{C_{bat}} \int (-I_{batt})dt(t + 1) \dots\dots\dots (7)$$

Open circuit voltage of a battery (Vbatt oc) is calculated using the current SOC value from a look-up table. Vbatt_oc and the internal battery resistance rbatt measure the terminal voltage as shown in Equation.

$$Vbatt = Vbatt_{oc} - Ibatt * rbatt \dots\dots\dots (8)$$

The simulation technique was first to construct an EV model using the available data for testing of vehicle parameters. The engine power for this first iteration has been set to zero such that the model was an EV [80], [81]. This approach was introduced, since it is critical that the vehicle model is first tested in a real-world vehicle like the EV to ensure accurate simulation performance.

4.5.1 Look-Up Block Operations

A sampled expression of a function in N variables is evaluated by the 1-D, 2-D, and n-D Lookup Table blocks, it shown in **Fig 4.10** [82].

$$y=F(x1,x2,x3,\dots,xN) \dots\dots\dots (9)$$

Where it can be analytical for the attribute F. By looking up or linear interpolation a table of values you specify with block parameters, the block maps the inputs to an output value. The block supports interpolation methods of flat (constant), linear (linear point-slope), Lagrange (linear Lagrange), closest, cubic-spline, and Akima spline. These techniques can be extended to a table of any size from 1 through 30.

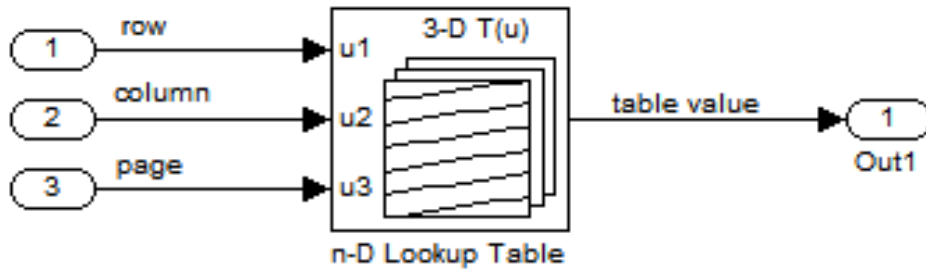


Fig 4.10 Internal block diagram of lookup-table block

The first input recognizes the first dimension (row) breakpoints in the following block, the second input identifies the second dimension (column) breakpoints, etc. The 2-D and n-D Lookup Table block behavior switches from column-major to row-major when the Math and Data Types > Usage algorithms designed for row-major array structure configuration parameters are set. The column-major and row-major algorithms for these blocks may vary in the order of the performance calculations, probably resulting in numerical values being slightly different. A Simulink Coder™ or Embedded Coder license is mandatory for this functionality. See Code Generation of Matrix and Arrays for more detail on row-major support (Simulink Coder).

4.6 EV Driving Pattern

EV can be used as a load that is controllable. However, the representation of EV charging power as a particular load curve is complicated. Since EV drives in a stochastic form, probabilistic methods for the imitation of EV driving characteristics are used. The parameters for the plug-in charging time and travel distance for each vehicle type under consideration is as shown in **Fig 4.11**, **Fig 4.12** , **Fig 4.13** , **Fig 4.14** .

The charge-depleting mode is believed to run EVs until the SOC is 0.4, then up to 1. This ensures the battery life's lifespan. The first SOC of EV before the following charge is used for the all electrical range of R_d before the end of a moving R distance.

$$SOC_{in} = \begin{cases} (1 - \frac{R_d}{R}), & 0 < x < n * R_d \\ 0.4, & otherwise \end{cases} \dots\dots\dots (10)$$

The energy required to fully charge the EV battery can be expressed as:

$$P_{EV} = (1 - SOC_{in}) * \frac{40KW}{90\%} \dots\dots\dots (11)$$

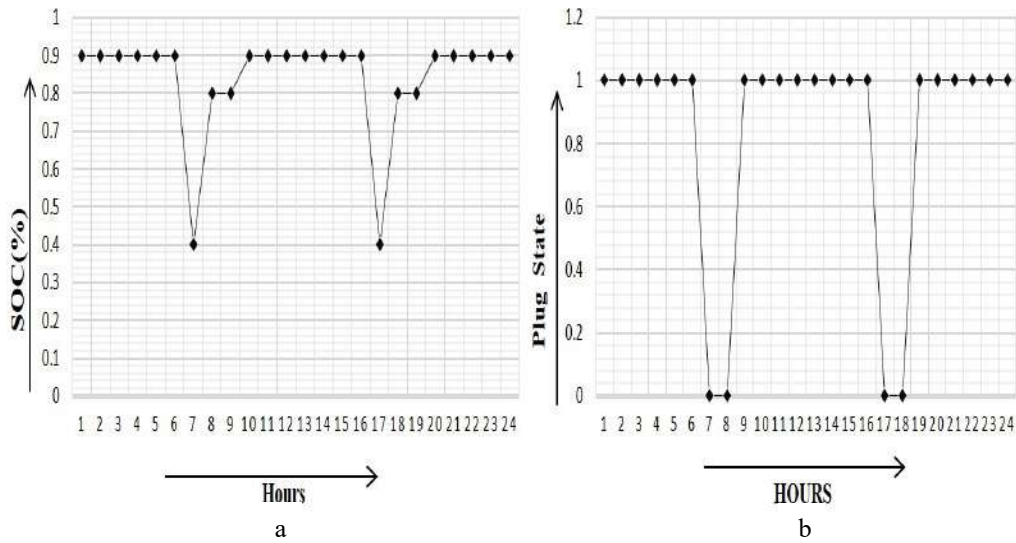


Fig 4.11 (a) State of charge condition of charging Profile 1 **(b)** Plug State condition of charging Profile 1

