EV Charging effect on Power quality of Grid Power.

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Abstract. *The Economic Survey predicts that India's domestic electric vehicle market will see a 49 percent compound annual growth rate (CAGR) between 2022 and 2030, with 10 million annual sales by 2030.As the EV vehicles require Batteries this batteries charging power drawn by electric grid by using power converters. As there are fast chargers which consume less time for charging the battery, this type of chargers suddenly increases load, Harmonics and imbalance in power system and cause low PF in power system. Power quality issues arise such as harmonics distortion and their effects in charging the electric vehicle. In India day by day there are increases in Electrical vehicles. In EV charging mainly requires Battery charging which requires AC to DC converter due to that there is issue of Power quality as the number of chargers increased there is continues decrease in the THD of the combined currents. There are many bad effects of Power quality problems that can contribute to more energy costs, less production and faults in your electrical power system. Proactively addressing power quality issues from design stage can offer significant reliability and cost benefits. The presence of harmonics in the system may not always create an issue in a short run, however long term consequences should be considered the main issues are Deterioration of equipment leading to reduced lifespan ,Increased losses , Overheating, Reduced reliability leading to increased* process *interruptions ,Failures of drives, PLC's or Power Supplies* & *Communication interference.*

Key words: **Power quality, Harmonics, EV, Power factor, simulation, THD**.

1. Introduction

Power quality is a predominant factor in the efficiency and security of grids and, more freshly, of smart grids, and is likely to be strongly affected by PEV development over the forthcoming years. EV interface systems use power electronic converters because of their operating principles and the nature of its switching power semiconductor components, and these are highly nonlinear systems. Therefore, in the input current of the converter, high levels of harmonics are typically present and these are generally handled with using PWM control and filtering. Producers say that their converters, both in charging and regeneration modes, generate good power quality (With regard mainly about harmonics & the power factor) India may need a minimum of 1.32 million charging stations by 2030 to facilitate the rapid adoption of electric vehicles (EVs), according to a report released by the Confederation of Indian Industry (CII) on 'Charging Infrastructure for Electric Vehicle'. Electric vehicle charging uses a large number of switch mode Power supplies where it converts AC to DC Power to charge the battery. This conversion process ,in turn , generate harmonics predominantly 3rd ,5th and 7th .The third harmonic don't get cancelled at star point and get added up in the neutral, increasing the neutral current drastically . This overheats the neutral and increases the neutral to earth voltage, which might be a major cause of concern for other electronic equipment in vicinity. In addition to this, most of the load distribution is balanced, but due to random charging patterns, we will always have instantaneous unbalance in the 3 phases All these are major concern related to power quality caused by EV chargers.

2. Power Quality

Power Quality (PQ) has two aspects - Voltage and Current which are directly linked to each other. We can define power quality for current based on four load parameters i.e. Power factor, Harmonics, Unbalance and Neutral. These four parameters can directly assess the impact on the grid due to load characteristics. In the case of voltage, the major issues are Unbalance, Sags, Swells, Interruptions etc - these are factors that define the power quality of the source side.

Power Quality is important in order to safeguard the proper functioning of the power grid system and the loads connected to it. PQ requirements should be a characteristic of both parts of the system, i.e. the energy supplied by the power grid, as well as the energy consumed by the equipment connected to the grid.

3. Impact of EV charging on power quality

In India, there are certain regulations in place for Power Quality, and they are applicable to all LT and HT consumers. Globally, in 2011 SAE issued power quality requirements for plug-in electri vehicle (PEV) chargers in response to rising sales of PEVs and concerns about their potential impact on utility systems and on other devices connected to them.
Electrical power is delivered upon demand, and utility systems are impacted by the demand of power and the duration of that demand. Distinctions must be made about real power, which does work, and apparent power, which is the impact on the electrical system.
With respect to harmonics, IEEE 519-2014 standard forms the basic guideline for harmonic regulation in India. The billing as recommended by CEA has to be through KVAh and most state have already implemented the same. KVAh billing automatically takes care of any deviation in power factor and penalises the user for leading as well as lagging power factor. Since the powe quality recommended practice was issued, interest has emerged for measuring and regulating power quality and energy efficiency of EV charging systems and work is happening on improvin the specifications of the EV chargers so that they are designed to take care of PQ issues internally.

