As per UGC guidelines an electronic bar code is provided to seure your paper

International Journal for Modern Trends in Science and Technology
Volume 9, Issue 07, pages 126-131.
ISSN: 2455-3778 online
Available online at: http://www.ijmtst.com/vol9issue07.html
DOI: https://doi.org/10.46501/IJMTST0907020

Off-Board Bidirectional Electric Vehicle Charger Featuring Reactive Power Compensation and Reduced Total Harmonic Distortion for Enhanced Efficiency and Power Quality

Thogaru Srilekha[1] | Dr. Ram Babu Thogaru[2]

[1]Lecture, Department of Electrical and Electronics Engineering, Government Polytechnic College, Warangal, Telangana, India. srilekha.thogaru@gmail.com
[2]Tech Lead, L&T Technology Services, Hyderabad, Telangana, India. ramvarma.thogaru@gmail.com

To Cite this Article
Thogaru Srilekha and Dr. Ram Babu Thogaru, Off-Board Bidirectional Electric Vehicle Charger Featuring Reactive Power Compensation and Reduced Total Harmonic Distortion for Enhanced Efficiency and Power Quality, International Journal for Modern Trends in Science and Technology, 2023, 9(07), pages. 126-131. https://doi.org/10.46501/IJMTST0907020

Article Info
Received: 02 July 2023; Accepted: 18 July 2023; Published: 26 July 2023.

ABSTRACT

The purpose of this study is to explain a recently developed off-board battery charger system for electric vehicles (EVs) that is capable of supporting grid-to-vehicle (G2V) and vehicle-to-grid (V2G) operations, in addition to adjusting for reactive power. A utility-connected AC-DC cascaded H-bridge (CHB) converter is included into the system design. This converter is responsible for controlling the power exchange that occurs between the grid and the battery while a bidirectional DC-DC converter is located at the rear end of the system. There is galvanic separation between the grid and the user end of the charger, which is included for the purpose of increasing safety. In order to manage electric vehicle power and battery current, the suggested system makes use of an ANFIS controller. This controller adheres to active power orders for both G2V and V2G modes, and it also provides reactive power adjustment when it is necessary. Furthermore, a control algorithm that is based on an adaptive notch filter has been developed in order to estimate network phases and achieve accurate current synchronization without the need for phase-locked loops (PLLs). This has resulted in the simplification of controller design and an improvement in both the steady-state and dynamic performance of the system. The efficiency of the suggested system in regulating reactive power in V2G and G2V scenarios is shown by the experimental results that were achieved in a MATLAB environment.

Keywords—Grid to vehicle, EV charger, Power quality, Vehicle to grid.

1. INTRODUCTION

Electric vehicles (EVs) have acquired a substantial amount of momentum in industrialized nations owing to the fact that they use less fuel and produce less emissions of greenhouse gases. The rise in the number of charging stations that are located off-board is a significant contributor to the widespread adoption of electric vehicles. These systems that are located off-board are capable of functioning in both unidirectional and bidirectional modes. The active exchange of power in both directions is made possible by bidirectional operation, which includes grid-to-vehicle (G2V) and vehicle-to-grid (V2G) procedures. Additionally, V2G activities are especially advantageous for the storage of energy in the grid.

Despite the benefits, there is still a worry over the possible deterioration of electric vehicle batteries that might occur during V2G operations. Off-board chargers, on the other hand, have the ability to alleviate this problem by providing supplementary power quality services. These services include voltage control, reactive power compensation, harmonic compensation, and power factor correction. These services are provided without dependency on the integration of electric vehicle batteries with utility systems. When it comes to these services, off-board solutions are often favored over on-board systems because of their ability to handle larger power levels.

Reactive current is normally supplied by the power source in traditional power systems. This may result in extra losses over the vast transmission and distribution reactances, which in turn reduces the efficiency of the system and the quality of the voltage. Consequently, the creation of reactive power demand need to be done locally wherever possible. Additionally, reactive electricity is drawn by domestic equipment such as compressors, freezers, and smart gadgets. Users are often not sufficiently compensated for this kind of power. An electric vehicle bidirectional charger, on the other hand, is able to offer reactive power locally without the need for extra variables of resistance sources.

For the purpose of improving grid service, this article focuses on the functioning of an electric vehicle charger. It is possible to encourage the usage of electric vehicles by installing off-board charging stations that provide auxiliary services in public areas that are not being exploited to their full potential. These public areas include parking lots, restaurants, retail malls, residential complexes, and office buildings.

