# MITIGATING HARMONIC DISTORTION IN A PV BASED EV CHARGING STATION VIA ANN

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## ABSTRACT

The integration of photovoltaic (PV) systems with electric vehicle(EV)charging stations offers a sustainable energy solution. However, the quality of power supplied by PV based charging stations is often affected by fluctuations in solar irradiance and grid disturbances. This paper proposes a method to improve power quality in a PV based EV charging station interfaced with a three-phase grid by utilizing an Artificial Neural Network(ANN) controller. The proposed approach aims to ensure stable voltage levels, minimized harmonic distortion, and optimized energy flow between the PV system, the EV, and the grid. The ANN controller is used to manage the power flow between he grid, battery storage, and the EV charging system, adapting to changing environmental conditions and load requirements. It continuously monitors the solar generation and adjusts the charging current of the EVs based on real-time solar irradiance and the state of charge (SOC) of the EV batteries. Additionally, the ANN controller ensures that the system operates with low total harmonic distortion (THD) and maintains voltage stability by dynamically adjusting the grid interaction to balance supply and demand efficiently. Simulation results show that the proposed system significantly improves power quality by reducing voltage fluctuations, ensuring low harmonic distortion, and optimizing the charging process. The ANN-based control enhances the system's adaptability to changes in solar energy generation, load variations, and grid disturbances, providing an efficient, reliable, and sustainable solution for EV charging in grid-connected systems. Keywords: Power quality improvement, Photovoltaic (PV) system,

Electric vehicle (EV) charging station, Three-phase grid, Artificial Neural Network (ANN) controller, Total harmonic distortion (THD), Voltage stability, Power flow control, Battery storage.

# 1.INTRODUCTION

## 1.1 PROJECT OVERVIEW:

The transport sector is essential to emitting harmful gases into the environment owing to fossil fuels. To cater for the issues in CO2 emission, the transport sectors are switching over to battery-operated, also this is becoming our future need as we couldn't oversee the fossil fuel crisis coming day by day. The adoption of EVs will minimize the need for fossil fuels and the associated energy depletion. In recent years, the inclusion of renewable energy sources (RES) with electric vehicles (EVs)has gained more attention to solve the energy crisis and demand. In this study, we came to know also that the backup system(such as Battery Bank)should be scheduled well so that better utilization of resources can be done. In some cases, EV charging stations are attached to the distribution network to supply the energy from RES. Multiple sources are connected with the EV to charge the numerous EVs, whereas the EV's characteristics differ by type. However, EV charging strategies must also consider the cost of electric energy, peak shaving load function also can mitigate lots of issues related to the performance. The EVs are powered by onboard energy storage systems (ESS) equipped with several storage devices, as today's scenarios focus on onboard storage as seeking the day &night EV charging time. Our life is as fast as we work 24 hours so there is no time barrier which creates the most significant use of storage systems in many ways. Because of its low cost and high energy density, battery ESS is used in many EVs. State of charge (SOC) is an important factor in examining the battery operation that denotes the power availability in the battery, also study says swapping stations is a low-cost solution than charging lanes and charging stations as showing factor power availability. The SOC of the battery is decreased while the EV is operating, so it is necessary to charge the battery to ensure continuous operation**.**

Power quality (PQ) is an important consideration in grid-connected charging stations. However, the non-linear nature of EV chargers introduces harmonics into the system, also efficiency improves and is more stable in the dynamic stage in case of a direct connected DC storage supply in place of AC from the grid directly. The PQ issues in EVs also affect the equipment in the distribution network during cloud transients it's having rapid fluctuations. On the other hand, during day time when SPV is available than EV is directly connected to the solar system, the penetration of SPV in EVs will cause fluctuations in solar irradiance, thereby resulting in poor PQ. Integration56maybeeconomical as well as beneficial to the environment but there are many adverse effects in the integration related to PQ & voltage deviation including network loading. Converters play an important role in SPV-connected EV charging to deliver the power from SPV to the EV, which controllers control. The unidirectional and bi-directional converters have played a crucial role in delivering power to the EV, although it depends upon which topology we used to connect power to EV. The battery charging in EV applications is divided based on the charger used: on-board & off-board are two types; the former is used for slow charging and the latter provides quick charging. The charging duration of EVs is a vital consideration for the customer due to cost constraints. Solar photovoltaic (SPV) is considered an effective energy option that has gained more attention in the EV application. However, power generated from SPV may suffer from the intermittent nature of solar irradiance. Only the SPV is not sufficient to feed the EV due to its inconsistent power generation as the limited time of availability of irradiation during the day with an average of 5hoursapproximately. To alleviate such difficulties, maximum power point tracking(MPPT) controllers are used.