4. Different kinds of charger's impact on PQ

There are three types of chargers. Single-phase AC chargers and two-phase AC chargers cause high neutral current and unbalance in the grid. Then we have DC chargers, which are 3- phase chargers that generate harmonics and have a leading power factor impact on the grid.
Currently, EV charging is at its initial stages and therefore, the impact on the grid is not visible and, in fact, minuscule. But a surge in EVs is expected going forward. The next ten years will see a huge infusion of EVs and EV charging infrastructure, putting an extreme level of stress on the existing electrical infrastructure across the country. The electrical demand will almost double in the coming years. And as the percentage of EV charging and renewables increases in the grid, it will become more and more unstable.
Things need to be tackled proactively with proper regulations and equipment to safeguard the impact on the grid due to these power quality concerns raised by the growing EV charging infrastructure. When large-scale EVs are charged simultaneously, unwarranted peaks in power consumption and consequent PQ issues, including current distortion, increased power flow in power cables, transformer overloading, voltage drop, voltage imbalance and harmonic contamination, are bound to arise. In addition, EV charging at home will result in heavy single- phase loads in residential low voltage (LV) distribution systems.

4.1. Impact of EV charging on the overall power distribution system.

A large deployment of EVs and PHEVS is expected to lead to PQ problems for the existing power networks. A surge in EV penetration could result in violation of supply/demand matching and maintaining statutory voltage limits and distortions. Under certain operating conditions, it may also lead to power quality problems and voltage frequency control, voltage imbalance. The latter is unlikely to exceed the statutory limit if EVs are reasonably distributed among the three phases. Active power filters should be installed to minimize or even eliminate the effect of EVs on the network.
In addition to the above, it is really important that the chargers as well as EVs adopt V2G technology and can be seamlessly integrated into the grid. In fact, with appropriate control and communication with the grid, EVS could be designed to operate as part of the smart grid to provide ancillary services such as supply/demand matching and voltage/frequency control.

The sine wave is the voltage, the spike is the current draw. This is true because most of these types of load charge a capacitor, and the capacitor will only draw current when the input voltage exceeds the voltage across the cap. This occurs only at the peak of the voltage waveform.

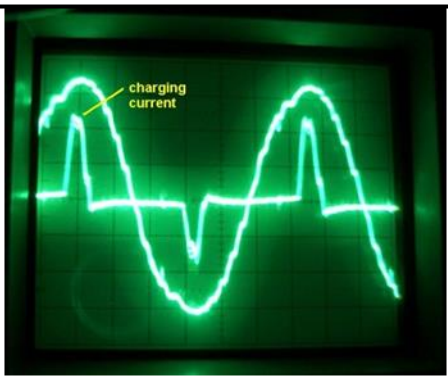

Figure 1 .Charging and AC voltage waveform

Power factor is a measure of the phase angle difference between the current and the voltage. From above figure that, while the current isn't sinusoidal, it's absolutely in phase with the voltage. So, generally DC loads don't significantly affect power factor. What they can affect is harmonic distortion. Having said that, phase-angle fired DC supplies (variable speed DC drives, oven controls, etc.) don't draw current that way.
These draw current whenever the SCR is switched on. As you can see, the power factor can vary widely, but generally at lower power settings the current draw is minimal. These also can generate significant harmonic content.

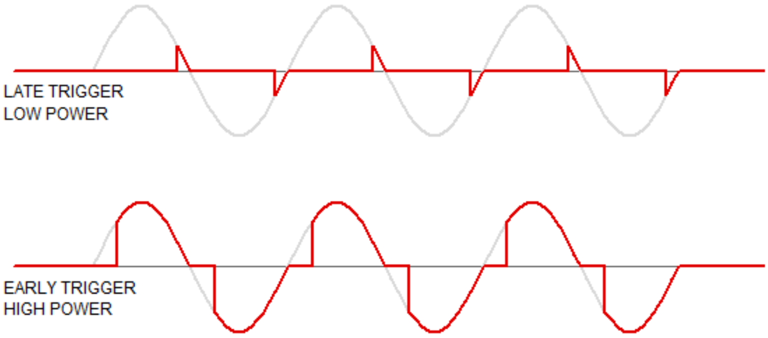

Figure 2.Changes in PF due swiching of SCR

There are two ways to affect the power factor. The usual way that you are taught relates to the phase angle between the current and voltage. The other way is non-linear loads such as bridge rectifiers or Power converters used in EV charging. The non-sinusoidal shape of the current waveform does produce harmonics.
But even though the current pulses are in phase with the voltage, they reduce the power factor. The harmonic currents do not contribute to real power, and they do not affect the watt meter or watt-hour meter. But they do cause additional heating in the wires, just as reactive currents do. As it is require power factor correction on large non-linear loads. But it's not as simple as adding a PF capacitor.