By altering the DC connection voltage via the electric vehicle battery system, the charging system that is being studied intends to compensate for reactive power consumption. This will have an effect on the battery's lifespan and will result in more charge-discharge cycles. The capacity of the charger to work concurrently in V2G and G2V modes with reactive power compensation is not substantially addressed, despite the fact that this technique is helpful in regulating reactive power. In a similar vein, while the architecture of the system makes it easier to provide reactive power assistance to the grid, changing the voltage of the DC connection with electric vehicle batteries may reduce their efficiency and shorten their lifespan. Despite the fact that the suggested charger management approach focuses on managing the DC system via batteries and regulating reactive power in V2G operations, it does not investigate the potential of the charger to function in more than one operational mode concurrently.

2. MATERIALS AND METHODS

The purpose of this article is to offer a description of the creation of an effective control mechanism for a two-directional off-board electric vehicle charger in order to provide reactive power adjustment with the recommendation of the utility system. In addition, the charger regulator that has been proposed is capable of performing reactive power correction even while the charger is functioning in either the V2G or G2V mode. During the course of this investigation, the reactive power compensation was accomplished by operating in the V2G mode. The galvanic isolation that is included in the proposed charger design is another factor that contributes to the increased dependability of the electric vehicle charger in practical applications. After correction, the charger controller offers the highest possible power factor with unity while the device is being charged. In order to achieve synchronization with the grid, the charger regulator approach that is currently being designed makes use of an adaptive notch filter (ANF), meaning that PLL is removed from the controller. Because of this, the regulatory body has increased the number of variants and decreased the complexity of the implementation. In addition, the controller makes advantage of direct control of power in order to accomplish a rapid transient reaction in response to a change in the command power. An boost in the charger's performance in long-term stable operation may be achieved with the use of ANF rather than PLL. The DC connection output voltage regulator is included into the loop of the internal current controller in order to maintain the DC connection voltage at the value that corresponds to its orientation.

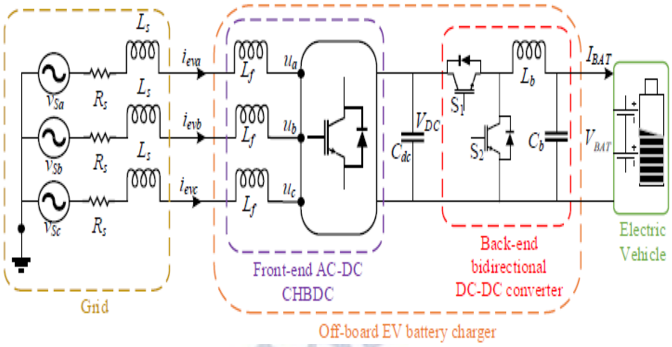

FIGURE.1: Suggested system configuration

Bidirectional Electric Vehicle Charger

Figure 1 provides a description of the off-board electric vehicle indicting conventional configuration. An evaluation of the charger's V2G and G2Vworking operation, as well as its reactive power adjustment capabilities, is carried out with the help of the electric vehicle designer that was brought into existence. An example of a model that has a single motivating voltage source is the grid-connected front ended AC-DC-CHBDC component. A comprehensive design of the utility-looking converter is shown in Figure 2, which features the whole construction. Within the current arrangement of the converter, there are three H-bridge components for each phase.

There is a connection made between the main side of a single-phase toroidal core transformer (TCT) and each and every H-bridge output. The secondary winding components of the three transformers are linked in series, and the yield voltage is calculated by adding the secondary voltages of all of the transformers together. Every single H-bridge contributes the same amount to the output phase voltage, which is 33.33 percent, as can be seen in Figure 2. While TCTs are used in front-end converters as a high frequency connection, their application at the yield end allows for a presentation that is superior to that of transformer-based systems that have become obsolete. With the help of the TCT, the system is able to function with a single DC excitation voltage. In addition to this, it eliminates the need for additional voltage equivalent sensors, which are necessary in order to guarantee that the segments get the same amount of power. Another characteristic of the H-bridge design that has been documented is that it has very minimal galvanic isolation, voltage and current control experiences, and charging current Harmons. As shown in Figure 1, the network-connected CHBDC is connected to the utility system via an L-filter in order to improve the quality of the voltage output from the converter. The L-filter is able to eliminate switching harmonics of higher-order nature due to the fact that it is constructed with many layers. In the back-end DC-DC operation, the electric vehicle batteries are drained and charged throughout the process. A full presentation of the BBDC's circuit layout may be seen in Figure 1. By adjusting the settings of both switches (S1 and S2), the configuration that has been described may operate in two different modes, namely boost and buck operation. Switch S1 may be manipulated to allow the BBDC to function as a buck operation, while switch S2 can be manipulated to engage boost mode. As a consequence of this, the process of draining and charging electric vehicle batteries may be accomplished by operating the BBDC in boost and buck mode.

