ELECTRIC VEHICLE CHARGING STATION PERFORMANCE AND IMPACT ON ELECTRICAL DISTRIBUTION NETWORKS

Yogesh K. Kirange[1*], Vineetkumar V. Patel[2], Krunalkumar J. Gandhi[3], Nilesh S. Mahajan[4], Rupesh S. Patil[5], Dhanesh S. Patil[6], Sachin Y. Sayais[7]

Abstract

The intention of research is since the beginning of the 20th century, there has been a steadily growing need for transportation, yet the internal combustion engine is quickly becoming obsolete. It is becoming increasingly common for electric vehicles to replace polluting fuels such as gasoline and diesel in favor of cleaner, more efficient fuels. Due to the fact that electric vehicles emit no harmful emissions from their tailpipes, they are a far better alternative for the environment. We are at the threshold of a revolution in electric vehicles. Due to environmental concerns, rising petroleum product prices, and state government policies, the EV market continues to flourish exponentially. In order to meet this growing demand, more and more EVCS power stations are being installed. As there are extra electric vehicles on the road, there are further electric-charging stations on the electrical grid. The prime objectives of this research paper are to study of negative effect of excessive rise in temperature on resistance of cable, harmonics on resistance of cable, power loss, temperature, expected useful life, harmonics derating factor (HDF).

EV charging stations use power semiconductor converters that take non-sinusoidal current from the power source, causing harmonics to occur in the power distribution network, lead to in lower power quality. Due to this, EV integration could impact the current electrical power distribution system's service life, particularly those components like power cables that are crucial to the distribution system's operation. The influence of EV charging stations on distribution networks, including the resulting power loss, temperature, capacity loss, and shortened service life, is simulated using MATLAB/SIMULINK in this research paper. It also offers several solutions for reducing this impact.

Keywords: Power Distribution Networks, EVCS (Electric Vehicle Charging Stations), XLPE Power Cable, Power Quality, Harmonic Reduction Techniques.

[1*]Electrical Engineering Department, R. C. Patel Institute of Technology, Shirpur, Maharashtra, India, Contact e-mail: yogesh.kirange@gmail.com
[2]Electrical Engineering Department, R. C. Patel Institute of Technology, Shirpur, Maharashtra, India Contact e-mail: krunalgandhi.rcpit@gmail.com
[3]Electrical Engineering Department, R. C. Patel Institute of Technology, Shirpur, Maharashtra, India Contact e-mail: patil.rupesh.rupesh@gmail.com
[4]Electrical Engineering Department, R. C. Patel Institute of Technology, Shirpur, Maharashtra, India Contact e-mail: sachinsayais@gmail.com
[5]Electrical Engineering Department, R. C. Patel Institute of Technology, Shirpur, Maharashtra, India Contact e-mail: vinitptl@gmail.com
[6]Electrical Engineering Department, R. C. Patel Institute of Technology, Shirpur, Maharashtra, India Contact e-mail: mahajan.nilesh1705@gmail.com
[7]Electrical Engineering Department, R. C. Patel Institute of Technology, Shirpur, Maharashtra, India Contact e-mail: dspatil0237@gmail.com

***Corresponding Author:** Yogesh K. Kirange
*****Electrical Engineering Department, R. C. Patel Institute of Technology, Shirpur, Maharashtra, India, Contact e-mail: yogesh.kirange@gmail.com

DOI: - 10.53555/ecb/2023.12.8.817

1. Introduction

Presently, India's economy is one of the world's fastest growing; yet, the country is experiencing enormous economic and social difficulties due to its increasing dependency on oil imports, rising environmental problems, and rising demand for sustainable transportation alternatives.

Since the early 2000s, India's demand for imported petroleum products has skyrocketed, exceeding a record peak of 3.98 thousand gallons every day in 2015. Rising by more quickly than either the United States (0.65%) or China (1.98%), India surpassed both of them in 2015 to become the third biggest user of crude oil worldwide. In 2016, India's trade surplus totaled US$108 billion, with a gap of US$51 billion attributable to crude oil. The present crude oil surplus is around US$102 billion, but by 2020, the trade imbalance is expected to have risen to almost US$205 billion. As of 2015, India accounted for 5.8 % of global carbon dioxide emissions from fossil fuel combustion, making it the third-largest carbon emitter globally. According to the WHO, worldwide air pollution database (2019), 13 of the 21 cities with the highest air pollution levels are situated in India. It is projected that India's population, which is currently at 1.18 billion, would increase to 1.6 billion by the year 2040. As of 2015, India was the world's fourth-largest manufacturer of vehicles powered by internal combustion engines (ICEs). With a 9.1 % increase last year, India's vehicle market was the fastest growing in the world. The current automotive sector is likely to face a threat from the recent shift in global automotive technology and the increasing popularity of electric vehicles if the country does not plan its transition towards newer mobility options and create the requisite manufacturing skills.

If EVs spread at the rate that is expected, their load will quickly become the dominant component of any utility load curve [1]. Distribution network location for an EV load is not predetermined throughout the day, in contrast to other grid-related static loads. Positions where EVs are loaded are very flexible. As a result, distribution networks are not designed to handle non-sinusoidal load patterns or large overloads. As a result, it is essential to examine the distribution network at both the circuit level and the system level. This is to determine the effect EVs have on the network. Thus, the electric vehicle load has a significant effect on the power grid. The harmonics that are produced when a lot of EV charging stations are linked to the grid may deteriorate the power supply. To confirm the reliable and secure functioning of the power distribution system, it is critical to evaluate the probable adverse consequences of EV charging stations. Significant research has been conducted in recent years into the effects of EV charging points on the functioning of electricity distribution networks [2]. This research examines how recharging EV affects the power grid.

