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Impact of EV Charging Stations on Power System Quality

Sangeetha SHANMUGAM[1] , Yoosaf VANNARATH[2], Poornima DHANDAPANI [3]

[1 ,2,3] *Sri Ramakrishna Institute of Technology, Coimbatore, India*

ABSTRACT

Landslides are among the most destructive natural disasters that may occur in hilly terrain such as the Himalaya. The study of landslides has gotten a lot of interest lately, mostly because people are becoming more conscious of the socio-economic consequences of landslides. Remote sensing pictures give a wealth of important land use information that may be combined in a GIS setting with other spatial characteristics that influence the incidence of landslides to get a more complete picture of the landscape. The creation of a landslide inventory is an essential step in conducting a landslide hazard analysis using geographic information systems (GIS)[1].
The use of geographic information systems (GIS) enabled the rapid analysis of a large amount of data, and the artificial neural network proved to be an excellent tool for landslide hazard estimates. In order to perform a risk analysis, the DEM, the distance from the danger zone, the land cover map, and the damageable items that were at risk were all considered. Demarcating catchments and masking risky zones in the landslide area were accomplished via the use of digital elevation models (DEMs). The hazard map was generated via the use of geographic information system (GIS) map overlaying technology. This information might be used to calculate the danger to people, property, and existing infrastructure, such as transportation.
As part of the effort to develop real-time weather forecasting and image processing methodologies, this study may benefit from the addition of concepts and technologies such as embedded systems, the Internet of Things, and digital image processing to its repertoire.

Keywords— ANN, SMOTE, Landsliding.

I. INTRODUCTION

The era of clean and efficient transport with advances in technology poses new social and technical challenges to the modern electric grid. The implementations of electromobility envision large number of electric vehicles (EVs) charging stations and electrification of roads fed from the low or medium-voltage distribution network. Increasing load from the charging infrastructure can set limits to the electricity grid and negatively affect other customers connected to the grid article guides a stepwise walkthrough Distribution
EV charging station is characterized by low voltage application and a minimum of five devices will be present in a single station, and this will be continuously connected and disconnected to the grid. In addition, the charging device might incorporate several switching devices in it so that the output of it may be disturbed.
Power Quality is one of major issues in the industries. Any abnormal condition in any electrical parameters accounts to power quality issues. Electric power quality is defined as the degree to which the voltage, frequency, and waveform of a power supply system conform to established specifications. Issues in power quality arises whenever there are disturbances in the supplied energy or when the load consumes the power. The power quality issues arise mainly due to the changes in the three factors viz., the Voltage, the Current and the power factor & phase angle when it comes to Alternating power supply
The article summarizes the synthesis of knowledge, research results and challenges regarding connection of large amounts of electric vehicles to the low and medium voltage network

II. LITERATURE REVIEW

Ahmaed A aslam .etl analyzes the impacts associated with the incorporation of EV charging stations into the distribution network using NEPLAN software with integrated coordinated and uncoordinated EV charging stations. Based on the simulation results, it is that the worst adverse effects are associated with an uncoordinated charging strategy, while the coordinated charging strategy demonstrates significant improvements [1].Electric Avenue, located on the Portland State University (PSU) campus along SW Montgomery Street., is a joint project between Portland General Electric (PGE), PSU and the City of Portland. It is intended as a research platform for understanding the impact of electric vehicles (EVs) on electric power distribution systems within the larger context of the city [3].
Nonlinear loads, such as EV chargers, will often introduce power quality (PQ) issues within distribution circuits, which can have detrimental effects on system components. PQ encompasses several specific concepts such as harmonic distortion, DC offset, phase imbalance, and voltage deviations, among others, and these are quantified in myriad ways. For this study, they focus on harmonic currents since these have the potential to affect the lifetime of magnetic assets

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such as distribution transformers and instrument transformers.
EV chargers pays specific attention to total harmonic distortion (THD) of individual EV chargers and total demand distortion (TDD) of the Electric Avenue service. The measurements were taken on the low voltage side of the Single – phase Transformer supplying that charging station [4]. It is observed that the degree of harmonics gets reduced as we operate more number of charging units simultaneously than operating a single or minimum number of units and the power factor varies between 0.72-0.99.Also noted phase imbalance, phantom loading and other PQ issues observed during the course of our study. Our objective is to expand the electric utility industry's understanding that EVs have on these issues.