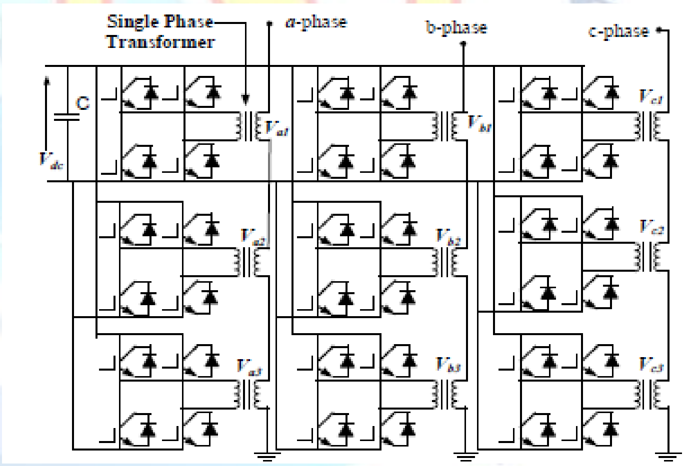

FIGURE.2: CHBDC internal structure

Control design of the suggested model

The control considered has two major goals: the first operation includes the EV battery charging in G2V operation and the second function includes the assignment of active power in V2G operation when grid requires it and also to supply sufficient reactive power when grid required for proper operations. Figure.3 presents the detailed structure of the controller. The suggested regulator method makes use of ANF to retain the grid and the pony in synchronization. The ANF functions successfully nevertheless of organization disorders and substitutes the ordinary PLL in the system controller.

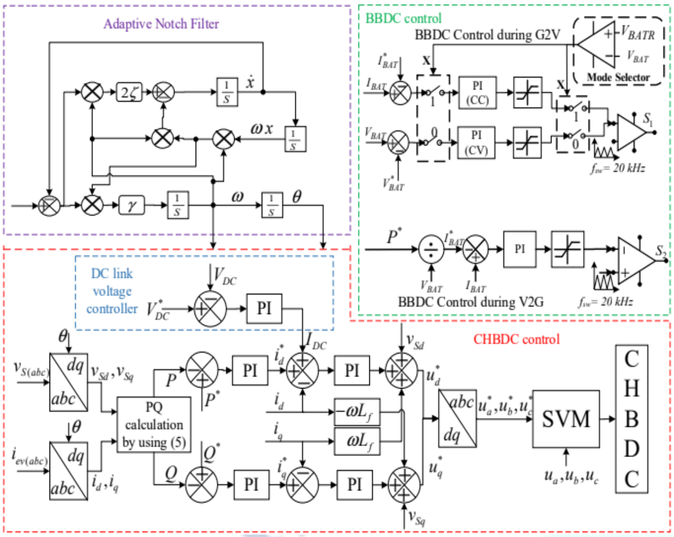

FIGURE 3: Detailed structure of the controller

Grid to Vehicle(G2V) Mode operation:

In G2V operation, the sufficient active power taken commencing the utility by the charger to control the batteries. For charging of the batteries, this study employs the constant voltage (CV) and constant current (CC) techniques. In the preliminary charging state, the charging current reference is fixed to the accurate power level below continuous current till the voltage of the battery reaches the manufacturer's rated permissible voltage level. Following that, the system is charged at highest voltage level by decreasing current checkout the current extents its esteemed threshold value and the voltage of battery extents its highest level. In this approach of operation, the CHBDC mechanism system follows the charging power instruction P and keeps UPF at its input. The reactive power value kept Q = 0 in this operating state. The BBDC acts as a buck operation during charging by managing the interchanging of S1 to manage the battery charging current (DEF) and voltage (GDEF). Figure.3 describes the BBDC control topology during G2V operation. The variables are identical to those in Fig 1.

Vehicle to grid(V2G) Mode of operation:

In this style of process, the EV charger maintains a 180 degrees phase shift among EV voltage and current by fixing the reactive power reference to zero value. The control method of the EV charger gets the command to create the reference current (reference power P and time interval). Without accounting for the loss of power in the EV charger, the current reference of the battery may be calculated. Energy storage to the electric grid. When an EV is associated to the utility, the charger's chief purpose is G2V working. Though, with the addition of a BBDC, power transmission in two ways is allowed for a limited time.

