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Electric Vehicle Charging and its Effects on the Power Distribution Network – A Review

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Abstract

The worldwide transition to e-mobility is a welcome step towards ensuring a greener planet. Countries across the world are planning to adopt Electric Vehicles (EVs) in a big way which calls for an increased number of charging stations. EV chargers, which are non-linear loads will impact the power quality of the system when connected to the distribution network leading to harmonics, frequency deviation, voltage unbalance, voltage fluctuation etc. Therefore, studies need to be carried out to analyse the effect of EV charging on the distribution system and to recommend possible remedial measures. This paper aims to review the research carried out on the analysis of the impact of EV charging on the distribution network.

Keywords: Electric Vehicles, Electric Vehicle Chargers, Harmonics, Power Quality

1. Introduction

The widespread use of EVs is anticipated to lessen air and noise pollution and also lead to the conservation of natural resources. The advantages of EVs over traditional automobiles are lower running costs, low maintenance costs, lower emissions, ease of driving and noise-free operation. However, numerous EVs connected to the distribution network through different charging stations can cause power quality issues. EV charger is a non-linear load as it contains power electronic devices and therefore, generates harmonics when connected to the power system which causes heating, overloading, increased losses, ageing of equipment, system unbalancing, transformer winding damage etc. "Power quality refers to an electric power system's ability to maintain the rated amplitude and frequency of noise-free sinusoidal voltage and current"[1]. With the increased use of EVs, there is a need to understand the effect of various EV chargers on the distribution network. This study provides a thorough review of the research carried out so far to understand the impact of EV charging on the distribution network. The paper discusses the key findings of the state-of-the-art research works and summarises the challenges and the future perspective in this area.

2. Electric Vehicles

Electric motors propel EVs and use electrical energy stored in batteries. The EV batteries can be charged using on-board chargers housed inside the vehicle or off-board chargers also known as EV Supply Equipment (EVSE). Components of an EV charging station include a transformer, rectifier and converter. A charger combines rectifiers and converters. EVs can be classified as Battery Electric Vehicles (BEV), Hybrid Electric Vehicles, (HEV) Plug-In Hybrid Electric Vehicles (PHEV) and Fuel Cell Electric Vehicles (FCEV). BEV are fully powered by electricity[2-4]. These types of EVs are charged using different chargers and are more efficient than other electric vehicles. Examples of BEVs are the Tesla X, Toyota RAV4, BMW i3 etc..HEV contain both the internal combustion engine and the battery. The petrol engine helps to drive and charge the battery when the battery is empty. Examples of HEV are the Toyota Prius Hybrid, Toyota Camry Hybrid, Honda Civic Hybrid etc. PHEV use both the internal combustion engine and the battery. The battery is charged with the help of an external socket. Examples of PHEVs are BMW 330e, Hyundai Sonata and BMW X5 xdrive40e etc. FCEV obtain power from chemical energy, where the vehicle tank contains hydrogen fuel. Here chemical

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energy is converted to electric energy, which powers the motor of the EV. Examples of FCEVs are the Hyundai Nexo and Honda Clarity Fuel Cells etc.

3. Electric Vehicle Chargers

The technology for EV charging can be broadly classified into conductive charging, wireless charging and battery swapping. However, only conductive technology is used in the commercially available EV chargers as wireless charging and battery swapping technologies are still under research and development. Conductive EV chargers can be classified into two basic types, Alternating Current (AC) and Direct Current (DC) chargers. While the output of DC chargers can be directly fed to the EVs, the output of AC chargers requires rectification. Hence, AC chargers are slow chargers. DC chargers are also called DC fast chargers. While an AC charger may take 6-8 hours to charge a vehicle, a DC charger can do so in less than an hour. Chargers available in the market are classified based on the charging current and power provided as slow chargers or Level 1, fast chargers or Level 2 and rapid chargers or Level 3[5,6]. Charging of an EV can be done in two ways, through onboard chargers or off-board chargers. The AC power supplied by the Level 1 and Level 2 chargers is converted to DC by the onboard charger of the EV. The Level 3 chargers are called off-board chargers because they directly charge the EV battery completely bypassing the onboard charger.