Khalid etl. discusses about IEEE standards for power quality, an innovative technology management by critical analyzing about power quality problems, issues, related international standards, and their effect[5].These quality issues not only disturb the performance of the system also increases the cost of power from generation to end user. So it becomes necessary to analyze the rise in expense due to power quality problems [6].It helps
to follow some code of conduct as the availability of electric power with high quality is crucial for the running of the modern society.
The penetration of EV charger in the low voltage residential grids is expected to increase rapidly in the coming years. It is expected that EV consumers will prefer overnight
home charging because of its convenience and lack of charging infrastructure. The imminent increase of EV load requires upgrading or managing the existing power system to support the additional charging load [8].

Narasimha Pandit presence the insights on different Power Quality (PQ) problems experienced by the Indian electricity consumers, and the reasons for those problems and proposes feasible solutions to assist in employing or implementing appropriate mitigation techniques with an optimism of an improvement in the field scenario as more and more investments are proposed in Generation, Transmission and Distribution Sectors, and stringent codes and standards are being imposed for those who do not maintain minimum PQ level in the field[9].

III. POWER QUALITY

Electrical power engineers have always been concerned about power quality. They see power quality as anything that affects the voltage, current, and frequency of the power being supplied to the end user, i.e., the ultimate user or consumer of electricity[10]. They are intimately familiar with the power quality standards that have to be maintained and deals at all levels of the power system, from the generator to the ultimate consumer of electrical power. Every industry who are using sophisticated equipment are concerned about power quality as this may affect the performance and durability of the equipment.

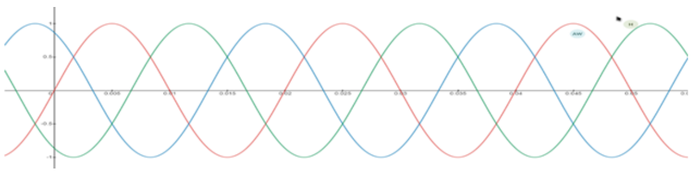

Figure 1 Fundamental sinusoidal waveform

Power Quality (PQ) refers to maintaining a sinusoidal waveform of bus voltages at rated voltage and frequency as shown in figure 1.Power quality problems occur when the alternating-voltage power source's 50-Hz sine wave is distorted [12]. In the past, most power-consuming equipment tolerated some distortion. Today, highly sensitive computers and computer-controlled equipment require a power source of higher quality and more reliability

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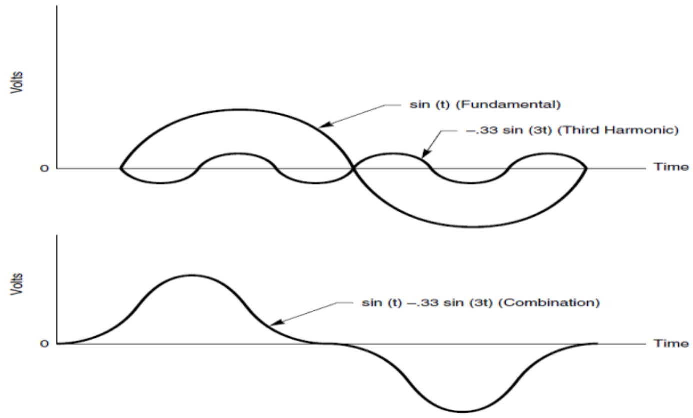

Figure 2 Harmonic waveform

Figure 2 shows the distorted voltage waveform due to the effect of third harmonics. The first one shows the original sine wave and also a third harmonic waveform. The second waveform shows the combined effect of a sine wave and a third harmonic wave, which clearly shows the distortion.

Gerry Heydt in Electric Power Quality defines power quality as "the measure, analysis, and improvement of bus voltage, usually a load bus voltage, to maintain that voltage to be a sinusoid at rated voltage and frequency." The type of equipment being used by the end user affects power quality at the end-user level.