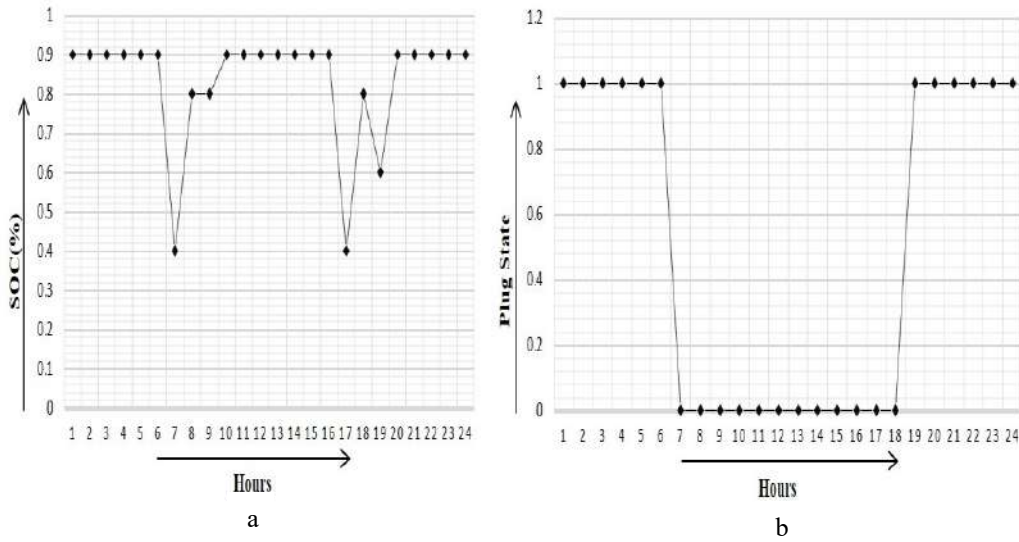


Fig 4.12 (a) State of charge condition of charging Profile 2 **(b)** Plug State condition of charging Profile 2

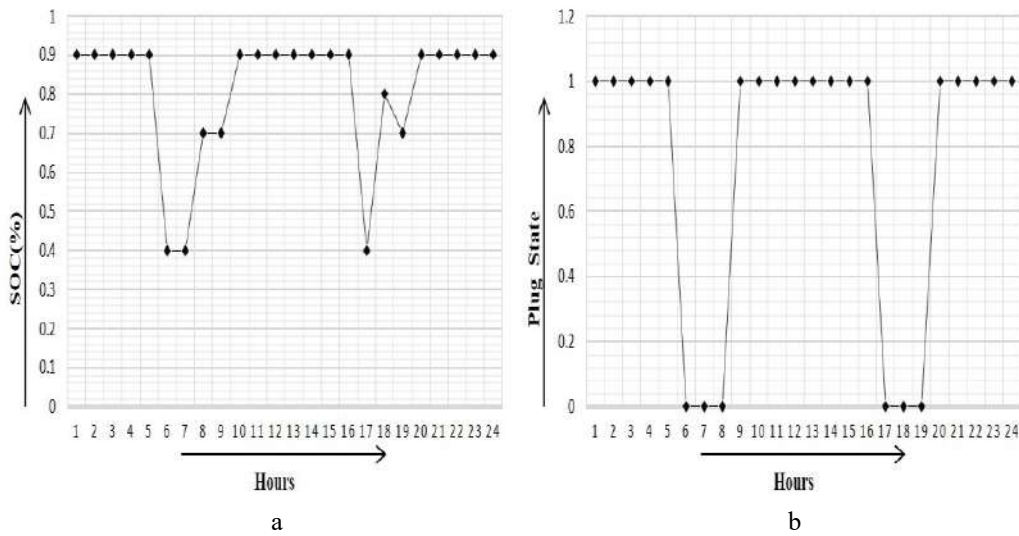


Fig 4.13 (a) State of charge condition of charging Profile 3 **(b)** Plug State condition of charging Profile 3

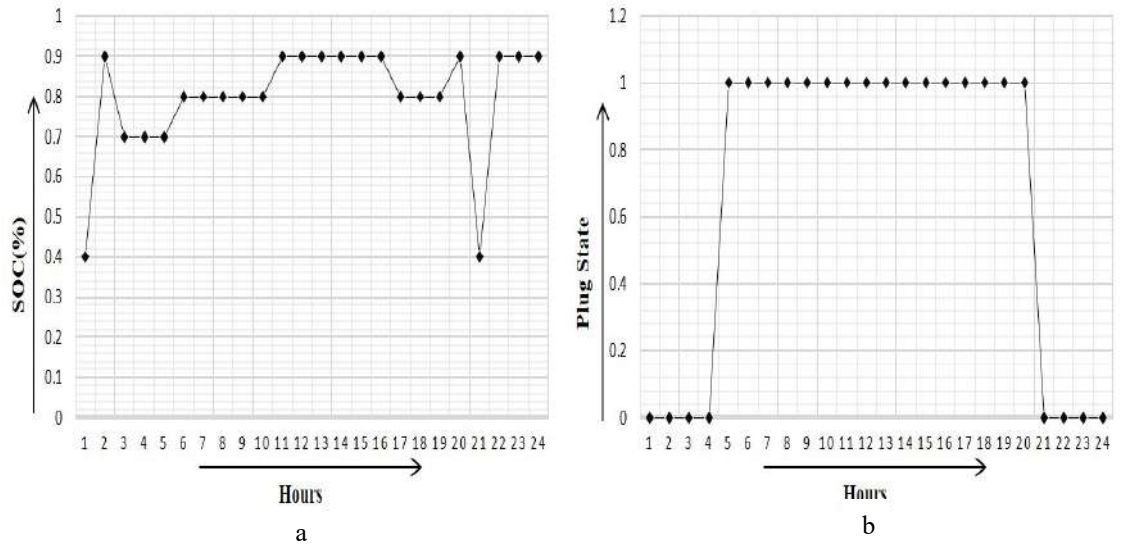


Fig 4.14 (a) State of charge condition of charging Profile 4 **(b)** Plug State condition of charging Profile 4

CHAPTER 5 RESULTS

5.1 Introduction

The electric vehicles charging station has a significant impact on power demand in residential grid. The analysis and comparison between residential power demand without electric vehicle charging station in grid and with electric vehicle charging station in grid. Fast charging and different schedule charging are responsible for increasing power demand.

