Journal of Theoretical and Applied Information Technology
28th February 2025. Vol.103. No.4

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

DESIGN AND IMPLEMENTATION OF ELECTRIC VEHICLE CHARGING STATION INTEGRATED WITH DIFFERENT ENERGY SOURCES USING ANFIS CONTROLLER

B. MOHAN[1], M.V. RAMESH[2], MOTURU SESHU[3], P. MUTHU KUMAR[4], MADHU VALAVALA[5]

[1, 2, 3] EEE Department, PVP Siddhartha Institute of Technology, Vijayawada, Andhra Pradesh, India
[4]EEE Department, Savitha School of Engineering, Tiruvallur, Chennai, Tamilnadu, India
[5]EEE Department, Swarnandhra College of Engineering and Technology, Narsapur, Andhra Pradesh, India

[1]mohan.victory1@gmail.com, [2]vrmaddukuri@gmail.com, [3]moturuseshu@gmail.com, [4]muthukumarvlsi@gmail.com, [5]vmadhu.eee@gmail.com

ABSTRACT

This paper uses the multi-mode operation of solar energy, diesel generator (DG) set, grid, and battery-dependent Electric Vehicle Charging Station (EVCS) for uninterruptable charging and continuous power for in-house loads. A single voltage source converter (VSC) helps EVCS to work in standalone mode, Grid-tied Mode (GTM), and DG set-tied Mode (DTM). Also, VSC deals with different issues in managing proper power-sharing for electric vehicles (EVs) from various energy sources. In addition, to obtain maximum power of solar energy, for the control and monitoring frequency and voltage of the alternator, harmonic current reduction of nonlinear load demands, and required reactive power reduction of the proposed scheme ANFIS (Adaptive Neuro-Fuzzy Inference System) controller is presented. EVCS control strategy is designed to take power from solar energy and a battery. If solar energy and battery fails to supply the EVCS, then it receives electrical power from the main grid, and at the end, it consumes energy from a DG set. The DG set develops 33% additional power against its maximum capability without violating the maximum current flowing through its winding thus, the size of the DG set is minimized. In this work, an ANFIS controller is enforced in place of the PI regulator to regulate the voltage and reduce the THD. Proposed controller reduced the Total Harmonic Distortion (THD). Finally, it enhanced the overall system's performance by improving the power quality.

Keywords: *Diesel Generator, Solar Energy, Voltage Source Converter, Electric Vehicle Charging Station, ANFIS Controller*

1. INTRODUCTION

EVs on the road, are accumulating daily, and in 2016, the sum of EVs on the highway, has overlapped the verge of 2 million utilizing above 750 thousand entities traded [1]. It was noticed that 2.3 million electric points were available for EVs up to 2016. EVCS is getting the supply from the grid [2]. To meet the EVs' primary objectives such as minimization of CO_2 emissions, decreasing fossil fuel usage, and enlarging energy security. So, to fulfil the EV objectives and to meet the additional power required to charge EVs there is a need to integrate distributed generation with grid [3]. Even though there are different renewable energy resources, solar energy integrated with CS is preferable [4], [5]. Much work has been done and devoted to developing the CS integrated with non-conventional energy resources. Verma et al. [6], Shariff et al. [7], and Wang et al. [8] have done their work. In much reported literature, the same configuration was mostly adapted to integrate solar energy into the EVCS over a boost converter and MPPT [9]. Eliminating the DC-DC converter increases the efficiency of the EVCS and reduces its dimension and amount. Thus, the boost converter is excluded in this proposed work, and solar energy is integrated into the DC connection. Instead of having the advantage of using solar energy for EV charging, the EVCS working is disturbed by its intermittent nature. Islam et al. [10] have explained the disadvantages of radiation changes in EV charging. Thus, in this work, the EVCS is planned to function in grid-tied and standalone modes as per the convenience of solar energy output and EV charging required. Also, the controller is planned for the continuous mode adjustment among GTM and standalone mode so that the CS habitually and continuously adjusts the mode to decrease the disturbances of radiation changes and to use solar energy extremely.

Also, it was observed that the energy sources of the EVCS, are not properly utilized [11] if EVCS is utilized alone for EV charging. So there is a need to use EVCS for additional works for example vehicle-to-grid (V2G) and to decrease reactive power requirement [12], vehicle-to-home [6], V2V [13], etc. For illustration, Khan et al. [14] combined distributed generation through a smart grid to keep the superiority of voltage and the harmonics of deformation fatalities at the EVCS. Monteiro et al. [13] mentioned various smart grid and household functioning approaches. Many controls and converters are used in the existing works for different modes of function. Moreover, the charger's operation is limited by the grid accessibility (GTM or standalone), and modes of exchanging among functioning approaches (continuous or discontinuous). Since solar energy isn't accessible at night, the EVCS must be supported by the battery. Due to the limited storage capability of batteries and when solar energy, battery, and grid power, aren't available there's a need for a backup power generator for a limited period. Hence, this proposed work implements solar energy, grid energy, battery, and a DG set-dependent EVCS. This integrated charging setup enhances the trustability of the EVCS and minimizes the amount of charging. Wies et al. have shown the gainful investigation and valuation of the ecological effects of solar energy by diesel, battery systems in isolated areas. It was also observed from various studies, that they've committed to the synchronized function of the solar energy, battery, and DG, reducing the handling costs, and CO_2 emissions.

Therefore, the practice of a DG set has increased for supplying an EVCS, which burdens the best usage of the DG set to attain extreme energy effectiveness. Also, it was observed that it will happen only when a DG set is overloaded at 80-85% of its maximum capacity. Hence, to guarantee the constant overloading of the maximum capability, a power supervision approach is needed. Thirugnanam et al. [11] have specified the power supervision approach of solar energy, a DG, and a battery integrated with a Microgrid. The power supervision approach is substantially focused on minimizing the number of hours of DG usage using a battery. P. Muthu Kumar et al. [21] have worked on the best methods to develop hierarchical energy integration with multiple energy resources and emphasize the heuristic technique.

The selection of the core concerns in this research is driven by the need to enhance the performance, sustainability, and reliability of EVCS. The growing demand for EV infrastructure, combined with the desire to reduce reliance on non-renewable energy sources, necessitates the development of more intelligent, flexible, and cost-efficient systems. The integration of renewable energy, advanced power quality management, and intelligent energy control ensures that this proposed EVCS meets present-day needs and addresses future challenges in the growing EV ecosystem.

The important points of this proposed work are as follows.