5. Aspects of power quality

Voltage values, current, active, and reactive power, and harmonic voltage and current content are the most important aspects of power quality. In order to conclude that energy has a good power level, the values of the energy must be between the limits, defined by the specifications.

5.1 Voltage

The quantitative concept of power quality is voltage quality, which includes both the steady-state variations in power quality and momentary disturbances as it can impact loads. Tension rating categories include: power level, voltage magnitude, harmonics and inter harmonics, unbalanced voltage, flicker, dips, swells, momentary interruptions and transients.

5.2 Power

For proper operation, the power system needs all forms of power-actual and reactive-.Reactive power flow is needed in an AC transmission system to allow the transfer of real power over the network .In electrical engineering, the power factor of the AC electrical power system is defined as the ratio between the actual power flowing to the load and the apparent power in the circuit, and the dimensionless number in the closed interval is -1 to 1.Active power is the ability of the circuit to perform work at a given time. For the same amount of available power transmitted, a load with a low power factor produces more current in an electrical power system than a load with a high power factor .

5.3Harmonics

Harmonics are the sinusoidal element with a frequency of a periodic waveform that is a multiple integer of the fundamental power frequency. Harmonic power-waveform distortion occurs when the first, second, third, and other harmonics are mixed [8]. On the sinusoidal waveform, the effect is voltage and current contaminations .As nonlinear devices draw current, harmonics are emitted in short pulses [9]. The harmonics in load current can often lead to overheated transformers, overheated neutrals, blown fuses and the discharged circuit breakers. Depending on the charging profile or mode of one or more EV users, the harmonic levels may rise to extreme levels that can increase stress on grids [10, 11].EV charging can lead, in addition to harmonic distortions, inappropriate voltage deviations and additional specific and harmonic losses of power.

EV charging is likely to take place in public or private parking lots, electric charging stations or on a customer's premises. The total harmonic signal distortion, or THD, is the measurement of the current harmonic signal distortion [12, 13]and is defined as the ratio of the power sum of all the harmonic components to the power of the basic frequency. The linearity and power efficiency of audio systems are defined by THD.

5.4 Harmonic Distortion

Harmonic distortion, recognized as the crucial PQ problem, can occur without the proper filtering method being used because of the use of power inverters in REG systems [14]. Harmonic distortion may increase the risk of parallel and serial resonances, condenser bank and transformer overheating, neutral overcurrent, and false protective system activity.

5.5 THD For Current and Voltage

Harmonics distort the waveforms of voltage and current and thus affect electricity performance [15, 16]. Absolute harmonic distortion can be determined by current & voltage(THD).

6. Electric Vehicle Charging Station

There are not enough electric vehicle charging stations. The two charging station forms are, i.e., Public charging and private charging stations. In various locations, the government has set up a few charging stations, but the maximum charging stations are private [17, 18]. A higher rate of charging has been introduced by these private charging stations. Figure 1 displays an EVCS block diagram that includes the transformer, rectifier, and converter. Basically, for charging EVs, the rectifier and converter create a charger[19].

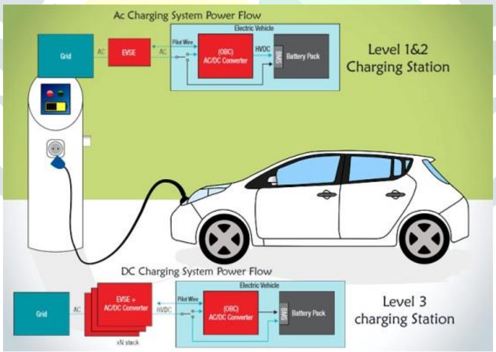

Figure 3. Schematic Representation of a Charging Station of Electric Vehicles

7. Different Level of Charging

7.1 Level 1 Electric Vehicle Charging Stations

Level 1 Electric Vehicle Chargers **utilize a 120V AC plug** which can be plugged into a standard wall outlet. These chargers need not require any additional installation. Level 1 Electric Vehicle Chargers are used at home.

Figure.4 Level 1charging

Level 1 Electric Chargers are the cheapest in all the available charging stations, but they also consume the more amount of time to charge car's battery. Car-Owners typically use this category of chargers to **charge their vehicles overnight.**

7.2 Level 2 Electric Vehicle Charging Station

Level 2 Electric Vehicle Chargers are utilized in both commercial and residential charging stations to fuel up the vehicle. The commercial charger uses a **208V AC plug** while at the home charger uses a **240V AC plug**.