At the time of electric vehicle charging the grid voltage drop from its nominal value. This term is called voltage sag. The voltage deviation also happened at that moment. The use of power electronics device and fast charging are responsible for this sorts of event. Power demand, voltage profile and current profile have been discussed and illustrated in this chapter.

The increase of residential power demand have been discussed and illustrated from section 5.2.1 to 5.2.4. The voltage profile and current profile of grid have been discussed and illustrated from section 5.2.5 to 5.2.8.

5.2 Impact on local residential power demand

To evaluate the local impact of coordinated EVs charging on the electric power distribution infrastructure, in this study consider a residential distribution transformer connected to 1000 house-holds. The impact of coordinated charging of EV on the residential electric power distribution infrastructure is summarized in Table 3 for fast EVs charging, assuming a EVs market share of 40% (100 EVs: the entire electric load is due to residential consumption), and four different charging profile .

1. Profile 1: People would have the possibility of charging their car at work.
2. Profile 2: People will have the opportunity to charge their car at work, but they will have a longer ride.
3. Profile 3: People going to work with no possibility to charge their car at work.
4. Profile 4 : People working on a night shift

Table 3 Impact of coordinated in-home EVs charging on residential electricity demand for a sample electricity distribution transformer connected to 1000 households

Charging Profile	Profile 1	Profile 2	Profile 3	Profile 4
Number of EVs	100	100	100	100
Average Power demand (kW) without EV	8500	8500	8500	8500
Average Power demand (kW)	10850	9200	11800	8800
Peak power demand (kW)	0.53			
Power demand Increase daily (%)	27.05	8.23	37	4.17
Average hourly transformer load factor	0.43	0.368	0.47	0.36
Peak transformer load factor	0.512	0.56	0.512	0.156

5.2.1 Profile 1: People would have the possibility of charging their car at work.

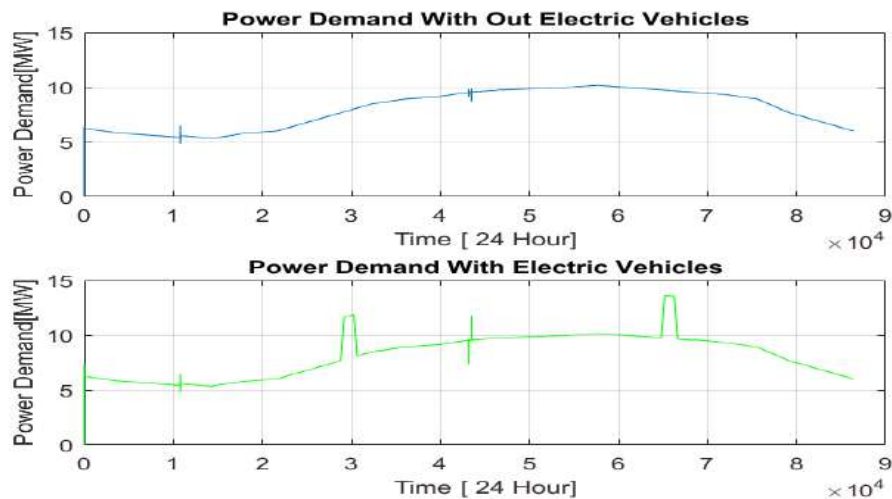


Fig 5.1 (a) Power demand of residential grid without electric vehicles **(b)** Power demand of residential grid with electric vehicles

Results for the 40% EVs adoption scenario for Profile 1 show in **Fig 5.1** from 7.15am to 8.30am the is in charging this time the power demand increase 7.5MW to 12.8MW . In morning time the power demand increase in grid 53%. Afternoon 5.15pm to 6.45pm EV in charging fleet the power demand rise 10MW to 14.2MW. The power demand increase in grid 42% than conventional residential demand. The daily power demand increase in residential grid is 27.05%.

$$\text{average transformer load factor} = \frac{\text{average hourly power consumption}}{\text{transformer nominal power}}$$

Show an average transformer load factor of 0.43 when EV charging station integration with residential power grid. Average transformer load factor of 0.34 when residential power grid have no EV charging station.

$$\text{Peak transformer load factor} = \frac{\text{peak hourly power consumption}}{\text{transformer nominal power}}$$

From 7.15am to 8.30am peak transformer load factor of 0.512. At afternoon 5.15pm to 6.45pm peak transformer load factor of 0.568.

Note that the transformer load factors are computed on the basis of the hourly load, rather than on the 75 min and 90 min load, since transformers are designed to withstand significant overloads for short periods of time and hourly. loads are usually considered in the literature.