TABLE.1: Test system modelling parameters

Parameters	Specifications
Charger apparent power	12.6KVA
CHBDC Filter	L_f=2.5mH(25A)
BBDC elements	L_b=3.7mH,C_b=660µF
Grid Impedance (Z_s)	R_s=0.1Ω of a,L_s=1.6mH
DC link capacitor(C_{DC})	2200µF/500V
Transformer(CHBDC)	1kVA,1-φ,Toroidal core
Supply System	230Vrms,50Hz
EV Battery	Nominal voltage= 192V

3. SIMULATION RESULTS AND VALIDATION

The Simulink design is created to assess the suggested EV charger operation efficiency throughout the charger's described modes of operation. Table-I lists the test system parameters utilized in this work. The charger first operates in G2V mode, accusing the battery through the consideration which would give sufficient reactive power when it is required from the effectiveness system. Based on the recommendations of the reactive power, the charger changes its modes of operation.

If the utility requires reactive power, the designed controller can operate with various charging power. Figure.4represents the charger's presentation in G2V operation when charging with P=12 kW. Fig.5 depicts, the EV charger output voltage THD in G2V condition which is 1.26% with proposed controller. Fig.6 presents the yield current of EV charger in G2V condition whereas Fig. 7 represents the yield current THD of EV feeder in G2V condition is 6.95%. Fig. 8 represents the active power output of 12 kW in G2V operation. Fig.9 represents reactive power requirement of EV charger in G2V condition which is fixed at zero to operate the system at unity power factor and the Fig. 10 illustrates the DC link voltage variation. The utility recommends inductive reactive power from the charger during charging at 1.5 s by changing its operational mode from G2V to G2V with V4G.Q= 9.8 KVAR and P= 6.8 kW are the power commands sought from the grid.

