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# Converter Topology for Electrical Vehicle Charging Station: A Review

***[1]Suvigya Srivastava, [2]Abhay Chaturvedi***

*[1]M.Tech Scholar, Technocrats Institute of Technology, Bhopal (M.P.), INDIA, Mail id-6707suvigya94@gmail.com*
*[2]Assistant Professor, Technocrats Institute of Technology, Bhopal (M.P.) INDIA, Mail id-abhaytit@gmail.com*

**ABSTRACT**

Anticipated rise in electric vehicles EVs and the associated demand for charging infrastructure necessitate advancements in control electronics. This will enable cost effective. It will also enable reliable and efficient battery charging solutions. This paper provides a detailed review of external EV chargers. The focus is on AC and DC-DC control stages. They are then integrated with EV batteries.EV chargers are categorized into on-board and off-board types. External chargers are essential for DC fast and ultra-fast charging. This is due to their compact design. The design also shows enhanced performance. Advanced topologies and control strategies are also highlighted. They are for AC-DC and DC-DC converters in external chargers. They incorporate specialized components. Hence they address emerging challenges.Moreover, a comparative analysis is provided. It is of converter topologies and control strategies. The analysis is based on parameters. Parameters like performance voltage levels, power factor and efficiency. This analysis has an aim. The aim is to guide future developments in EV charging infrastructure..

**Keywords:** Electric Vehicles; Batteries; Converters; Multi-Converters; Rectifiers.

## I. Introduction

The world is making a global move. It is transitioning to EV-based transportation systems. This is driven by concerns. Concerns about the environmental impact of conventional internal combustion engine vehicles. These vehicles account for 29% of greenhouse gas emissions. By linking EVs to the power grid, we can reduce fossil fuel dependency [1], [2]. There is a significant reduction. This reduction directly impacts fossil fuel dependency. This happens when EVs are connected to the power grid. In 2020 there were more than 10 million EV registrations made worldwide. These figures reflect a 43% rise from 2019. This increase occurred even during the COVID-19 pandemic [3]. Sales of EVs are expected to grow swiftly. By 2025, 14 million units are expected to be sold. [4].

This growth is backed by improvements in DC fast and ultra-fast charging infrastructure. This infrastructure upgrades EV usability and driving range.The technology of battery is essential in EV adoption. It accounts for nearly one-third of total cost of an EV. An EV's weight is also significantly increased by the inclusion of battery packs. Lithium-ion (Li-ion) batteries are currently the most efficient solution. They have energy densities between 200–300 Wh/kg. In 2010 cost of Li-ion batteries was $1,100/kWh. In 2020, it reduced to $137/kWh according to Bloomberg NEF reports [7]. This limit reduction is expected to narrow price gap by 9% between EVs and internal combustion engine vehicles in 2030. [8], [9].

## II. DC Fast Charging Converter Topologies

Several converter topologies are utilized for DC fast charging and ultra-fast charging of EVs. Notable configurations include:

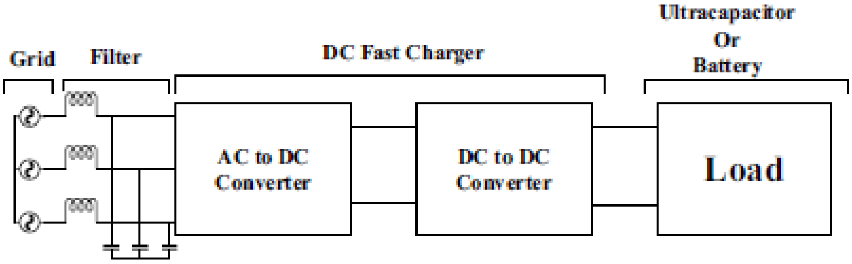


**Figure 1- Ggrid connected converter**

### 1. Unidirectional Boost Converter

A unidirectional boost converter, as shown in Fig. 2, enhances power factor, minimizes harmonics, and provides controlled DC output voltage under varying AC input conditions [10].