- The EVCS is planned to operate in multiple modes, such as the GTM, standalone, and DGM, using VSC to charge the EVs and deliver uninterrupted power as per the load demand. The coordination controller is planned mainly to utilize solar energy and battery power to charge the EVs. If, in case solar energy and batteries are not able to supply the power it shifts to GTM and draws minimum power. Moreover, if GTM also fails, then the DG set supplies electrical power to the EVCS.
- Solar energy is set to continuously supply maximum power that is attained through VSC and bi-directional DC-DC converter in standalone mode and GTM / DGM.
- In the standalone approach, VSC performs as an inverter and induces the standard voltage for powering the EVs and supplying the load demands utilizing solar energy and battery. In GTM, the regulated energy by the main grid is switched to a unity power factor for worthy energy superiority. In DGM, it controls the frequency and voltage of the DG set deprived of a motorized governor and balances the harmonic current required by EVs and nonlinear demands. Also, in GTM and DGM the maximum power is extracted from solar energy.
- Depending on the accessibility of various energy sources, for EV charging, and to meet load, the united controller selects the action approaches and executes selected tasks. It also confirms the continuous approach for alteration to get uninterrupted charging of EVs.
- The EVCS offers harmonics reduction and reactive power backing to increase its utilization effectiveness. In addition, the EVCS cares for the local energy demands and sends the energy to the solar and battery energy to the main grid.
- EVCS progresses the energy superiority of the main grid's voltage and current keeping the THD specified limits. In standalone mode, the produced

voltage also maintains the standard limits.
• When serving energy to power the EVs, the DG set is overloaded up to 80% capacity for extreme energy effectiveness. The DG set develops 33% more energy than the generator's maximum. Here, the VSC delivers the harmonic current required for the nonlinear load and EVs, and the DG set supplies the required active power.
• The main grid accompanies the standalone system or DG set using the VSC stranded management method for a smooth change.

When compared to prior literature, this work stands out by effectively addressing several critical objectives in the EVCS domain, which have been under-explored or inadequately solved in earlier research such as providing continuous power supply with minimal grid dependency, optimizing power quality in the presence of nonlinear loads, maximizing energy efficiency with dg integration, achieving smooth transition between energy sources.

The increasing demand for EVs has led to the establishment of EVCS as a crucial infrastructure element. However, current EVCS systems are often limited by the reliance on grid power, which can lead to issues of inefficiency, energy shortages, and interruptions in the charging process. A sustainable solution involves integrating renewable energy sources like solar power and backup systems such as batteries and DG to ensure uninterrupted EV charging and enhance grid stability. Despite the promising advantages, the optimal coordination of these energy sources and power quality management within an EVCS remains a complex challenge. In particular, ensuring efficient energy usage, maintaining power quality THD, and minimizing dependency on the main grid are crucial yet underexplored aspects.

This research aims to explore the design and implementation of a multi-mode EVCS that effectively coordinates renewable energy, battery storage, the main grid, and DG sets for optimal power delivery to EVs while maintaining power quality standards. Specifically, it will focus on the development of a coordination controller that seamlessly switches between modes, utilizing solar energy as the primary source while ensuring grid stability and continuous power delivery.

The proposed work is planned as follows section I describes the significance of the objectives considered, section II illustrates the proposed configuration, section III materials, and method used Section IV explains results obtained in different cases, and Section V concludes the paper.

2. BLOCK DIAGRAM

Figure 1 represents the configuration of CS consisting of two-leg VSC, used to convert AC to DC and DC to AC depending on the requirement. BDC is linked to the DC tie of the VSC to connect a battery. To eliminate the requirement of a DC-DC converter, solar energy is associated with the DC tie of VSC. A diode is linked to avoid the reverse power flow in solar energy flow. The grid, SEIG, a nonlinear load, and two EVs are associated at the PCC of CS. An inductor is utilized to join the EVs, SEIG, grid, and load to VSC. A filter is linked at the PCC to suppress switching harmonics from the DG and grid. The supplementary winding of SEIG is linked with an excitation capacitor, and a capacitor is linked through the main winding of SEIG for voltage maintenance.

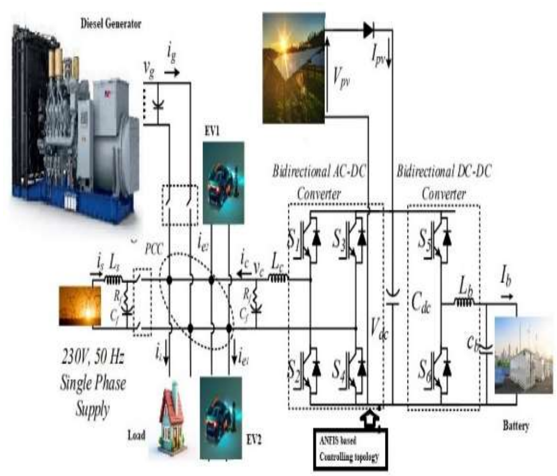

Figure 1: Block diagram of integrated CS with various energy sources.

3. MATERIAL AND METHODS

In this section control modes and control methodology are discussed.

3.1 Control Methods:

EVCS is designed for the charging of EVs by utilizing a maximum of solar energy and delivering uninterruptable energy to connected demands. Thus, its regulator is planned to function EVCS in standalone, GTM, and DG set mode. In standalone mode, solar energy and battery power are used for EVCS. Moreover, EVCS generates a standard voltage (V_C) of 230V and 50 Hz frequency. The reference standard voltage (V_C*) is checked with the verified PCC voltage (V_C), and the error voltage (V_{ce}) is given as input to the ANFIS controller. The main grid and DG set connected approaches and VSC are used to create the DG current (I_g) or main grid current (I_s) standard indeed although total current (I_L, I_{e1}, I_{e2}) is non-sinusoidal.

The basic structure of ANFIS is shown in Figure 5. ANFIS controller is a mixture of fuzzy logic and neural networks. A neural network takes many inputs and gives standard results depending upon the inputs and results obtained neural network is guided, after guiding the neural network the result is provided as input to the fuzzy logic then it produces the IF THEN instructions and membership functions. Input-1, input-2, and output of the ANFIS supervisor are demonstrated in Figures 2, 3, and 4 correspondingly.

3.2 ANFIS CONTROL MODEL:

The basic structure of ANFIS is shown in Figure 5. ANFIS controller is a mixture of fuzzy logic and neural networks. A neural network takes many inputs and gives standard results depending upon the inputs and results obtained neural network is guided, after guiding the neural network the result is provided as input to the fuzzy logic then it produces the IF THEN instructions and membership functions. Input-1, input-2, and output of the ANFIS supervisor are demonstrated in Figures 2, 3, and 4 correspondingly.