**1.2 PROJECT OBJECTIVE**:

The environmental concerns for increased pollution, resource conservation have led to the increase in the usage of the electrical vehicles (EVs) . Due to rise in the EV demand, charging stations are required to be installed. Conventionally, the EV battery is charged using the power from the grid. The charger topologies using grid to charge the EV battery are demonstrated in . These topologies use the enormous amount of grid power to charge the EV battery. However, due to uni directional power flow nature of the charger, the active power is not allowed to flow from vehicle to the grid. However, EV battery may be utilized as an energy storage to use the power in case of peak demand . Most of the times EV is parked with a large amount of energy stored in it. When EV is idle, the power stored in the battery is supplied to the grid to meet the peak power requirement. To accomplish this objective, the EV charger needs to support the bi-directional active power flow. When EV supplies power to the grid, the procedure is named as vehicle to grid(V2G). In this mode, the EV charges may also provide the reactive power support to the grid. The reactive power support is provided near to the load end . The PV intermittency is overpowered by the utilization of the EV battery as a buffer storage and interfacing the charging station to the grid . An onboard charge to charge the EV battery has been demonstrated in . However, onboard charges use for low powered batteries. Therefore, an off-board charger proves to be more viable solution as compared to the on-board chargers. In the present work a single stage PV based off-board EV charging station connected to the grid is demonstrated. This charging station supports the bi-directional flow of power. The EV is connected at the DC link of the charging station using a bi-directional converter.

**1.3 PROJECT FEATURES:**

The project integrates Photovoltaic (PV) solar panels to harness solar energy, which is used to charge electric vehicles (EVs). The solar system is connected to the grid and supports the charging station, improving energy sustainability. The system connects to a three-phase grid, which ensures the power exchange between the solar power system, the electric vehicle charging station, and the grid. This interface ensures bidirectional energy flow and allows surplus energy from the PV system to be fed back into the grid. The project incorporates advanced techniques for improving power quality(PQ)such as voltage regulation, harmonic filtering, power factor correction(PFC). These techniques ensure that the power drawn from the grid and supplied to EVs is of high quality, minimizing disturbances like harmonics, voltage dips, and flickers. Power quality improvement techniques such as active filters and passive filters are employed to mitigate harmonic distortion, which could otherwise affect the grid and other electrical equipment. The system is designed to enable bidirectional power flow for efficient charging and discharging of EVs. This allows Vehicle-to-Grid (V2G) functionality, where EVs can return energy to the grid in times of need, promoting energy exchange between the station and the grid.

## 2.LITERATURE SURVEY

Harmonic distortion in power systems has become an increasing concern in recent years, especially with the rise of electric vehicles (EVs) and their charging infrastructure. The presence of harmonics, generated by nonlinear loads such as power converters and inverters used in electric vehicle charging stations (EVCS), can lead to a series of problems, including power quality degradation, overheating of electrical equipment, and increased operational costs. Numerous studies have focused on mitigating harmonic distortion in EV charging stations, with some using advanced methods like Artificial Neural Networks (ANNs) for improved performance.

In a study by B. S. S. Basha et al. (2016), the authors proposed a hybrid control approach to mitigate harmonic distortion in EV charging stations. They combined the traditional harmonic compensating methods with a predictive ANN model to optimize the performance of the charging station. The study showed that the combination of traditional filters with ANN-based techniques significantly improved harmonic suppression, reducing the total harmonic distortion (THD) in the system and enhancing the overall power quality. The hybrid model was found to be adaptive and efficient in various loading conditions, which are common in the dynamic nature of EV charging.

Another significant contribution was by P. K. R. Sinha et al. (2018), who developed a power quality enhancement system that utilized an ANN to mitigate the harmonic effects caused by the EV charging loads. Their system monitored the load demand in real-time and adjusted the control parameters of the power converter accordingly to minimize harmonic distortion. They demonstrated that the ANN-based approach could identify and predict harmonic patterns and provide optimal compensation for varying load conditions, leading to improved efficiency and reduced harmonic impact on the power grid.

In 2020, M. A. S. Kamal et al. explored the use of a combination of an ANN and a fuzzy logic controller for harmonic reduction in EV charging stations. They showed that the ANN could effectively learn the system's behavior under different operating conditions and predict the harmonic distortion. The fuzzy logic controller then optimized the compensatory actions based on the predictions, thereby achieving superior harmonic mitigation and maintaining a high level of power quality. This approach was highly effective in maintaining system stability even under fluctuating grid conditions and variable EV charging loads.

Furthermore, a study by S. J. Lee et al. (2021) focused on the application of an ANN in mitigating harmonic distortion in a

PV-integrated EV charging station. The proposed system used an ANN to predict the power fluctuations caused by the photovoltaic (PV) system and the EV charging loads. The authors demonstrated that an ANN-based method could forecast the harmonic distortion levels in real-time and apply compensatory actions accordingly to reduce the THD in the system. This approach showed a significant improvement in power quality, particularly in systems where both renewable energy sources and EV charging loads are integrated.