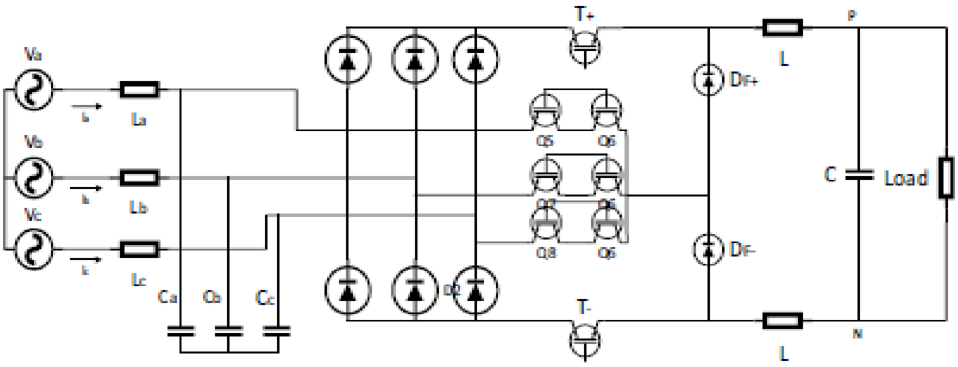


**Figure 2- Unidirectional Converter**

### 2. SWISS Rectifier

The SWISS rectifier (Fig. 3) improves efficiency over conventional rectifiers. It offers a wide output voltage range, power factor correction, dynamic current limitation, and direct start-up capability [11].

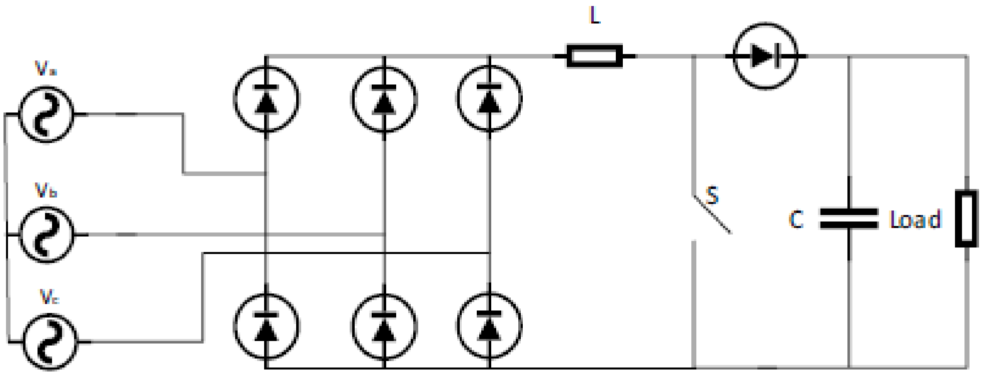


**Figure 3- SWISS Converter**

### 3. Matrix Converter

The matrix converter (Fig. 4) supports vehicle-to-grid applications with high efficiency. It operates with bidirectional switches, eliminating the need for a DC-link circuit or large energy storage elements, while improving power factor and reducing line current harmonics [12].

