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HARMONIC ANALYSIS WITH INTIGRATION OF ELECTRIC VEHICLES TO THE POWER GRID

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Abstract

A lot of electric vehicles (EVs) being connected to the grid, especially for fast charging, can cause a number of technical issues or have a big impact on power systems that incorporate harmonic current injection. When numerous electric vehicles are being quickly charged at once, the voltage distortion should be more than the allowable limit. A good way to charge electric vehicles is via solar (PV) systems. The enhanced control of PV inverters utilised as active filters is presented in this research. Simulations are used to validate the suggested control. Simulation findings demonstrate that the suggested control reduces total harmonic distortion (THD) of current and voltage within the established limits.

Keywords: Power Grid, Electric Vehicle (EV), Power quality issues, Harmonics , EV chargers

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1. Introduction

The use of electric vehicles is a relatively recent innovation in the transportation industry. due to a number of benefits. EVs are becoming quite popular these days because to the reduced environmental pollution, cheaper cost of transportation, and usage of less petroleum. Plug-in hybrid electric vehicles (PHEV), hybrid electric vehicles (HEV), and battery electric vehicles are the three main types of electric vehicles that are now on the market worldwide (BEV)[2]. A single phase or three phase supply system can power EV batteries. The system includes EV charging because single supply points are widely available. Yet, a three-phase supply system offers faster charging and more power[1].

These EV chargers are essentially non-linear loads that act as power electronic converters. This EV charger's non-linear property can introduce harmonics into the current and mess with the power network's voltage profile[5]. The voltage waveform may be impacted by high non-linear loading, which can also create a nonlinear voltage drop. On the other hand, a non-linear load can affect a distribution transformer's performance by increasing power losses in the winding and lowering its output of power[6]. Hence, the power quality is affected when EV chargers are linked to the power grid or distribution network. [1].

The rapid adoption of electric vehicles could have a considerable impact on the electric grid, despite the fact that they have several environmental advantages . For instance, the Los Angeles Department of Water and Power's (LADWP) Integrated Resource Plan forecasts the use of plug-in electric vehicles and further projects that by 2020, electric vehicles would account for about 500 GWh of power. This increased load growth corresponds to about 6% of LADWP's total residential energy consumption in 2012 . It is crucial to research the function harmonics play in electric vehicle charging to determine what effects these vehicles will have on the grid[6].

The implications of harmonic distortion and other power quality issues on the charging of electric vehicles are examined in this paper. Using the Simulink model, the harmonics generated by the charger are measured and analysed. This study evaluates the harmonics and voltage profiles when a single EV charger, three EV chargers, and five EV chargers are all connected to the grid. It also offers a mitigation strategy to lower harmonics and distortion in the voltage waveform by attaching a filter in a MATLAB simulation..

Smart Grid

A. Smar grid architecture:

A new smart grid gradually formed with the incorporation of EVs. When EVs are regarded as load, optimal charging can be achieved by technical and economic means to arrange charging EVs are regarded as distributed energy storage units, they can supply power to grid so as to improve the safe reliability of power system [7] Two way communication between EVs and grid can be realized by V2G technology. Compared with the traditional grid, a large quantities of distributed generations using RESs as fuel are applied in smart grid. For the intermittent characteristic of distributed energy such as wind power, photovoltaic cell,it is difficult for these generations to balance the load with out the load without the adjustment of smart grid[8].

The architecture of smart grid is shown in Figure 1. Advanced metering infrastructure (AMI) is an electronic equipment which can record and obtain the real-time information of user electricity usage . Home Automation Networks (HANs) plays the role of functional entity that allows the access to metering devices and message transfers with the home display devices . One major feature of smart grid is that users can be able to interact with power grid actively.

