eISSN: 2976-1190

Journal of Engineering and Sciences
Vol. 3 Issue 1 May 30, 2024 / ***DOI:*** *https://doi.org/10.3126/jes2.v3i1.66294*
Journal homepage: ***Journal of Engineering and Sciences (nepjol.info)***
Publisher: Research Management Cell, Pashchimanchal Campus, Lamachour, Pokhara

Mitigation of Harmonics Due to Electric Vehicle Charging

Rasik Neupane[1*], Sunil Thapa Magar[1], Manish Pandey[1], Abhishek Simkhada[1], Bhrigu Raj Bhattarai[1]
[1] *Department of Electrical Engineering, IOE, Pashchimanchal Campus, Tribhuvan University, Nepal*

(Manuscript Received 17/03/2024; Revised 27/05/2024; Accepted 29/03/2024)

Abstract

The increasing adoption of electric vehicles (EVs) has led to an increase in demand for charging infrastructure. However, EV charging can introduce harmonic distortion into the electrical distribution network, causing power losses, reduced efficiency, and equipment damage. This project developed an EV charging system with harmonic reduction to ensure a stable and efficient charging process. The research methodology allowed the team to develop an EV charging system with harmonic reduction that was effective in reducing the total harmonic distortion (THD) level from 56.3% to 1%. The system was also found to be stable and efficient during charging. The findings of this project have the potential to make a significant contribution to the development of EV charging infrastructure. The proposed system can help to mitigate the negative impacts of EV charging on the electrical distribution network, while also ensuring a stable and efficient charging process.

Keywords**:** Constant Current Constant Voltage; Proportional Integral Derivative; Shunt Active Power Filter; State of Charge; Total Harmonic Distortion

1. Introduction

The increasing popularity of electric vehicles (EVs) is leading to an increase in the number of EV charging stations. However, EV charging stations can introduce harmonics into the power grid, which can cause problems for other equipment on the grid [1]. Harmonics are caused by the non-linear nature of EV chargers, which draw current in a way that is not sinusoidal. The non-linear load can affect the performance of the distribution transformer by increasing power losses in the winding and thereby reducing its power output [2]. The two main types of harmonics that are caused by EV chargers are current harmonics and voltage harmonics. Current harmonics can cause overheating and increased losses in transformers and other equipment on the grid. Voltage harmonics can cause voltage distortion, which can interfere with the operation of sensitive equipment. There are several ways to mitigate the effects of harmonics, including using filters to remove harmonics from the power grid, using power factor correction to reduce the number of harmonics generated by non-linear loads, and designing equipment to be more tolerant of harmonics [3]. The EV Charging Station comprises of transformer, rectifier, converters and batteries.

2. Methodology

The overall methodology of the project is shown in figure1. Initially, the grid (power source) is stepped down using a distribution transformer. The output of the transformer is then converted into DC supply with the help of a rectifier. The rectified DC output is converted into variable DC as required by the load (EV Battery). Here the charging of the battery is done through CCCV, Constant Current Constant Voltage Scheme. The harmonics reduction is done with the help of a SAPF, Shunt active power filter.

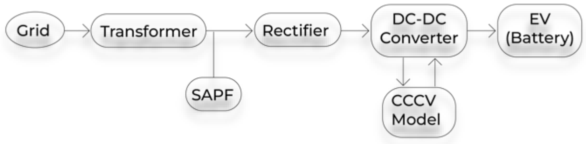

Figure 1: Proposed block diagram

---

[*] Corresponding author. Tel.: +977- 9848248952,
E-mail address: neupanerasik5@gmail.com

2.1 Buck -Boost converter

The buck-boost converter is a type of DC-to-DC converter that can step up or step down the input voltage to provide a stable output voltage, making it versatile for various power applications. Two different topologies are called buck-boost converters. It is also called an inverting converter. The buck-boost converter works on the principle that the unexpected changes in input current will be countered by the inductor in the input circuit. Energy from the input will be stored in the inductor in the form of magnetic energy during the ON state of the switch and it is discharged during the OFF state of the switch [4].