While the Level 1 and Level 2 chargers are AC chargers, Level 3 rapid chargers are DC chargers. The Level 3 chargers take less time to charge the battery compared to Level 1 and Level 2 chargers. Level 1 chargers are found in households and the output of these chargers is AC. The Level 2 chargers are found in public places like shops and parks and the output is AC. The output of the Level 3 chargers is DC and these chargers can charge an EV battery up to 80% within 20 minutes. The fast chargers require a separate charging station to power the vehicle.

4. Impact of EV Charging

The number of EVs connected to the grid at a time, location of connection, charging time and power consumption details cannot be predicted in advance. The effects of Plug-in Electric Vehicle (PEV) charging on the distribution network, such as harmonics, thermal loading, unbalances, voltage fluctuations and loss of life of the transformer have been studied[7]. In this paper, the single-phase PEV charging and discharging characteristics are analysed using time domain simulation under unbalanced conditions. The load (current) unbalance occurring at unity and non-unity power factors have been analysed.

The impact of uncontrolled charging of EVs on the low-voltage grid was analysed with the help of key indicators in[8]. The impacts of EV penetration on the California distribution network are analysed in[9]. The charging data is collected for 64 different EV modules for various charging levels, levels 1, 2 and 3. The energy distribution curves are plotted and analysed daily, monthly, seasonally and yearly. The results provide an insight into the load variation due to EV charging[10] and investigate the mechanism of harmonic generation during the EV charging process based on the existing charging methods. EV charger pile is modelled and the harmonics produced are analysed based on the measured data. The author concludes with the presence of a three-phase current imbalance. In[11] the impacts of EVs on the voltage level, power demand and active power losses of the distribution network are studied for various levels of EV penetration. It is concluded that EV charging adversely affects the system's voltage level and equipment life while also increasing the power demand.

4.1. Increased Power Demand

EV charging requires a huge amount of power. More EVs connected to the grid simultaneously lead to a sudden increase in the power demand which affects the stability of the system. The additional power demand overloads the power system equipment, sometimes necessitating load shedding.

The impact of fast charging stations on urban distribution systems has been discussed in[12]. The paper reports that EV charging causes higher power demand during the summer season as compared to the winter season. Lower penetration of EVs does not have much impact on the distribution network. EV penetration of 40% disturbs the grid operation. The fast charging station affects the grid's voltage profile and power losses. In[13] selection of the best location for EVCS based on voltage stability and power losses is discussed. Voltage stability studies have been carried out to investigate how EVCS distribution affects the system loading margin. Locating the EVCS in a planned manner helps to reduce system losses and network reinforcement costs. Many charging stations set up in close proximity create more instability because the allowable voltage limit is violated. Thus, the location of EVCS is crucial for maintaining system stability. In[14,15] describes the impact of EV penetration with various seasonal loads. Numerous EVs are connected to the distribution system via different charging infrastructures like level 1, 2, and DC fast chargers. The impact on the distribution system during peak and off-peak hours is studied. The chargers are found to induce harmonic currents thereby generating voltage distortion. An increase in EV penetration is found to have an increased impact on the distribution system.

4.2. Transformer Overloading

Transformer overloading occurs at a high peak load due to increased power demand. At the same time, integrating more EVs into the grid increases the transformer load and lowers the system voltage beyond acceptable limits. It also produces stress on the transmission lines and uneven distribution of current in the transformer winding, which leads to a decrease in the life and efficiency of the transformer.