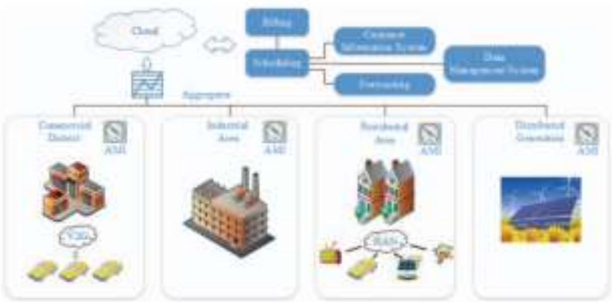

Fig1.smart grid architecture

B. Effects of Electric Vehicle

Study of EV effects is necessary since EV loads are rapidly growing day by day [4]. The effect of widespread EV adoption on the electrical grid is depicted in Fig. 2 below. EV penetration has the least expensive transportation system, facilities with fewer GHG emissions, and smart grid facilities. Yet, adverse effects on the electricity grid are very considerable. Electric vehicle chargers cause harmonics, power loss in distribution transformers as non linear loads and a low voltage profile [5].

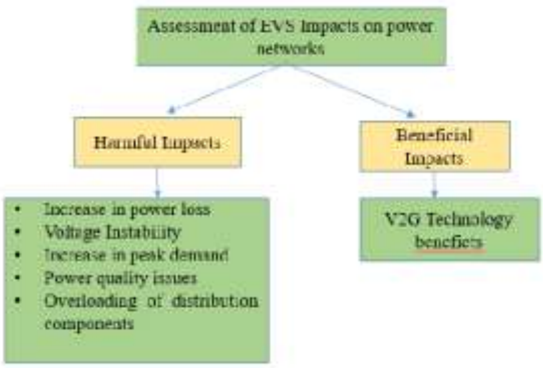

Fig 2. Assessment of EVs impact on power network

a. Beneficial impacts of V2G Technology:

EVs with bidirectional chargers offer a unique benefit through a process known as vehicle-to-grid.technology (V2G). According to a V2G technology, when EV batteries are not in use but are still connected to a network, they can supply energy to a power grid at its peak demand of load and so improve the efficiency of the grid [7]. The implementation of V2G technology is made possible by the anticipated rise in EV penetration.Power can potentially travel between the power network and EVs in both directions thanks to bidirectional charging. EVs have the capacity to both draw power from the grid and act as load. EVs can be seen as load in the eyes of the utilities.

b. Impact on power quality

- The unreliable charging characteristics of EVs result in power quality disruptions, such as overvoltages, a decline in power quality, enhanced line damage, a failure of distribution transformers, an increase in fault currents, etc.

- High frequency converters converts AC power to DC,Which charges EVs.They also injects harmonics into the grid ,which causes power quality issues.
- The result of these harmonics also creates overloading in distribution transformers,so they life expectency gets disturbed.

Because of the impact of EVs on the power grid, EVs require a high power demand to recharge their batteries, resulting in voltage instability, power quality degradation, transformer stress, and other issues.

The effeciency of power output of distribution system also gets affected due to the power electronic converters,which have non linear load to EV chargers.These non linear characteristics deteriorates the voltage profile of the electric grid.

c. Effect on Voltage Stability

- Voltage stability is defined as the power grid's ability to maintain stable voltage after disturbances have been removed.
- Voltage instability is caused by a abrupt rise in the load. Due to EV chargers, there will be an abrupt increase in load, which can cause issues with voltage stability[10].
- The use of EVs affects node voltage fluctuations as well. When a greater number of EV chargers are connected to the distribution system, the voltage at the distribution end degrades[12]

d..Impact on transformer life

- The Stress on the distribution transformers is also due to the large scale disposition of EVs.
- Congregated charging of EVs increased the burden on the transformer, resulting in higher harmonic current and current loss in the transformer core[6].
- The transformer's KVA rating is also affected by current loss, which raises the total energy loss.

e.Harmonics Impact Analysis

- The involvement of power electronics devices in charging operation of EVs may increase the power quality problems in distribution network due to the occurrence of switching phenomenon[13].
- The harmonic issue is needed to consider significantly as harmonic distortion plays a major role in derating of distribution components[14].
- The supply quality of power network can be affected due to massive integration of EVs. In charging process of EVs the arbitrary number of EVs batteries with random demand of energy may lead to a demand side management issue .
- The current and voltage spectra are used to represent harmonics. The unwanted values of these spectrums are expected in a power network due to non-linear loads, for instance, EVs[9]

Model of an Electric Vehicle Charging Station in Matlab/Simulink:

The power quality is impacted when an electric vehicle charging station (EVCS) is connected to the utility grid to recharge the batteries. The MATLAB SIMULINK model shown in Fig. 3 is used to investigate the effects of EVCS on the utility grid. The three-phase source is introduced as the utility grid in this scenario. Rectifier and a DC-DC converter circuit are the key components of a charger.

