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Power Converter Topologies for Electric Vehicle Fast Charging Applications: A Review

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Abstract: *The expected growth of large charging and electric vehicles (EV) requires research and improvement of control electronics to achieve long-term monitoring, low cost and reliable charging schemes for EV batteries. This paper presents a comprehensive survey of EV external chargers consisting of AC and dc-dc control stages, from control organization to EV batteries. Although EV chargers are divided into two types, on-board and off-board chargers, it is important to use external chargers for dc fast and ultra-fast charging due to their size and weight. EV can be completely reduced. Here, we review advanced topologies and control strategies of ac-dc and dc-dc control stages for external chargers based on special thin elements, progress and ongoing challenges. By extension, many more EV chargers are included in PV, including battery life, EV and frame. In addition, comparative analysis of topologies and control schemes of ac-dc rectifiers, dc-dc converters and multi-converters in terms of engineering, control and voltage levels, performance, bias, control factors, advantages and disadvantages. It can be used to obtain information about the header in the future EV charging setup.*

Key Word: *Electrical Vehicle; Batteries; Converters; Multi converters; Rectifiers.*

I.INTRODUCTION

In the United States, government, industry, and academia are working together to develop an electric vehicle (EV)-based transportation system due to concerns about the environmental impact of our daily transportation, which is responsible for 29% of greenhouse gas emissions. connected to the grid, which significantly reduces fossil fuel consumption [1], [2]. In 2020, the total number of global EV units exceeded ten million, a 43% increase compared to 2019, and despite the COVID-19 pandemic, EV registrations are increasing in major markets around the world [3]. Furthermore, EV sales are expected to increase rapidly in the coming years, from 3.1 million in 2020 to 14 million in 2025 [4]. With the development of fast DC and ultra-fast charging infrastructure, EV driving range

Internal combustion (IC) engine-based vehicles that can be compatible and plug into the power grid will facilitate reactive power support, ancillary services, peak load shedding, load balancing, and integration of renewable energy sources [5].
Battery technology is central to progress in EV adoption, as battery costs can account for up to a third of total EV costs, and EV weight increases significantly with the inclusion of battery packs. Li-ion, currently the most efficient battery technology, has a gravimetric energy density between 200Wh/kg and 300Wh/kg [6]. According to Bloomberg NEF, Li-ion battery prices have dropped to 137 kWh starting in 2020. $1,100/kWh in 2010 [7]; However, IC engine vehicles still exist Cheaper than EVs. In 2030, the price difference between them is expected to be only 9% due to the decrease in battery costs [8], [9].

II.DC FAST CHARGING CONVERTER TOPOLOGIES

The DC fast charging grid connected inverter. There are several numbers of converter topologies available for the rapid charging of batteries or ultra-capacitors. Some feasible options are highlighted. They are:

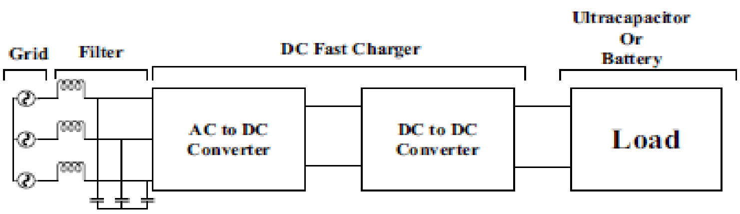

Figure 1- DC fast charging grid connected converter

- **Uni Directional Boost Converter**

The unidirectional boost converter is shown in fig.2, and these converters are employed where the output voltage has to be boosted up for loads which require higher voltage [10].

The primary goal of using a boost converter instead of the conventional diode bridge rectifier is to improve power factor, to reduce the harmonics at the end, and to have a controlled DC voltage at the output if unwanted perturbations occur at the AC end.

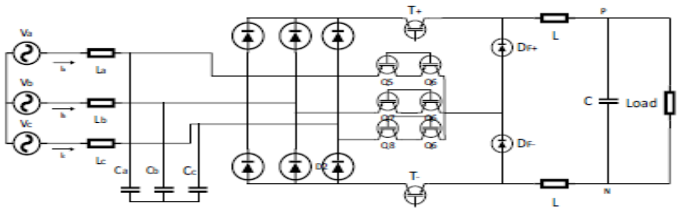

Figure 2- Unidirectional Boost Converters

- **SWISS rectifier**

The SWISS rectifier is shown in Fig. 3, and these rectifiers are employed where the efficiency has to be increased based on the application requirements. The significant achievement in using the SWISS rectifier is to provide better efficiency compared to the conventional rectifiers. Compared to boost-type converter, buck-type system provides a wide output voltage control range, while maintaining PFC capability in the input, enables direct start-up, and allows for dynamic current limitations at the output[11].

