Measurement and Analysis of Power Quality Issues Due to Electric Vehicle Charger

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Abstract. This paper analyzes the aspects of power quality issues such as harmonics distortion and their effects in charging the electric vehicle. The harmonics produced is measured by using fluke power quality meter. The on-board and off board chargers are also discussed with their circuit diagram. It includes the fluke meter for measuring the harmonic distortion that occurs in the charger of the electric vehicle. The harmonics produced in the charger is measured and analyzed using simulink model also. The harmonic disturbances generated are also noted. The recommendations and suggestion based on the result analysis are also discussed

Key words: Power quality, Harmonics, on-board charger, off-board charger, simulation, Total harmonic distortion.

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[1]. 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)

2. 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 [2, 3]. 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.
2.1. 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 [4]. Tension rating categories include: power level, voltage magnitude, harmonics and inter harmonics, unbalanced voltage, flicker, dips, swells, momentary interruptions and transients.

2.2 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 [5, 6]. 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 [7].

2.3 Harmonics

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.

3. 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.

3.1 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).

4. 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].
4.1 Impacts of E-Vehicle

The effect of E-Vehicle intrusion on the power system is shown in Figure 2. While the cheapest transportation system is EV penetration, lower emissions of GHGs facilities, Installation of smart grids. There are very important adverse effects on the power network.

![Figure 1. Schematic Representation of a Charging Station of Electric Vehicles](image)

**Figure 1.** Schematic Representation of a Charging Station of Electric Vehicles

**Figure 2.** Impacts of Electric Vehicle.

5. Types of EV Chargers

The two types of electric vehicle chargers are described below,

5.1 On Board Chargers

On-board chargers are slow chargers, restricted by the mass and volume [20, 21]. In Figure 3 the configuration of the on-board charger is seen. Chargers of the same kind have been. For electric taxis, chargers of the same kind have been used and the charging capacity is around 2 kW on total.
5.2 OFF Board Chargers

These chargers, which have an average charging power of more than 30 kW, are used for fast charging. Figure 4 shows the structure of off board charger.

Although there is an inductive form, the EV charger typically has a conductive form. Conductive chargers have a direct plug-in link to the supply, such as using an ex-voltage power cable to plug the wall outlet into the EV. On the other hand, magnetic coupling is used by inductive chargers as an energy transfer mode.

It is simpler to build conductive chargers, has higher performance and is more common compared to these two types. The above Figure 5 shows the circuit diagram of battery charger.
6. Harmonic Measurement

6.1 Fluke 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[22].

6.2 Analysis Using Simulation

Above Figure 7 shows the voltage and current at bus level were calculated using the MATLAB Simulink model to estimate the output of the proposed power.

6.3 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 grid.
The harmonics are produced at the different ratio of EV charging in the MATLAB Simulink modeling is shown[23]Figure8. This frequency spectrum shows 29.16 percentage TH for source current due to presence of smart charger connected in power system.

7. Hardware Results & Discussions:

The total harmonic distortion value due to smart / fast charger integration into power system was measured using fluke power quality analyzer

![Figure 9. Total voltage and current Harmonic Distortion](image)

The three figures in figure 9, shows the hardware results taken from fluke power quality analyzer about (a) input waveform for EV charger and (b) voltage THD which may around 1.5 percentage and (c) current THD around 11.6 percentage due to presence of smart charger in the power system. The allowable limit for THD level from IEEE standated as 5 percent only. Thus suitable filter must be designed to elimate or minimize these THD levels.

7.1 Recommendations and Suggestions

- The criterion for the EV charger power factor is not sufficiently correct. Power factor limits should be combined with the power range for charging.
- Inter-harmonics are found. There should be important requirement in the specifications.
- To avoid the unbalanced charging load induced by a single phase on borad charger, a smart guide should be incorporated into he coordinated charging system.

Harmonics as well reactive power compensation devices are required when adopting chargers without PFC circuits
8. 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 total harmonic distortion (THD) value. From this result analysis the efficiency of the electric vehicle charger is improved by proposing a suitable filter to eliminate these issues and implemented as future work.

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