비엔나 정류기를 이용한 전기자동차용 급속충전기 개발

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Development of EV Fast Charger using Vienna Rectifier

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ABSTRACT

The paper describes the development of Fast Charger by using Vienna Rectifier as AC/DC converter. The Vienna Rectifier is proven to have a high efficiency performance as well as a prominent power quality performance on AC side of the fast charger. The Vienna Rectifier is compared to other topology, especially T-type inverter, and analyzed carefully. Experimental results from a 10kW prototype are provided to validate the theoretical consideration.

1. Introduction

Electric Vehicles (EV) have been considered as the most likely future transportation due to the depletion of the fossil fuel reserve. The development of EV must be implemented along with the development of charging infrastructure as well. The fast charger has been an emerging technology because of the need of short-time charging of EV battery [1]. The development of EV Fast Chargers arise the challenges to provide a suitable topology, which has a high power rating and grid-friendliness. One of popular EV charger architecture is an AC/DC converter followed by an isolated DC/DC converter [2]. The AC/DC converter is usually implemented by using a bridge diode rectifier, which has a poor input current THD performance. To overcome the drawbacks , two-level full bridge PWM converter is introduced to EV Fast Charger technology [3]. In advance, the three-level T-type inverter is used in late EV Fast Charger technology, considering its high power capability and better THD performance. However, in order to guarantee the operation of three-level topology, additional control method must be added to balance the DC-link capacitors voltage.

This paper describes the development of an EV Fast Charger using Vienna Rectifier. The 50kW EV fast charger will be built from five 10kW modules as shown in Fig. 1. Firstly, Vienna Rectifier will be analyzed and the performance is compared to the three-level T-type inverter topology. A 10kW Vienna Rectifier prototype module is built and the performance of the Vienna Rectifier is validated by experimental results.

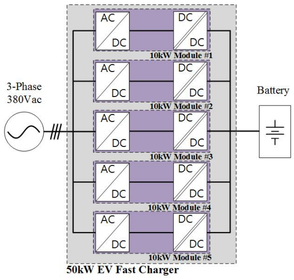
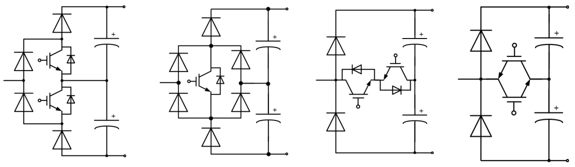


Figure 1. Proposed 50kW EV Fast Charger architecture



(a) (b) (c) (d)

Figure 2. Several topologies per phase of Vienna Rectifier

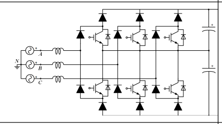
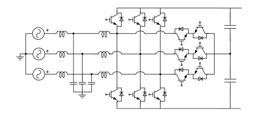
2. Vienna Rectifier for EV Fast Charger

There are several topologies of Vienna Rectifiers as shown in Fig. 2. It can be seen that topologies (a) and (b) have half of V_{dc} voltage stress for all components while the fast recovery diodes in topologies (c) and (d) have the voltage rating of V_{dc}. Since the $R_{ds(on)}$ of the MOSFET becomes lower as the voltage rating decreases, the conduction losses of topologies (a) and (b) is lower. Also, topology (a) is proven to have lower conduction losses compared to topology (b) due to smaller number of components in the current path.

The comparison of Vienna Rectifier and T-type inverter topology are shown in Table 1. Both of topologies have a three-level characteristic, which is prominent in terms of THD performance and high power capability.

