Industrial Engineering Journal
ISSN: 0970-2555
Volume : 52, Issue 4, May : 2023

Efficient and Intelligent Energy Management for Electric Vehicles: On-Board Converter Integration of Solar PV and Grid Power with Neural Network Controller

K.Sailaja, Vempalle Rafi,B.Sai Vignesh,M.Keerthi,Y.Bhavya deepthi, C. Jayasree, B. Poornima, P.Phanindra sai
Department of Electrical and Electronics Engineering,
JNTUA College of Engineering Pulivendula, Kadapa, India.
Corres mail: vempallerafi@gmail.com

Abstract
This project proposes a novel solution for energy management in electric vehicles (EVs) using an on-board converter that integrates solar photovoltaic (PV) and grid power with a neural network (NN) controller. The proposed system optimizes the utilization of available energy sources while ensuring the vehicle's energy demands are met.The developed configuration accomplished all modes of vehicles (charging, propulsion (PP) and regenerative braking (RB)). The proposed power electronic converter works simultaneously using both grid and solar pvi.e it can charge the battery by both grid and solar pv system simultaneously. Battery can also be charged through regenerative braking (RB) operation. The proposed converter operates as an isolated SEPIC in plug-in charging (PIC) mode and as a non-isolated SEPIC in solar PV charging mode. Further, in PP and RB modes, operation of the proposed PEC as a conventional boost converter and conventional buck converter, respectively.The performance of the proposed method evaluated results using MATLAB/Simulink software.

Keywords: Electric vehicles, On-board charger, SEPIC converter, Neural Network Controller

I. Introduction

The non-stop depletion of fossil fuels and growing environmental issues led to analyse in pollutants-free electric powered vehicles (EVs) or plug-in EVs (PEVs) the world over. The primary additives of an EV are charging device, battery management gadget (BMS) and inverter force gadget. For complete commercialisation of EVs in market, the battery charging mechanism and development of battery era are nonetheless challenges for vehicle producers. As we realize that electric automobiles are increasing day by day and charging the battery is an important factor in electric motors. So electric powered car charging creates an impact on voltage unbalance in a city disbursed community and additionally generation of energy is particularly dominated by using fossil fuels. So, to make electric vehicles sustainable we should use renewable energy sources like solar, wind etc. The use of solar for charging the battery isn't always dependable as solar energy varies consistent with climatic situations. So, to conquer these problems proposed device integrates both solar pv and grid for charging the battery. so integration of both solar pv and grid reduces dependency on fossil fuels as well as reduces impact on voltage unbalance in distribution network.

The battery chargers for electric vehicles (EVs) are commonly referred to as off-board chargers and on-board chargers [1]. In an off-board charging device, the charger is located at a charging station outside the car's premises and offers a dc output that is connected directly to the battery. Because this type of charger isn't always responsible for the weight of the car, its weight is extremely excessive. It may thus be rated for excessive power, which allows the EV battery to be charged in a matter of minutes. But the cost is a barrier to the advancement of these chargers. As a result, there is a limited selection of these chargers, and they might not be widely available. The battery in on-board chargers may receive direct ac power charging which could be easily found anywhere. This type of charger may be used everywhere and does not require expensive infrastructure, which is a clear advantage.

Due to the fact that EVs and PEVs may be charged anywhere, on-board chargers are more common in these vehicles. The on-board charger, however, is confined in terms of size and space because it is housed inside the vehicle.

II. Literature

Single-stage chargers and two-stage chargers are additional categories for on-board chargers. Additionally, multiple components are used in two-stage chargers [3]–[5], making them unattractive for on-board charging system implementation. A single-stage charging system is more appealing for EV on-board applications since it uses fewer components than a two-stage charging system. For power flow during the PP and RB modes, a bidirectional DC-DC converter is connected between the DC-link of the inverter and the battery in a traditional single-stage charging system [6]. Researchers in power electronics have suggested integrated chargers as a way to do away with the bidirectional DC-DC converter used in single-stage charging systems [6] through [10]. The traditional single-stage bidirectional DC-DC converter of the integrated charger is linked to the battery and the DC-link at the expense of few more switches, is combined with front-end converter. Comparing the whole integrated system to a single-stage charging method, fewer components make up the overall system.