3.1 Nonlinear Loads

Nonlinear loads are simply any piece of equipment or appliance that increases and reduces its consumption of electricity over time in a nonlinear fashion. With nonlinear loads the current and voltage do not follow each other linearly. In Article 100 of the NEC, a nonlinear load is defined as "a load where the waveshape of the steady state current does not follow the waveshape of the applied voltage." This usually occurs when the load is not a pure resistance, capacitance, or inductance, but instead contains electronic components to control the function of the equipment to meet the requirements of the load. Often the nonlinearity of the load results in the generation of harmonics that cause overheating of electrical equipment.

3.2 Harmonics

Harmonics are the major source of sine waveform distortion. The increased use of nonlinear equipment has caused harmonics to become more common. Figure below shows the architecture of a standard sine wave. An analysis of the sine wave architecture shown in figure.3 provides an understanding of the basic anatomy of harmonics.

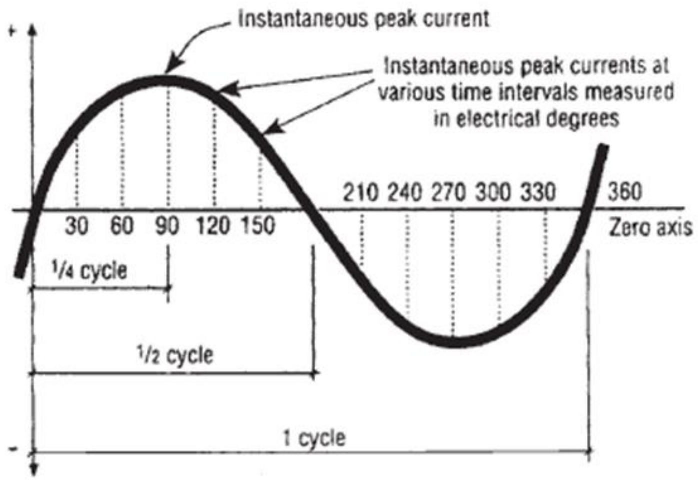

Figure 3 Sinewave architecture

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Harmonics are integral multiples of the fundamental frequency of the sine wave shown in Figure.3 that is, harmonics are multiples of the 50-Hz fundamental voltage and current[11]. They add to the fundamental 50-Hz waveform and distort it. They can be 2, 3, 4, 5, 6, 7, etc., times the fundamental. For example, the third harmonic is 50 Hz times 3, or 150 Hz, and the sixth harmonic is 50 Hz times 6, or 300 Hz .

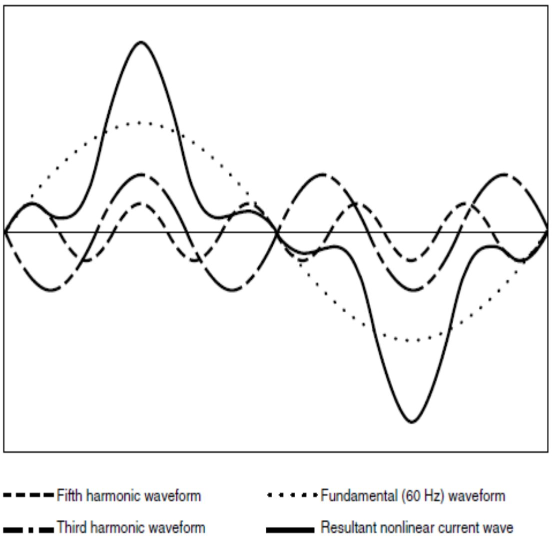

Figure 4 Composite harmonic waveform

The waveform in Figure 4 above shows how harmonics distort the sine wave. What causes harmonic currents? They are usually caused by nonlinear loads, like adjustable speed drives, solid-state heating controls, electronic ballasts for fluorescent lighting, switched-mode power supplies in computers, static UPS systems, electronic and medical test equipment, rectifiers, filters, and electronic office machines. Nonlinear loads cause harmonic currents to change from a sinusoidal current to a non-sinusoidal current by drawing short bursts of current each cycle or interrupting the current during a cycle. The total distorted wave shape is cumulative. The resulting non-sinusoidal wave shape will be a combination of the fundamental 50-Hz sine wave and the various harmonics.