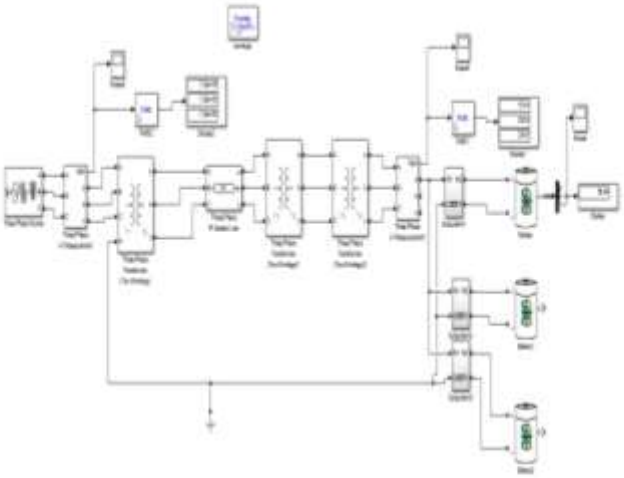

Fig 3. EV Charging station simulink model

- Three step-down transformers with ratings of 132/33 KV, 33/11 KV, and 11/0.4 KV are used in this study, and a 132 KV utility grid is also taken into account.
- It uses a switching mode power supply (SMPS) charger with an output voltage of 36/48/60V and an input voltage range of 180V to 240V AC. It uses a transmission line with a -section that is 60 kilometres long.
- The simulation takes into account lead acid batteries, which are used in nearly all battery-powered electric vehicles.

Parameters	**Specifications**
Grid	132Kv,50Hz,Short-circuit MVA:200MVA
Transformer1	132/33 Kv,75MVA
Transmission line	Three phase pi section,50 Hz,60km
Transformer2	33/11 Kv,20MVA
Charger	SMPS Charger, Input Voltage-180-240 V AC, Output Voltgae 36/48/60 V DC,1000W
Battery	Lead acid Battery,36/48/60 V ,100-130 Ah,SOC (initial):30%

TABLE 1: MATLAB MODEL SPECIFICATIONS

2. Results

A. Harmonic Disturbance

Harmonics are the disturbances of a power system.EV charger is non linear load and when it is interconnected with the power grid then it produces harmonics[5].As EV charger normally connected at the power distribution network for charging, the aggregated impacts of harmonics can be threat for the entire power system. In the MATLAB Simulink modeling, the harmonics produced at the different ratio of EV charging is shown in below Fig. 4,5 and it is observed that THD is reduced to 2.76 % in Fig 5 after connecting charger with filter.