For the design of a Buck-Boost Converter following parameters are required:

Supply Voltage = Vs

Output Voltage = Vo

Resistance= R

Ripple, r= 1%

Switching frequency= 40 kHz

Duty Ratio, D= $\frac{Vo}{Vo+Vs}$

Minimum Inductance, L min = $\frac{R(1-D)^2}{2f}$

Minimum capacitance, C min = $\frac{D}{Rrf}$

Parameters used:

V_S= 60V

V_O= 110V

F= 40 kHz

Calculated Parameters:

D= 0.647

L= 2.336e-5 H

C=1.078e-4 F

R=15 Ω

2.2 CCCV Charging Control of Battery

This charging scheme incorporates both CC and CV, the battery current is kept constant initially and the battery voltage is allowed to increase until it reaches at a predefined value. This mode is called the Constant Current (CC) mode. Once the voltage reaches this value, the current is allowed to decrease and the voltage is maintained constant at the predefined value. This is known as the Constant Voltage (CV)

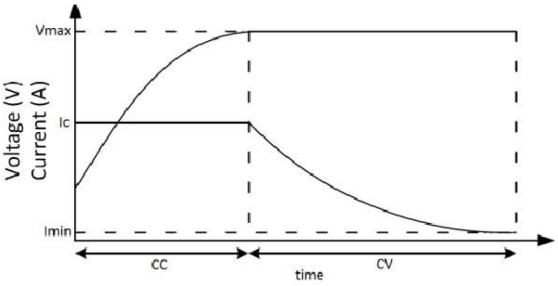

Figure 2: Charging curve of CCCV method

If the $V_{battery}$ is less than the maximum specified voltage, V_{max}, which is the corresponding voltage at 90% State of Charge (SoC) of the battery, the charging is done using Constant Current mode. When the $V_{battery}$ reaches up to V_{max}, the charging mode is switched to

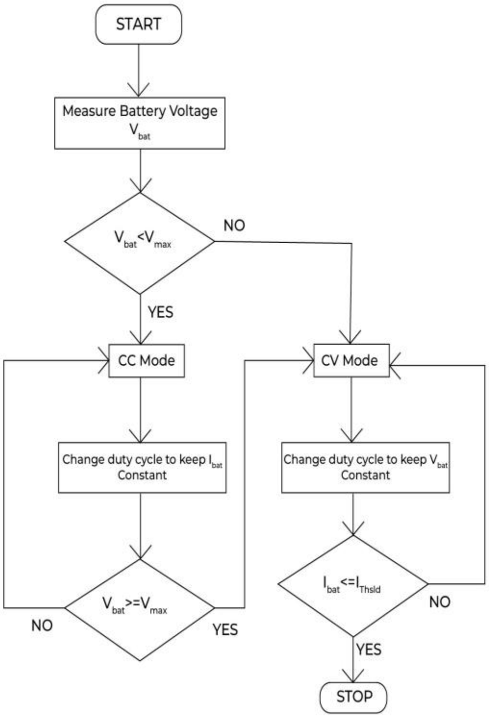

Figure 3: Working flowchart of CCCV model

2.3 Shunt Active Power Filters (SAPFs)

Shunt active power filters (SAPFs) are a type of active filter that is used to compensate for current harmonics. SAPF can help reduce harmonics of various orders (e.g., 3rd, 5th, 7th) effectively, providing a more targeted approach to harmonics mitigation compared to passive filters. Also, by actively compensating for harmonics, SAPF helps improve power quality, ensuring stable voltage and current levels within the system. This leads to enhanced efficiency and reduced risks of equipment damage. Therefore, it is preferred to use SAPF over other filters. Furthermore, several control techniques can be used to control an SAPF.

One popular control technique is the instantaneous reactive power (p-q) theory. The p-q theory consists of transforming the three-phase voltages and currents into the α-β-0 coordinates and then calculating the instantaneous reactive power [5]. The SAPF then injects a current that is equal in magnitude to the instantaneous reactive power but with the opposite phase. The p-q theory is a well-established control technique that provides good harmonics compensation. However, it can be sensitive to noise and transients. Another control technique called the synchronous reference frame (SRF) theory is less sensitive to noise and transients, and it can provide better harmonics compensation. The choice of control technique for a SAPF depends on the specific application. For applications where high accuracy and robustness are required, the SRF theory is a good choice, and for applications where cost is a major consideration, the p-q theory may be a better choice [6].