5.2.2 Profile 2: People will have the opportunity to charge their car at work, but they will have a longer ride.

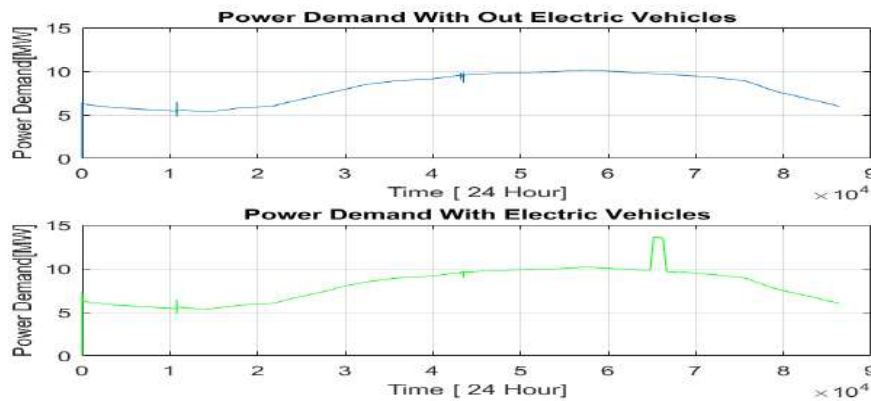


Fig 5.2 (a) Power demand of residential grid without electric vehicles **(b)** Power demand of residential grid with electric vehicles

Results for the 40% EVs adoption scenario for Profile 2 show in **Fig 5.2** Afternoon 5.15pm to 6.45pm EV in charging fleet the power demand rise 10MW to 14.2MW. The power demand increase in grid 42% than conventional residential demand. The daily power demand increase in residential grid is 8.23%.

$$\text{average transformer load factor} = \frac{\text{average hourly power consumption}}{\text{transformer nominal power}}$$

Show an average transformer load factor of 0.368 when EV charging station integration with residential power grid. An average transformer load factor of 0.34 when residential power grid have no EV charging station.

$$\text{Peak transformer load factor} = \frac{\text{peak hourly power consumption}}{\text{transformer nominal power}}$$

At afternoon 5.15pm to 6.45pm peak transformer load factor of 0.56.

Note that the transformer load factors are computed on the basis of the hourly load, rather than on the 90-min load, since transformers are designed to withstand significant overloads for short periods of time and hourly. loads are usually considered in the literature.

5.2.3 Profile 3: People going to work with no possibility to charge their car at work.

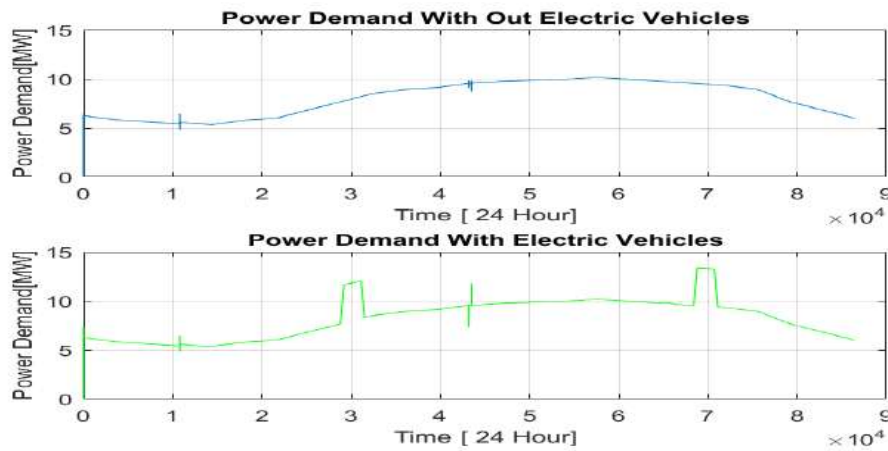


Fig 5.3 (a) Power demand of residential grid without electric vehicles **(b)** Power demand of residential grid with electric vehicles

Results for the 40% EVs adoption scenario for Profile 3 show in **Fig 5.3** from 7.40am to 8.50am the is in charging this time the power demand increase 7.5MW to 12.4MW . In morning time the hourly power demand increase in grid 53%. Afternoon 6.50pm to 7.45pm EV in charging fleet the power demand rise 10MW to 14MW. The hourly power demand increase in grid 42% than conventional residential demand. The daily power demand increase in residential grid is 37%.

$$\text{average transformer load factor} = \frac{\text{average hourly power consumption}}{\text{transformer nominal power}}$$

Show an average transformer load factor of 0.47 when EV charging station integration with residential power grid. An average transformer load factor of 0.34 when residential power grid have no EV charging station.

$$\text{Peak transformer load factor} = \frac{\text{peak hourly power consumption}}{\text{transformer nominal power}}$$

From 7.40am to 8.50am peak transformer load factor of 0.512. At afternoon 6.50pm to 7.45pm peak transformer load factor of 0.568.

Note that the transformer load factors are computed on the basis of the hourly load, rather than on the 70 and 55 min load, since transformers are designed to withstand significant overloads for short periods of time and hourly. loads are usually considered in the literature.

5.2.4 Profile 4: People working on a night shift

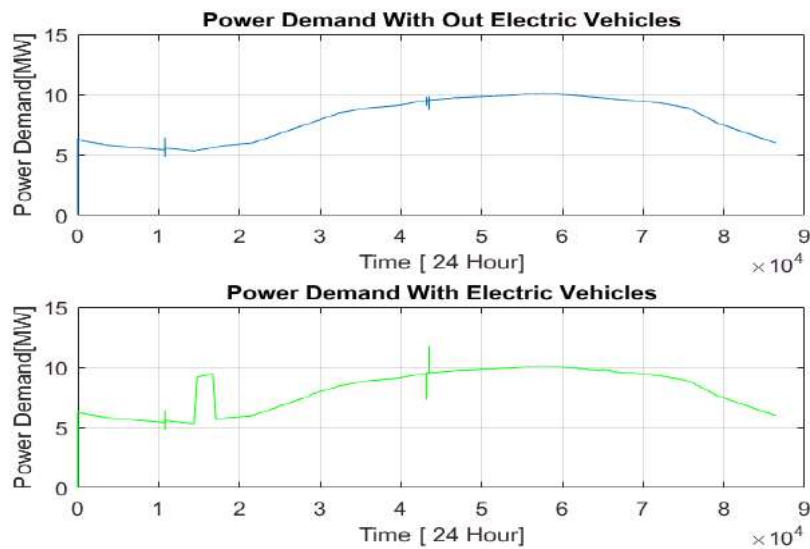


Fig 5.4 (a) Power demand of residential grid without electric vehicles **(b)** Power demand of residential grid with electric vehicles