Figure.5 Level 2 Charging

Level 2 Electric Vehicle Chargers undergo a proper installation process that has to be performed by a professional electrician. These chargers can also be installed as a part of a solar panel system. These chargers can deliver 10 to 60 miles of range per hour of charging. Level 2 Electric Vehicle Chargers takes 2 hours to charge a car battery.

7.3 Level 3 Electric Vehicle Chargers

Level 3 Electric Vehicle Chargers which are also known as DC Fast Chargers having CCS2 or CHAdeMO connectors offer around **100+ miles of range for your electric vehicle in just 30-40 minutes of charging**. However, DC fast chargers are usually used only in industry and commercial applications.

Figure 6. Level 3 charging

These DC charging stations require high-powered, highly specialized equipment to install and maintain. All-electric cars do not support charging with these Level 3 Chargers. Many plug-in hybrid EVs don't have this charging capability, and few all-electric vehicles cannot be charged with a DC Fast Charger.

Table:1 Different level of EV charging.

Charging Station Type	Charger Level	AC Supply Voltage and Current	Charger Power	Time to change a 24kWH battery pack
AC charging	Level 1 residential	Single phase - 120/230V and 12 to 16A	1.44 kW to 1.92kW	17 Hours
AC charging	Level 2 commercial	Single phase - 208/240V and 15 to 80A	3.1 kW to 19.2kW	8 Hours
AC charging	Level 3 supercharger	Single phase - 300/600V and 400A	120 kW to 240 kW	30 minutes

8.0 Power quality measuring instruments

8.1 Spectrum analyzers and harmonic analyzers

Figure **7**. Fluke power quality meter.

A few field measurement activities were performed during EV charging to investigate the harmonics. The calculation is carried out with the fluke energy efficiency meter .The meter has the ability to show voltage and current waveforms directly in real times. Furthermore, the measurement data can be stored for further study into the meter's memory. For the individual harmonics, three electric vehicle types are contrasted. The first type of EV is a type of modern commercial EV. Harmonic analyzers have several capabilities. They capture harmonic waveforms and display them on a screen. They calculate the K factor to de rate transformers and the total harmonic distortion (THD) in percent of the fundamental. They also measure the corresponding frequency spectrum, i.e., the harmonic frequency associated with the current and voltage up to the fiftieth harmonic.

They display the harmonic frequency on a bar graph or as the signal's numerical values. Some measure single-phase current and voltage while others measure three-phase current and voltage. All of them measure the power factor (PF). The power factor provides a measurement of how much of the power is being used efficiently for useful work. Some can store data for a week or more for later transfer to a PC for analysis. This makes them powerful tools in the analysis of harmonic power quality problems. Some of the more powerful analyzers have add-on modules that can be used for computing fast Fourier transform (FFT) calculations to determine the lower-order harmonics. However, any significant harmonic measurement requirements will demand an instrument that is designed for spectral analysis or harmonic analysis. Important capabilities for useful harmonic measurements include Capability to measure both voltage and current simultaneously so that harmonic power flow information can be obtained.

8.2 Flicker meters

Over the years, many different methods for measuring flicker have been developed. These methods range from using very simple rms meters with flicker curves to elaborate flicker meters that use exactly tuned filters and statistical analysis to evaluate the level of voltage flicker. Because of the complexity of quantifying flicker levels that are based upon human perception, the most comprehensive approach to measuring flicker is to use flicker meters. flicker meter is essentially a device that demodulates the flicker signal, weights it according to established "flicker curves," and performs statistical analysis on the processed data.

Generally, these meters can be divided up into three sections. In the first section the input waveform is demodulated, thus removing the carrier signal. As a result of the demodulator, a dc offset and higher-frequency terms (sidebands) are produced. The second section removes these unwanted terms using filters, thus leaving only the modulating (flicker) signal remaining. The second section also consists of filters that weight the modulating signal according to the particular meter specifications. The last section usually consists of a statistical analysis of the measured flicker.

8.3 Disturbance analyzers

Disturbance analyzers and disturbance monitors form a category of instruments that have been developed specifically for power quality measurements. They typically can measure a wide variety of system disturbances from very short duration transient voltages to long-duration outages or under voltages. Thresholds can be set and the instruments left unattended to record disturbances over a period of time. The information is most commonly recorded on a paper tape, but many devices have attachments so that it can be recorded on disk as well.