In addition to many other nonlinear devices static power converters (EV Chargers) also often generate or amplify existing harmonic currents that distort the voltage wave. These voltage distortions can be transmitted to the utility's system and from the utility's system to nearby interconnected end users. All these types of loads result in one customer causing power quality problems for another customer. Utilities cannot afford to allow such problems to continue; they affect the utilities' and their customers' competitiveness. IEEE 519 sets limits on total harmonic distortion (THD) for the utility side of the meter and total demand distortion (TDD) for the end-user side of the meter[7]. The table 1 gives Voltage distortion limit. This means the utility is responsible for the voltage distortion at the point of common coupling (PCC) between the utility and the end user. Total harmonic distortion is a way to evaluate the voltage distortion effects of injecting harmonic currents into the utility's system

Table.1 Voltage distortion limit

Bus Voltage V at PCC	**Individual Harmonic (%)**	**Total Harmonic Distortion THD (%)**
$V \leq 1.0$ KV	5.0	8.0
1KV < $V \leq 69$ KV	3.0	5.0
69KV < $V \leq 161$ KV	1.5	2.5
161KV < V	1.0	1.5

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IV. ELECTRIC VEHICLE CHARGERS

Similar to every battery charger, an EV charger is also taking power from the AC supply, rectified to the desired DC voltage and charging the batteries kept inside the vehicle. There are different types (level) of EV chargers some of them are inbuilt in the vehicle itself and some others are kept in charging stations.

4.1 Types of EV battery chargers

Depending up on the charging speed, EV battery chargers classified as level 1, level 2 and level 3 chargers depicted in figure 5. In level-1 (Slow charging) charger, the cable is connected to ac supply and the entire ac-dc converter is inside the car. These are very basic low power chargers that can be connected to the normal power socket of the home and need more time for full charge. It's an inbuilt A.C. Charger inbuilt with the vehicle. Its mandatory with every vehicle. The features of level 11 charger are

- Plugged in (115V-15A or 230V-6A).
- Typical Power rating is 1.5KW
- Charge time 7 to 30 hours.
- Universal for all EV
- EV driving range per minute charge: 130m .

Level-2 (fast charging) chargers are medium power chargers which has higher than the level 1 charger and this need more ampere rated socket.

- Wall-mount 230VAC, 30A two pole
- Charges a mid-sized EV in 4 to 5 hours.
- This is the most common home and public charging station for EVs.
- It produces about 7kW to feed the 6.6kW on-board EV charger.
- EV driving range per minute charge: 670m

Level 3 or DC fast charger (Rapid Charging) where the ac-dc conversion happens in the charger kept outside the vehicle and which is of high power rated and ampere rating is up to 300 amperes

- DC Fast Charger; 400–600VDC, up to 300A
- Serves as ultra-fast charging by bypassing the on-board charger and feeding the power directly to the battery.
- Deliver 50 kW of power than can go up to 120kW
- Up to 80 percent in about 30 minutes.
- EV driving range per minute charge at 50kW: 4.6km
-

Figure 5 Types of EV chargers

Among the above EV battery chargers, level1 and level 2 chargers mostly will be installed at home in domestic connections can be used by all the EV car owners. The level 3 charger (DC fast charger) will be installed in all major roads, highways and cities double in very high numbers than the existing fuel stations as the installation cost is less compared to the fuel stations. These chargers are going to be the main power consumers in the very near future and the sudden switching of the electronic components in these chargers will become big threat to the power quality of the electricity network.

V. ASSESSMENT OF EV CHARGING STATIONS ON THE POWER SYSTEM QUALITY USING ETAP SOFTWARE

In order to make an analysis of a real system, either we have to connect the EV chargers on an existing power systems network and make necessary measurements and observation. To analyze the disturbance caused to power system or consumers, we will be model a power system with a software and connect the required load and study the performance on various aspects.