The effect of PEV charging on transformer loading, feeder loading and voltages at the endpoint of the feeders in low voltage grid was studied with different penetration levels of EVs[16]. The impact on transformer loading and feeder loading is analysed. Here two charging scenarios, uncontrolled/uncoordinated and indirectly controlled / coordinated charging are investigated. In uncontrolled charging, the PEVs start charging on arrival until they are fully charged. This type of uncoordinated charging leads to overloading of the distribution network at peak hours. In indirectly controlled charging, PEVs are charged based on the time of use pricing, encouraging EV owners to use their vehicles at off-peak (low) prices. The study reveals that coordinated charging can reduce the impact of charging PEVs on the low-voltage distribution grid.

The transformer temperature is increased due to the overloading of the transformer. The transformer lifespan depends on the health of the winding insulation. Increasing transformer temperature due to overloading reduces transformer life. In[17] studies the effect of EV charging on the loss of life of distribution transformers for various percentages of penetration of EVs. Monte Carlo-based simulation was carried out to simulate the EV load. Real-life data of the distribution transformers from the Modi Ganapati area, Pune, was used for these studies. Data pertaining to EVs such as mileage and State of Charge (SOC) details were obtained using the Monte Carlo method. It was found that EV charging causes considerable overloading of transformers when most EVs are charged simultaneously. To avoid transformer overloading, EVs may be charged at different times. In[18] investigates the synergistic effect of PEV charging and rooftop PV on the life of the distribution transformer. The studies show that the adverse effects of EV charging on the life of the distribution transformer can be offset by the integration of rooftop PV.

The frequent connection and disconnection of EVs affect the system frequency. More number of EVs when connected to the grid at peak time, leads to decreased system frequency due to high load[19].

In[20], the impact of EV chargers on transformers and distribution feeders in the Toronto distribution network is studied. The system performance during peak summer and winter loads, with and without EV penetration, are compared. Some other factors are also considered, such as charge size and charging during peak loads. Two of the most loaded distribution transformers in the distribution network and the cable feeders are studied using steady-state simulation in CYME software. It was concluded that chargers of the power level 3.3 KW and below do not lead to overloading problems, but 6.6 KW chargers create moderate overloading of the system components. Further, chargers of power level 10KW and more require a prior system upgrade to accommodate because it can cause overload to system components. Thus, safe operation boundaries are determined.

The impact of a PEV on three-phase, three-leg transformers is discussed in[21]. PEV charging stations comprise electronic devices which cause current harmonics. These harmonics create disturbances such as insulation failure, winding failure and reduced efficiency of the transformer. Transformer fundamental and harmonic losses based on non-linear models considering the sinusoidal and non-sinusoidal operation of charging stations are also discussed. A non-linear three-phase three-leg transformer model is implemented for the study. Finally, the author concludes that the onboard PEV charger can have a significant effect on the quality of power supply from a distribution transformer. The transformer's secondary voltage waveform contains some distortion due to rectification. The charger distorts the current waveform, leading to thermal stresses and temperature rise in the transformer. The temperature rise results in premature winding and insulation failure. Installing power quality compensation devices like active filters connected parallel to the charging station helps cancel the harmonics generated from the charger.

In[22] investigates the effects of high penetration of PEV, charging power and Photovoltaic (PV) generation on distribution transformer ageing. The Monte Carlo method is used to perform probabilistic analysis. The degradation of transformer insulation and transformer ageing depends on its internal temperature. The hottest spot temperature is considered for the analysis. Here, Level 1 and Level 2 chargers are studied under seasonal variation to determine the scenarios affecting transformer ageing. A 20 KVA distribution transformer is studied. The results show that high penetration of PEV has a detrimental effect on transformer life. Seasonal variations are found to have an impact on the ageing of the transformer. Level 1 chargers, when used during winter, do not affect the transformer ageing. However, level 2 chargers impact the transformer ageing even in the winter season.

5. Power Quality Issues

EV chargers are non-linear loads due to the presence of power electronics components. Power quality issues such as violation of voltage limits, harmonic problems, overloading and power loss etc. are likely to crop up with the increased integration of EV chargers into the distribution system. Therefore, evaluation of the power quality of the distribution system post-EV integration is crucial to ensure uninterrupted/reliable network operation.