Results for the 40% EVs adoption scenario for Profile 4 show in **Fig 5.4** from 3.40am to 5.00am the is in charging this time the power demand increase 5.1MW to 9MW .The

hourly power demand increase in grid 74.47% than conventional residential demand .
The daily power demand increase in residential grid is 4.71%.

$$\text{average transformer load factor} = \frac{\text{average hourly power consumption}}{\text{Transformer nominal power}}$$

Show an average transformer load factor of 0.36 when EV charging station integration with residential power grid. An average transformer load factor of 0.34 when residential power grid have no EV charging station.

$$\text{Peak transformer load factor} = \frac{\text{peak hourly power consumption}}{\text{Transformer nominal power}}$$

From 3.40am to 5.00am peak transformer load factor of 0.156.

Note that the transformer load factors are computed on the basis of the hourly load, rather than on the 45 and 90 min load, since transformers are designed to withstand significant overloads for short periods of time and hourly. loads are usually considered in the literature.

5.2.5 Impact on Voltage Profile in Electrical Network for Profile 1: People would have the possibility of charging their car at work.

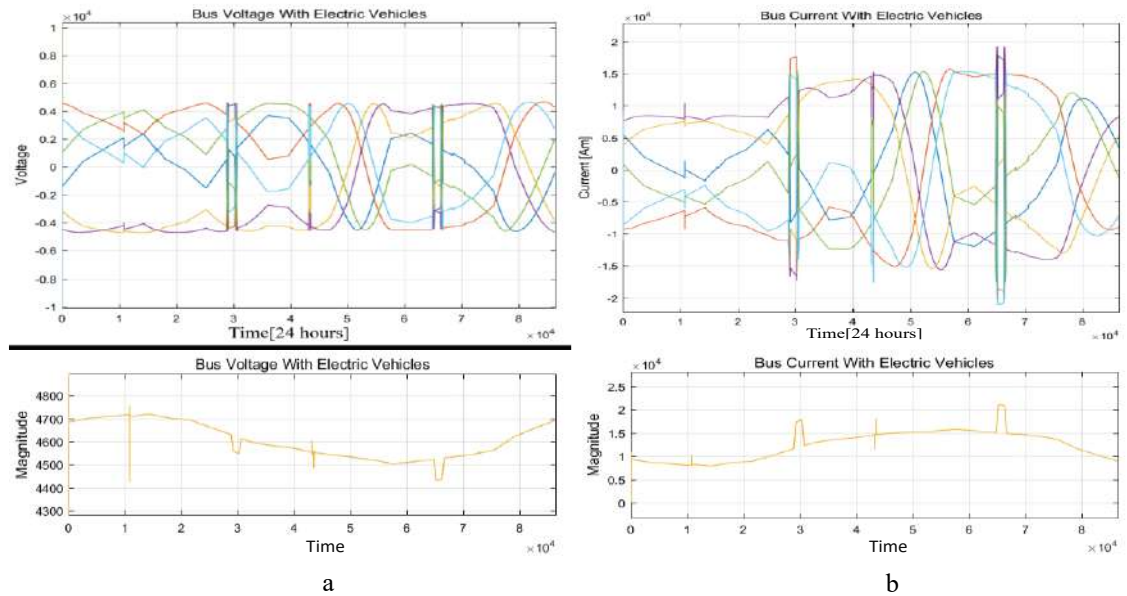


Fig 5.5 (a) Voltage profile of microgrid when electric vehicles in charging **(b)** Current profile of microgrid when electric vehicles in charging

The voltage sag of the residential grid with coordinated charging is shown in **Fig 5.5**. For the case of 40% EVs penetration, the maximum voltage sag reaches 1.96% at 7.15am to 8.30am.

The voltage sag increased to 1.77% at 5.15pm to 6.45pm. The root mean square value is usually used to calculate the voltage deviation according to the following equations.

$$V = \sqrt{\frac{\int_0^T v^2(t)dt}{T}} \dots\dots\dots (14)$$

The voltage deviation of the residential grid with coordinated charging. For the case of 40% EVs penetration, the voltage deviation increased to 8% at 7.15am to 8.30am and 10% at 5.15pm to 6.45pm. The figure illustrates that by increasing the penetration level of EVs, the system energy losses increase. At 40% EVs penetration level for the coordinated charging the energy losses increased to 4 MWh.

5.2.6 Impact on Voltage Profile in Electrical Network Profile 2: People will have the opportunity to charge their car at work, but they will have a longer ride.