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5.1 ETAP software

ETAP is the global market and technology leader in modeling, design, analysis, optimization, monitoring, control, and automation software for electrical power systems.
With the Harmonic Analysis module, one can simulate harmonic current and voltage sources, identify harmonic problems, reduce nuisance trips, design and test filters, and report harmonic voltage and current distortion limit violations. Comprehensive load flow and frequency scan calculations are performed using detailed harmonic source models and power system component frequency models. Results are shown graphically, including harmonic order, harmonic spectrum plots, and harmonic waveform plots, as well as Crystal Reports.

5.2 Methodology

Using the ETAP software for simulation of a 110/11KV substation and all its loads. Harmonic analysis is done with and without EV chargers to see the effect of EV chargers.

5.2.1 System Specification:

(i)Two Transformers 110/11KV, 12.5MVA and 10MVA
(ii)Feeders – Seven 11 KV feeders with load ranging from 100-150A
(iii)Each of the feeders are having around 20-25 transformers of rating ranges form 100-250KVA.
(iv) Two EV chargers 60KW and 20KW are connected which is fed from a 250KVA transformer.
The substation is modelled in ETAP, the harmonic values are estimated without EV chargers, existing EV chargers and future expected EV chargers separately, and analyzes its impact in the system. Due to increasing the usage of EVs many more slow, fast and rapid EV chargers expected to install in the near future.

5.2.2 CASE STUDY-1 :Connecting the existing load in a 11KV feeder without EV chargers and get the parameters.

ETAP model of the substation with two 110/11KV, 20 MVA transformers is shown in the fig . Six 11KV feeders are feeding the power supply to all nearby areas around 5-10 KM range some of them are OH lines and others are UG and OH cables. Distribution transformers are installed at different locations to feed that locality. Cables are inserted to show that each of these feeders are long run.

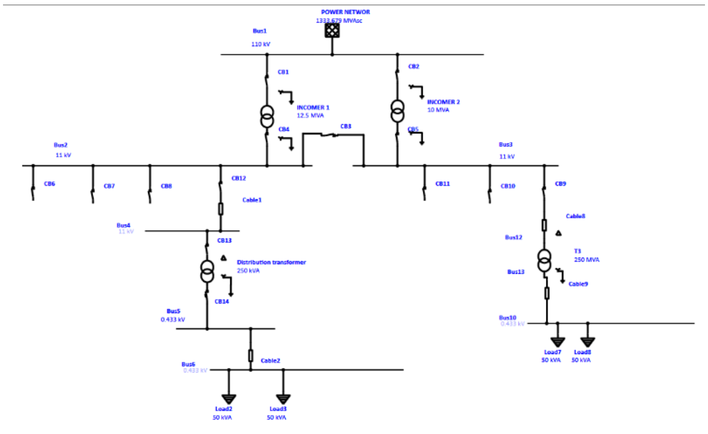

Figure 6 Typical 110/11KV substation with normal loads

From bus 2 and bus 3, cables connected to feed transformers are supplying power to far away feeding to two different 11/0.433KV, 250KVA transformers. Later we will be connecting the EV chargers to this transformer. Two sample loads are shown in bus 6 and bus 10 as normal loading of transformer. Harmonic study of the system without connecting the EV chargers are carried out. Fig .7 shows the harmonic values in each of the bus with normal load

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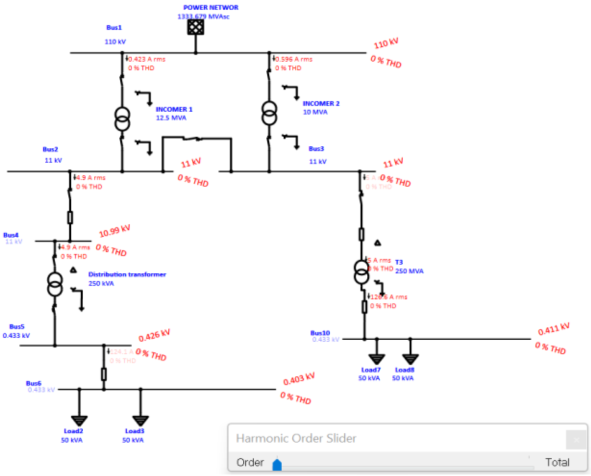