5.1 Low Voltage Profile

EVs consume more power for a short duration. The sudden increase or decrease in load disrupts the voltage stability and grid reliability. So, the voltage profile of the distribution system will be disturbed due to the bulk charging of EVs and the system may become unstable. The effect of voltage sag or swell and voltage flickers and notches are expected to increase due to the high integration of EVs. The voltage sag is introduced when there is a sudden substantial increase in load. Voltage sag decreases the Root Mean Square (RMS) voltage between 10 and 90% of the nominal voltage from 0.5 cycles to 1 minute[23].

In[24] investigates the voltage deviation challenges for different types of chargers. The voltage profile is analysed for three different scenarios, fast charging, level 2 charging and both fast and level 2 charging. The higher power demand of fast chargers leads to voltage distortion.

The impact of EV charging on the voltage profile is analysed in[25] using load flow analysis with and without EV load. Here, voltage responses are evaluated with increasing penetration of EV and clustering of EV loads. A high level of EV penetration creates voltage drops at primary and secondary services. The study reveals that the voltage drop on the secondary side is higher than that on the primary side due to EV charging. However, the voltage drop on the primary side will increase with an increase in EV load penetration. The clustering of EV loads creates an imbalance in three-phase power demand which results in voltage sag in one phase and voltage swell on the others.

The balanced and unbalanced scenarios of the effect of EVs on low-voltage feeders are discussed in[26]. In the balanced scenario, EVs are randomly allocated to the customers and in the unbalanced scenario, EVs are sequentially allocated to the customers on the three phases. The voltage profile of the low-voltage feeder depends on the distribution of the EV chargers. The study reveals that the voltage imbalance limit is not violated in the balanced scenario even at higher penetration levels. Whereas the same is violated in the unbalanced scenario even at a lower EV penetration level. Thus, studies on the siting of EV chargers in the distribution network is very much essential. Time of use tariff was used in this work to mitigate voltage imbalance and drops.

The impact of high EVCS penetration on the distribution system's voltage profile is analysed in[27]. The Qatar electricity and water company distribution network and EV charging stations are simulated using Matrix Laboratory (MATLAB)/ Simulink. EVCS is connected to a specified bus. Finally, the impact of significant EVCS penetration and Total Harmonic Distortion (THD) on the distribution system is discussed. The paper suggests that large EVCS in the range of kilowatt (KW) should be integrated into high-voltage feeders, and small EVCS could be connected to low-voltage feeders for better results.

The voltage-dependent charging solution for a single-phase EV charger current in a real unbalanced Danish low voltage distribution network is simulated using MATLAB simpower systems in[28]. Four controllers (C1, C2, C3 and C4) in the proposed system regulate the EV's charging current with each node voltage. C1 is a basic droop controller designed to enhance network performance. To reduce voltage fluctuations and balance the phases during crucial hours, the controllers C2, C3, and C4 are utilised. This results in higher voltage levels even when no EVs are connected.

In[29] studies the impact of charging PHEVs and single-phase charging of EVs on system voltage. Bulk single-phase charging of EVs causes unbalance in the distribution system. The paper reveals that the voltage unbalance factor exceeds the permissible limit due to bulk single-phase charging of EVs /PEVs.

6. Harmonics Analysis

Harmonics are defined as integer multiples of the fundamental frequency due to non-linear loads in the system. An EV charger is a non-linear load, and when it is connected to the power system, it generates harmonics. In fast charging, the power electronic components usage is high, increasing the harmonics in the distribution system. Current harmonics originate from non-linear loads like variable speed drives, PCs, and power electronic devices in the system that act as harmonic current sources. The flow of current harmonics through system impedance causes a harmonic voltage drop across the impedance by distorting the supply voltage waveform and generating voltage harmonics.