In the future, when EV penetration is strong, EV load will start to control any utility load profile. During the course of the day, the position of EVs burden is not defined as in a distribution line, unlike other, lesser mobile stationary loads linked to the grid. On top of that, distribution networks aren't designed to handle non-sinusoidal load patterns or high overload capabilities. Therefore, when evaluating the effect of EV load on the distribution system, it is necessary to take into account both of the circuit and system level.

Results from this research study and analysis will aid in the development, construction, and rollout of an electrical grid suitable for EV charging stations. Both the system's longevity and dependability will improve as a result of this. The findings will also be useful for figuring out how to connect EV charging stations to the grid. The findings will have positive effects on i) lowering overall costs, (ii) boosting reliability, and (iii) raising people's quality of life. Following are some of the primary aims of this study: 1. Negative effect of excessive rise in temperature on resistance of cable 2. Negative effect of harmonics on resistance of cable 3. Negative effect of harmonics on power loss 4. Negative effect of harmonics on temperature 5. Impact of harmonics on expected useful life 6. Negative result of harmonics-on-harmonics derating factor.

2. Analysis of the Deficiencies in EV's Adoption

It is critical to consider consumers' expectations and concerns to understand why the EV market has slowed growth. The single most significant problem in electric vehicles' low market penetration is their exorbitant price, which is around 2.5 times greater than a conventional automobile with equivalent equipment. Another significant problem with EVs is their range on a single charge. To get more range, the car must have a larger battery capacity, which raises the price of the EV practically correspondingly. However, since their operational costs (running and maintenance costs) are frequently significantly lower than those of conventional vehicles, electric vehicles also have a significant advantage.

The average private car travels four to five times farther per day than commercial vehicles, including cabs, buses, and three-wheelers.

Therefore, for vehicles that get many miles per gallon, the money saved on petrol will more rapidly compensate for the higher purchase price. Electric vehicles can be used more rapidly and affordably with a favorable power tariff, making up for the high initial investment cost. Most people prioritize aspects like total cost of ownership, fuel efficiency, repair costs, and level of comfort while looking for a personal vehicle. However, buyers of commercial vehicles prioritize both immediate and long-term cost savings.

India has a lower affordability index than industrialized nations because of a lower per capita income. Therefore, manufacturers will need to offer options for the medium range to keep the price of electric vehicles within the reach of the majority. Consequently, more frequent charging is required, especially for commercial fleets where the average daily mileage maybe 200–250 kilometers [2]. In a fleet charging system, faster charging stations would be necessary to decrease vehicle turnaround time. Slow chargers would be useful for personal automobiles with daily ranges of up to 50 kilometers.

3. Electric Vehicles- Present Scenario in India

India should think about electric vehicles for three main strategic reasons.

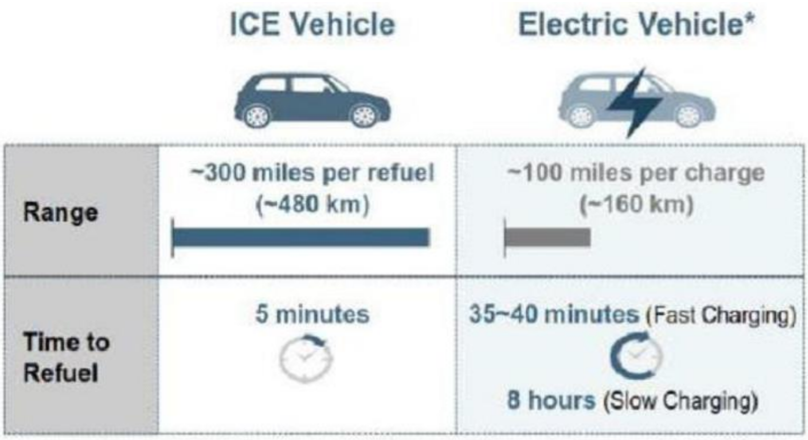

Fig. ICE V/S EV's

1. Boosted Carbon Dioxide Emissions India's key development goals include lowering its carbon releases to collect its climate requirements. Using EVs might decrease CO2 emissions by 37%.
2. The industry cannot be sustained since the power demand has not risen in line with the capacity of power plants. Future growth in the number of electric vehicles could help to stabilize the grid. Electric vehicles provide a promising opportunity for the power sector because they may eventually result in stable requirement and a "paying customer section."
3. Energy supply threats: Currently, India imports a significant amount of oil to meet most of its needs for transportation fuel. By implementing a communal, electric, and networked solution, India may lower its energy usage for passenger travel by 64% by 2030. It could result in a 156 Mtoe (US $ 60 Bn) reduction in annual fuel and petrol use.

4. VEHICLE-TO-GRID (OR EV-TO-GRID) CONVERTERS

Electric vehicle supply equipment (EVSE) is the first component of the fundamental EV charging setup. The EVSE connects to the grid via a control system and a hardwired link to without harm charge electric automobiles. An EVSE control system permits capabilities like user authentication, charging authorization, information recording, data privacy, and security, to name a few. EVSEs with at minimum the most fundamental administration and control features should be employed for all charging needs.