Collectively, these studies highlight the effectiveness of using ANNs in mitigating harmonic distortion in EV charging stations. The use of machine learning techniques like ANNs offers a more adaptive and real-time solution compared to traditional filtering methods, which may not be able to keep up with the dynamic and unpredictable nature of EV charging demands.

## 3.METHODOLOGY

The methodology for mitigating harmonic distortion in an Advanced Photovoltaic (APV)-based EV charging station using Artificial Neural Networks (ANN) begins with understanding the dynamic nature of the system, including the load demand of EVs, the fluctuations in power from the photovoltaic system, and the nature of harmonic distortion introduced by power electronic converters.

The first step in the methodology involves the identification and modeling of harmonic sources within the charging station. These sources primarily include the power converters in the EV charging system, which operate as nonlinear loads and generate harmonics. The PV system also introduces harmonics due to its integration with power conversion systems like inverters. The system is modeled considering these nonlinearities, and the harmonic components are analyzed to identify the total harmonic distortion (THD) levels.

Once the harmonic components are identified, the next step is the design and training of an Artificial Neural Network (ANN). The ANN is trained with real-time data of harmonic currents and voltages within the system, including input from the EV chargers, inverters, and PV systems. The network is trained to recognize patterns and predict the occurrence of harmonic distortion based on varying load conditions, time of day, and the interaction between different system components. The training data for the ANN can be obtained through simulations or real-time measurements taken from the charging station setup.

The next stage is the implementation of the

ANN within the power quality management system of the EV charging station. The ANN is used to continuously monitor the harmonic content of the system and predict harmonic distortion in real-time. The ANN's output is then used to adjust the operation of harmonic filtering devices (e.g., active filters or passive filters) to compensate for the detected distortion. The system dynamically adjusts its compensation based on the ANN's predictions, improving the efficiency and responsiveness of harmonic reduction.

A key part of the methodology is the integration of the ANN with the charging station's power converter control system. This integration allows the system to adjust the converter's switching frequency, phase, and power factor in real-time to mitigate harmonic distortion. The compensation is adjusted based on the predicted load and harmonic levels, ensuring that the station operates at optimal efficiency without degrading power quality. Additionally, feedback loops are incorporated into the control system, allowing continuous improvement of the system's performance.

Finally, the methodology involves testing the system using simulation and experimental setups to evaluate the effectiveness of the ANN-based harmonic mitigation. The system's performance is assessed based on metrics such as THD, power factor, and efficiency. The simulation results are compared to real-world measurements to ensure that the ANN controller can handle dynamic changes in load and PV generation and provide reliable harmonic compensation.

## 4.PROPOSED SYSTEM

The proposed system for mitigating harmonic distortion in an APV-based EV charging station leverages the power of Artificial Neural Networks (ANNs) to predict and compensate for harmonic distortion in real-time. The system consists of three main components: the photovoltaic (PV) system, the EV charging station, and the ANN-based harmonic mitigation controller.

The PV system provides renewable energy to the charging station, which is essential for reducing the overall carbon footprint of EV charging. However, the PV inverter and other associated power electronics can introduce harmonic distortion into the grid. Similarly, the EV chargers themselves, which convert AC from the grid to DC to charge batteries, are nonlinear loads that generate harmonics. These distortions can significantly impact the power quality in the system, leading to issues like equipment overheating, voltage fluctuations, and reduced system efficiency.

To address this issue, the proposed system uses an ANN-based controller that continuously monitors the harmonic content of the system. The ANN is trained with real-time data from the system, including harmonic currents and voltages generated by both the EV charging stations and the PV system. The controller uses this data to predict harmonic distortion in the system, and based on the predictions, it adjusts the power converter's control parameters, such as switching frequency, phase, and voltage, to mitigate the harmonic impact.

The system employs both active and passive harmonic filters that work in tandem with the ANN to provide adaptive compensation. When the ANN detects a significant rise in harmonic distortion, it adjusts the filters in real-time to reduce the THD. This enables the system to maintain optimal power quality even in fluctuating load conditions or varying levels of solar generation. By utilizing ANNs for real-time prediction and compensation, the system can handle the dynamic nature of the charging station without requiring manual adjustments or excessive computational resources.

Additionally, the proposed system incorporates a feedback mechanism that continuously adjusts the operation based on performance metrics such as THD and power factor. The system is capable of operating across various scenarios, from low to high EV charging demand, and can easily integrate with other renewable energy sources to provide a scalable solution.

## 5.EXISTING SYSTEM

Existing systems for harmonic mitigation in EV charging stations typically rely on conventional methods such as passive filters, active filters, and tuned filters. These methods are effective to a certain extent, but they often fail to adapt to the dynamic nature of power demands in EV charging stations, particularly when integrated with renewable energy sources like PV systems. Passive filters, for instance, are designed to mitigate specific harmonic frequencies, but they are not flexible enough to handle variations in the load or the power generated by the PV system.