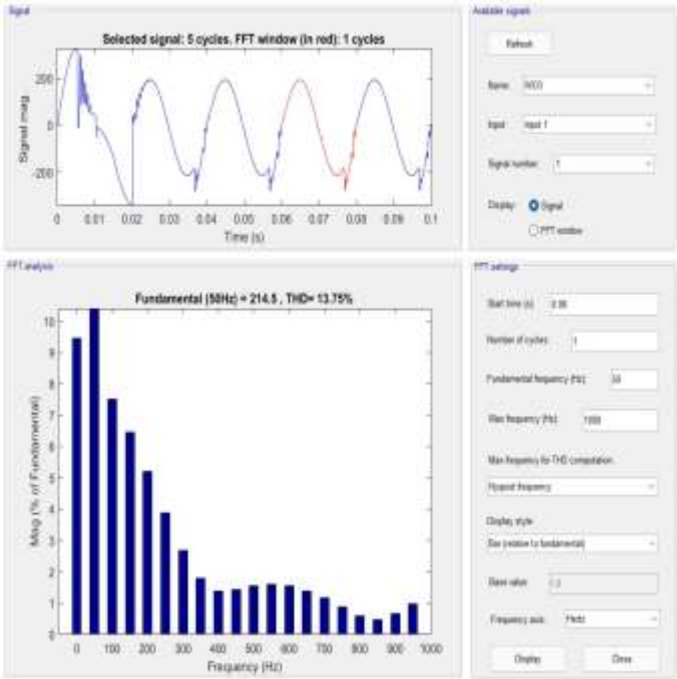

Fig 4:Harmonics ,without filter EV to grid

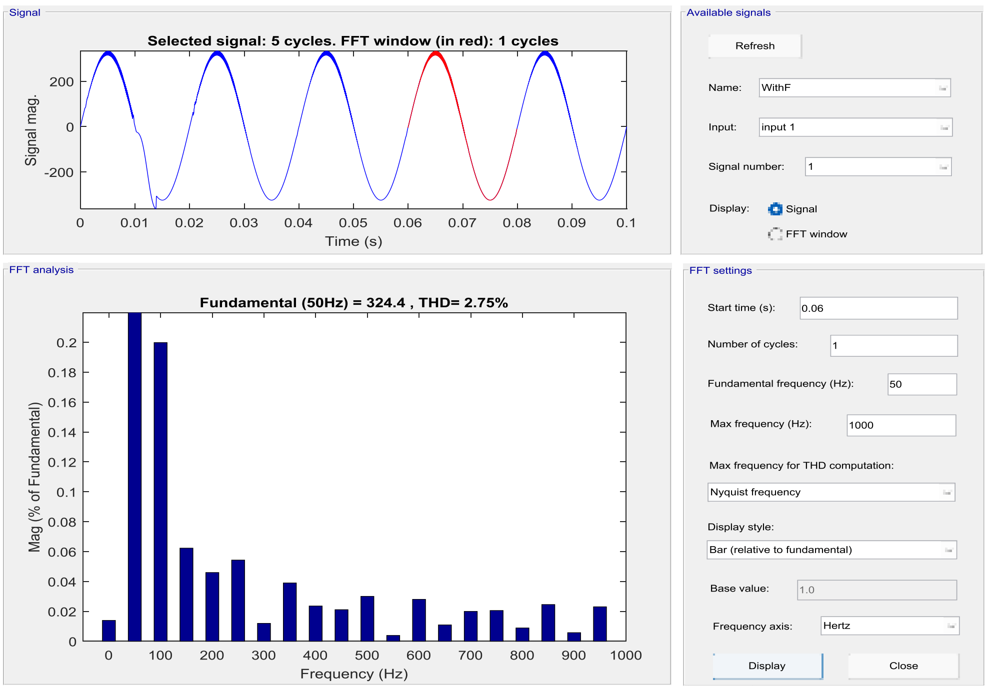

Fig 5 :Harmonics ,when filter connected to grid

B. Voltage Disturbance

The fluctuations in node voltage are determined by the EV's usage. When a many number of EV chargers are installed, voltage at the distribution end is also affected. This issue is caused by overcrowding caused by multiple EVs. Fig 6 shows the voltage profile variation as the number of EV chargers increases and also shows that the voltage variation is due to harmonic disturbance when compared to the voltage without EV chargers connected. In Fig 6 shows that voltage sag and swelling are caused by harmonic disturbances.Fig 7 shows voltage waveform after connecting filter.Fig 8 shows battery voltage.