There are basically two categories of these devices:

1. Conventional analyzers that summarize events with specific information such as overvoltage and under voltage magnitudes, sags and surge magnitude and duration, transient magnitude and duration, etc.

2. Graphics-based analyzers that save and print the actual waveform along with the descriptive information which would be generated by one of the conventional analyzers

It is often difficult to determine the characteristics of a disturbance or a transient from the summary information available from conventional disturbance analyzers. For instance, an oscillatory transient cannot be effectively described by a peak and duration. Therefore, it is almost imperative to have the waveform capture capability of a graphics-based disturbance analyzer for detailed analysis of a power quality problem. However, a simple conventional disturbance monitor can be valuable for initial checks at a problem location

9.0 Analysis Using Simulation

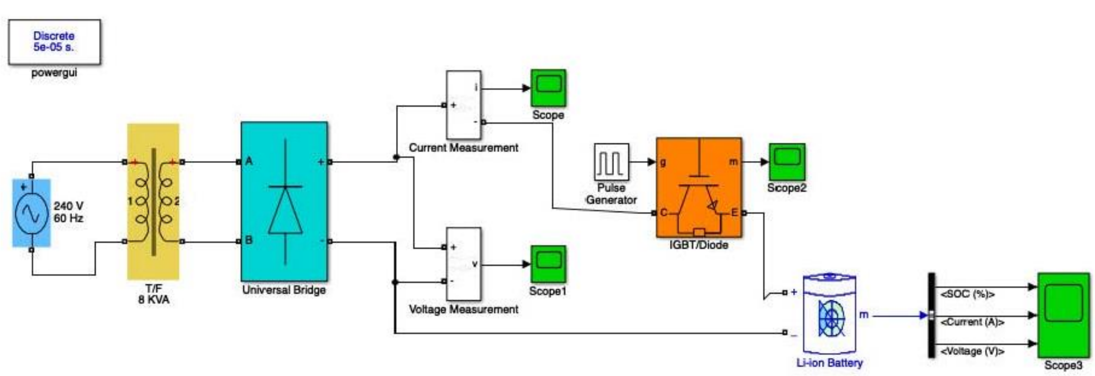

Figure 8. Simulation network in Matlab/Simulink

Above Figure 8 shows The voltage and current at bus level were calculated using the MATLAB Simulink model to estimate the output of the proposed power.

9.1 Harmonic Disturbance

The EV charger is a nonlinear load and produces harmonics when attached to a power device. Because the EV charger is usually linked for charging to the power distribution network, the combined effects of harmonics can be a threat to the entire power

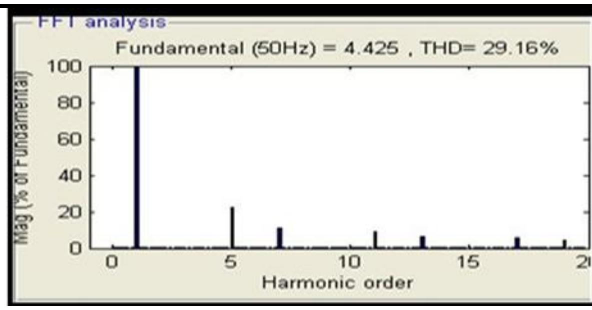

Figure 9. Frequency Spectrum of Source Current waveform

The harmonics are produced at the different ratio of EV charging in the MATLAB Simulink modeling is shown Figure 8. This frequency spectrum shows 29.16 percentage THD for source current due to presence of smart charger connected in power system

10 .Improving Power quality

The battery charging stations are power electronic devices that cause harmonic distortions in the distribution networks. The charge point operators can install Active power filters to ensure that they address the PQ impact of the charging infrastructure on the grid.
This solution is connected in shunt on the AC side of the EV chargers to solve the power quality problems. They prevent the propagation of harmonic distortions and also take care of leading and lagging power factors in the distribution network, eventually also helping CPOs to save on energy bills. A large deployment of EVs and PHEVS is expected to lead to PQ problems for the existing power networks. A surge in EV penetration could result in violation of supply/demand matching and maintaining statutory voltage limits and distortions. Under certain operating conditions, it may also lead to power quality problems and voltage frequency control, voltage imbalance. The latter is unlikely to exceed the statutory limit if EVs are reasonably distributed among the three phases. Active power filters should be installed to minimize or even eliminate the effect of EVs on the network.
In addition to the above, it is really important that the chargers as well as EVs adopt V2G technology and can be seamlessly integrated into the grid. In fact, with appropriate control and communication with the grid, EVS could be designed to operate as part of the smart grid to provide ancillary services such as supply/demand matching and voltage/frequency control.