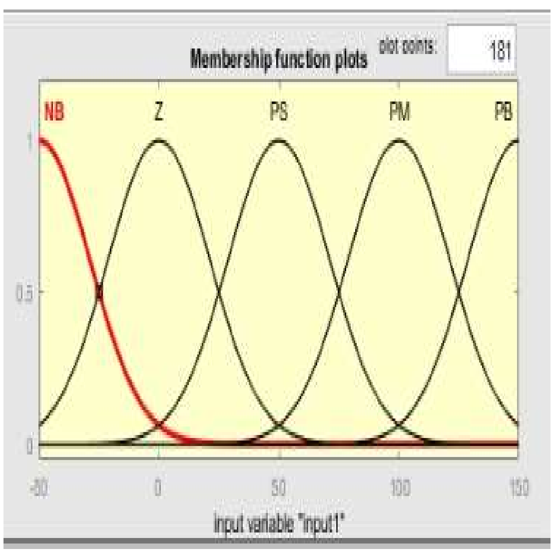

Figure 2: Input-1 for ANFIS-based supervisor.

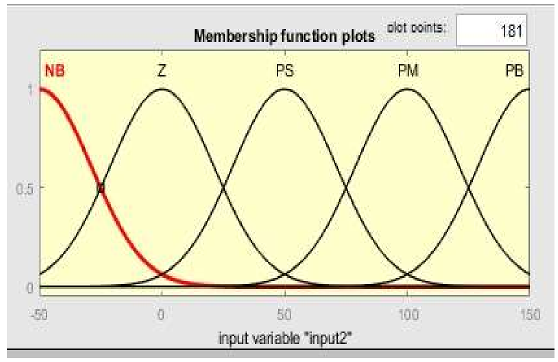

Figure 3: Input-2 for ANFIS-based supervisor.

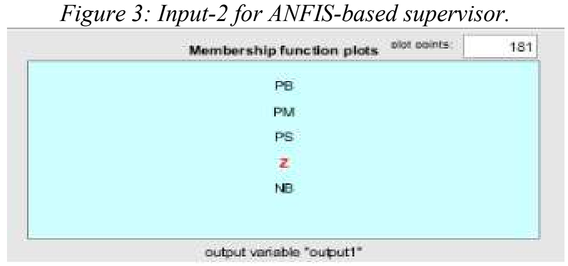

Figure 4: Output for ANFIS-based controller.

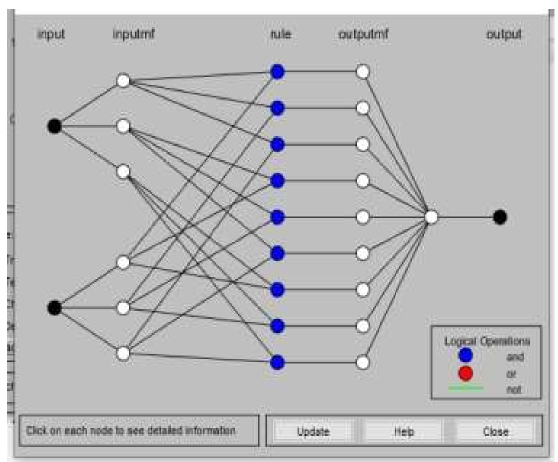

Figure. 5: Structure of ANFIS.

4. SIMULATION RESULTS

This section describes the results obtained when constant solar irradiation and when there is variation in irradiation

Journal of Theoretical and Applied Information Technology
28th February 2025. Vol.103. No.4

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

4.1 When Constant Radiation is Present:

4.1.1. When DG Set Supplies EV

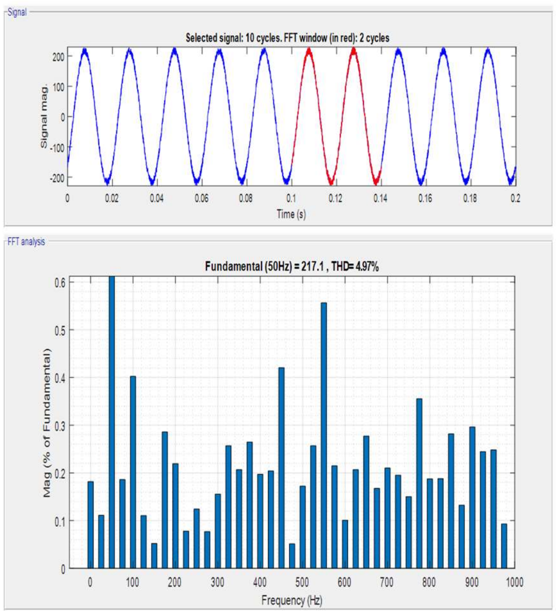

Figure 6: THD of DG Set Voltage V_g

Figures illustrate the CS performance when EV, battery, and non-linear loads are provided by the DG set. This case arises when solar and grid power aren't accessible and the battery is discharged.

It was observed that the 3.7 kW rated DG set developed 1.1 kW extra power by maintaining the maximum DG current (I_g) 24A even though it is supplying the nonlinear loads.