2.4 Modeling of Charging Station using a buck-boost converter with CCCV charging and SAPF

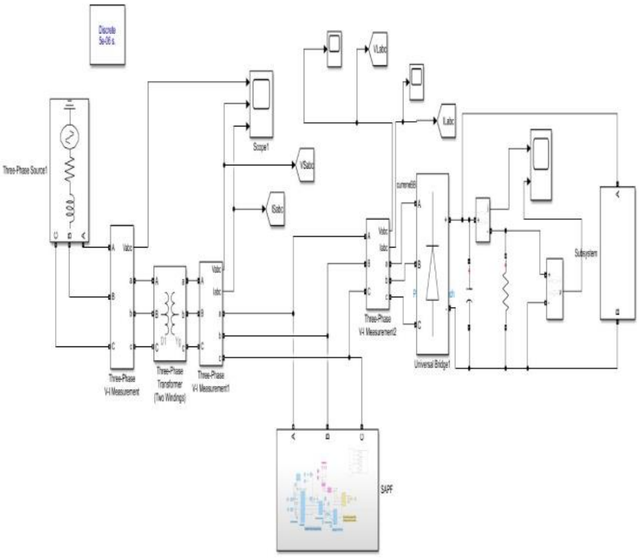

Figure 4: Charging station with BB converter and CCCV charging and SAPF

As seen in the figure, the input supply of Three Phase 11kV is taken as a source which is stepped down to 415V using a transformer. The output is converted into DC using a Rectifier. The constant DC obtained from the rectifier is converted into a variable DC source of 200V using a Buck-Boost converter which is then used to charge the battery acting as EV load. The battery used is 144Ah and 200V. For the reduction of harmonics Figure 3 Charging station with BB converter and CCCV charging and we have used a Shunt Active Power Filter (SAPF) connected parallel to the non-linear load i.e. battery.

Table 1 Parameters used in modeling of charging station (BB with SAPF)

Parameters Used	Values
Power Supply	11KV
Transformer(distribution)	11KV/415V
Buck-Boost converter Output	200V
Battery Capacity	144Ah
Battery nominal voltage	200V
DC link Voltage	600V

3. Results and Discussion

3.1 Buck-Boost Converter

3.1.2 Battery charging characteristics

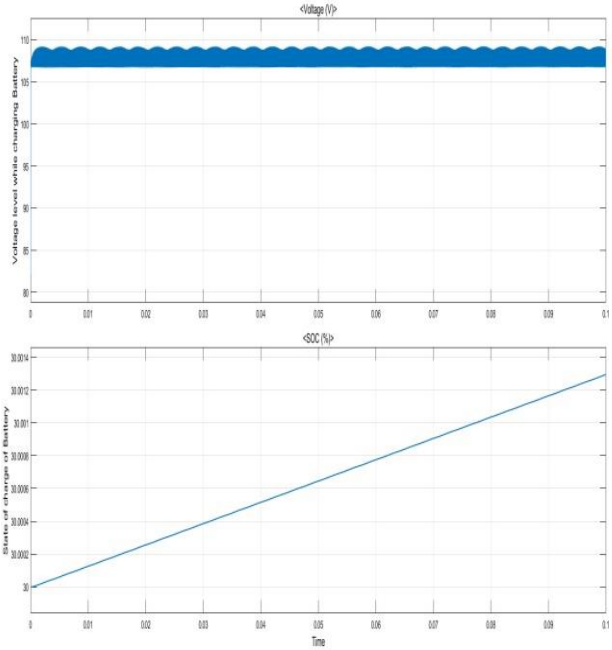

Figure 5: Charging voltage and SoC of a battery while charging

The figure below shows the battery characteristics of EV load. The charging voltage is maintained around 100V with the help of **a** Buck-Boost converter. The SoC of battery