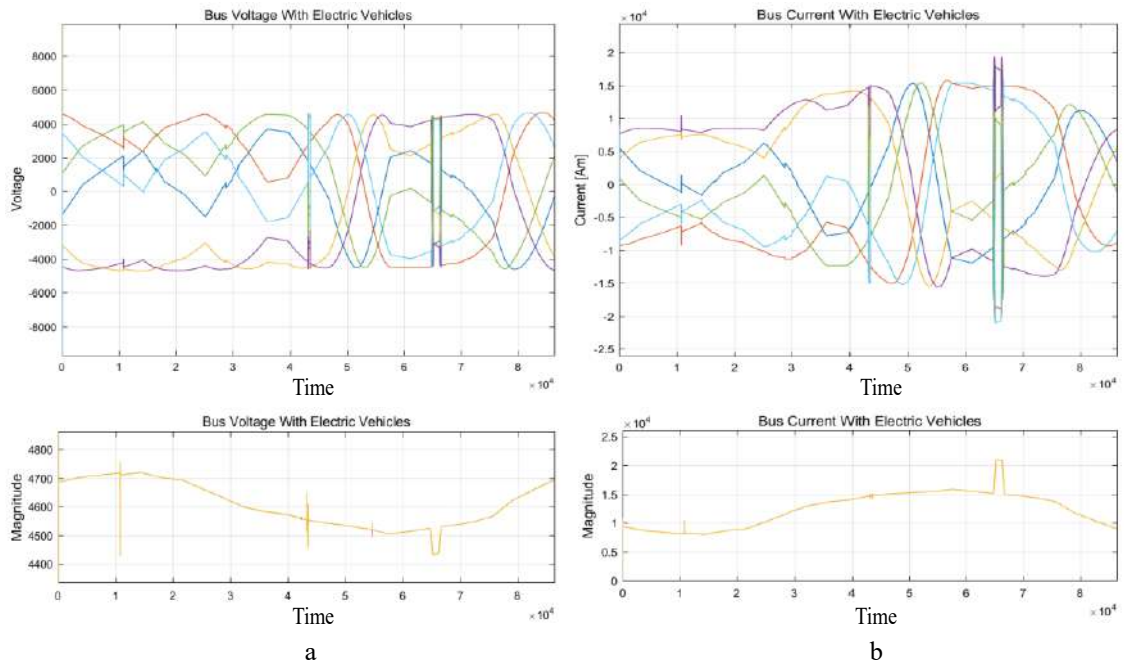


Fig 5.6 (a) Voltage profile of microgrid when electric vehicles in charging **(b)** Current profile of microgrid when electric vehicles in charging

The voltage sag of the residential grid with coordinated charging is shown in **Fig 5.6**. For the case of 40% EVs penetration, the maximum voltage sag reaches 2.21% at 5.15pm to 6.45pm.

The root mean square value is usually used to calculate the voltage deviation according to the following equations.

$$V = \sqrt{\frac{\int_0^T v^2(t)dt}{T}} \dots\dots\dots (15)$$

The voltage deviation of the residential grid with coordinated charging. For the case of 40% Eve’s penetration, the voltage deviation increased to 10% at 5.15pm to 6.45pm. The figure illustrates that by increasing the penetration level of Eves, the system energy losses increase. At 40% EVs penetration level for the coordinated charging the energy losses increased to 4 MWh.

5.2.7 Impact on Voltage Profile in Electrical Network Profile 3: People going to work with no possibility to charge their car at work.

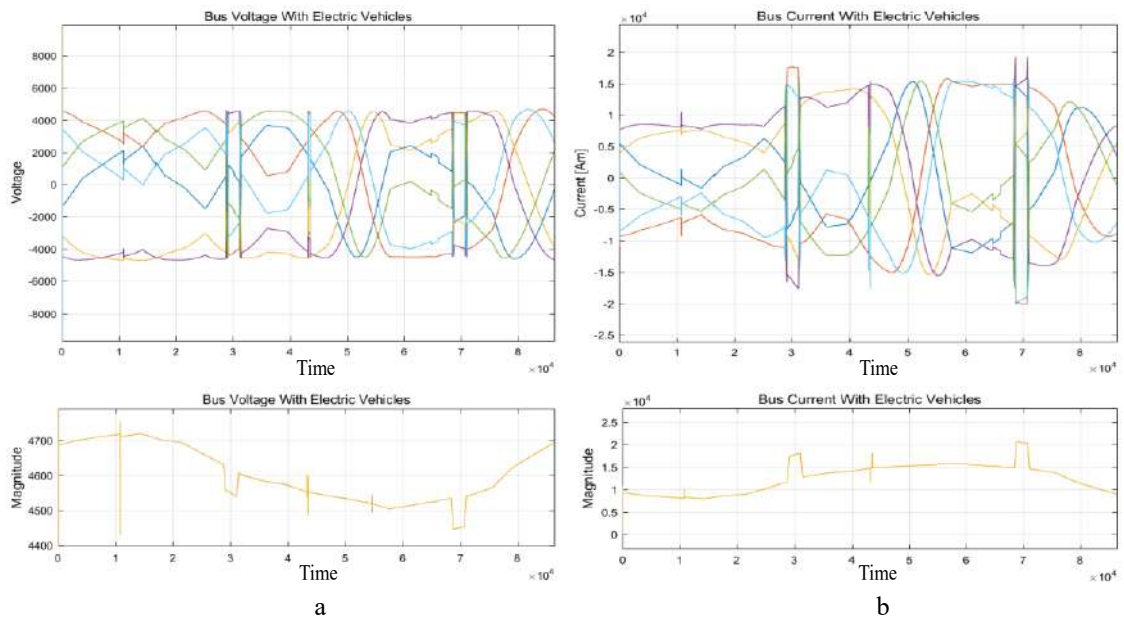


Fig 5.7 (a) Voltage profile of microgrid when electric vehicles in charging **(b)** Current profile of microgrid when electric vehicles in charging

The voltage sag of the residential grid with coordinated charging is shown in **Fig 5.7**. For the case of 40% EVs penetration, the maximum voltage sag reaches 2% at 6.50pm to 7.45pm. The voltage sag increased to 1.521% at 7.40am to 8.50am.

The root mean square value is usually used to calculate the voltage deviation according to the following equations.

$$V = \sqrt{\frac{\int_0^T v^2(t)dt}{T}} \dots\dots\dots (16)$$

The voltage deviation of the residential grid with coordinated charging. For the case of 40% EVs penetration, the voltage deviation increased to 8% at 7.15am to 8.30am and 10% at 5.15pm to 6.45pm. The figure illustrates that by increasing the penetration level of EVs, the system energy losses increase. At 40% EVs penetration level for the coordinated charging the energy losses increased to 4.8 MWh.