Conductive charging, commonly referred to as plug-in (wired) charging, is the extremely accepted kind of charging method. A few factors determining the EVSE requirements for conductive charging are vehicle characteristics, battery size, charging methods, and power ratings. It is expected that three-wheelers, such as people movers, and light electric vehicles (LEVs) like scooters and motorbikes will set the pace for India's transportation electrification over the next ten years. Light commercial vehicles (LCVs) and automobiles are two more significant vehicle types happening electrified. Numerous electric transports will be accessible for use. The characteristics of the battery define the required voltage and current for charging an electric car. The typical EV battery capacity and voltage vary throughout EV segments, as illustrated in the table.

Table 1 Types of Electric Vehicles and Their Typical Battery Requirements

Type of Vehicle	Battery Capacity	Battery Voltage
E-2W (Scooty/Scooter)	1.1 kWh to 3.2 kWh	48 V to 72 V
E-3W (Passengers/Goods)	3.5 kWh to 7.9 kWh	48 V to 60 V
E-Cars (First Generation)	20 kWh	72 V
E-Cars (Second Generation)	29 kWh to 81 kWh	350 V to 500 V

The input power required for charging setup is determined by the power ratings or levels of EVSEs, which vary depending on charging requirements. According to their maximum power output, EV charging stations are categorized below as low-power (22kW) or high-power (200kW). Due to the widespread availability of EVSEs with power levels up to 500kW, big vehicles like buses and lorries are their primary applications.

Table 2 EVSE Power Rating

	Level of Power	Type of Current
Normal Power Charging	Power less than 8 kW	AC &DC
	8 kW < P < 20 kW	AC &DC
High Power Charging	20 kW < P < 45 kW	DC
	45 kW < P < 205 kW	DC

5. BHARAT EV Charging Details (AC and DC):

Experts in standardizing the infrastructure for electric vehicle charging have made recommendations that include ratings for both AC and DC outlets. The related standards are Bharat EV Charger AC-001 and Bharat EV Charger DC-001.

1. A 230V/15A single-phase socket, which can send up to 2.5KW of electricity, is often used to charge devices at home. The rate cap for vehicles is this sum and nothing more. There are billing procedures for home electricity meters as well. This practice will continue unless legislation is enacted to charge home EV users differently. Bharat EV Specs advises using the IEC 60309 Industrial connector on both ends of the vehicle.
1. 2 Public Charging: According to Bharat EV regulations, the power used for public charging needs to be metered and billed. In the future, the power providers may wish to control how much energy these chargers use.
2. "Slow" AC charging, where the current is given gradually, is used to recharge most electric vehicles. An EVSE sends AC electricity to an automobile's onboard charger, transforming it into DC power to charge its battery; as a result, an ac-charging EV, whether put a Mahindra 13e2o, e2o Plus, or lithium-ion-powered e-Scooter into a 15-amp wall outlet or a smart charger. The two types of AC charging are as follows: As was previously said, all-electric vehicles in India are charged using conventional AC. It covers vehicles with two, three, and four wheels. 3KW or 2.5KW AC motors Using a fast charger, a two-wheeler with a 2 KWh battery can be fully charged in an hour; a four-wheeler or larger vehicle with a 12 KWh or greater battery would require five to six hours.

Global electric vehicles such as the Nissan Leaf and Tesla feature in-vehicle chargers with higher power ratings, enabling faster AC charging. The power output of typical household outlets is increased from 7.7 KW to 22 KW; as a result, enabling quicker AC charging.

6. Development of system

This research aims to provide an efficient and quick way to estimate the line losses and heat increase in power distributing cables in harmonics-rich environments, such as those created by the charging of electric vehicles. In Figure 1, we see a straightforward plan for installing EV charging stations within existing electrical infrastructure. Charging an electric car can be broken down into two primary categories.

Firstly, the involvement of harmonics and THD (as defined by the IEEE 519 specification) in the electrical system is an annoyance that is not simple to remedy by switching to a different power source. Total Harmonic Distortion (THD) indicates the degree to which a signal's voltage or current has been distorted due to THD's. To ensure optimal operation, audio, communication, and power systems should normally, but not always, have the lowest THD possible.

Secondly, Electric vehicle charging equipment is a stationary source of electricity for recharging plug-in electric automobiles. Fast DC chargers and standard AC charging stations are the two most common varieties. Batteries can only be charged with direct current (DC) electricity, while utmost electricity in the United States is delivered by alternating current (AC) (AC). Most EVs have a charger and an AC-to-DC converter built right in because of this (a rectifier). To power the onboard charger, the vehicle is plugged into an AC outlet. Since DC fast chargers require a considerably bigger AC-to-DC rectifier for their higher power output, Instead of being created for the vehicle, the converter is made for the charging station, and DC power is sent into the vehicle without going via the onboard converter. Modern fully electric vehicles typically take both alternating current (AC) and direct current (DC) charging.