O. C. Onar, J. Kobayashi, D. C. Erb, and A. Khalighv This paper primarily focuses on two major thrust areas of PHEVs. First, it introduces a grid-friendly bidirectional alternating current/direct current ac/dc–dc/ac rectifier/inverter for facilitating vehicle-to-grid (V2G) integration of PHEVs. Second, it presents an integrated bidirectional non inverted buck–boost converter that interfaces the energy storage device of the PHEV to the and driving modes. The proposed bidirectional converter has minimal grid-level disruptions in terms of power factor and total harmonic distortion, with less switching noise. The integrated bidirectional dc/dc converter assists the grid interface converter to track the charge/discharge power of the PHEV battery. And in this only grid power is used for charging the battery.

Jos Schijffelen2, Mike van den Heuve This paper presents the development of a 10kW EV charger that can be powered from both a PV array and the three-phase AC grid. The goal is to realize a high-power density and high-efficiency three-port power converter that integrates the EV, PV, grid and meets the Chademo and CCS/Combo EV charging standards. The EV port is designed to be isolated and bidirectional, so that both charging and vehicle-to-Grid (V2G) can be implemented. As PV and EV are both DC by nature, the converter uses a central DC-link to exchange power between the EV and PV, thereby increasing efficiency. Hence the converter operates as a PV inverter, a bidirectional EV charger and a combination of both. But the problem in this method is that design of converter is very complex and they used more components.

Ankit Kumar Singh ,Yogesh N. Tatte This paper proposed a multifunctional on board converter for electric vehicles by using solar pv and gridand here they used pi controller which is not effective and have high total harmonic distortion in the output.

III. Proposed Methodology

The proposed methodology is development of multifunctional power electronic converter (PEC) utilizing dual power sources(solar pv and grid) for charging phenomenon of plug-in electric vehicles(PEVs) by using Neural Network Controller(ANN).

Industrial Engineering Journal
ISSN: 0970-2555
Volume : 52, Issue 4, May : 2023

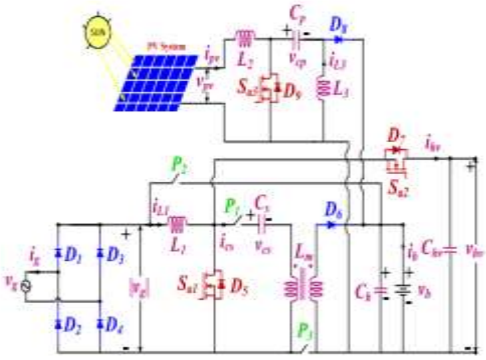


Fig 1. configuration of proposed pec

A. Grid mode

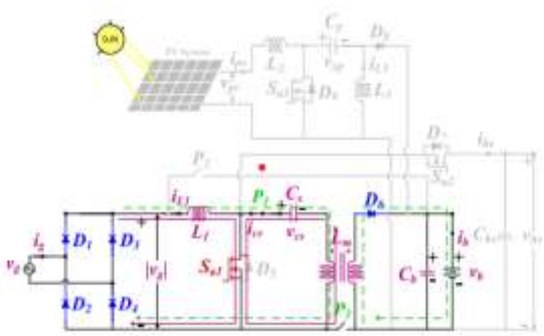


Fig 2. Operation of the proposed PEC during PIC mode

When solar power is not available, the battery is charged through grid power. When switchSa1 turns ON, the rectified grid voltage is applied to inductor L1 and current through it builds up and L1 stores magnetic energy. The path of current through inductor L1 is shown by solid lines in Fig. 2. Moreover, the capacitor Cs transfers its stored energy to magnetizing inductor Lm of high frequency transformer (HFT). In this duration, the battery is disconnected from the grid hence, capacitor Cb supplies power to the battery. When Sa1 turns OFF stored energy of Lm is transferred to the battery through diode D6 as shown by green dashed line and shown in Fig. 2.