5.2.8 Impact on Voltage Profile in Electrical Network Profile 4: People working on a night shift

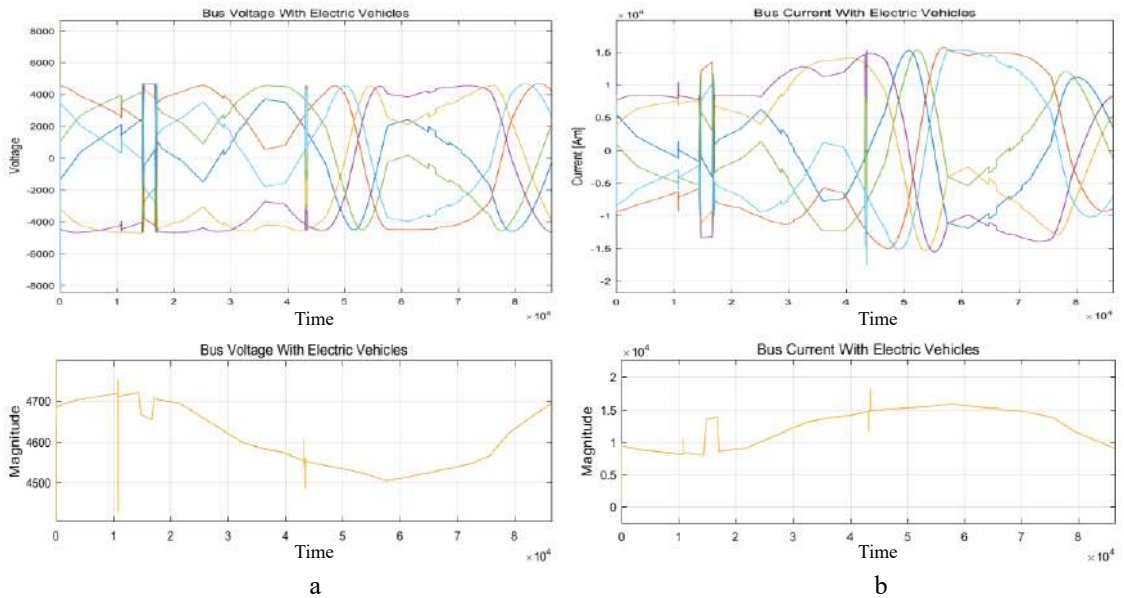


Fig 5.8 (a) Voltage profile of microgrid when electric vehicles in charging **(b)** Current profile of microgrid when electric vehicles in charging

The voltage sag of the residential grid with coordinated charging is shown in **Fig 5.8**. For the case of 40% EVs penetration, the maximum voltage sag reaches 1.93% at 3.40am to 5.00am.

The root mean square value is usually used to calculate the voltage deviation according to the following equations.

$$V = \sqrt{\frac{\int_0^T v^2(t)dt}{T}} \dots\dots\dots (17)$$

The voltage deviation of the residential grid with coordinated charging. For the case of 40% EVs penetration, the voltage deviation increased to 8% at 3.40am to 5.00am. The figure illustrates that by increasing the penetration level of EVs, the system energy losses increase. At 40% EVs penetration level for the coordinated charging the energy losses increased to 3.8 MWh.

5.3 Result Analysis

The analysis demonstrated the total demand at the residential distribution transformer during a sample day for four cases and 40% EVs integration. These are chosen to represent the minimum impact (EV connected to the distribution transformer) and a medium-penetration scenario. Fast charging is considered to illustrate the impact of different EV charging power levels. The study confirms the significant impact of the EV charging power level on the local residential electricity demand. Even when EV is connected to the distribution transformer, sharp peaks in the local electricity demand are introduced when fast charging is used. This effect is exacerbated for higher EV electric market shares.

Table 3 shows that the use of fast charging (40 kW) significantly exacerbates the impact of EVs on the residential distribution infrastructure since charging events are shorter but steeper when fast charging is adopted. The peak demand could increase for 40% EVs market share and an increase of about 27.05% for profile 1, 8.23% for profile 2, 37% for profile 3, 4.17% for profile 4 is shown when 100 EVs is considered. Increasing the charging power leads to reduced charging times and thus fewer vehicles are simultaneously charged when a more powerful charging infrastructure is available. According to the modelling used in this paper and assuming fast charging, for EVs market share of ~ 40%, up to 100 electric vehicles are charged at a different time in the simulated day.

To better assess the stress on the distribution transformer due to the additional load introduced by fast EVs charging, Table 3 also reports the operation time above the transformer nominal capacity and above 115% and 150% of the nominal capacity, both in terms of share of overall time and in terms of continuous hours of operation (out of the total 24 hours in the day). While do not attempt to fully assess the impact of coordinated EVs charging on useful transformer life (which will also depend on the operating temperature), and earlier study [83] shows that, *ceteris paribus*, the maximum load factor impacts the expected transformer life exponentially: the expected life of a transformer decreases by two orders of magnitude when the maximum load factor reaches values 50% above its nominal capacity. For a maximum load factor 75% above the nominal capacity, the expected life decreases by two additional orders of magnitude. A load factor approximately 15% above the transformer nominal capacity (that is, the

estimated peak demand increase due to the introduction of 100 EVs with fast charging in the residential distribution network considered in this paper) is reported to reduce the transformer's expected life by about one order of magnitude. The results in Table 3 show that, while only very medium adoption of EVs using fast charging leads to 24 hour of continuous transformer operation at a power level 15% above the nominal capacity, potentially reducing the transformers expected life by about one order of magnitude. Again, the higher charging level considered is shown to significantly exacerbate the impact of EVs charging on the residential distribution infrastructure.

