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# SINGLE PHASE SINGLE SWITCH VIENNA RECTIFIER AS A PFC ELECTRIC VEHICLE BATTERY CHARGER

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## ABSTRACT

A single phase bridgeless Vienna rectifier with high power factor and increased efficiency is designed as an onboard electric vehicle (EV) battery charger. This can offer low cost and high power density charging system to EV. This single-phase bridgeless topology will generate three level voltage waveform at the input by using small size filters. As the rectifier is just a single phase Vienna rectifier it uses only one semiconductor switch and can be appealing for EV industry for developing a PFC compact charger. The proposed single phase Vienna rectifier is been controlled by a cascaded PI controller which can regulate the DC voltage at 400V to charge EV battery and it will draw low current harmonics from the grid thus maintaining its stability by ensuring unity power factor operation of converter. Simulation results validate the dynamic performance of the proposed single phase Vienna rectifier in generating low DC ripple voltage which can be given to EV batteries.

**Keywords:** Active Filter, Single Switch Rectifier, Electric Vehicle, Battery Charger, Active Power Factor Correcter.

## I. INTRODUCTION

Historical Context: The pursuit of reducing reliance on fossil fuels and mitigating environmental pollution has been a primary driver in the evolution of Electric Vehicles (EVs) [1, 2]. Early EV charging systems were rudimentary, often employing simple diode bridge rectifiers. However, the need for more efficient and controlled charging led to a gradual shift towards more sophisticated techniques. The initial stages of EV adoption were marked by significant hurdles, including the high cost of batteries and the limited availability of charging infrastructure. This period primarily saw the use of Level 1 and Level 2 charging, which typically relied on single-phase AC power, suitable for residential settings [3, 5, 6, 7].

Advancements in EV Charger Technology: As power semiconductor technology advanced, so did EV charger capabilities. The transition to active Power Factor Correction (PFC) rectifiers marked a significant improvement, enhancing efficiency and power quality [5, 6]. To improve charging times, and to be able to have charging stations in public places, three phase charging systems where implemented. The development of charging infrastructure became a critical focus, with the introduction of Level 3 and DC fast charging for public applications, addressing the issue of range anxiety [7, 8, 9, 10, 11]. This evolution enabled faster charging times, making EVs more practical for long-distance travel and everyday use.

Current Research and Future Directions: Current research in EV charging is heavily concentrated on developing advanced converter topologies, such as multilevel rectifiers, to further optimize efficiency, power density, and grid integration [10, 11]. Researchers also are attempting to make on board chargers smaller, and more efficient. The goal is to create robust and reliable charging solutions that can support the growing EV market.These ongoing efforts aim to overcome the remaining challenges and pave the way for widespread EV adoption.

**Working principle of Vienna rectifier:**

As shown in Table I, capacitors charge in only one switching state, leading to high voltage ripple. This creates a significant challenge for generating 200 V DC from a 120 V RMS grid. The issue arises because the required voltage (100 V) is lower than the maximum grid voltage (170 V), which is calculated by multiplying the RMS voltage by the square root of 2. As a result, the topology may struggle to produce the desired output voltage, making it a limitation for certain applications.

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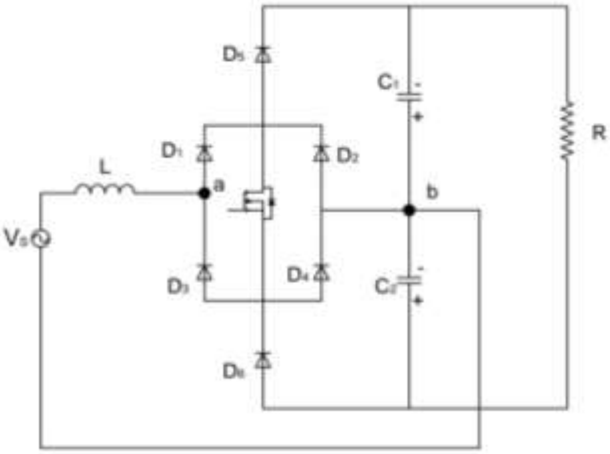


**Fig 1:** Proposed single phase single switch boost PFC Vienna rectifier

**Table 1:** switching states of Vienna rectifier

| 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 |

However, this topology is particularly well-suited for electric vehicle (EV) battery chargers, which require a high DC output voltage of 400 V. In this case, each capacitor voltage is 200 V, which is within the acceptable range. Furthermore, since each component only needs to handle half the DC voltage (200 V), this topology offers several advantages. These include lower power losses, reduced manufacturing costs, and simplified design. Overall, the topology is a viable solution for high-voltage DC applications, particularly in the context of EV battery charging.