B. Solar mode

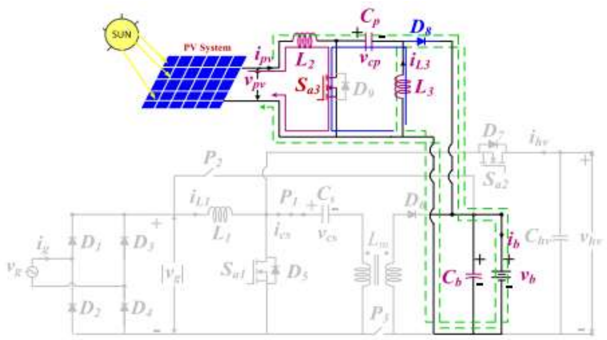


Fig.3.OperationoftheproposedPEC duringsolarPVmode

If grid power is not available, the battery is charged through only solar PV system and it is connected to the battery through SEPIC converter. The perturbed and observed based maximum power point Tacking (MPPT) controller is implemented through this SEPIC converter to optimize the performance of PV array. The equivalent circuit representation of this mode is

Industrial Engineering Journal
ISSN: 0970-2555
Volume : 52, Issue 4, May : 2023

shown in Fig. 3. When switch Sa3 is turned-on, current through inductors L2and L3 flow as path indicated by pink and blue solid lines. When Sa3 is turned-OFF, inductor L3 imparts its stored energy to the battery through the diode D8. While inductor L3 charges the capacitor Cp

C. Solar PV and grid mode

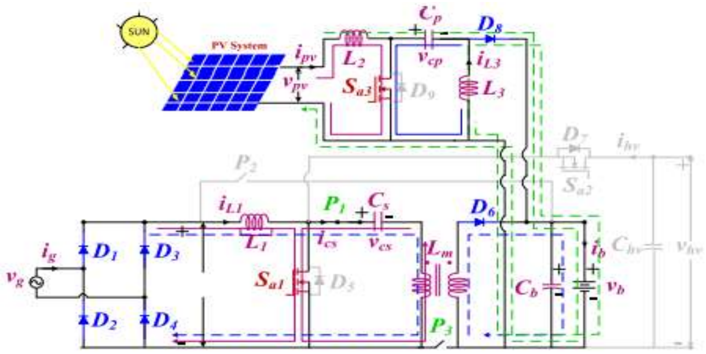


Fig.4 Operation of the proposed PEC during PIC and solar PV modes (simultaneously)

This mode occurs when solar PV system is not able to generate required power (reference charging power) to charge the battery. In such condition, grid is supplying remaining power (reference power − solar PV power). The grid and solar PV system both simultaneously charge the battery. If reference charging power is not met by solar PV system the rest of the power is supplied by the grid. The switch Sa3 is operated through PWM to achieve MPPT operation and supplying power to the battery. The switch Sa1 is operated for supplying power from grid to the battery. The equivalent circuit of this mode is shown in Fig. 4

D. PP mode

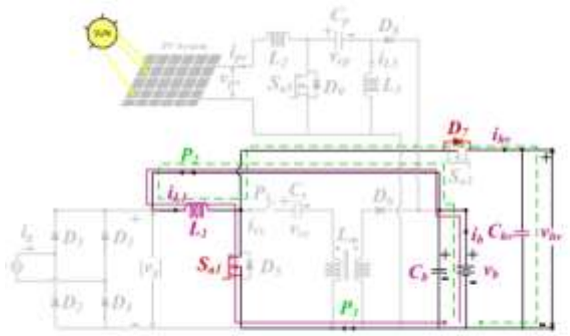


Fig. 5(a). Operation of the proposed PEC during in PP mode

The proposed system in this mode is operated as a conventional boost converter. The switch Sa1 is operated through PWM signal, and mechanical switches P2 and P3 ON permanently ON. When Sa1 is turned-on voltage Vb is applied to inductor L1 and it stores magnetic energy and current flows through the path indicated in Fig. 5by solid pink line. When Sa1 is turned- OFF, inductor L1 is supplied its stored energy to the DC- link capacitor Chv. The current path through various circuit elements has been shown with dotted lines in Fig.5 The DC-link capacitor transfers its stored electrostatic energy to the load (motor drive system though an inverter). The vehicle will be in running mode as along as the battery is supplying energy to the DC-link