Figure 7 Simulation Result with Harmonic Parameters When No EV Chargers

The figure.7 above shows that the harmonic distortion (THD) is zero in any of the bus when there is no nonlinear loads or EV chargers. Now let us observe the voltage wave form and spectrum of the buses when no nonlinear loads or EV chargers are connected

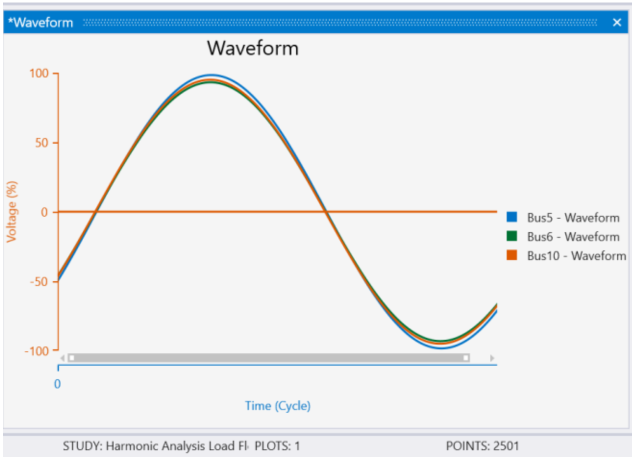

Figure 8 ETAP voltage waveform display with no EV chargers

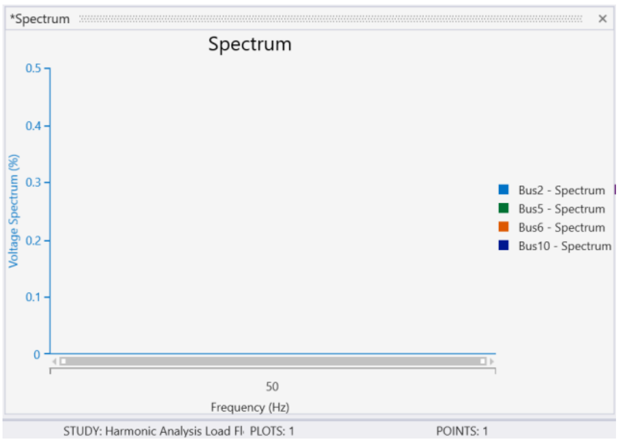

Figure 9 ETAP Spectrum display with no EV chargers

Fig .8 shows the voltage waveform from ETAP which is pure sine wave and hence the power quality to the consumers are very high when there is no nonlinear loads or EV chargers are connected. In addition, the spectrum in fig .9 clearly

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shows that there is no disturbance in the voltage supplied when no EV chargers or other nonlinear loads are connected.

5.2.3 CASE STUDY-2 : Connecting the existing load in a 11KV feeder with two EV chargers and get the parameters.

Now let us analyze the THD value with existing two EV chargers connected to the 250KVA Transformer. One EV charger is rated 60KW and other is rated 20KW. The fig.10 shows the simulation result of the system when EV charge is connected to the particular feeder of the substation. It is evident that the current drawn from the line is high and a sudden switching on and off of the circuit will have big impact on the feeder compared to other loads of the feeder

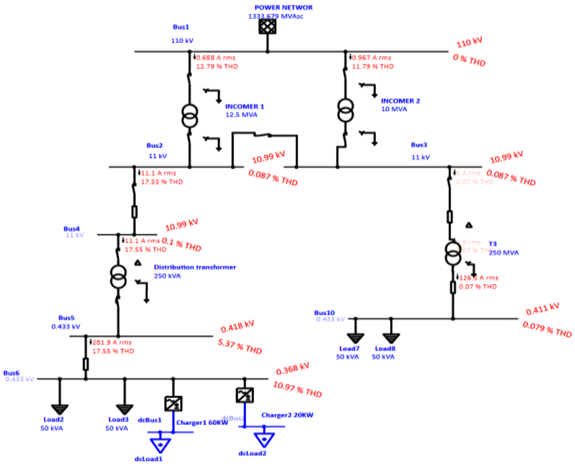

Figure 10 ETAP simulation of substation layout with two EV chargers .