10.1 STATCOM
STATCOM is a fast-acting device capable of providing or absorbing reactive current and thereby regulating the voltage at the point of connection to a power grid. It is categorized under Flexible AC transmission system (FACTS) devices. The technology is based on VSCs with semi-conductor valves in a modular multi-level configuration
The dynamic reactive current output range is symmetrical (during normal disturbed network conditions); however, non-symmetrical designs are possible by introducing mechanically or thyristor switched shunt elements with unified control systems to cover most conventional applications. The STATCOM design and fast response makes the technology very convenient for maintaining voltage during network faults, enhancing short term voltage stability. In addition, STATCOMs can provide power factor correction, reactive power control, damping of low-frequency power oscillations (usually by means of reactive power modulation), active harmonic filtering, and flicker mitigation and power quality improvements. Typical applications are in the electric power transmission, electric power distribution, electrical networks of heavy industrial plants, arc furnaces, high-speed railway systems and other electric systems, where voltage stability and power quality are of the utmost importance.
Modern designs are modular and allow for a high level of scalability and flexibility, ensuring the total required dynamic and steady state rating. Via the addition of shunt elements, the symmetrical output range of the pure STATCOM device can be adjusted to also meet non-symmetrical performance requirements. For conditions where a fast non-symmetrical dynamic range is required, on the one hand, thyristor-switched reactors and capacitors can be operated in parallel to form hybrid solutions. On the other hand, mechanically switched

reactors and capacitors can be added to optimize slow response performance and provide additional steady-state capacity as required by e.g. typical intra-day load flow changes.

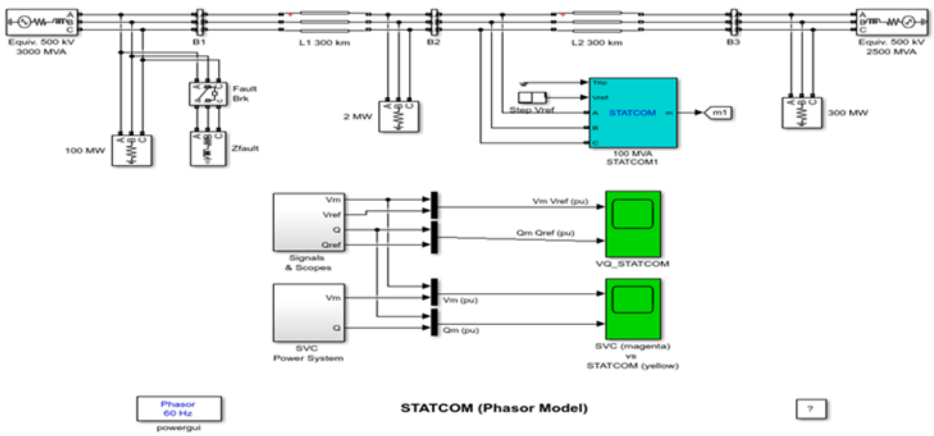

Figure 10.STATCOM used for midpoint voltage regulation on a 500-kV transmission line.

10.2 PASSIVE HARMONIC FILTERS

Passive harmonics filters are the more economical solution and can be used in a variety of capacities and voltages. These filters utilize components like inductors, capacitors and resistors to reduce, or mitigate, harmonics to tolerable levels as defined by IEEE-519. Passive Harmonic Filters have a lower physical and financial footprint; they also have guaranteed stability and little to no power consumption.

10.3 ACTIVE HARMONIC FILTERS

Active filters are the more permanent flexible solution. These filters actively monitor the system and use a set of transistors and capacitors to filter the current waveform by injecting inverse currents to cancel out the undesired harmonic components. These filters have a higher physical and financial footprint compared to passive filters.

11. Conclusion

As a particular form of electrical load, it is important to pay attention to power quality issues caused by EV charging. The harmonics calculation research and also analysis during electric vehicle charging have been discussed in this paper. The calculation is carried out on a simulation model, which also shows that these electronic power loads cause significant disruption on the source side. The voltage and current are calculated in order to estimate the proposed control output. From the harmonic disturbance graph, it is possible to find the THD value. From this result analysis the efficiency of the electric vehicle charger is improved by proposing a suitable filter & STATCOM to eliminate these issues.

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