3.1.3 Total Harmonics Calculations

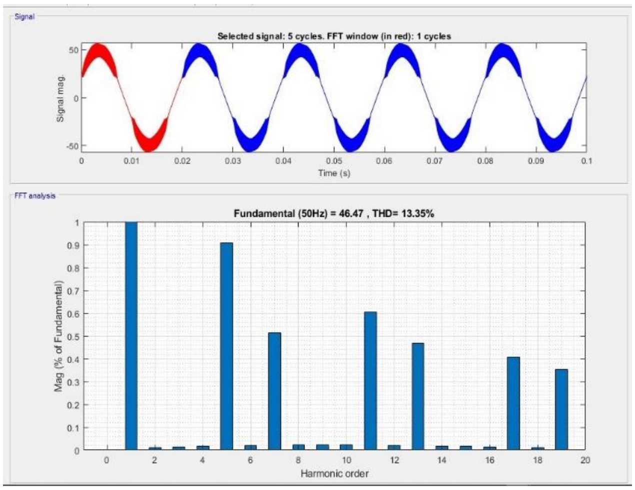

Figure 6: THD content (Voltage Harmonics)

As seen in Figure 5, the total harmonic distortion of voltage in the R-phase was found to be 13.55 %, that of the Y-phase was 13.28% and that of the B-phase was 13.34%.

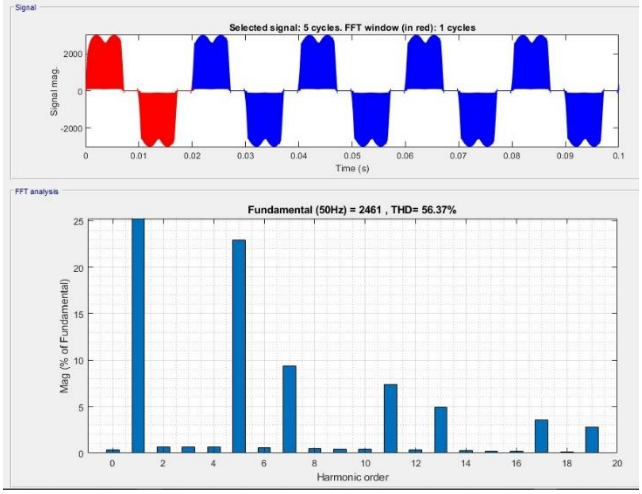

Figure 7: THD content (Current Harmonics)

While looking at the current harmonics, the Total Harmonic Distortion in R-Phase was found to be 56.37%, that of Y-Phase was 58.31% and that of B-Phase was found to be 57.09%.

3.2 Charging Station using Buck-Boost Converter with CCCV charging and SAPF

The figure below is the input side waveform of voltage and current waveform of both the sources and load side while the batteries are charged through a Buck-Boost Converter with CCCV charging control and SAPF for harmonic reduction.

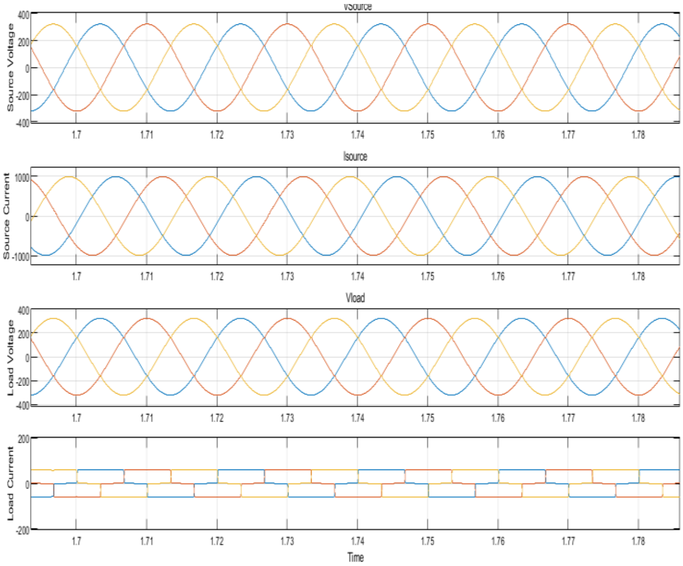

Figure 8: Charging station with BB converter, CCCV charging and SAPF

3.2.1 Battery Charging Characteristics

The figure below shows the battery characteristics of EV load. The SoC of the battery while charging is shown. Until the SoC reaches 90%, the charging current is maintained to be around 28.8 Amperes at constant current mode. And beyond 90%, the charging voltage is maintained at around 214 Volts at constant voltage mode.