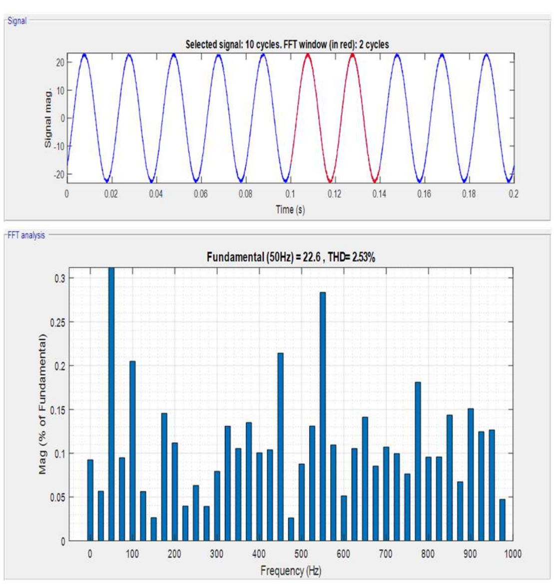

Figure. 7: THD of DG Set Current I_g

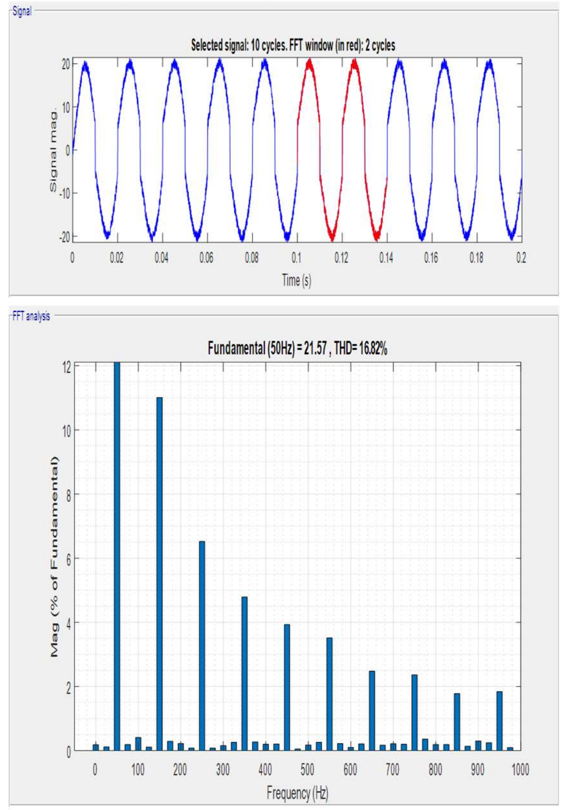

Figure. 8: THD of Sum of Load Current, EV_1 Current, EV_2 Current ($I_L + I_{ev1} + I_{ev2}$)

As represented in Figure 6 voltage is 217.1V and Figure 7 shows a current of 22.6A, the Ig, Vg, and THDs are between 2.3% and 5%.

4.25 kW of power was used for EVs and nonlinear loads linked at PCC from a total of 4.8 kW. Figures 8, and 9 represent the power, voltage (V_c) 230V, current (I_l, I_{e1}, I_{e2}), and THD of total current consumed by the load (21.57A) and EVs. The leftover energy is served to the battery as represented by the voltage (V_b), current (I_b), and power in Figures. The voltage (V_c), current (I_c), and power of VSC. Figures show the voltage (V_a), current (I_a), and control of the supplementary winding of DG.

4.1.2. Solar Panel Supplying the Load

The performance of the solar panels when supplying the load, charging EVs, and the battery are discussed in this section.

The figure illustrates the performance of solar energy when it supplies the load, battery, and EVs. In the daytime, when solar power is accessible, the EVCS uses solar energy to provide the power

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

demand and charge the EV and battery. Also in this case it was observed that CS produces the standard voltage (V_c) of 230V and frequency 50Hz at PCC. By using the MPPT algorithm, the maximum power obtained from solar panels is 3.45 kW. The solar panel voltage (V_{pv}) and current (I_{pv}) are represented in the above figures. As the total supply required at PCC is only 2.82 kW, the remaining energy is sent to power the battery. The battery voltage (V_b), current (I_b), and power are represented in Figures representing the THDs of produced voltage at PCC (V_c) and total current (I_l, I_{e1}, I_{e2}). The voltage (V_C), current (I_{e1}, I_{e2}), and power of both EVs allied at the PCC of the CS.

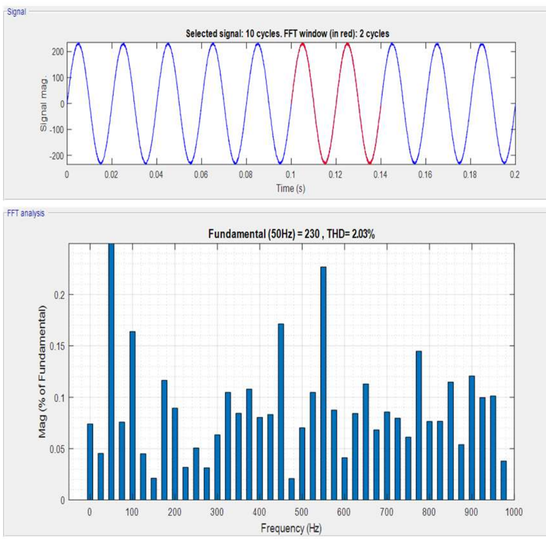

Figure. 9: THD of PCC Voltage (V_c).

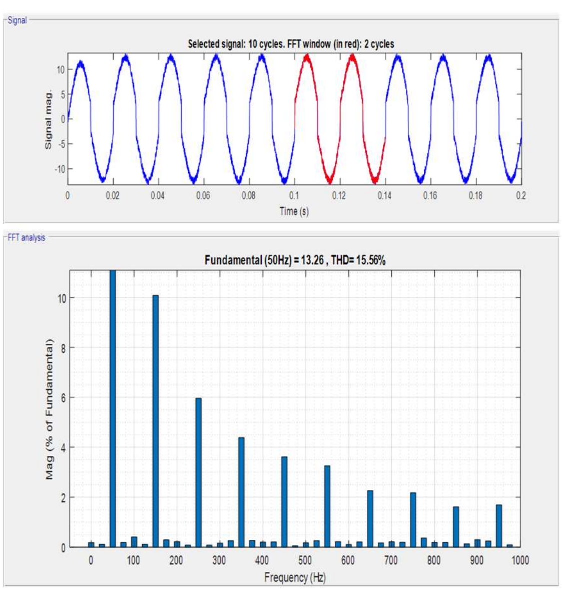

Figure. 10: THD of PCC Current I_c

4.1.3 Grid-Tied Operation

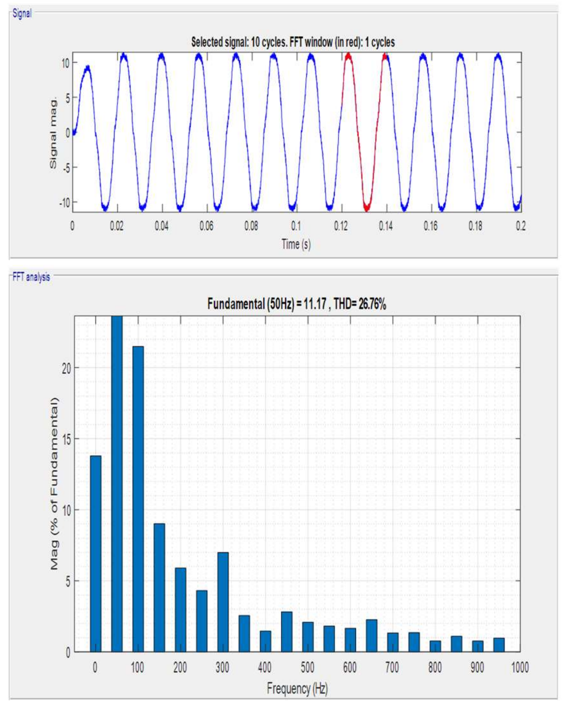

Figure. 11: Harmonic spectra of Load Voltage V_L.