Industrial Engineering Journal
ISSN: 0970-2555
Volume : 52, Issue 4, May : 2023

E. RB MODE

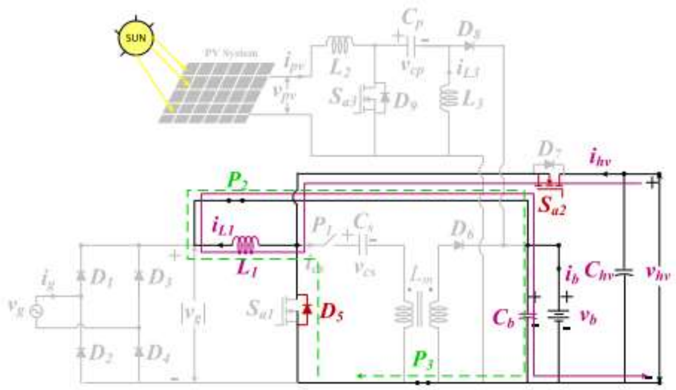


Fig.5(b) Operation of the proposed PEC during in RB mode

The proposed system in this mode is operated as a conventional buck converter. The switch Sa2 is operated through PWM signal, and mechanical switches P2 and P3 is permanently ON similar to the PP mode. When switch Sa2 is turned ON inductor L1stores energy through the path indicated by pink solid line in Fig.5. When Sa2 is turned OFF, stored energy of L1 is supplied to the load through the path indicated by green dotted lines, which is shown in Fig.5

Operation mode	Figure	S_{a1}	S_{a2}	S_{a3}	P_1	P_2	P_3	D_5	D_6	D_7	D_8	D_9
PIC mode	Fig. 2	PWM	OFF	OFF	ON	OFF	OFF	OFF	ON	OFF	OFF	OFF
Solar PV mode	Fig. 3	OFF	OFF	PWM	ON	OFF	OFF	OFF	OFF	OFF	ON	OFF
solar PV and grid mode	Fig. 4	PWM	OFF	PWM	ON	OFF	ON	OFF	ON	OFF	ON	OFF
PP mode	Fig. 5(a)	OFF	PWM	OFF	OFF	ON	ON	OFF	OFF	ON	OFF	OFF
RB mode	Fig. 5(b)	OFF	OFF	PWM	OFF	ON	ON	ON	OFF	OFF	OFF	OFF

states of switches during charging

ANNCONTROLLER

An Artificial Neural Network (ANN) controller is a type of control system that uses an ANN to control a process or system. The ANN controller is a computational model that is designed to simulate the behavior of the human brain and consists of interconnected artificial neurons that can learn and adapt to changing conditions

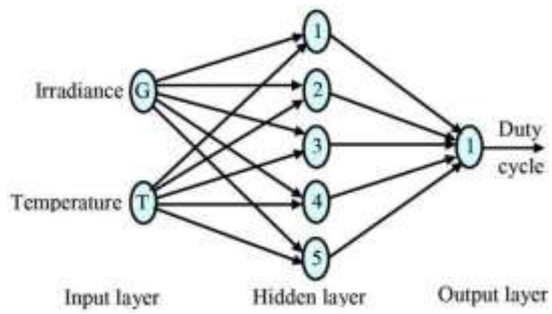
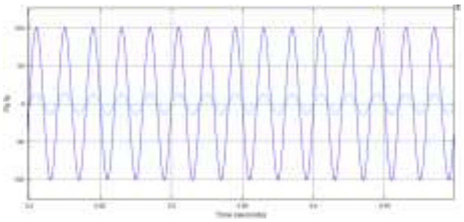
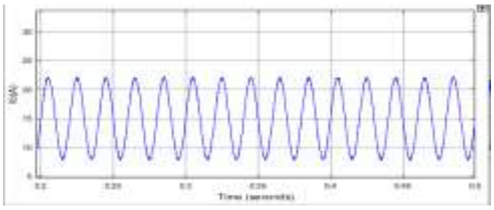


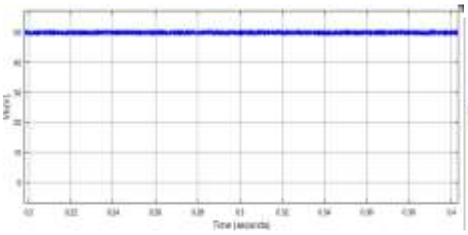
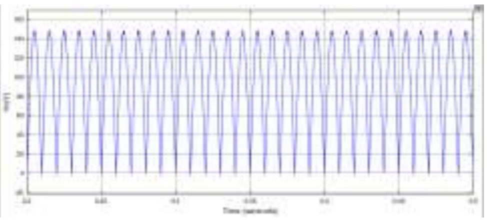
Fig 7 structure of ANN controller