Vehicle charging mainly, it consists of transformer which steps up or down ac voltages, AC- DC converter (Uncontrolled or Controlled Rectifiers) that converts AC signal into DC signal, DC-DC Converters (Choppers) which converts fixed DC signal into Variable DC signals, Electric Vehicle charging. Generally, EV charging load effects on power quality, which means the voltage profile [3] [4] [5] [6] of any distribution system is used to assess its power quality. Power quality issues arise with EV charger loads since the current they use is largely non-sinusoidal in nature. Principal harmonic components when standard 3-Ø diode bridge rectifiers are castoff for high power EV charger claims are the fifth, seventh, eleventh, thirteenth, etc. After that, the principle or fundamental frequency component current and the harmonic components currents make up the current consumed by EV charger loads from the supply system in light of flow, the voltage drops across the distribution lines are sinusoidal in form and have a fundamental frequency component current [7].

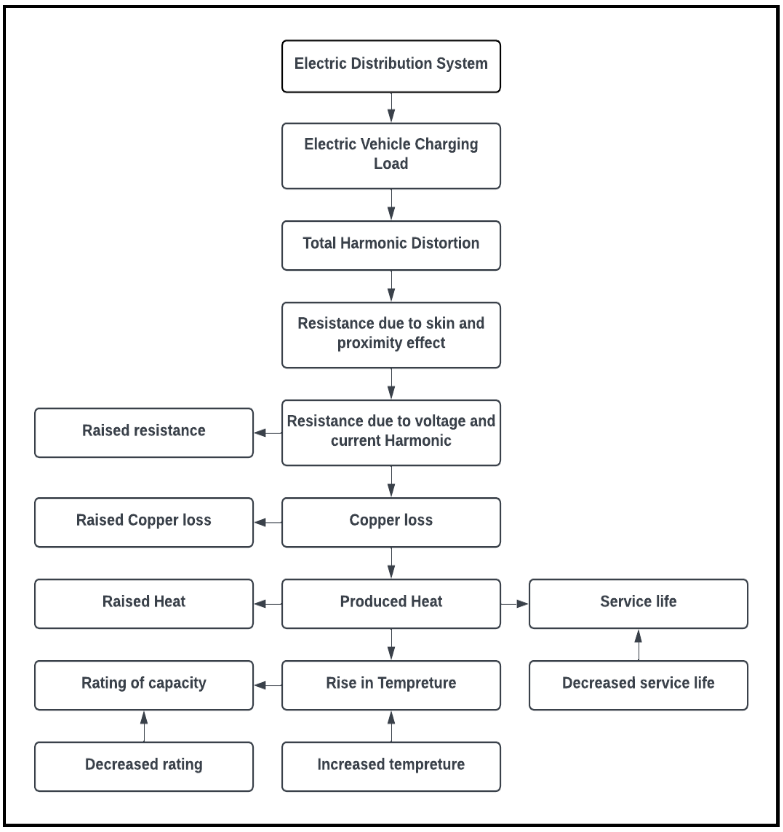

Fig. 1. Process of development of a system

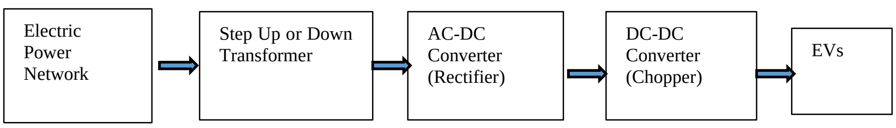

Fig. 2. Block diagram of "EVCS"

The straightforward charging station block diagram is shown in Figure 2, as a result, the system's voltage profile continues to be sinusoidal. However, because of the system's harmonic component current flow, voltage dips that occur in the impedances are evidently very non-sinusoidal. Ultimately, the total voltage at the points of common coupling (PCC) includes voltage elements with frequency components and harmonic frequency, culminating in a harmonic component of the system voltage that is also being used to supply power to other normal sinusoidal loads at PCC. These sinusoidal loads only drain sinusoidal current from the system when they are operating normally [8]. However, the current they consume is made up of both fundamental and harmonic frequency components due to the system voltage waveform distortion at PCC. When an induction motor (IM) is given such harmonic component current, it will experience more losses, less efficiency, a higher operating temperature, and eventually more stress on its insulation.

The power distribution system is responsible for supplying the harmonic components currents needed by the non-sinusoidal EV loads. By increasing power losses, decreasing efficiency, and increasing heating, this harmonic element current increases the temperature as it travels through the cabling and lines. Harmonic mitigation circuits or harmonic component filters are employed to stop this. Due to their fixed frequency tuning, these harmonic filters have, however, limited advantages. With the output rectifier of the EV charger, power factor enhancement devices are occasionally utilised [9]. The input current now has a roughly sinusoidal shape. Active filters may occasionally be naturally connected to the EV loads in parallel. However, only fast and super-fast charging benefits from passive and active power quality improvement strategies due to cost considerations.

Also, we are made a MATLAB/SIMULINK model for evaluation of various parameters mentioned in objectives on EVCS on power distribution network in figure 2-(a). Also, we obtained the results on harmonics spectrum of EVCS Load, effect of temperature rise on aluminum cable conductor resistance, effect of harmonics frequency on aluminum cable phase conductor resistance, effect of frequency on equivalent resistance of aluminum cable conductor, effect of conductor material on the effect of harmonics frequency on the resistance of phase conductors, effects of EVCS harmonics in power distribution system on power loss in XLPE power cables, effects of EVCS harmonics in power distribution system on temperature rise in XLPE power cables, impacts of EVCS harmonics in power distribution system on service (useful) life of XLPE power cables: effects of EVCS harmonics in power distribution system on harmonics derating factor (HDF) of XLPE power cables.