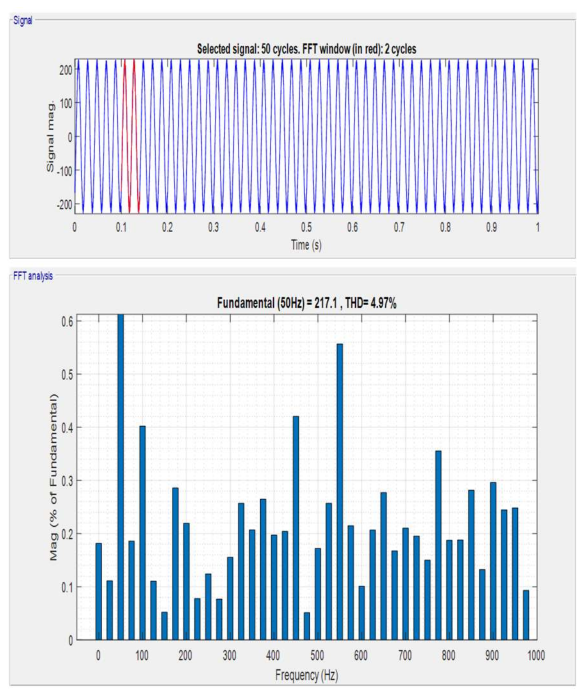

Figure. 12: Harmonic spectra of DG-Set Voltage V_g.

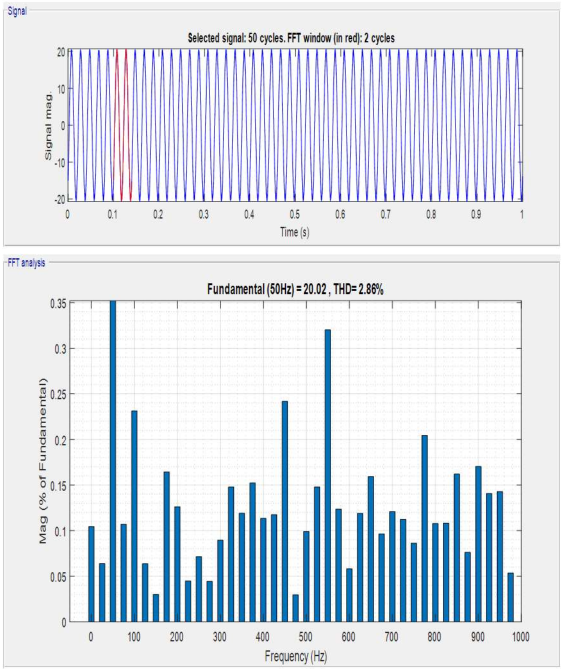

Figure. 13: Harmonic spectra of DG-Set Current I_g

In GTM, the grid's power factor is unity which enhances the quality of power through the load, and EVs interconnected at PCC receive non-sinusoidal current. The harmonic currents required for the EV and nonlinear loads are powered by VSC. The THDs of grid current (I_s) and voltage (V_s) are 2.1%, and 4.3% respectively, and for load current (I_l) 21.8%.

4.1.4 When Solar Radiation Varies

The figure illustrates the dynamic demonstration of the CS in standalone mode, the performance of the solar energy under solar radiation variation, the VSC current (I_c) also varies when there is a change in nonlinear load but there is no variation observed in the EV_1 charging current (I_{ev1}) and DC link voltage (V_{dc}).

4.2 THDs Related to ANFIS Controller:

Figure. 17 describes the grid voltage and grid current THD of load changing mode obtained in the ANFIS Controller-based system.

Figures. 18, 19 describes the grid voltage and grid current THD of grid-connected mode obtained in an ANFIS controller-based system. The above Figures. 20, 21 describes the grid voltage and grid current THD of DG Set connected mode obtained in the ANFIS Controller-based system.

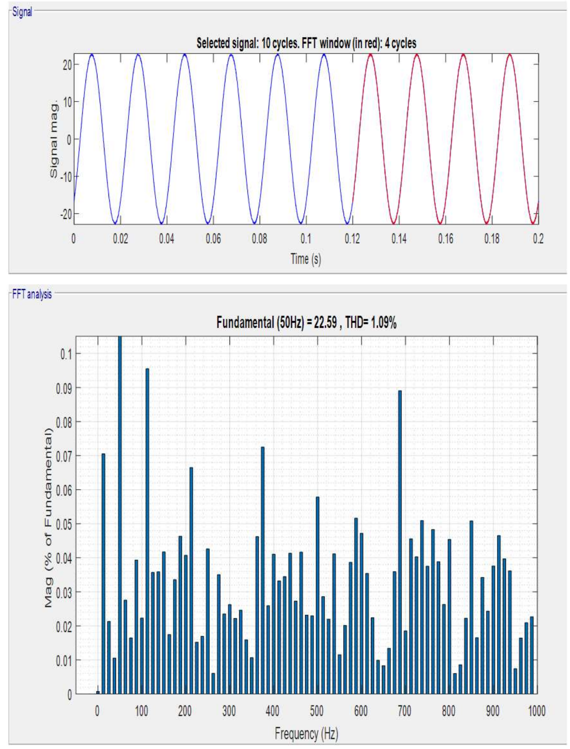

Figure. 14 THD of DG-Set Current I_g with ANFIS controller.

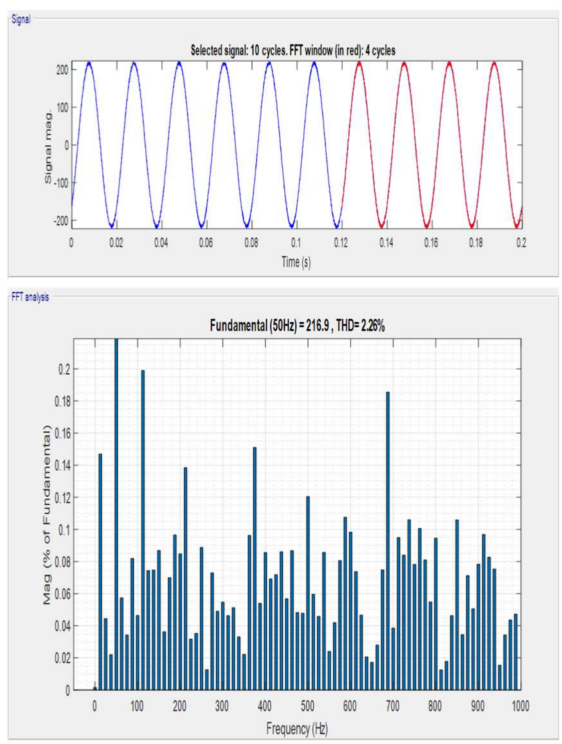

Figure. 15: THD of DG-Set Voltage V_g with ANFIS controller.