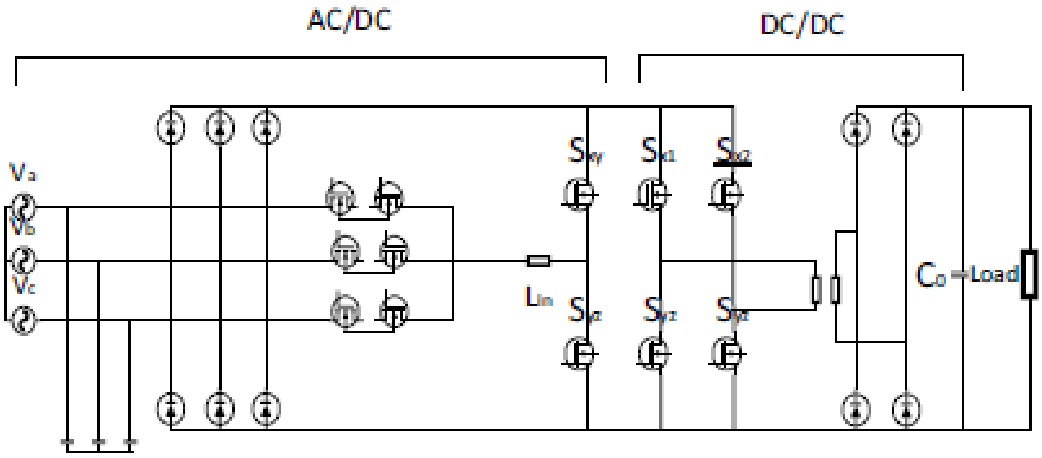


**Figure 4- Matrix Converter**

**4. Vienna Rectifier**

The Vienna rectifier (Fig. 5) achieves high power factor and low harmonic distortion with minimal switching losses. Its design, featuring one active switch per phase and a boost inductor for power factor correction, makes it efficient and compact. It is well-suited for high-power EV charging applications [13], [14].

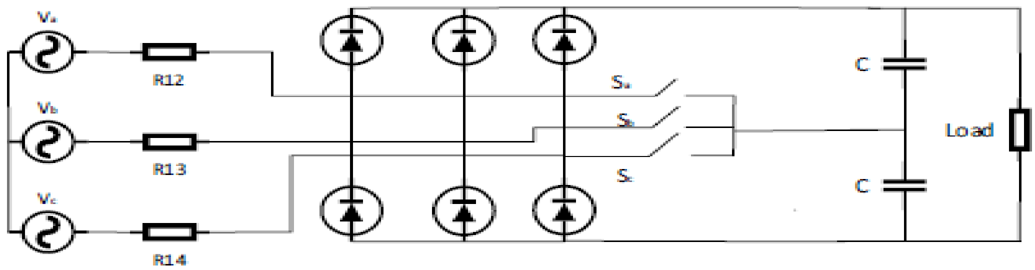


**Figure 5- Vienna Converter**

## III. Comparative Analysis of Charging Converter Topologies

The analysis of converter topologies indicates that the Vienna rectifier is the most suitable for high-power EV charging stations due to the following reasons:

- Minimal switch count per phase.
- Effective harmonic compensation.
- Superior efficiency compared to other topologies.
- High power factor (≈ 0.99).

A comparison of the topologies reveals that both the SWISS rectifier and Vienna rectifier achieve efficiency levels exceeding 98% with total harmonic distortion (THD) below 5%. However, the Vienna rectifier stands out with a power density of 12 kW/dm³, significantly higher than the SWISS rectifier's 4 kW/dm³. Table 1 summarizes the performance metrics for each topology.

| **Converter Topology** | **Mode of Operation** | **Phase Current THD (%)** | **Efficiency (%)** | **Power Density (kW/dm³)** |
|---|---|---|---|---|
| Unidirectional Boost Converter | Boost | 30 | 63.5 | 2.6 |
| SWISS Rectifier | Buck | 5 | 99.3 | 4 |
| Matrix Converter | Buck-Boost | 20 | 98 | 4 |
| Vienna Rectifier | Boost | 5 | 98 | 12 |

## IV. Conclusion

This paper reviews and analyzes various converter topologies for EV charging stations, focusing on their efficiency, power factor, and harmonic performance. Among the studied configurations, the Vienna rectifier emerges as the optimal choice for fast-charging applications. Its high power density, low THD, unity power factor, and compact size make it well-suited for modern EV charging infrastructure. Future research may focus on enhancing the reliability and scalability of such systems to meet the growing demand for EV adoption.

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