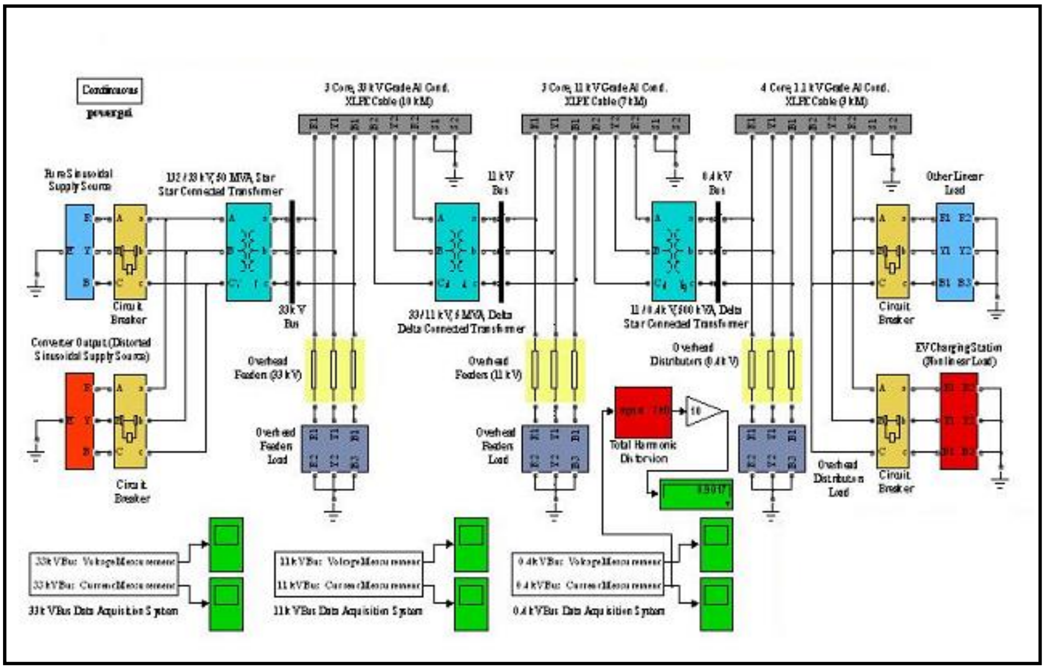

Fig. 2-a. MATLAB/SIMULINK model of EVCS parameters

7. Design Methodology

Basically, this system is designed in five modes of different parameters of Electrical Vehicle charging. They are as 1. Effects of temperature rise on cable resistance 2. Effects of EVCS harmonics on cable resistance 3. Harmonics' effects on power loss 4. Effects of harmonics on temperature 5. Effects of harmonics on expected useful life 6. Effects of harmonics-on-harmonics derating factor.

The frequency dependent feature of this resistance owing to the skin and proximity effect is utilised to assess the impact of harmonics on the conductor resistance of XLPE power cable [12]. The resistance of the aluminum and copper conductors of the XLPE power cables is significantly impacted by temperature rise. For every 10 °C increase in wire temperature, DC resistance increases by around 4% [14].

Any conductor carrying alternating current has an irregularly distributed current density. Skin and proximity effects [10-11] exist with solid cylindrical and tubular homogeneous conductors. Variable contact resistances between the strands of stranded homogeneous conductors can potentially impact the current distribution; however, this effect is not taken into account in the current work. Any conductor's AC resistance is a function of the frequency of the current passing through it since this affects how much the proximity and skin effects are amplified. At power frequencies, resistance typically varies little with frequency, but when harmonic frequencies are present in the current carried by XLPE power cable conductors, the conductors' AC resistance will vary significantly. A MATLAB programme is created to implement the aforementioned method for evaluating the impacts of harmonics on conductor resistance, which involves calculating the conductor resistance (Rac) value at the target frequencies from fundamental to all odd harmonics up to 49th order. The neutral conductor and other phase conductors' AC resistance are calculated as needed using the same methodology.

Total power loss in XLPE cable is inclusive of power loss in conductors, power loss due to sheaths, power loss due to armor, power loss due to dielectric in XLPE cable [15] [16] 17]. It takes much time and effort to calculate the overall power loss in an XLPE power cable under non-sinusoidal conditions (WNS). In order to accomplish this process, a MATLAB/Simulink programme is created in this work.

To calculate the temperature, rise in XLPE power cable, the MATLAB/Simulink programme that was originally developed to compute power loss in XLPE power cable is further expanded. To determine how long an XLPE power cable may be expected to last, the MATLAB/Simulink algorithm originally designed to estimate line losses and thermal rise in the cable is modified. It is clear that the HDF is never greater than one. When calculating the HDF, it is also necessary to take into account how unevenly heat is generated inside the cable. The maximum permitted temperature shall not be exceeded by either the average cable temperature or any point along the cable's insulation. As a result, for HDF, the maximum losses for neutral conductors and phase conductors are taken into account, not their average. Following Figure 3, it is a block diagram clearly indicates the design methodology of proposed work;