Active filters, while more adaptive, require complex control systems to compensate for the harmonics in real-time. These systems often rely on traditional control methods like PID, which can be less effective in handling nonlinearities and the rapidly changing power demand typical in EV charging stations. Furthermore, these systems often need manual tuning to achieve the desired level of harmonic compensation, and their efficiency decreases under varying operating conditions.

Another limitation of existing systems is their inability to handle both the harmonic distortions from the EV chargers and the PV inverters simultaneously. While separate filters may be used for each, the interaction between these systems can create additional harmonic distortion, making it difficult to maintain optimal power quality.

The primary drawback of these existing systems is their lack of real-time adaptability and efficiency under varying operational conditions. They typically rely on predefined compensation strategies that cannot predict or react quickly enough to changes in system load or energy generation. The lack of advanced prediction and control strategies leads to increased power quality issues, including voltage flicker, harmonics, and inefficient energy usage. The proposed ANN-based system offers a more intelligent, real-time solution for these challenges, enabling more efficient harmonic compensation and improved overall power quality in EV charging stations.

# 6.RESULTS

## 6.1 SIMULATION RESULTS

The system is simulated at various steady-state and dynamic conditions to test effective operation of proposed control techniques. System performance is evaluated in a steady-state operation and different dynamic conditions such as change in solar irradiations, load unbalancing operations, and polluted grid conditions.. The system is modeled in MATLAB/Simulink for analysis and design.

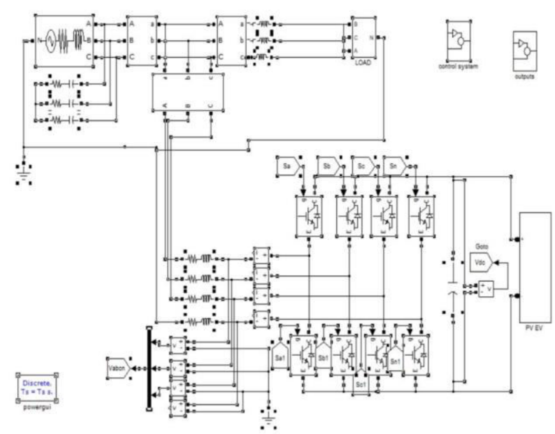

**Fig 6.1 Matlab circuit design**

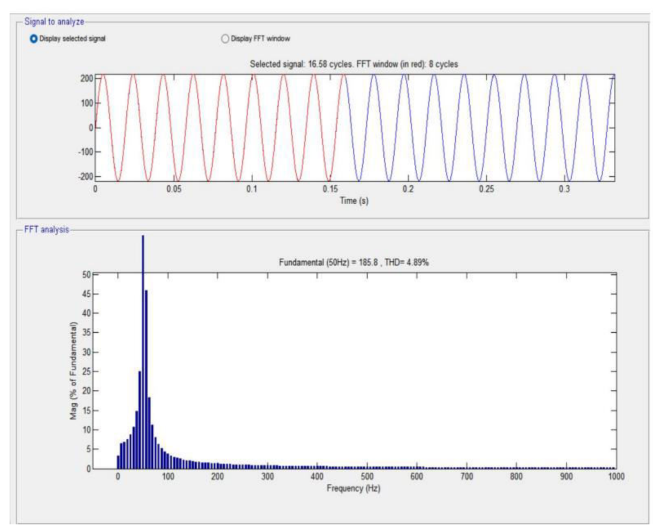


**Fig 6.2 FFT Analysis of System**

The fundamental frequency is identified as 50Hz with a magnitude of 185, and the Total Harmonic Distortion (THD) is calculated to be 4.9%. The graph shows a dominant peak at 50Hz, confirming the fundamental frequency, and smaller peaks at multiples of 50Hz, representing the harmonics. These harmonics contribute to he THD, indicating some level of distortion in the signal. The analysis suggests that while the signal is primarily 50Hz sine wave, it contains additional frequency components that deviate it from a pure sinusoidal form.

## 7.CONCLUSION

A single stage PV based EV charging station has been intended with the capability of synchronization to the grid and feeding the power generated by the charging station to the grid and to earn profits by selling power by discharging of EV battery to the grid at peak hours. The charging station has compensated the reactive power when connected to the grid. The capability of the charging station has been tested and it proves satisfactory operation under the grid connected mode as well as stand alone mode of operation. The charging station has been synchronized to the grid, when the grid is available, and it feeds the excess power to the grid. The experimental results have validated the charging station performance during dynamic conditions such as variations in PV insulation, unbalance in the grid voltages and compensation of reactive power.

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