THD is a measure of the level of harmonic distortion in a current/voltage waveform can be measured. The voltage THD (THD_V) and current THD (THD_i) can be measured by using the following equations.

$$THDv = \frac{\sqrt{\sum_{n=2}^{N} V_n^2}}{V_1} * 100 \quad (1)$$

$$THD_i = \frac{\sqrt{\sum_{n=2}^{N} I_n^2}}{I_1} * 100 \quad (2)$$

Equation (1) and (2) gives the THD value of voltage THD_V and current THD_i respectively. V_n, I_n are the voltage and current components of the n^{th} harmonic and V_1, and I_1 are the fundamental components respectively.

TDD[30,31] indicates the impact of harmonic distortion in the system and is measured by using the following equation.

$$TDD = \frac{\sqrt{\sum_{n=2}^{N} I_n^2}}{I_L} * 100 \quad (3)$$

I_n is the current component of the n^{th} harmonic and I_L is the maximum demand load current.

In[32] the harmonics generated by EV chargers are analysed using a simulation model of the charger. The study reveals that the harmonic content generated by the charger consists predominantly of odd harmonics.

In[33], power quality measurements were carried out at a bus depot in the Netherlands, where many fast and slow electric buses were charged daily in the same bus depot. The bus depots under study comprised ten 300KW fast chargers and twenty-two 50KW chargers. The voltage, current and power parameters of the transformers supplying power to the chargers were monitored by Distribution Automation Boxes (DAB). This article summarises various power quality measurement results and their impact on the source current and voltage quality. Results of power quality measurements in this bus depot show harmonic and superharmonic emissions from EV charging points.

The impact of EVs on the distribution system is analysed in[34]. Here, the load characteristics of level 2 and level 3 chargers connected to the grid were studied by measuring field data with the help of a power quality analyser. Secondly, the harmonics generated by level 2 and 3 chargers such as 2^{nd}, 3^{rd} and 7^{th} harmonics were analysed. The data was captured from May to June 2017. This study concluded that level 3 chargers generate more harmonics than level 2 chargers. Higher harmonics from the level 3 chargers are likely to impact transformers and other equipment. Further, the author concludes that high penetration of level 2 and 3 chargers may cause issues for the distribution grid.

In[35] analyses the level of harmonic contamination due to the integration of buck-boost and KY converter-based charging stations. The buck-boost converter-based and KY converter-based chargers were simulated using circuit modelling. The buck-boost converter topology is found to result in high THD and ripples compared to the KY converter topology.

In[36] presents measurements of power quality parameters such as voltage and current imbalance, voltage and current harmonics etc. Further, this study reports steady state and dynamic assessments of EV charging, especially DC fast charging on weak distribution grids. The challenges of levels 1, 2 and Direct Current Fast Charging (DCFC) on the weak distribution system were analysed under grid-connected and microgrid mode. In microgrid mode, tripping of load happens due to frequency oscillations arising from EV charging. DCFCs connected to a weak grid will cause high power demand, which may lead to brownouts and blackouts. The paper recommends time-staggered charging of EVs for improved power quality.

The voltage and current harmonics effect on the low voltage distribution system during the charging of an electric vehicle is studied in[37]. The EV is connected to a low-voltage grid through a single-phase charger. The formula for charger energy conversion efficiency and battery charge level during charging are also discussed. The voltage and current harmonics data are measured using a harmonic analyser. The distribution system response is analysed based on THD_V and THDi. The study reveals that a THD_V

value of less than 5% is not dangerous for the equipment, but a THD_V value between 5 to 8% can cause disturbance in apparatus operation. Whereas a THD value of less than 10% is not dangerous, a THDi value between 10 to 50% indicates significant harmonic disturbance. THDi value above 50% indicates a significant disturbance to the system.

The current, voltage, power and harmonics data during the charging of different EVs was collected from multiple charging stations and analysed in[38]. The simulation is carried out using DIgSILENT software. The investigation reveals that voltage distortion remains unchanged with increased power demand. Current THD values are found to be higher than 15%. The high THD_i causes current distortion, resulting in higher losses thereby damaging other equipment in the grid.