From Table 1, it is clear that the total number of components in Vienna Rectifier is higher than T-type inverter. However, the employment of controllable switch of Vienna Rectifier is half of controllable switches in T-type inverter. It means less gate drivers will be needed. Moreover, fast diodes in Vienna Rectifier is implemented by using SiC diode, which has a good performance in terms of losses. And from [2], it has been proven that the switching losses of Vienna Rectifier is low, so that the switching

Table 1. Comparison of Vienna Rectifier and T-type inverter

	Vienna Rectifier	T-type inverter
Topology		
Controllable Switch	6	12
Diodes	6 (Line Frequency) 6 (Fast Diode)	-
Component Voltage Stress	1/2 V_{dc} for all switches	V_{dc} for line switches $1/2V_{dc}$ for neutral clamp switches
Conduction Losses	Lower	Higher
Reliability	High due to less controllable switches and gate drivers	Low due to high number of controllable switches and gate drivers
Switching Losses	Lower	Higher
Preferable Filter	L	LCL
Cost (Switches + Filters)	~$1800 (for 50kW)	~$2200 (for 50kW)
Efficiency	~ 97%	~ 97%

frequency of Vienna Rectifier can be increased. As the switching frequency is increased, the usage of L filter is plausible to attenuate the switching frequency in the AC side. Consequently, the filter size as well as overall size and weight can be reduced. While the bi-directional power flow is not a basic requirement for fast charger technology, Vienna Rectifier can be a viable topology for fast charger.

3. Experimental Results

A 10kW module prototype has been built and tested. The prototype and control of Vienna Rectifier are shown in Fig. 3. and Fig. 4, respectively. The prototype specification is as follows,

- P_o = 10kW
- $V_{ac,rms}$ = 380V
- V_{dc} = 750V
- f_s = 40kHz
- L = 1mH
- C_{dc} = 3300μF

The performance of Vienna Rectifier during automatic start-up and at full load are shown in Fig. 5(a) and Fig. 5(b), respectively. The experiment shows that the control does work well to control the desired DC output value during start-up as well as at full load, and also the voltages across each DC-link capacitors are well balanced during the operation. Fig. 6 shows the measured efficiency of Vienna Rectifier. Fig. 7 shows the power factor at AC side as well as the input current THD.

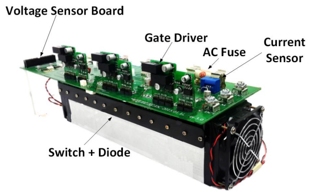


Fig. 3. First prototype of 10kW Vienna Rectifier Module

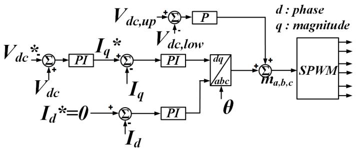
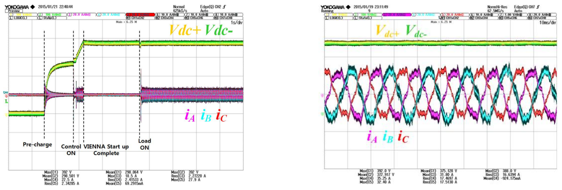


Fig. 4. Control diagram of Vienna Rectifier



(a) Automatic start-up (b) Full-load operation

Fig. 5. Experimental waveforms

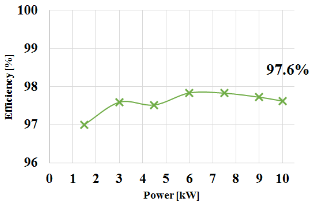
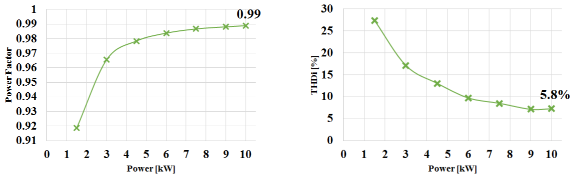


Fig. 6. Measured efficiency of Vienna Rectifier (Yokogawa WT3000)



(a) PF (b) THD

Fig. 7. Input performance at various load

4. Conclusion

The paper shows that the usage of Vienna Rectifier is promising in fast charger application. The features, which are provided by Vienna Rectifier, such as high efficiency, prominent power quality performance, reduced filter as well as reduced overall size, seem to be suitable for the EV fast charger application. The suggestion has been supported by experimental results from the 10kW module that showed the efficiency of 97.6% at full load.

References

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