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

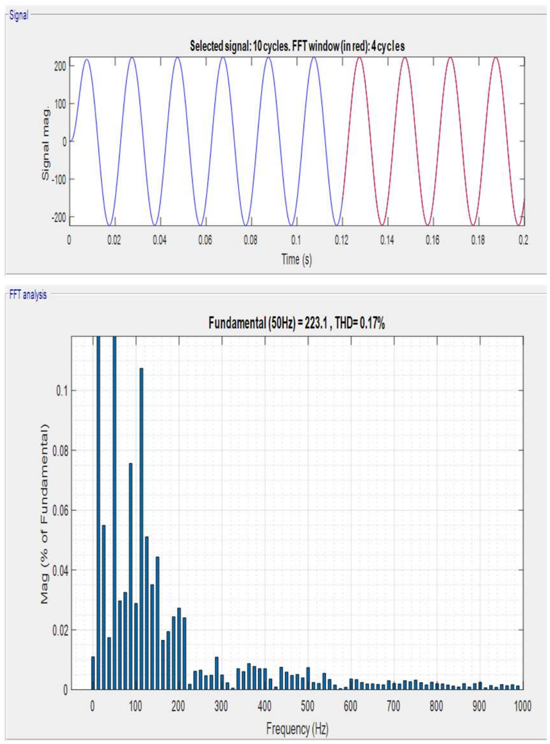

Figure. 16: THD of Point of Common Coupling Voltage V_c with ANFIS controller.

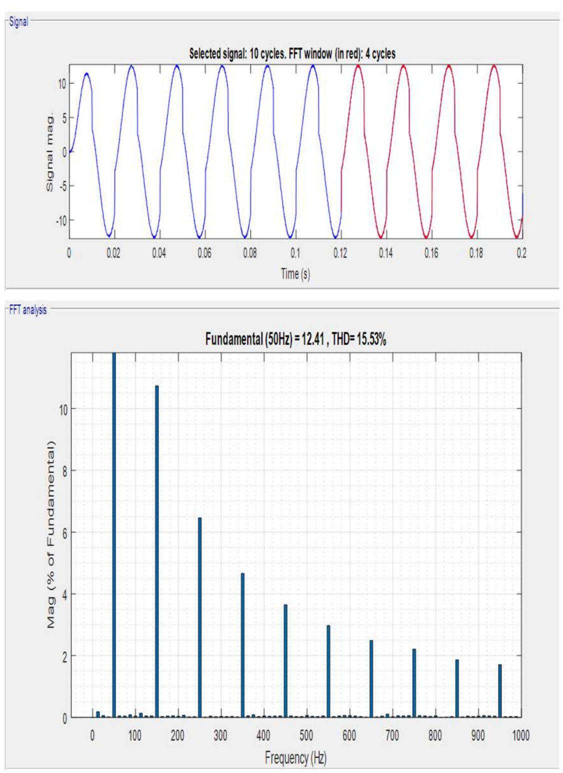

Figure. 17: THD of the sum of Load, EV_1, and EV_2 Current I_{sum} with ANFIS controller.

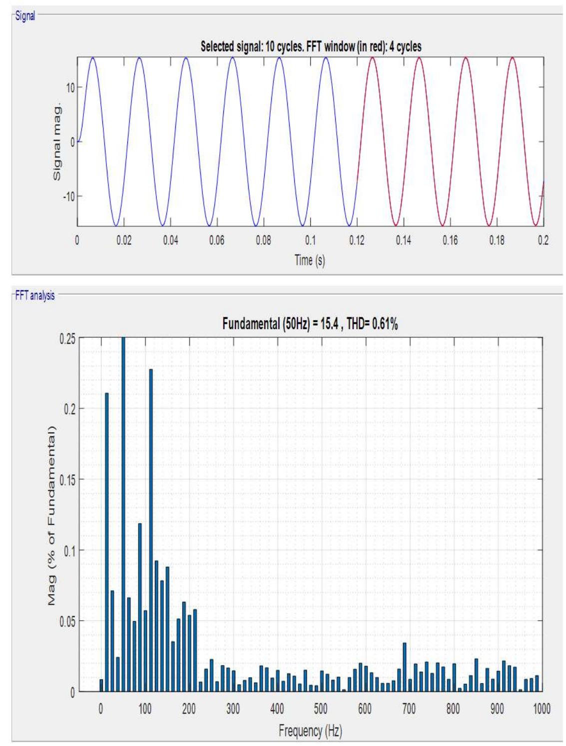

Figure. 18 THD of Grid Current I_s with ANFIS controller.

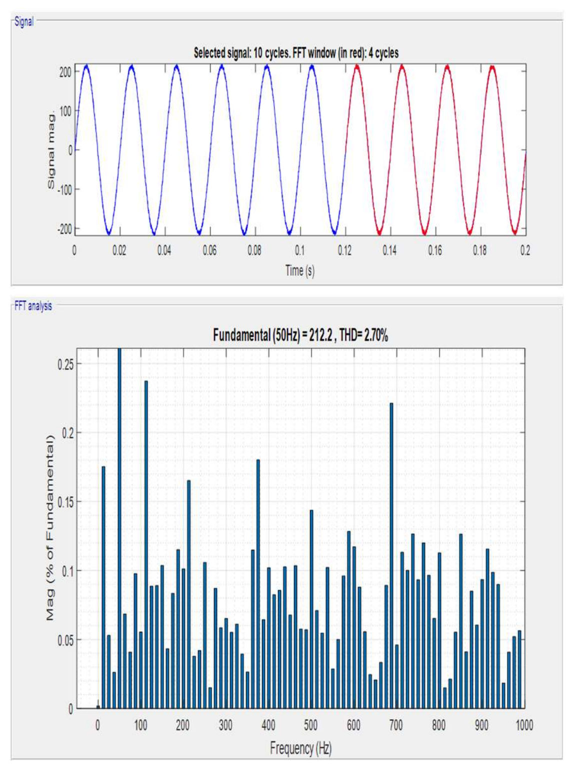

Figure. 19 THD of Grid Voltage V_s with ANFIS controller.

