International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

Electric Vehicle Battery Charger with Power factor correction using single phase single switch Vienna Rectifier Topology

***Khushi Tirpude*[*1]*, Narayan Naghate*[*2]*, Aditya Kirnapure*[*3]*, Prathamesh Shriwas*[*4]*, Arti Kudmate*[*5]*, Vishakha Gedam*[*6]*, Dr.Ajay Mendhe*[*7]**

[*1,2,3,4,5,6] Student Of Department Of Electical Engineering (E&P) , RTMNU, Priyadarshini J.L. College Of Engineering Nandanvan Nagpur, Maharashtra, India.

[*7] Associate Professor Of Department Of Eletrical Engineering(E&P), RTMNU, Priyadarshini J.L. College Of Engineering Nandanvan Nagpur, Maharastra, India.

ABSTRACT :

This project presents a single-phase bridgeless Vienna rectifier designed as an onboard electric vehicle (EV) battery charger, offering a low-cost and high-power-density charging solution. The proposed topology generates a three-level voltage waveform at the input using compact filters. With only one semiconductor switch, this single-phase Vienna rectifier is an attractive option for the EV industry to develop a compact Power Factor Correction (PFC) charger. A cascaded PI controller regulates the DC voltage at 400V, ensuring low current harmonics and unity power factor operation. Simulation results demonstrate the rectifier's dynamic performance, producing a low DC ripple voltage suitable for EV batteries.

Keywords: Electric Vehicle (EV) Battery Charger,Power Factor Correction (PFC),Single-Switch Rectifier,Active Power Factor Corrector (APFC)

Introduction：

The development of Electric Vehicles (EVs) has been driven by the pressing need to reduce dependence on fossil fuels and mitigate environmental pollution. As concerns about climate change and air quality continue to grow, the demand for sustainable transportation solutions has become increasingly urgent. Early EV charging systems, which employed basic diode bridge rectifiers, have given way to more advanced techniques.

The initial adoption of EVs faced significant challenges, including high battery costs, limited charging infrastructure, and concerns about range anxiety. To address these issues, the industry has focused on developing more efficient and controlled charging systems.

The early days of EV charging saw the widespread use of Level 1 and Level 2 charging, which relied on single-phase AC power and were primarily used in residential settings. However, as the demand for faster and more convenient charging grew, the industry began to shift towards more advanced charging technologies.

Advances in power semiconductor technology have played a crucial role in improving EV charger capabilities, enabling the development of more efficient and reliable charging systems. The introduction of active Power Factor Correction (PFC) rectifiers has been particularly significant, enhancing efficiency and power quality while reducing the strain on the grid.

Today, the focus is on developing advanced converter topologies, such as multilevel rectifiers, to optimize efficiency, power density, and grid integration. Researchers are also working to miniaturize onboard chargers and improve their efficiency, with the ultimate goal of creating reliable and robust charging solutions that can support the growing EV market.

As the industry continues to evolve, it is likely that we will see even more innovative charging solutions emerge, paving the way for widespread EV adoption and a more sustainable transportation future.

Working principle of Vienna rectifier:

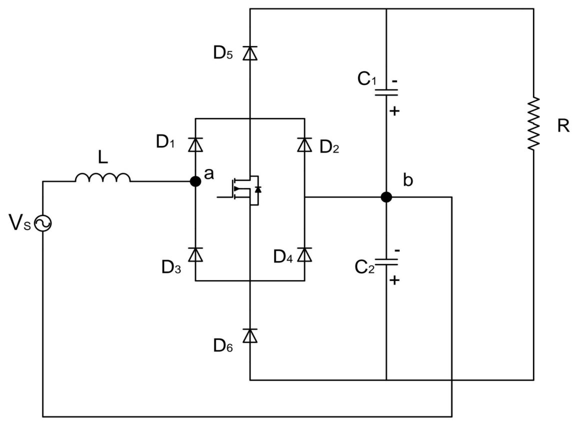

Fig1. Proposed single phase single switch boost PFC Vienna rectifier

Table 1: switching states of Vienna rectifier

As illustrated in Table I, capacitors charge in only one switching state, resulting in significant voltage ripple. This poses a challenge when generating 200 V DC from a 120 V RMS grid, as the required voltage (100 V) is lower than the maximum grid voltage (170 V). However, this topology is well-suited for electric vehicle (EV) battery chargers, which require a high DC output voltage of 400 V. With each capacitor voltage at 200 V, the topology offers several advantages, including lower power losses, reduced manufacturing costs, and simplified design. Since each component only needs to handle half the DC voltage (200 V), this topology is a viable solution for high-voltage DC applications, particularly in EV battery charging.

Switching state	**Sign of Is**	**Switch operation**	**Vab**	**C1**	**C2**
1	**+ve cycle**	**OFF**	**+Vdc/2**	**Charging**	**Discharging**
2	**+ve cycle**	**ON**	**0**	**Discharging**	**Discharging**
3	**-ve cycle**	**ON**	**0**	**Discharging**	**Discharging**
4	**-ve cycle**	**OFF**	**-Vdc/2**	**Discharging**	**Charging**

MODELLING AND CONTROLLER:

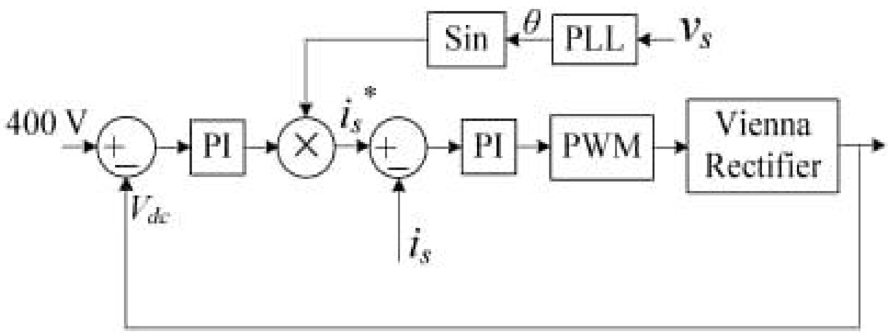

Fig. 2. Implemented controller on the EV battery charger system

A cascaded PI control scheme is implemented to regulate the DC voltage at 400V, minimize current harmonics at the input, and ensure unity power factor operation. The control architecture, depicted in Fig. 2, utilizes a Phase Lock Loop (PLL) to synchronize the electrical current and optimize its efficiency. The system consists of two primary components: an outer voltage control loop that generates reference signals for the inner current control loop. Multicarrier PWM is employed to produce the control signals. While PI controllers are effective for regulating slow-changing signals, they may introduce errors when dealing with fast-changing signals, such as sinusoidal currents, due to their limited bandwidth.

RESULTS:

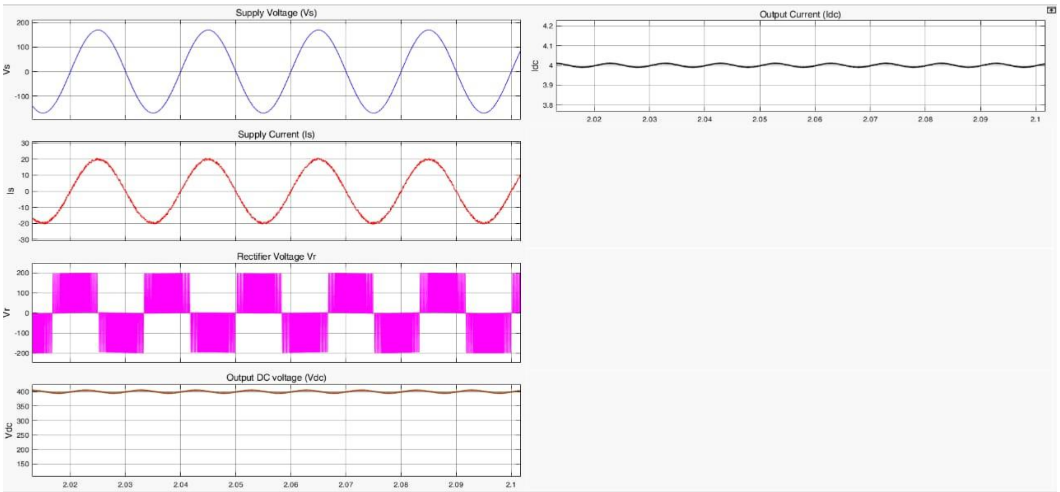

Fig. 3

Figure 3 illustrates the waveform when the rectifier produces 400V and 4A DC at the output. The voltage ripple is within acceptable limits, accounting for less than 5% of the total value. Additionally, the Total Harmonic Distortion (THD) is reduced to 3.95%. The waveform demonstrates that the supply current is in phase with the system voltage and exhibits low harmonic content. These results showcase the excellent dynamic performance of the proposed single-phase Vienna rectifier and its controller in regulating the output DC voltage, making it suitable for charging EV batteries.

CONCLUSION:

This paper presents a comprehensive study on the application of a single-phase single-switch PFC boost Vienna rectifier in electric vehicle (EV) charging systems. The rectifier's simple structure and compact size make it an attractive solution for EV chargers. Derived from the three-phase Vienna rectifier, this topology offers advantages such as low voltage stress on each switch and high efficiency. A detailed modeling and control design have been performed, and a cascaded PI controller has been implemented based on the system's dynamic equations. The simulation results demonstrate the acceptable performance of the proposed rectifier as an EV charger. Future research directions may include developing and implementing alternative control strategies to enhance the rectifier's performance under faulty conditions, making it even more suitable for EV system applications.

REFERENCES:

[1] S. Williamson, A. Rathore, and F. Musavi, "Industrial Electronics for Electric Transportation: Current State-of-the-Art and Future Challenges," IEEE Trans. Ind. Electron., vol. 62, pp. 3021-3032, 2015.

[2] H. Abu-Rub, M. Malinowski, and K. Al-Haddad, Power electronics for renewable energy systems, transportation and industrial applications: John Wiley & Sons, 2014.

[3] 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, pp. 2151-2169, 2013.

[4] B. Singh, B. N. Singh, A. Chandra, K. Al-Haddad, A. Pandey, and D. P. Kothari, "A review of single-phase improved power quality AC-DC converters," IEEE Trans. Ind. Electron., vol. 50, pp. 962-981, 2003.

[5] F. Sebaaly, H. Y. Kanaan, and N. Moubayed, "Three-level neutral-point-clamped inverters in transformerless PV systems—State of the art," in IEEE Mediterranean Electrotechnical Conference (MELECON), 2014, pp. 1-7.

[6] M. Ehsani, Y. Gao, S. E. Gay, and A. Emadi, Modern Electric, Hybrid Electric, and Fuel Cell Vehicles. Boca Raton, FL: CRC Press, 2005.

[7] C. C. Chan and K. T. Chau, "An overview of power electronics in electric vehicles," IEEE Trans. Ind. Electron., vol. 44, no. 1, pp. 3–13, Feb. 1997.

[8] CHAdeMO Association, "Desirable characteristics of public quick charger," Tokyo Electric Power Company, Tokyo, Japan, Jan. 2011.

[9] D. Aggeler, F. Canales, H. Zelaya - De La Parra, A. Coccia, N. Butcher, and O. Apeldoorn, "Ultra-fast dc-charge infrastructures for EV-mobility and future smart grids," in Proc. IEEE Power Energy Soc. Innovative Smart Grid Technol. Conf. Europe, Oct. 2010, pp. 1–8.

[10] K.-M. Tsang and W.-L. Chan, "Multi-level multi-output single-phase active rectifier using cascaded H-bridge converter," IET Power Electron., vol. 7, pp. 784-794, 2014.

[11] IEEE Recommended Practices and Requirements for Harmonics Control in Electric Power Systems, IEEE Std. 519, 1992.