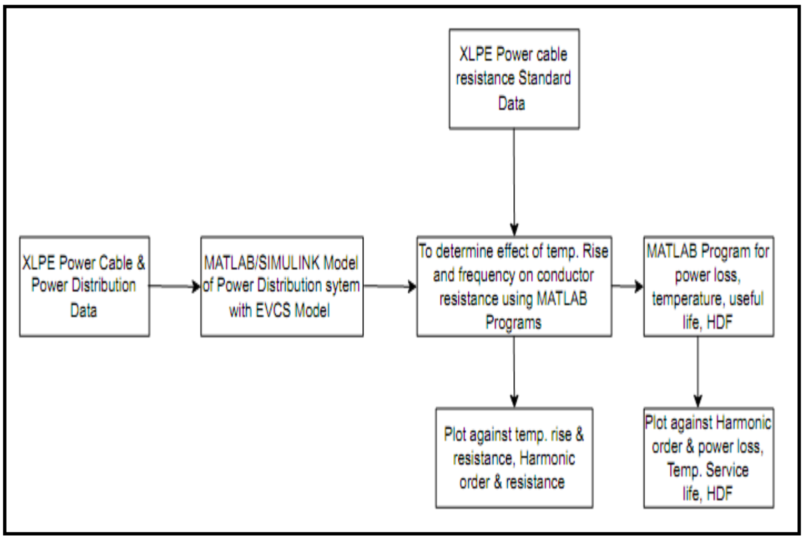

Fig. 3. Block diagram of entire proposed work of EVCS

8. EVCS Topologies

Charging infrastructure for electric vehicles (EVs) in India is inadequate. A charging station can be either publicly accessible or operated by the private sector. Multiple charging stations have been set up across India by the federal and state governments.

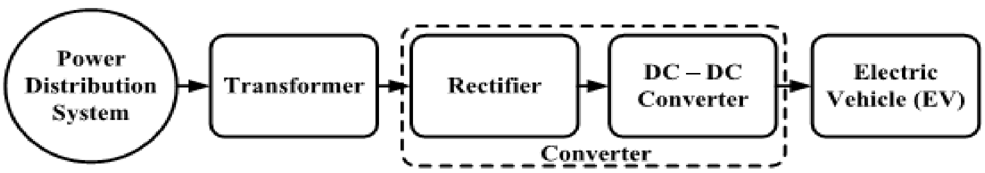

Fig. 4. Configuration Diagram of EVCS

In Figure 4, we see a simplified representation of an EVCS. There are two main categories of EVCS systems. As can be seen in Figure 4, one type of system is the common AC bus system, in which fast chargers are equipped with their own individual AC/DC converter stage and high bandwidth transformer.

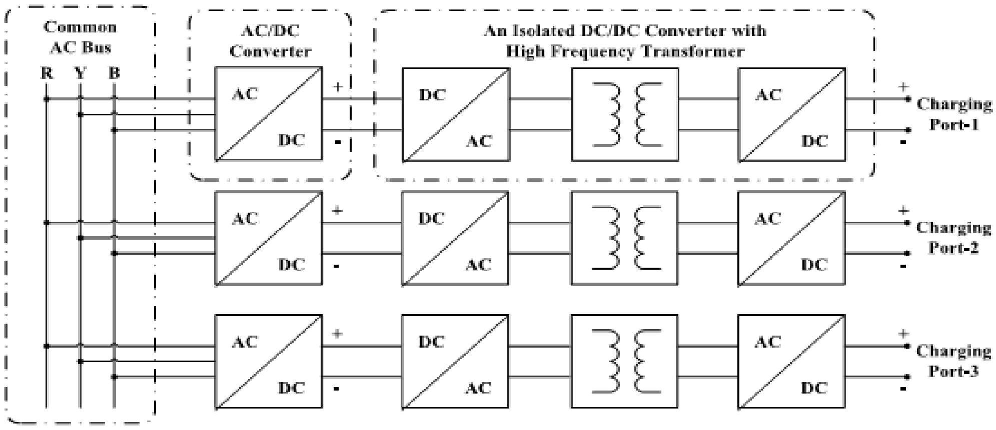

Fig. 5. EV Communication System using a Standardized AC Bus

The common DC bus system is another option; it consists of a single power frequency transformer and a single common AC/DC conversion [13] stage, as shown in figure 5. Both forms of DC bus systems are used in practice. Both use DC bus systems, however one is unipolar while the other is bipolar. An AC/DC rectifier, an input ripple filter, and a DC/DC converter are the three steps that make up the DC bus system in most fast chargers. Power factor is controlled and a stable DC voltage is provided for the DC/DC converter in the AC/DC rectifier stage. The harmonic currents generated by the AC/DC rectifier stage are reduced by the input ripple filter stage, which has a 35. Ultimately, the DC charging current is controlled by the DC/DC converter's final stage to enhance its response

9. Impact of EV's Charging Load

A. Power Quality

Figure 6 indicates the typical common DC bus system for EVCS. Distribution systems' voltage profiles determine power quality. Since EV chargers draw non-sinusoidal current, power quality events occur. For high-power EV chargers, ordinary three-phase diode bridge rectifiers have 5th, 7th, 11th, 13th, etc. primary harmonic components. EV charger loads draw fundamental frequency and harmonic component currents from the supply system. Fundamental frequency component current causes sinusoidal voltage dips across distribution lines [7]. Thus, system voltage remains sinusoidal. However, system impedance voltage drops are substantially non-sinusoidal due to harmonic component currents.