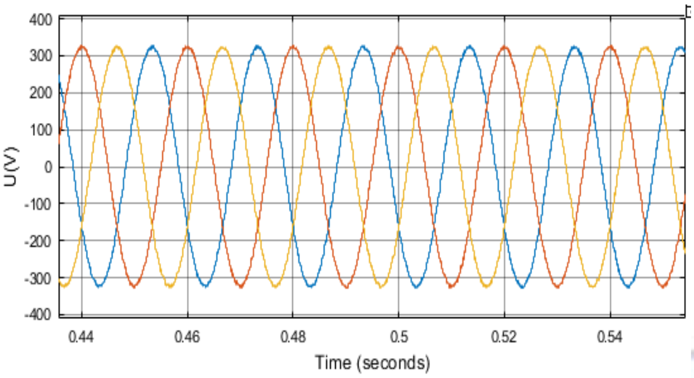

FIGURE.4: EV charger output voltage in G2V condition

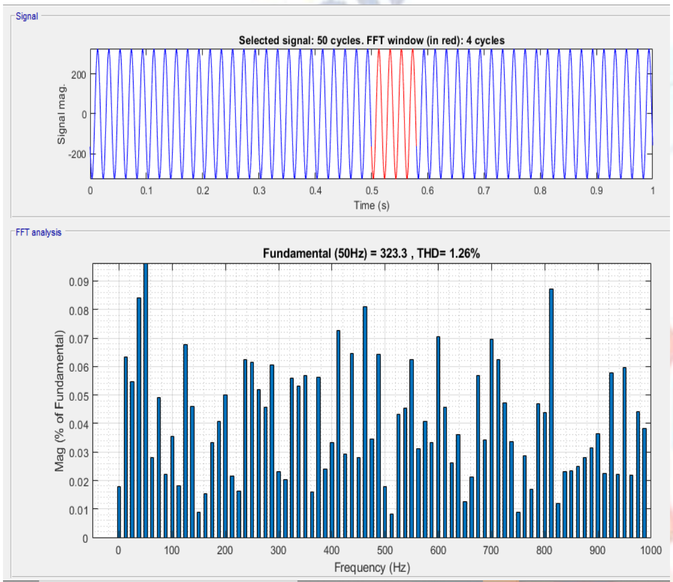

FIGURE.5: EV charger output voltage THD in G2V condition

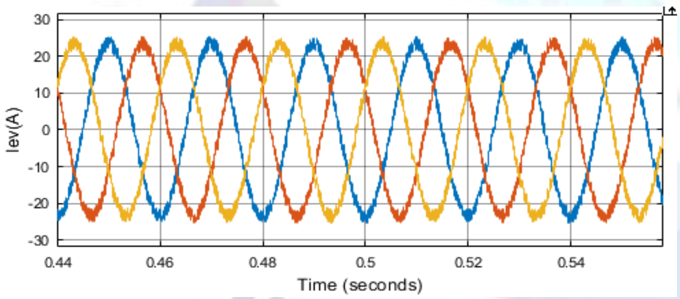

FIGURE.6: Output current of EV charger in G2V condition

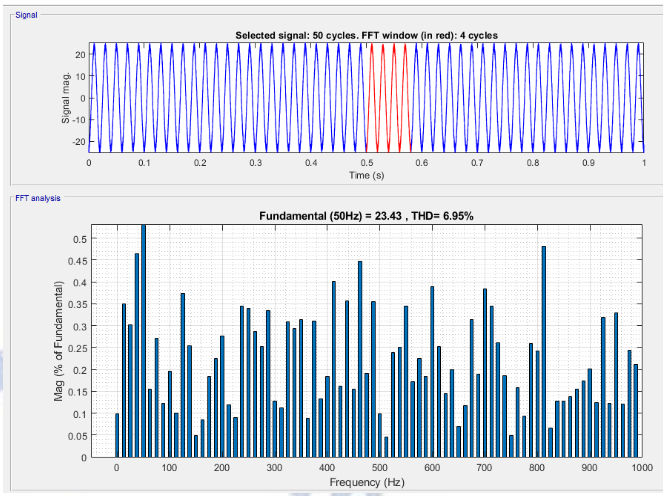

FIGURE.7: Output current THD of EV charger in G2V condition

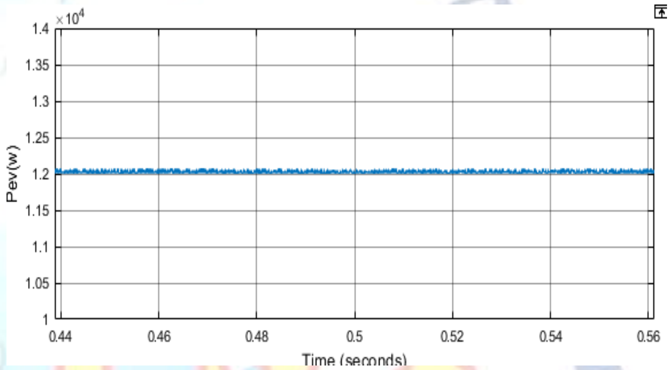

FIGURE.8: Active power output of EV charger in G2V condition

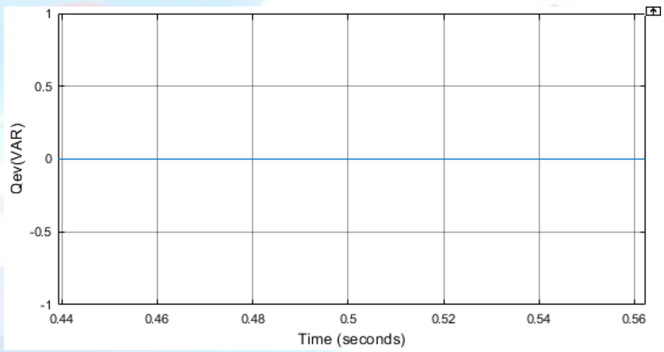

FIGURE.9: Reactive power output of EV charger in G2V condition

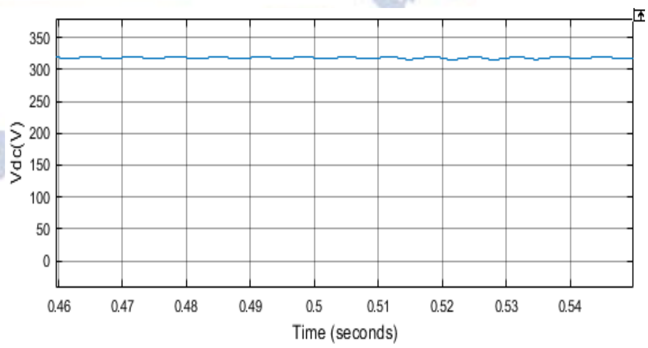

FIGURE.10: DC link output voltage of EV charger in G2V condition

4. CONCLUSION

This paper presents an effective controller method that considers into description G2V and V2G modes, as healthy as compensation of reactive power, and includes EVs as an active system that may supply and feed the energy with storage advancement. For safety reasons, the charger setup includes galvanic separation at the operator area. The devised control procedure performs adequately in various operational conditions, and the approaches of process are healthy implemented when the power instruction is sent. The design offers excellent steady and transient presentation. In lesser than two grid cycles, the off-board charger works to the power signal variation. The battery system is unaffected by reactive power value, which extends life of the battery. The results satisfactorily recommends the suggested controller operation throughout various power signal operations. The results demonstrate that the proposed charger is a good contender for reactive power support amenities to be used by the grid system.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