The impact of voltage THD due to single-phase EV charging in low-voltage distribution systems is analysed in[39]. The EV chargers were modelled as the current harmonic source. The voltage THD is analysed for different levels of EV penetration, 45%, 65% and 35%. The safe penetration level of EVs which can be allowed without any negative impact on the system, is identified in this paper.

In[40] studies the impacts of harmonics produced by level 1, 2 and 3 charging on the distribution transformer at different SOC of the EV battery. Studies were conducted on transformer losses, temperature rise and lifetime reduction. The author draws the conclusion that when the load demand for EV charging reaches its maximum level, the temperature rises, losses, ageing acceleration factor and distribution transformer lifetime reduction peak. Compared to level 1 and level 2 charging, the distribution transformer is more negatively impacted by the harmonics of level 3 charging. In[41] focuses on evaluating and reducing the effects that various EV chargers have on distribution transformers and the distribution networks' voltage quality. The effects of EV harmonic currents on the losses and ageing of transformers are studied. The effect of SOC on the harmonics generated is considered in this study. A Decoupled Harmonic Power Flow (DHPF) technique is applied to measure the system distortion resulting from EV charging. The Institute of Electrical and Electronics Engineers (IEEE) 33-bus system with EVCS and PV-based Distributed Energy Resource (DER) units is simulated. Optimal dispatch of the harmonic currents from solar photo voltaic-based DER limits the maximum voltage THD within the tolerable limit of 5% which controls the harmonic current distortion through the main substation transformer and enhances the transformer's life without the help of costly active power filters.

In[42] harmonic current flow calculation methodology in distribution networks is developed using harmonic profiles and open DSS-based calculation tool. Three AC chargers (low power single phase charger, 1*10A, high power single phase charger, 1*20A, high power three-phase chargers, 3*32 A) and one DC charger of power level 130KW are considered for this study. The harmonic current flow in the network is calculated using an open Decision Support System (DSS) tool.

In[43], the power quality is examined in relation to various EV penetration levels and battery state of charge. In this study, only level 1 and level 2 chargers are taken into account. The standard distribution networks for the IEEE 13 bus and IEEE 34 bus are simulated. Both test systems experience higher harmonics as a result of bulk EV penetration. To reduce harmonics, series active filters and shunt active filters (with PQ theory) are used for the buses of the IEEE 13 bus and IEEE 34 bus distribution systems, respectively, that have the highest voltage sensitivity coefficients. After filters are applied and kept within the required limits, the voltage and current THD values are decreased.

in[44] investigates how the load connected to the system is affected by the harmonics produced by EV rapid charging stations. For this study, an IEEE 14 bus distribution network was used. With the Electric Transient Analyser Program (ETAP), a rapid charging station time domain harmonic model is created. The study reveals that the distance between the load and the charging station as well as the charging station's capacity determine the harmonic impact on the load.

7. Impact of Harmonics on the Power Equipment

Current harmonics negatively impact the power equipment such as transformers, cables, protective equipment and capacitors. The harmonic component in the current increases the RMS value of the load current, thereby increasing I^2R losses, leading to decreased efficiency of power delivery to consumers.

In the case of transformers, higher harmonic components lead to higher eddy currents and core losses, which causes a rise in the temperature of the windings. This rise in temperature affects the insulation, reducing the equipment's life span. The higher I^2R losses produce additional heating in power cables, increasing the skin and proximity effect and reducing the insulation component's lifetime. An increase in I^2R Losses due to harmonics leads to the premature operation of fuses. Further, high current harmonics may lead to resonance in the electric system, thereby reducing the lifetime of the equipment.

In[45] surveys the various charging station topologies available and compares the performance of the different topologies in terms of power transfer capabilities, grid support, power density and other factors. Even though the topology selection depends on the application requirements, the paper recommends the back-to-back AC/DC/DC topology as it provides all the desired features and performs well. In[46], the impact of EVCS on the grid is analysed based on power demand, harmonic disturbance, voltage distribution and transformer power loss and the harmonic mitigation techniques are also discussed. The distribution system is simulated in MATLAB and the EV rating is taken as per the EV models available in Bangladesh. The paper recommends that if the EV charging is scheduled at peak and off-peak periods, the problem related to the surge in power demand will be minimised. Further, the paper recommends selecting a transformer with a higher k-factor to minimise the transformer power loss due to harmonic effects.