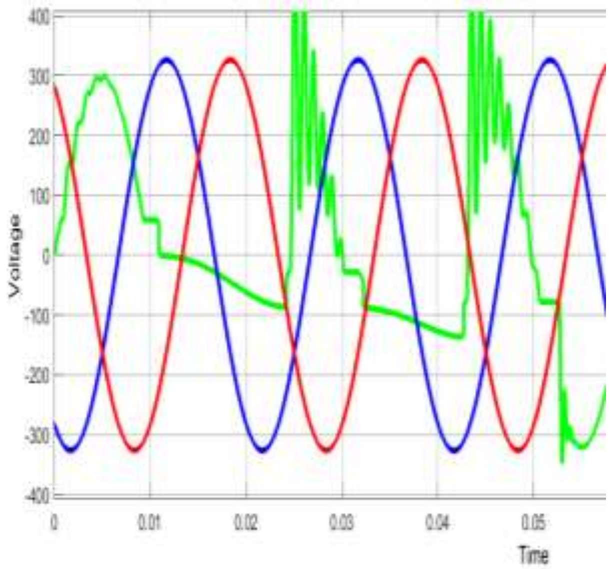

Fig 6: Input Voltage after connecting 3 EV chargers

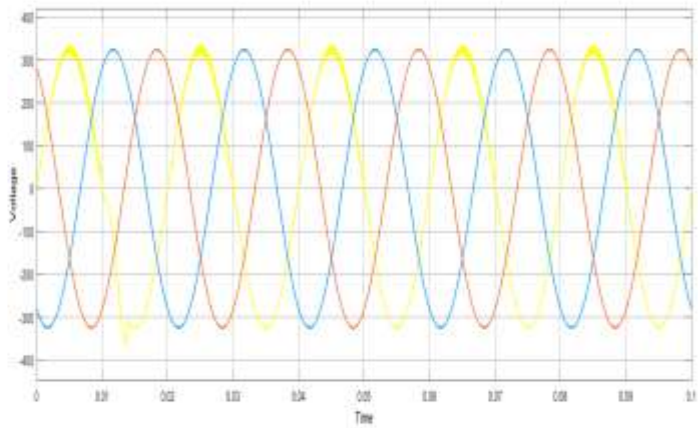

Fig 7:Input voltage with Filter

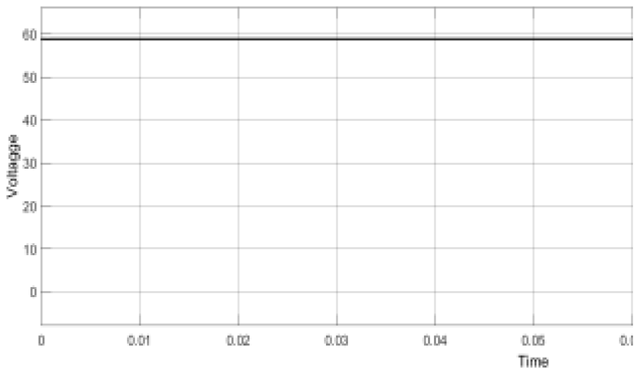

Fig 08 :Battery Voltage

In this proposed work total Harmonic Disturbance is observed by increasing number of chargers to the grid with filter and without filter case.without filter 3 EV'S connected to the grid the THD value is 13.75 and with filter the value is 2.75% is observed in MATLAB FET analysis.

Mitigation Technique for Power Quality Problem

Several disturbances found in the MATLAB simulation acts as a threatening factor for the power system stability. Thus the power quality disturbances should be minimized in order to obtain energy security & efficiency in power sector. Solar energy is available only for few hours in a day. But at cloudy, foggy environment and also at night time, this energy is absent. On the other hand, biomass resources like cow dung, poultry droppings and municipal solid waste (MSW) are available in some countriesThus, the hybrid power generation scheme like solar and biomass can be an effective solution to overcome these challenges for EV charging [12].

If the EVs are charged from hybrid stand-alone renewable based charging station, then the utility grid will not suffer from the excess energy required for the EV charging especially at peak hour. In that case, utility grid relieves from the threats as like power quality problems. Another research performed on GHG emission said that, EV charges from non-renewable resources emits more GHGs than renewable resources. So, renewable energy based EV charging scheme would be a greater one for improving power quality with lower GHG emission.

3. Conclusion

Prominent features of less environmental pollution & cheapest mode of transportation makes EV market more attractive to the consumers. However, due to some reasons EVs penetration makes power system more vulnerable and hampers power quality. In this paper, the power quality issues like harmonics, voltage fluctuation, are analyzed using MATLAB In addition to this, the mitigation technique using available renewable resources is also discussed in this paper. Although the EVs have several benefits as like stabilizing the grid at under loaded condition, lower GHG emission but the power quality issues should regulate properly for sustainable development in the power sector..

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