The fig.8 shows layout with the harmonics in each bus and the actual voltage of the bus (which is little less than original) when the chargers are loaded in full. Two Dc loads are connected to the charger to make sure that the chargers are loaded and current is drawn. The THD in bus is 10.96% which is much above the 8% limit of the IEEE standard limit for less than 1 KV

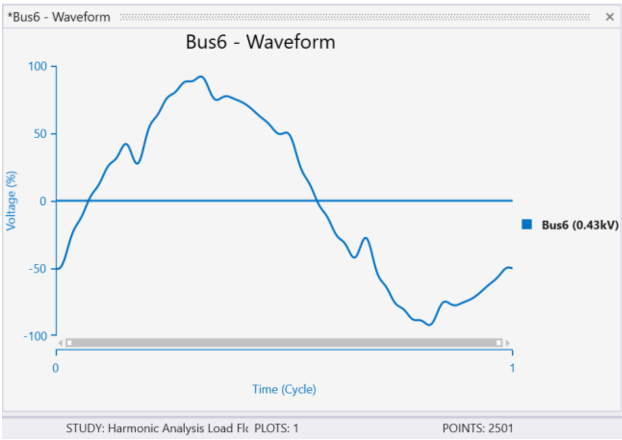

Figure 11 Bus 6 voltage waveform with two EV chargers

The above voltage waveform clearly indicates the disturbance of voltage in the distribution network due to the EV charger. The figure 12 shows the spectrum when two EV chargers are connected.

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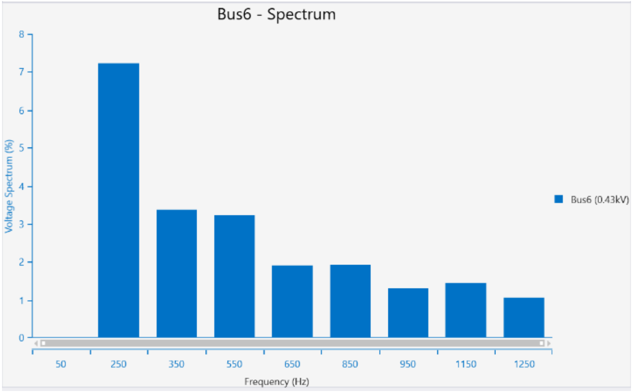

Figure 12 ETAP spectrum display with two EV chargers

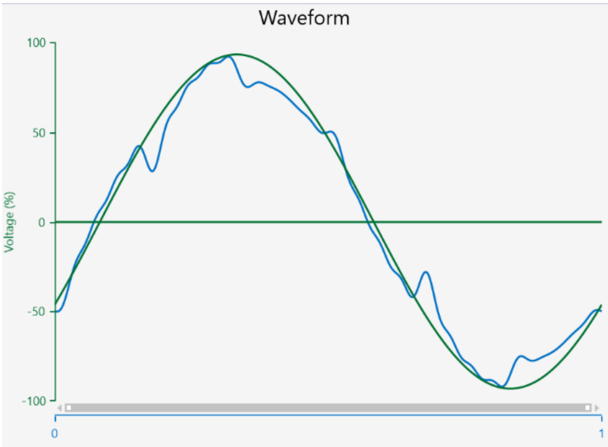

Figure 13 ETAP bus 6 voltage waveform comparison

Here, in the above figure 13, the voltage waveform of the same bus 6 in both cases are superimposed to see the actual difference when no EV chargers and with two EV chargers connected. It is clear that the Voltage wave is distorted when the EV chargers are connected to the feeder.

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VI. CONCLUSION

The power quality analysis are carried for the test distribution without EV chargers being connected, with two chargers. The impact of EV chargers are analyzed through harmonics analysis module in ETAP software. We have observed the harmonic generation without the non-linear loads/ EV chargers and again after connecting the EV chargers. It is observed when two EV chargers are connected the harmonic is generated which is above the IEEE standard for the given voltage level and It is obvious when we add more EV chargers the harmonic (THD) will increase with more and more chargers connected to the system. And the waveform distortion is also will increase. These are the observation from the waveform and spectrum displays.

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