CHAPTER 6

Conclusions

6.1 Introduction

Since initiatives continue to encourage electrical transport, the impact of EV charging on an electrical power grid must be carefully assessed. Passenger EVs are currently charged to the residences. The authors focused on the impact of electric vehicles charged on the demand for residential electricity. This study uses strongly resolved modelling of the housing demand and the usage of EVs based on a bottom-up approach that quantifies the energy use behaviours of consumers and the use by real-world vehicles in order to help evaluate the overall and local effects of coordinated EV charging.

6.2 Conclusions

The results suggest that the overall energy consumption of EV charging is relatively limited to the overall increase in the demand for residential electricity. However, the shape of the aggregate power demand in residential areas is impacted by the adoption of EVs, especially if fast charging is implemented. In particular, there is a 40% electric market share of the EV that means on the charging station to about 100 cars. Although the overall EV market share remains small, high EV adoption clusters can also be seen in some regions. This can increase the effect of EV charging locally (that is, impact on residential distribution transformers). The results suggest that, when a single EV is connected to a 1000-household residential distribution network, the distribution transformer's high load factor could likely be increased by rapid charge, which could lead to a substantial decrease in the expected lifetime of the transformer. In test scenarios the first charge case is used for the coupled network. Depicts the distribution of voltage at critical points. The weakest bus is smaller than normal bus is constant. The voltage of the bus varies in time, as can be seen in figure. The weakest value in the bus field is constant. From a vehicle energy network perspective, these busses are integrated with the residential network. Furthermore, these nodes of transport have much in common. They are clustered mostly in industrial and residential areas. The explanation for this function is that the electricity load in these two areas is sufficiently accurate. Charging would bring a heavy burden on the distribution network, there will be additional demand for electric energy. The electrical power supply would be interrupted as voltage collapses

in these regions, leading to significant social and power grid disruptions. Thus, when reforming the distribution network or charging network it is important to adjust bus integrated with charging stations or improve the energy of such substations, to ensure stable supply of electric energy. Load margin for residential bus in different first charging situations. There is a major variation in load growth multiples of varying charging behaviours. In the first charging scenario, the load margin of this bus is lower than the other. That means the distribution network generates varying electrical energy margins in different charging cases and that the availability of electricity supply from the distribution network would not satisfy the demand for electrical energy in extreme stages where a large number of EVs integrated into the distribution network or electricity load rises. The result shows that the breakdown of the electrical energy network is more direct than expected, which requires serious attention when evaluating the reliability of the distribution network. Understand the importance of integrating the transportation systems with the distribution grid to power delivery capacity. The results of four test cases was charged at various intervals, which reveals that the power grid is reliable if EVs are not attached to the grid. That is because the demand for mobile energy is far from heavy electric load busses, such as residential buses, which relieve the local electricity burden. Thus, changing the connection between transportation and distribution networks is an efficient way to gain more energy margins in the distribution grid and reduce electric energy interruption in the same electrical energy demand. The findings say that the coupling between the transportation network and the distribution network, suggesting the couple network reform, influences voltage stability. The different EV routes use different mobile energy, varying charging loads on the relevant electrical energy network. The destination node for the transportation system is established, if a connection is specified between the transportation network and the distribution network indicating that a suitable EV route could be generated.

Various charging profiles produce different SOC. The result indicates that the transport network has a serious impact on the mobile energy and charging behaviour of electrical vehicles, which results in changes in the electrical energy network's charging demand. The minimum power supplying energy margin occurs in this situation where the daily rate is increasing. The explanation is the limited power generating capacity, as the energy demand rises, accounting for large electricity consumption. The low load margin value means that the at risk delivery network has a high probability of electrical energy interruption. In comparison, the growth margin has declined over time due to the same

amount of rising energy load, which suggests that the electrical network is growing in unstable. As a result, the findings suggest that, as the power load rises, the electrical energy network is becoming more unreliable. Consequently, the charging load must be minimized in order to ensure the security of the operation of the distribution network. The fast charge level typically indicates that the effect of EV charging on the residential delivery system has greatly improved because costs are shorter but steeper when charging is carried out quickly. In consideration of the important local impacts of Electric vehicle charging, authors believe that future research needs to focus further on understanding consumers' drive and charge behaviour, and the complexities of the option of residential Electronic charging networks.

6.3 Limitation

In the literature additional limits were found. First, the limited purpose of MATLAB Simulink is to model practical grid circumstances, since the situation in the real world has a lot of implications for the grid. But Simulink must have been known in MATLAB as the ideal grid. Second, EVs are normally expected to be "smart" (that means "off peak" hour) charged all over the spot, which could not always be the case. Third, most research relies on regular data to estimate the amount of charging capacity of vehicles, which charging time generally calculate on the basis of supposed operational vehicle accessibility . The Methods provide specific information [8].

In order to meet these limitations, use a highly resolved modelling of residential power demand and EV's based on a bottom-up approach to measure consumer behaviour and use of real-world vehicles, in order to determine more accurately the aggregate and local impact of coordinated EV charging. Residential and commercial energy standards, in particular, are structured in a single framework, containing the whole energy footprint of a single home with all appliances, air-conditioning and other electric power demands.

These models create strongly solved power demand profiles for the residential area (24 hours of phasor resolution) and recharge the EV's, simulating real-world use of automobiles. This research has implemented various charging profile strategies to maximize the recharge of EVs in addition to assessing the impact of EV adoption in different circumstances under which smart grids are not completely deployed. The strongly solved electrical load profiles used in this paper including household consumption and electrical supplies charging suggest that even with a medium-level EV

market share of 40% the improvement in aggregate demand in total kilowatt hours may be marginal.

6.4 Future Work

In future Electric vehicle charging schedule managed with the help of AI technology that will decrease the load current. In the power electronics sector, voltage sag and current fluctuation may be compensated by series active power filter. Another suggestion is that using the FACTS device improves voltage stability of the distribution grid.

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