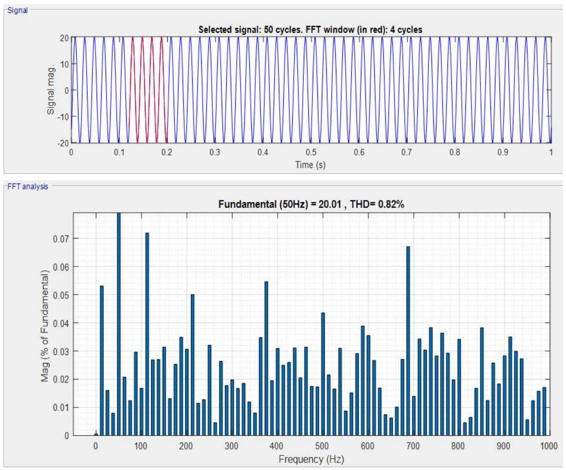

Figure. 20 THD of DG Set Current I_g with ANFIS controller.

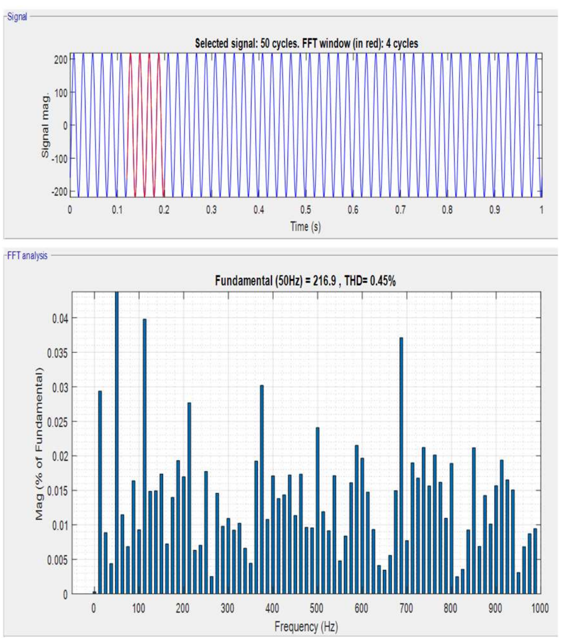

Figure. 21 THD of DG Set Voltage V_g with ANFIS controller.

4.3 Comparison of THDs:

This study primarily focuses on comparing THD reduction. The ANFIS Controller-based system demonstrates notably lower harmonic distortion levels than the PI-based system, underscoring the ANFIS controller's superior ability to reduce harmonics. Consequently, this emphasizes the ANFIS controller's effectiveness in improving power quality.

Table 1. Comparison of THDs.

Parameter	Using PI Controller	Using ANFIS Controller
DG set performance of I_g	2.53	1.09
DG set performance of V_g	4.97	2.26
Voltage obtaining at Point of Common Coupling V_c	2.03	0.15
Sum of Load Current, EV_1 Current, EV_2 Current (I_l+I_{ev1}+I_{ev2})	15.6	15.57
Load Current I_l	26.76	26.26
Grid Current I_s	1.67	0.62
Grid Voltage V_s	4.63	2.78
DG-Set Current I_g under solar irradiance change	2.86	0.87
DG-Set Voltage V_g under solar irradiance change	4.98	0.45

While the proposed multi-mode EVCS system demonstrates a promising approach to addressing key challenges in EV charging infrastructure—such as power intermittency, grid dependency, and power quality—the limitations outlined above must be carefully considered in the context of real-world application. The complexity of coordination, environmental concerns related to DG use, high initial costs, scalability challenges, and battery management issues represent key obstacles that may limit the universal adoption of the system. However, these limitations do not diminish the significant contributions this work makes to the development of more sustainable and efficient EV charging stations. Future work should focus on addressing these limitations through further optimization of control algorithms, advancements in renewable energy technology, and the exploration of alternative backup power solutions, ultimately creating a more resilient and scalable EVCS model.

The proposed work offers significant advantages over prior research by providing a holistic solution for EVCS that addresses the challenges of maintaining power quality, optimizing energy use, and ensuring continuous operation across various modes. The integration of solar, battery storage, grid, and DG systems under a unified control mechanism ensures the reliability and sustainability of EV charging infrastructure. However, the complexity of managing multiple energy sources, the reliance on DG sets, and the higher implementation cost are potential limitations that need to be carefully considered in future work. By improving the coordination strategies and exploring more sustainable backup options, this research contributes to advancing the field of EVCS in both technical and practical terms.

While prior work has addressed various aspects of renewable energy integration, power quality, and backup systems in isolation, this research takes a significant step forward by synthesizing these elements into a cohesive, adaptive system tailored specifically for EVCS. The ability to switch between multiple energy modes based on real-time availability, as well as the optimization of Diesel Generator operation, ensures that the system is both energy-efficient and cost-effective, ultimately reducing dependency on the main grid.

However, the proposed system is not without its challenges. The complexity of coordination, the reliance on Diesel Generators as a backup, and the initial cost of implementation are notable limitations. These must be carefully weighed against the long-term benefits of reduced grid dependency, improved power quality, and enhanced system resilience. Despite these challenges, the research provides compelling evidence that such a system is not only viable but necessary for the sustainable development of EV charging infrastructure.

This work supports the notion that for EVCS to meet the growing demand for electric vehicles and contribute to the global shift toward sustainability, a more sophisticated, multi-mode approach is required. By addressing key issues such as energy efficiency, power quality, and system reliability, the proposed system paves the way for future EVCS designs that can effectively balance renewable energy utilization, grid stability, and operational efficiency. The solutions offered here will be critical in advancing the EV charging ecosystem, ensuring its role in a sustainable and electrified future.

While the proposed multi-mode EVCS system demonstrates a promising approach to addressing key challenges in EV charging infrastructure such as power intermittency, grid dependency, and power quality the limitations outlined above must be carefully considered in the context of real-world application. The complexity of coordination, environmental concerns related to DG use, high initial costs, scalability challenges, and battery management issues represent key obstacles that may limit the universal adoption of the system. However, these limitations do not diminish the significant contributions this work makes to the development of more sustainable and efficient EV charging stations. Future work should focus on addressing these limitations through further optimization of control algorithms, advancements in renewable energy technology, and the exploration of alternative backup power solutions, ultimately creating a more resilient and scalable EVCS model.