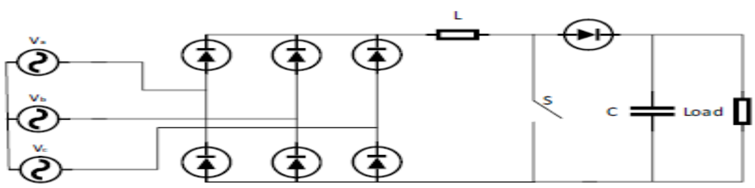

Figure 3- SWISS Rectifier Circuit

- **Matrix converter**

The matrix converter is shown in Fig.4, and these rectifiers are used for the regenerative operation of charging stations where it has to be used for the vehicle-to-grid applications with high efficiency [12]. Matrix converter is a forced commutated converter that uses an array of controlled bidirectional switches which allows high-frequency operations. This type of converter does not require DC-link circuit and any large energy storage element. It can improve the power factor and reduce the harmonics in the line current at the end.

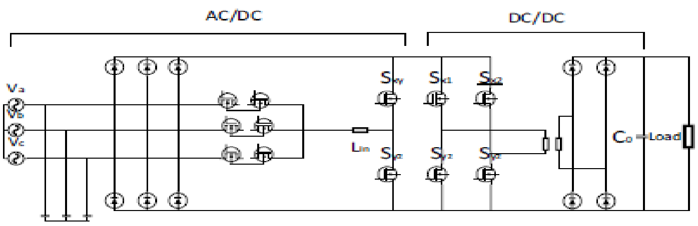

Figure 4- Matrix Converter Circuit

- **Vienna Rectifier**

Another famous power converter for power quality improvement is the Vienna rectifier, as shown in Fig.5. This is the popular choice when the aim is to achieve a high power factor and to attain lower harmonics distortion. The switching losses in Vienna rectifier are low because of low voltage stress in the switches [13, 14]. This converter consists of only one active switch per phase which makes the Vienna rectifier easier to control and makes it more dependable. This converter is basically a PWM converter [15], and the boost inductor at the input plays the role in ascertaining power factor correction. Basically, the stored energy acquired by the inductor when the switch is OFF is transmitted to the load through the diodes whenever the switch is ON. The advantage of employing this topology includes the absence of a neutral point connection [16].

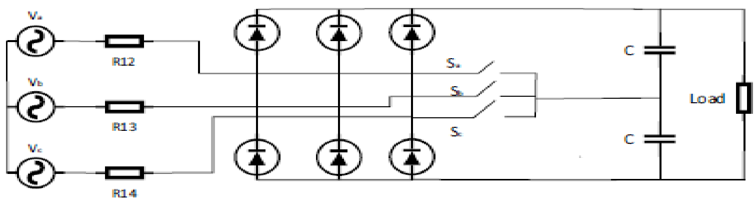

Figure 5- Vienna Rectifier Circuit

III.COMPARATIVE ANALYSIS OF CHARGING CONVERTER TOPOLOGIES

Some of the features of the converter topologies are discussed and are highlighted. From the detailed review of the few converter topologies, it can be concluded that the use of the Vienna rectifier for the implementation of the charging station is appropriate, due to the following reasons:

- It has less number of switches per phase.
- Harmonic contents are compensated.
- Good efficiency when compared to the PWM rectifier, SWISS rectifier, and matrix converter.
- Higher power factor, around 0.99, compared to the PWM rectifier, SWISS rectifier, and matrix converter.

From the analysis, both the SWISS rectifier and Vienna rectifier have high efficiency with less than 5% THD. However, the Vienna rectifier is the most optimal converter topology for the charging stations as it has the advantages of high power density (12 kW/dm3) [17] compared to the SWISS rectifier (4 kW/dm3). It is evident that the Vienna rectifier has been selected for designing DC fast charger as it has the advantage of high power density. The Vienna rectifier can be used for EV charging system as it features high efficiency, high power density, unity power factor, and low total harmonic distortion, and the size of the system is small compared to other converters. The number of switches, type, and the number of diodes for different topologies are given in Table-1.

Table 5.1 Device count of various topologies

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 presents an overview of the comprehensively explores different types of energy efficient converter topologies for power factor assessment at the electric vehicle charging stations. It is understood from the literature review, the Vienna rectifier is a preferred choice in the high power applications, due to superior power factor and excellent capability to cancel out current harmonics. The parameters that are compared are device count, power density and total harmonic distortion. It is observed that the Vienna rectifier is best suitable for fact charging applications.

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