REFERENCES

[1] Hemavathi, S., and A. Shinisha. "A study on trends and developments in electric vehicle charging technologies." Journal of energy storage 52 (2022): 105013.

[2] Awadallah, Mohamed A., Birendra N. Singh, and Bala Venkatesh. "Impact of EV charger load on distribution network capacity: A case study in Toronto." Canadian Journal of Electrical and Computer Engineering 39, no. 4 (2016): 268-273.

[3] Chen, Tianjin, Xiao-Ping Zhang, Jianji Wang, Jianing Li, Cong Wu, Mingzhu Hu, and Huiping Bian. "A review on electric vehicle charging infrastructure development in the UK." Journal of Modern Power Systems and Clean Energy 8, no. 2 (2020): 193-205.

[4] Ahmad, Aqueel, Zeeshan Ahmad Khan, Mohammad Saad Alam, and Siddique Khateeb. "A review of the electric vehicle charging techniques, standards, progression and evolution of EV technologies in Germany." Smart Science 6, no. 1 (2018): 36-53.

[5] Mouli, Gautham Ram Chandra, Jos Schijffelen, Mike van den Heuvel, Menno Kardolus, and Pavol Bauer. "A 10 kW solar-powered bidirectional EV charger compatible with chademo and COMBO." IEEE transactions on Power electronics 34, no. 2 (2018): 1082-1098.

[6] B. K. Santhoshi, K. M. Sundaram, A. Hussain, P. Sanjeevikumar, J. B. Holm-Nielsen, and V. K. Kaliappan, "Deep Learning for Fault Diagnostics in Bearings, Insulators, PV Panels, Power Lines, and Electric Vehicle Applications—The State-of-the-Art Approaches," in IEEE Access, vol. 9, pp. 41246-41260, 2021

[7] Falvo, Maria Carmen, Danilo Sbordone, I. Safak Bayram, and Michael Devetsikiotis. "EV charging stations and modes: International standards." In 2014 international symposium on power electronics, electrical drives, automation and motion, pp. 1134-1139. IEEE, 2014.

[8] Verma, Anjeet, Bhim Singh, Ambrish Chandra, and Kamal Al-Haddad. "An implementation of solar PV array based multifunctional EV charger." IEEE Transactions on Industry Applications 56, no. 4 (2020): 4166-4178.

[9] Xiao, Yang, Chunhua Liu, and Feng Yu. "An integrated on-board EV charger with safe charging operation for three-phase IPM motor." IEEE Transactions on Industrial Electronics 66, no. 10 (2018): 7551-7560.

[10] Restrepo, Mauricio, Jordan Morris, Mehrdad Kazerani, and Claudio A. Canizares. "Modeling and testing of a bidirectional smart charger for distribution system EV integration." IEEE Transactions on Smart Grid 9, no. 1 (2016): 152-162.

[11] Gan, Lingwen, Ufuk Topcu, and Steven H. Low. "Optimal decentralized protocol for electric vehicle charging." IEEE Transactions on Power Systems 28, no. 2 (2012): 940-951.

[12] Santhoshi, B.K., Mohanasundaram, K. & Kumar, L.A. ANN-based dynamic control and energy management of inverter and battery in a grid-tied hybrid renewable power system fed through switched Z-source converter. Electr Eng 103, 2285–2301 (2021).

[13] Lee, Zachary J., Tongxin Li, and Steven H. Low. "ACN-data: Analysis and applications of an open EV charging dataset." In Proceedings of the tenth ACM international conference on future energy systems, pp. 139-149. 2019.

[14] Kwon, Minho, and Sewan Choi. "An electrolytic capacitorless bidirectional EV charger for V2G and V2H applications." IEEE Transactions on Power Electronics 32, no. 9 (2016): 6792-6799.

[15] Kushwaha, Radha, and Bhim Singh. "A power quality improved EV charger with bridgeless Cuk converter." IEEE Transactions on Industry Applications 55, no. 5 (2019): 5190-5203