## II. MODELLING AND CONTROLLER

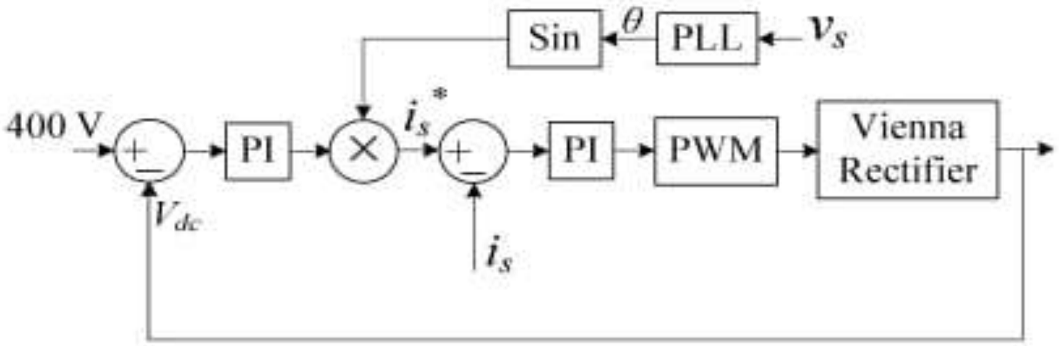


Fig. 2. Implemented controller on the EV battery charger system

A cascaded PI control scheme has been employed to regulate the DC voltage at 400V and mitigate current harmonics at the input, ensuring unity power factor operation. The control architecture is illustrated in Fig. 2. A Phase Lock Loop (PLL) is utilized to synchronize the electrical current, optimizing its efficiency. The system comprises two primary components: an outer voltage control loop that generates signals for the inner current control loop. Multicarrier PWM is employed to produce control signals. While PI controllers are effective for slow-changing signals, they may introduce errors when dealing with fast-changing signals, such as sinusoidal currents.

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## III. RESULTS

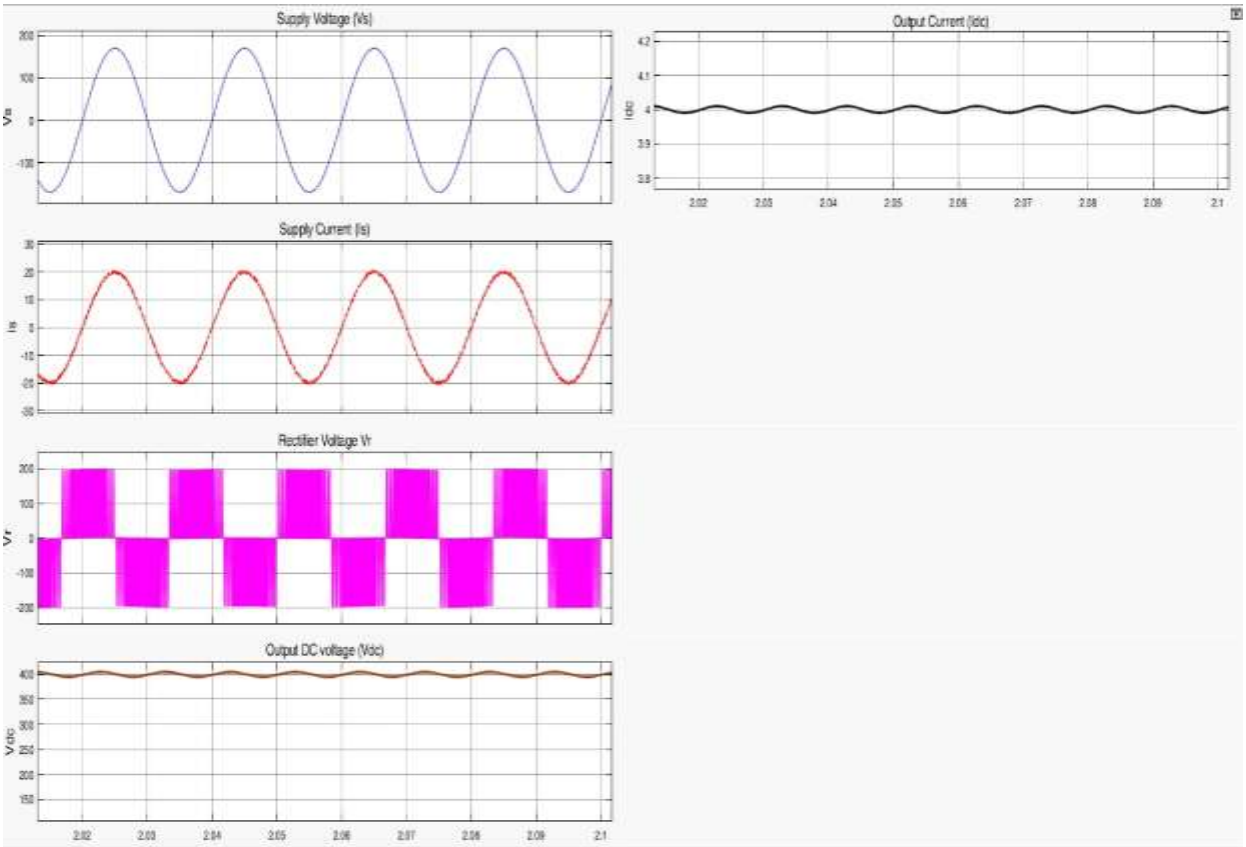


**Fig 3:**

Fig. 3 shows the waveform when the rectifier is generating 400V and 4 A DC at the output. Voltage ripple is acceptable with less than 5% of total value.And the THD is reduced to 3.95% .It is clear that is supply current in phase with the system voltage and contains low contents of harmonics. Waveforms prove the good dynamic performance of the proposed single-phase Vienna rectifier and implemented controller in regulating the output DC voltage which is used to charge the EV batteries.

## IV. CONCLUSION

In this paper, a single-phase single-switch PFC boost Vienna rectifier has been studied for EV charger applications due to its simple structure and compact manufacturing size. It has been derived from three-phase Vienna rectifier that has advantages such as low voltage stress on each switch and high efficiency. Detailed modelling has been performed and a cascaded PI controller based on the system dynamic equations has been implemented on the proposed rectifier. Simulation results proved acceptable performance of the proposed rectifier as EV charger. Different types of controllers can be developed and implemented as future work on this rectifier to make it more suitable in EV system applications under faulty conditions

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