Industrial Engineering Journal
ISSN: 0970-2555
Volume : 52, Issue 4, May : 2023

IV. Simulation Results

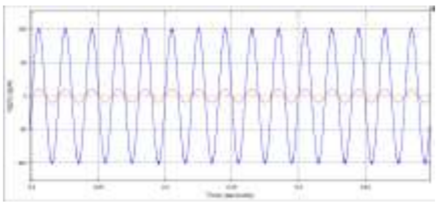
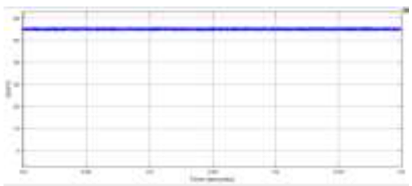
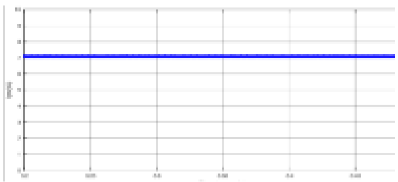



(a) (b)

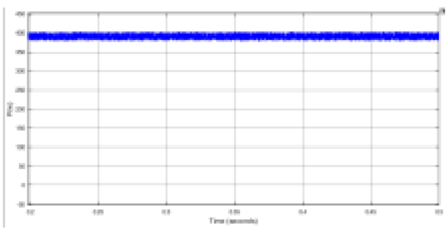
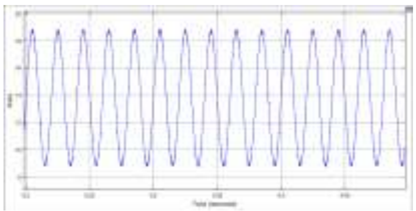
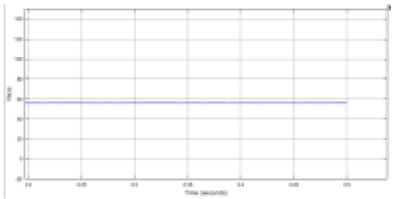



(b) (d)

Fig. 8. Simulation waveforms of PIC mode (alone)(a) grid voltage and grid current (b) battery current (c) battery voltage (d) voltage across capacitor Cs

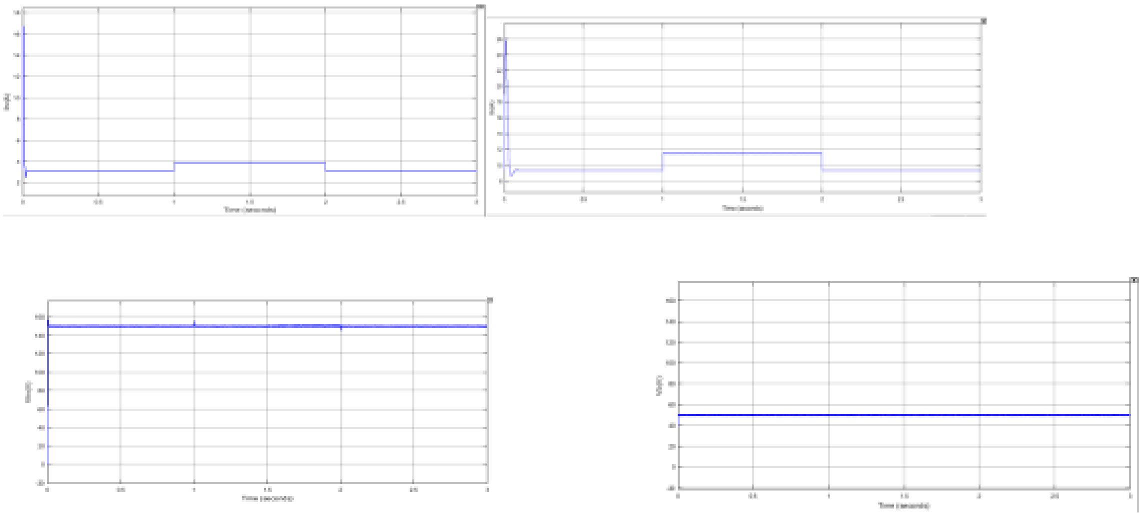




(a) (b) (c)