5. CONCLUSION

In this proposed work the performance of EVCS with multimode functioning is described. Experiments have been conducted to validate the results, at PCC it was observed that standalone mode induced the sinusoidal voltage to charge the EVs properly. The ability of the controller is tested for the extraction of maximum power from solar energy at variable solar irradiance, under EV charging, and variable load conditions. It was also observed that even though there is a step variation in solar irradiance level, unexpected connection/disconnection of EVs doesn't disturb the charging of other EVs and control. Here in this paper considered DG set generates additional power than its actual power without violating the limits of the current passing through windings of the DG. The existing PI controller in the controlling topology has high harmonic distortions and a slow speed of time response to the system. So, to overcome these issues, a new controlling topology, ANFIS, is used in this work. It's a combination of both Fuzzy and Neural Network topology. Also, important parameters of DG are regulated such as voltage and frequency. VSC's significant role in performing the proposed work's multi-functionality has been discussed. Simulation was done for both cases standard and dynamic state outputs have shown the effectiveness of the proposed scheme.

REFERENCES

[1] International Energy Agency-Global EV Outlook 2017-Two Million and Counting. [Online]. https://www.iea.org/publications/freepublications/publication/GlobalEVOutlook2017.pdf

[2] International Energy Agency-World Energy Outlook 2017 [Online]. Available: https://www.iea.org/weo2017/

[3] X. Lu and J. Wang, "A Game Changer: Electrifying Remote Communities by Using Isolated Microgrids," IEEE Electrification Magazine, vol. 5, no. 2, pp. 56-63, June 2017.

[4] M. P. Kazmierkowski, "Solar Powered Charging Infrastructure for Electrical Vehicles: A Sustainable Development [Book News]," IEEE Ind. Electron. Magazine, vol. 11, no. 2, pp. 72-73, June 2017.
[5] National Renewable Energy Agency-Distributed Solar Photo Voltaics For Electric Vehicle Charging [Online] Available: https://www.nrel.gov/docs/fy14osti/62366.pdf
[6] A. Verma and B. Singh, "Solar PV Array-WECS Based Integrated EV Charging System with Dual Mode of Operation," in IEEE 8th Power India Int. Conf. (PIICON), Kurukshetra, India, pp. 1-6,2018.
[7] S. M. Shariff, M. S. Alam, F. Ahmad, Y. Rafat, M. S. J. Asghar, and S. Khan, "System Design and Realization of a Solar-Powered Electric Vehicle Charging Station," IEEE Systems Journal, Early Access.
[8] B. Wang, X. Zhang, U. Manandhar, H. B. Gooi, Y. Liu and X. Tan, "Bidirectional Three-Level Cascaded Converter with Deadbeat Control for HESS in Solar-Assisted Electric Vehicles," IEEE Trans. Transportation Electrification., Early Access.
[9] V. Monteiro, J. G. Pinto and J. L. Afonso, "Experimental Validation of a Three-Port Integrated Topology to Interface Electric Vehicles and Renewables With the Electrical Grid," IEEE Trans. Ind. Informat., vol. 14, no. 6, pp. 2364-2374, June 2018.
[10] M. S. Islam, N. Mithulananthan and K. Y. Lee, "Suitability of PV and Battery Storage in EV Charging at Business Premises," IEEE Trans. Power Systems, vol. 33, no. 4, pp. 4382-4396, July 2018.
[11] A. Verma and B. Singh, "Energy Management Strategy of Solar PV Battery and Diesel Generator Based Electric Vehicle Charging Station," in IEEE Energy Convers. Cong. and Expo. (ECCE), Portland, OR, 2018, pp. 1043-1050.
[12] H. N. de Melo, J. P. F. Trovão, P. G. Pereirinha, H. M. Jorge and C. H. Antunes, "A Controllable Bidirectional Battery Charger for Electric Vehicles with Vehicle-to-Grid Capability," IEEE Trans. Vehicular Technology, vol. 67, no. 1, pp. 114-123, Jan. 2018.
[13] V. Monteiro, J. G. Pinto and J. L. Afonso, "Operation Modes for the Electric Vehicle in Smart Grids and Smart Homes: Present and Proposed Modes," IEEE Trans. Veh. Techno, vol. 65, no. 3, pp. 1007-1020, 2016.
[14] A. Khan, S. Memon and T. P. Sattar, "Analyzing Integrated Renewable Energy and Smart-Grid Systems to Improve Voltage Quality and Harmonic Distortion Losses at Electric-Vehicle Charging Stations," in IEEE Access, vol. 6, pp. 26404-26415, 2018.
[15] H. Kikusato et al., "Electric Vehicle Charge–Discharge Management for Utilization of Photovoltaic by Coordination Between Home and Grid Energy Management Systems," IEEE Trans. Smart Grid, vol. 10, no. 3, pp. 3186-3197, May 2019.
[16] M. Kwon and S. Choi, "Control Scheme for Autonomous and Smooth Mode Switching of Bidirectional DC-DC Converters in a DC Microgrid," IEEE Trans. Power Electron, vol. 33, no. 8, pp. 7094-7104, Aug. 2018.
[17] N. Saxena, I. Hussain, B. Singh, and A. L. Vyas, "Implementation of a Grid-Integrated PV-Battery System for Residential and Electrical Vehicle Applications," IEEE Trans. Industrial Electronics, vol. 65, no. 8, pp. 6592-6601, Aug. 2018.
[18] K. Chaudhari, A. Ukil, K. N. Kumar, U. Manandhar and S. K. Kollimalla, "Hybrid Optimization for Economic Deployment of ESS in PV-Integrated EV Charging Stations," IEEE Trans. Ind. Inform., vol. 14, no. 1, pp. 106- 116, Jan. 2018.
[19] S. A. Singh, G. Carli, N. A. Azeez and S. S. Williamson, "Modeling, Design, Control, and Implementation of a Modified Z-Source Integrated PV/Grid/EV DC Charger/Inverter," IEEE Trans. Industrial Electronics, vol. 65, no. 6, pp. 5213-5220, June 2018.
[20] M. Restrepo, J. Morris, M. Kazerani and C. A. Cañizares, "Modeling and Testing of a Bidirectional Smart Charger for Distribution System EV Integration", IEEE Trans. Smart Grid, vol. 9, no. 1, pp. 152-162, 2018.
[21] V. Sai Getha Lakshmi, M.devika Rani, P. Muthu Kumar "An Optimized Approach for The Development of Hierarchical Energy Integration with Multiple Energy Resources and Emphasizing the Heuristic Techniques", Journal of Theoretical and Applied Information Technology, vol. 101, no.9, pp. 3371–3379, May 2023.
[22] B. Mohan, M.V. Ramesh, P. Muthu Kumar, Rajan. Vr, "Charging Station for Electric Vehicle Using Hybrid Sources", Journal of Theoretical and Applied Information Technology, Vol.101, No. 7, pp. 2547-2560, April 2023.