In[47] aims to analyse the effect of THD produced by Level 2 EV chargers. The IEEE34 bus distribution system is simulated in the Power Systems Computer Aided Design (PSCAD) software. This paper investigates four scenarios, the impacts of harmonics on overhead transmission lines, underground cables, industrial areas and transformer and PV modules. This paper provides some suggestions for the location of EV charging stations and customers charging habits. For customers, charging an EV battery with a higher SOC value can cause less damage to both the grid and the battery. Installation locations for EV charging stations must be chosen away from transformers, which suffer from the harmonic effects of EVs and act as a harmonic source. The charging stations of EVs in nearby industrial areas should limit the number of EVs and be equipped with protection systems to ensure high power quality.

In[48] investigates the impact of EV charging's widespread adoption on the stability of the electrical supply. Power consumption rises as more EVs are charged simultaneously, although this can be mitigated by utilising Renewable Energy Sources (RES) like solar and wind power. By reducing grid dependency, this integration of RES aids in reactive power compensation and lowers the number of harmonics produced. The influence of harmonics caused by EV charging can be minimised by employing a transformer with a high K factor, as advised by the study.

The authors of[49] make recommendations for enhancing the system's power quality. To prevent uneven charging loads from single-phase on-board chargers, the article suggests using coordinated intelligent charging. When employing chargers without PFC circuits, the article also suggests using reactive power compensators and harmonics.

8. Challenges, Opportunities and Future Perspective

Increased adoption of EVs across the globe will reduce fossil fuel consumption and emission of Greenhouse Gases (GHG) such as CO_2, Nitrous oxide etc. Moreover, it opens up an ocean of business opportunities such as recycling of used batteries, public charging stations and battery swapping stations and technologies. To promote the widespread adoption of EVs, it is essential to set up a sufficient number of charging stations and to locate them properly. However, the charging infrastructure required for EVs brings several technical challenges. The technical impacts of fast charging on the electrical grid must be analysed and appropriately addressed. Fast charging being power intensive and driven by power electronic converters, growing numbers of charging stations bring operational challenges such as overloading of equipment, network congestion, power quality problems, poor voltage profile, increased system losses etc. However, coordinated and intelligent charging technologies could address overloading and congestion in the future. Power quality and voltage issues could be mitigated using properly designed filters and necessary compensation.

9. Conclusion

To mitigate global warming and related environmental issues, emphasis has been laid on the increased adoption of EVs across the globe. Electric vehicles do not emit any emissions when they're in use, in contrast to conventional cars that use internal combustion engines. Increasing the number of EVs on the road requires a large number of Public Charging Stations (PCS). Level 1, 2 and DC Fast Chargers (Level 3) are the three power levels into which EV chargers can be categorised. Disorganised, mass installation of charging stations is likely to throw the distribution system out of balance and degrade the quality of the power. Modern research on EV charging on the current distribution network was evaluated in this article. Future perspectives and difficulties are also deliberated. Some commercially available EV chargers have reviewed their current THDs recently and the results show that a large number of them draw significantly distorted current. Due to the non-linear nature of the charging infrastructure, a large number of EVs connected to the distribution network at once may result in harmonic problems because these systems incorporate power electronics converters. In this study, the effects of electric vehicle charging on the electricity distribution network are covered in detail. Growth in DC fast charger installations and unregulated EV charging poses issues concerning power quality, including harmonics, overloading, low voltage profiles, fluctuating voltage and power losses. Harmonics reduces the lifetime of electrical equipment connected to the distribution system. The effect of harmonics is expected to multiply with higher adoption of EVs, EV fleet charging and the setting up of battery swapping stations.

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