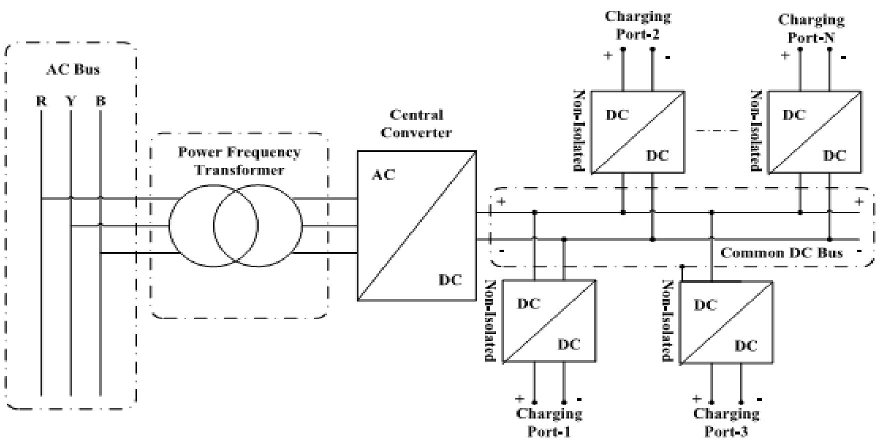

Fig. 6. Traditional DC Bus system for EVCS

At the "point of common coupling", the system voltage waveform is distorted by fundamental and harmonic frequency voltage components. This distorted waveform system voltage powers other PCC sinusoidal loads. These sinusoidal loads need just sinusoidal system current [8]. Due to system voltage waveform distortion at PCC, they draw fundamental and harmonic frequency component currents. Harmonic component current provided to an induction motor (IM) increases losses, efficiency, operating temperature, and insulation stress. The power distribution system supplies harmonic components currents from non-sinusoidal EV loads. Harmonic component current flowing across lines and cables increases power losses, efficiency, and temperature. Harmonic component filters or mitigation circuits avoid this. Fixed frequency tuning limits the benefits of harmonic filters. EV charger output rectifiers sometimes use power factor enhancement devices [9]. Input current is almost sinusoidal. Active filters may be natively parallel to EV loads. Passive and active power quality improvement strategies only benefit fast and super-quick charging stations because to cost [10].

B. Harmonics Data:

Many scientists across the world study the amounts of alteration in the current and voltage waveforms of EVCS. According to these numbers, the degrees of waveform distortion are far higher than permitted by the IEEE standard 519-1992 [11], especially in locations with low other loads. There was also a lot of waveform distortion in the heavy other loading regions. All harmonic components above the 21st order is disregarded in favor of just the odd ones for the purposes of this paper. The usual EVCS current waveform is depicted in figure 7, and the typical EVCS harmonics spectrum is depicted in figure 8.