(d) (e) (f)

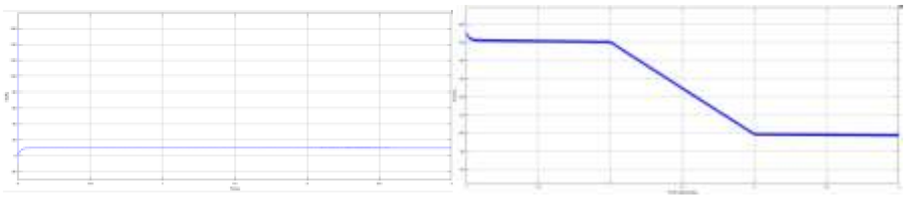
Fig.9.simulation waveforms of PIC and solar PV modes (simultaneously) (a) grid voltage and grid current (b)solar PV voltage (c) solar PV current(d) solar PV power(e) battery voltage (f)battery current



(a) (c)

(b) (d)

Fig. 8. Simulated waveforms of PP mode (a) DC-link voltage, (b) DC-link current, (c) battery voltage, (d) battery current



(a) (b)

(c)

Fig.10. Simulated waveforms of RB mode (a)battery current, (b)DC link voltage, (c) battery voltage

TotalHarmonicDistortionComparisonTable:

Parameter	THDs usingPI Controller	THDsusingNeural NetworkController
Grid Voltage during PIC mode	2.54	0.78

Grid Voltage during PICandsolarPVmodes		1.59
Grid Current during PIC mode	2.54	0.78
Grid Current during PICandsolarPVmodes		1.59

V. Conclusion

In conclusion, the integration of solar PV and grid power with a neural network controller for on-board converter integration in electric vehicles can lead to more efficient and intelligent energy management. This approach allows for the optimization of energy usage by switching between the solar PV and grid power sources depending on their availability and the demand for energy. The neural network controller can learn from past usage patterns and adjust the switching algorithm accordingly, making the system more adaptive and responsive to changes in driving conditions and energy availability. Overall, this technology has the potential to significantly reduce the environmental impact of electric vehicles and increase their efficiency and range, making them a more viable and sustainable mode of transportation.

References

[1] M. Yilmaz and P. T. Krein, “Review of battery charger topologies, charging power levels, and infrastructure for plug-in electric and hybrid vehicles,” IEEE Trans. Power Electron., vol. 28, no. 5, pp. 2151–2169, May 2013.
[2] T. W. Ching and Y. S. Wong, “Review of wireless charging technologies for electric vehicles,” in Proc. 5th Int. Conf. Power Electron. Syst. Appl., Dec. 2013, pp. 1–4.
[3] O. C. Onar, J. Kobayashi, D. C. Erb, and A. Khaligh, “A bidirectional high-power-quality grid interface with a novel bidirectional noninverted buck-boost converter for PHEVs,” IEEE Trans. Veh. Technol., vol. 61, no. 5, pp. 2018–2032, Jun. 2012.
[4] J. C. Bendien, G. Fregien, and J. D. van Wyk, “High-efficiency on-board battery charger with transformer isolation, sinusoidal input current and maximum power factor,” IEE Proc.B - Electric Power Appl., vol. 133, no. 4, pp. 197–204, Jul. 1986
[5] A. V. J. S. Praneeth and S. S. Williamson, “A wide input and output voltage range battery charger using buck-boost power factor correction converter,” in Proc. IEEE Appl. Power Electron. Conf. Expo., Mar. 2019, pp. 2974– 2979.
[6] A. K. Singh and M. K. Pathak, “Integrated converter for plug-in electric vehicles with reduced sensor requirement,” IET Elect. Syst. Transp., vol. 9, no. 2, pp. 75–85, 2019.
[7] Y. J. Lee, A. Khaligh, and A. Emadi, “Advanced integrated bidirectional AC/DC andDC/DC converter for plug-in hybrid electric vehicles,” IEEE Trans. Veh. Technol., vol. 58,no.8, pp. 3970–3980, Oct. 2009.
[8] S. Dusmez and A. Khaligh, “A charge-nonlinear-carrier-controlled reduced-part single- stage integrated power electronics interface for auto motive applications,” IEEE Trans. Veh. Technol., vol. 63, no. 3, pp. 1091– 1103, Mar. 2014.
[9] S. Dusmez and A. Khaligh, “A compact and integrated multifunctional power electronic interface for plug-in electric vehicles,” IEEE Trans. Power Electron., vol. 28, no. 12, pp. 5690–5701, Dec. 2013