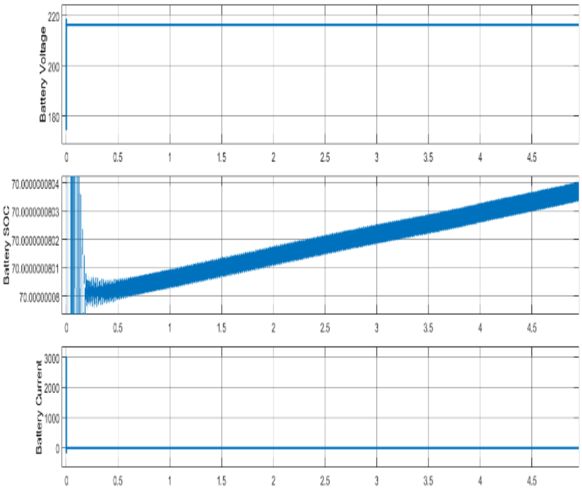

Figure 9: Battery Characteristics with SAPF

3.2.2 Total Harmonic Distortion

The results of the Fast Fourier Transform in MATLAB is shown in the figure below:
As seen in the figure the voltage harmonics were reduced to 0.19%.
Similarly, the current harmonics were also reduced up to 1% with the help of the shunt active power filter.

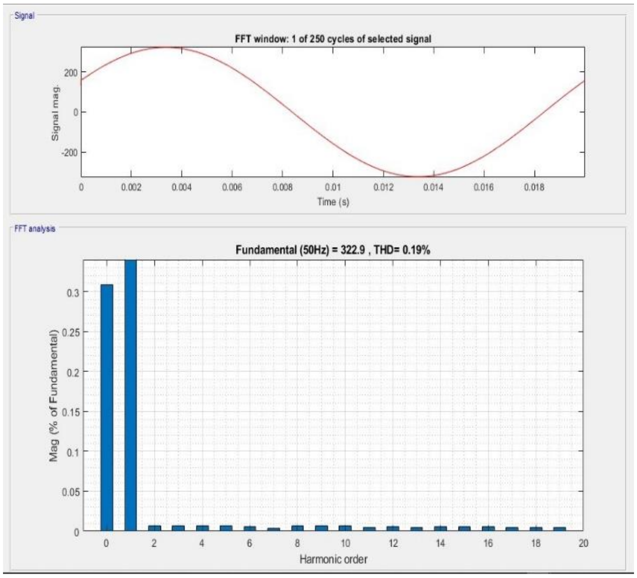

Figure 10: THD in the current waveform

4. Conclusions

For the analysis of harmonic contamination, a charging station with Buck-Boost converters was used. While using Buck-Boost converter the total harmonic distortion in voltage was about 13% and in current was about 56-59%. By the use of a Shunt Active Power Filter with a controlled Buck Boost converter-based EV charger, we were able to reduce the total harmonic distortion. The total harmonics distortion in voltage was found to be 0.19% while in current it was found to be 1% by the use of the above-mentioned mitigating technique.

References

[1] Megha, A., Mahendran, N. and Elizabeth, R. Analysis of Harmonic Contamination in Electrical Grid due to Electric Vehicle Charging. *2020 Third International Conference on Smart Systems and Inventive Technology (ICSSIT)* (2020)

[2] Kutt, L., Saarijarvi, E. Lehtonen, M., Molder, H. and Niitsoo, J. A review of the harmonic and unbalanced effects in electrical distribution networks due to EV charging. *2013 12th International Conference on Environment and Electrical Engineering* (2013)

[3] Yang, W., Wang, J., Zhang, Z. and Gao, Y. Simulation of the electric vehicle charging station and harmonic treatment. *2012 International Conference on Systems and Informatics (ICSAI2012)* (2012)

[4] Stanchev, P. A., Vacheva, G. I. and Hinov, N. L. Harmonic Resonance Analysis of Buck-Boost DC-DC Converter, International Scientific Conference on Computer Science (COMSCI), Sozopol, Bulgaria (2023)

[5] Imam, A. A., Kumar, R S.. and Al-Turki, Y. A. Modeling and simulation of a PI controlled shunt active power filter for power quality enhancement based on PQ theory. *Electronics* (2020)

[6] Belgore, A. U. T. and Najashi, D. B. U. G. Control techniques for shunt active power filters. *International Journal of Engineering Research & Technology* (2020).