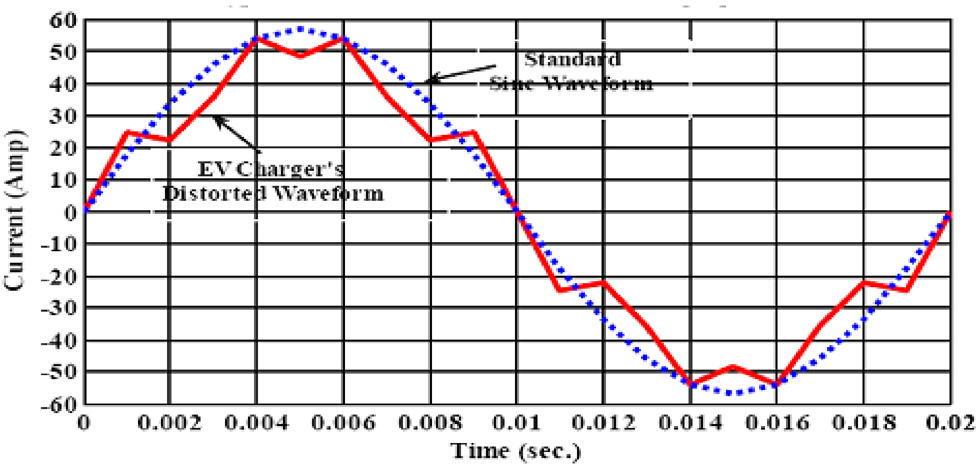

Fig. 7. EVCS: Distorted Current Waveform

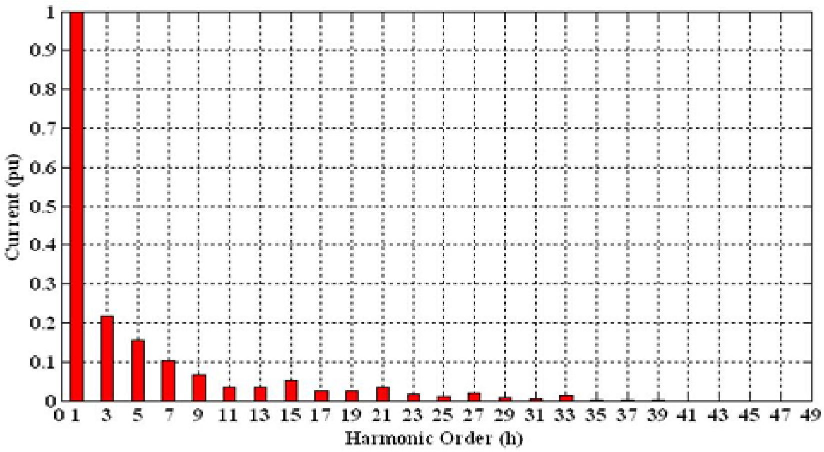

Fig. 8. EVCS: Harmonic Spectrum

10. Conclusion and Future Scope

When the harmonics load from EVCSs rises, the conductor resistance of the power cables in the distribution system also rises significantly. When the load on an EVCS's harmonics increases, the conductor power loss in the distribution system's power cables grows exponentially. As, the harmonics load on an EVCS rises, so does the temperature rise in the power cables that make up the distribution system. The HDF (Harmonics Derating Factor) of power cables in the distribution system likewise rises exponentially as the harmonics load from EVCSs rises. Distribution system power lines are severely harmed by EVCS harmonics. Harmonics are especially problematic for large power connections. When designing and running the power distribution system cables, it is crucial to account for the harmonics that are penetrating the system due to EVCS. Harmonics from EVCS charges must be reduced, hence steps must be taken to do so.

In this research, we analyse and report data on how EVCS-caused harmonics in the distribution system affect key performance characteristics of XLPE power cables in the distribution system. Data from both a simulated EVCS and a real-world power grid are used to make an assessment. To say that the work described here is complete would be a gross exaggeration, as there is always room for improvement and expansion in every evaluation endeavor. The potential for future enhancements and extensions of this work are as an alternative to using harmonics data generated by an EVCS simulation, this work can be evaluated using real-world harmonics data. It is possible to incorporate the design of filters to reduce harmonics in EVCSs into this research work. A working model or prototype can be created on this work in physical form.

References

1. Ashish Kumar Karmaker, Sujit Roy and Md. Raju Ahmed, "Analysis of the Impact of Electric Vehicle Charging Station on Power Quality Issues", 2019 International Conference on Electrical, Computer and Communication Engineering (ECCE), 7-9 February, 2019
2. Chirag Panchal, Sascha Stegen and Junwei Lu, "Review of static and dynamic wireless electric vehicle charging system", ELSEVIER -International Journal on Engineering Science and Technology, vol.21, Oct.2018, pp. 922–937.
3. J. Guo, J. Yang, P. Ivry and C. Serrano, "Analysis of the Impacts of V2G Chargers on LV Grid Harmonics", 2020 9th International Conference on Renewable Energy Research and Application (ICRERA), pp. 88-92, 2020.
4. Jizheng Liu;Zhenpo Wang;Lei Zhang, Integrated Vehicle-Following Control for Four-Wheel-Independent-Drive Electric Vehicles Against Non-Ideal
5. KPMG, CII, "Shifting the Gears the Evolving Electric Vehicle Landscape in India", October 2020, pp. 1-40.
6. K. D. Patil and W. Z. Gandhare, "Threat of Harmonics to Underground Cables" IEEE 2012 Students Conference on Engineering and Systems, pp. 1-6, 16 – 18 March 2012.
7. Ministry of Power, GOI, "Electric Vehicles Charging Infrastructure and Impacts on Distribution Network" White Paper, pp.1-118, June 2020.
8. Qin Yan and Mladen Kezunovic, "Impact Analysis of Electric Vehicle Charging on Distribution System" 2012 North American Power Symposium (NAPS), 9-11 September 2012.
9. Rares Catalin Nacu and Daniel Fodorean, "Harmonics Mitigation in DC Based Charging Stations for EVs, 2021 10th International Conference on Renewable Energy Research and Application (ICRERA), Istanbul, Turkey, 2021
10. Rwamurangwa Evode, "Modeling of Electric Grid Behaviors having Electric Vehicle charging stations with G2V and V2G Possibilities", IEEE 2021 International Conference on Electrical, Computer, Communications and Mechatronics Engineering (ICECCME), 2021
11. Shubham Mishra et al, "A Comprehensive Review on Developments in Electric Vehicle Charging Station Infrastructure and Present Scenario of India", Sustainability, vol. 13, no.2396, pp. 1-20, February 2021.
12. Sajib Chakraborty et al, "DC-DC Converter Topologies for Electric Vehicles", MDPI Energies, pp. 1-43, December 2019.
13. Syed Rahman, Irfan Ahmad Khan, and M. Hadi Amini, "A Review on Impact Analysis of Electric Vehicle Charging on Power Distribution Systems" 2020 2nd International Conference on Smart Power & Internet Energy Systems, 2020, pp.420-425.
14. Sanchari Deb and Karuna Kalita, "Review of impact of Electric Vehicle Charging Station on the power grid", 2017 IEEE International Conference on Technological Advancements in Power & Energy. pp.1-6.
15. Sanchari Deb et al, "Impact of Electric Vehicle Charging Station Load on Distribution Network", MDPI Energies, pp. 1-25, Nov. 2018.
16. S. Afshar, P. Macedo, F. Mohamed and V. Disfani, "A literature review on mobile charging station technology for electric vehicles", 2020 IEEE Transportation Electrification Conference & Expo (ITEC), pp. 1184-1190, 2020.
17. V2X Communication, IEEE Transactions on Vehicular Technology, Volume: 71, Issue: 4, 2022
18. Wanke Cao; Zhiwen Zhu; Jinrui Nan; Qingqing Yang; Guangjian Gu;Hongwen He, "An Improved Motion Control With Cyber-Physical Uncertainty Tolerance for Distributed Drive Electric Vehicle, Vol. 10, 2022.