[10] A. K. Singh and M. K. Pathak, “A multi-functional single-stage power electronic interface for plug-in electric vehicles application,” Electric Power Compon. Syst., vol. 46, no. 2, pp. 135–148, 2018.
[11] D. Patil, M. Sinha, and V. Agarwal, “A cuk converter based bridgeless topology for high power factor fast battery charger for electric vechicle application,” in Proc. IEEE Transp. Electrif. Conf. Expo., Jun. 2012, pp. 1– 6.
[12] S. Biswas, L. Huang, V. Vaidya, K. Ravichandran, N. Mohan, and S. V. Dhople, “Universal current-mode control schemes to charge Li-ion batteries under DC/PV source,” IEEE Trans. Circuits Syst. I: Reg. Papers, vol. 63, no. 9, pp. 1531–1542, Sep. 2016.
[13] J. Traube et al., “Mitigation of solar irradiance intermittency in photovoltaic power systems with integrated electric-vehicle charging functionality,” IEEE Trans. Power Electron., vol. 28, no. 6, pp. 3058–3067, Jun. 2013.
[14] D. Venkatramanan and V. John, “Dynamic modeling and analysis of buck converter based solar PV charge controller for improved mppt performance,” in Proc. IEEE Int. Conf. Power Electron., Drives Energy Syst., Dec. 2018, pp. 1–6.
[15] G. R. C. Mouli, J. Schijffelen, M. van den Heuvel, M. Kardolus, and P. Bauer, “A 10 kw solar-powered bidirectional EV charger compatible with chademo and combo,” IEEE Trans. Power Electron., vol. 34, no. 2, pp. 1082–1098, Feb. 2019.
[16] G. R. C. Mouli, P. Bauer, T. Wijekoon, A. Panosyan, and E. Barthlein, “Design of a power-electronic-assisted OLTC for grid voltage regulation,” IEEE Trans. Power Del., vol. 30, no. 3, pp. 1086–1095, Jun. 2015.
[17] T. M. U. N. Mohan and W. P. Robbins, Power Electronics: Converters, Applications and Design. Hoboken, NJ, USA: Wiley, 2009.
[18] Vempalle, R. and Dhal, P.K., 2020. Loss minimization by reconfiguration along with distributed generator placement at radial distribution system with hybrid optimization techniques. Technology and Economics of Smart Grids and Sustainable Energy, 5(1), pp.1-12.
[19] Vempalle, R. and Dhal, P.K., 2021. Maximization of economy in Distribution Networks with most favorable Placement of Type-1 and Type-2 Distributed Generators Along with Reorganization Using PSOWOA Hybrid Optimization Algorithm. ARPN Journal of Engineering and Applied Sciences, Vol 16, No 22.
[20] V. Bist and B. Singh, “A unity power factor bridgeless isolated CUK converter-fed brushless dc motor drive,” IEEE Trans. Ind. Electron., vol. 62, no. 7, pp. 4118–4129, Jul. 2015.
[21] A. S. Ahmed, B. A. Abdullah, and W. G. A. Abdelaal, “MPPT algorithms: Performance and evaluation,” in Proc. 11th Int. Conf. Comput. Eng. Syst., Dec. 2016, pp. 461–467.
[22] S. Deo, C. Jain, and B. Singh, “A PLL-less scheme for single-phase grid interfaced load compensating solar PV generation system,” IEEE Trans. Ind. Informat., vol. 11, no. 3, pp. 692–699, Jun. 2015. [23] A. K. Mishra and B. Singh, “Control of SRM drive for photovoltaic powered water pumping system,” IET Electric Power Appl., vol. 11, no. 6, pp. 1055–1066, 2017.
[23] Vempalle, R. and Dhal, P.K., 2022. Optimal analysis of time varying load radial distribution system with photovoltaic and wind generating system using novel hybrid optimization technique. Renewable Energy Focus, 41, pp.246-257.