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Comparative Analysis of Different Topologies of Vienna Rectifier

Kumar Nishant[a], K. Prabha Rani[b] and K. V. S. R. Murthy[c*]

[a,b]*Department of EEE, Aditya College of Engineering and Technology, Surampalem, India*
[c] *Department of EEE, Aditya Engineering College, Surampalem, India*
[c*]murthy.kvs@aec.edu.in

Abstract. This paper provides a comparative evaluation of different topologies of Vienna rectifiers. Vienna rectifier is used for AC-DC conversion and has a reduced number of switches. The PWM-based control mechanism of the rectifier reduces the losses of the capacitor and provides better efficiency. There is a different type of topologies for Vienna rectifiers and this paper evaluates different topologies. Three-phase converters are available in a number of different topologies. The major advantage of a three-level power electronic converter is the reduction in the number of switches required, as well as the reduction in overall harmonic distortion, voltage stress, and AC side voltage ripple. The Vienna rectifier is one of the most effective devices for unidirectional power flow and boosts type power factor correction (PFC) circuits. The Vienna rectifier is modular in design, but its space and weight are restricted.

Keywords. Vienna rectifier, AC-DC rectifier, Topology, Three-phase

1. Introduction

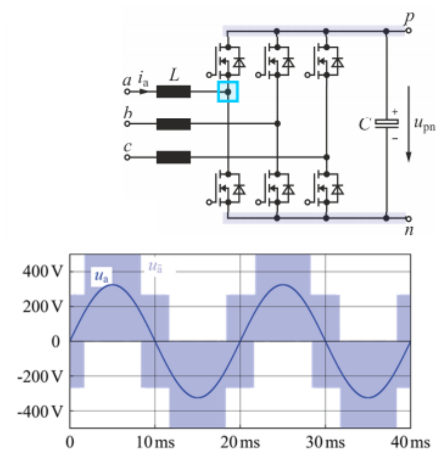
AC-DC converters find application in various applications. Active three-phase AC-DC converter find a lot of application in telecommunication application [1-5]. Different topologies are there for three-phase converter. The major advantage of 3-level power electronic converter is reduced number of switches, lower total harmonic distortion, reduced voltage stress and lower AC side voltage ripple [6-9]. For unidirectional power flow, boost type power factor correction (PFC) circuit, Vienna rectifier is one of the best. Vienna rectifier is modular, volume and weight are limited [10-12]. A significant amount of literature has been there which discuss the topology aspect of Vienna rectifier. Initial investigation of three-phase PWM based modular rectifier started in late 90's. Detailed description of 3-phase PWM rectifier has been provided in [13-15]. The operation of three-phase PWM rectifier using dual boost converter has been discussed in [4]. Different topologies of Vienna rectifier have been provided in [5]. Vienna rectifier is used in more electric aircraft (MEA) and different topologies of Vienna rectifier used in MEA has been discussed in [6, 16, 17]. Large signal modeling and analysis of a 1.5-kW 3-phase

Vienna rectifier has been discussed in [6]. DC-DC Converter topologies have been discussed in [10-14].

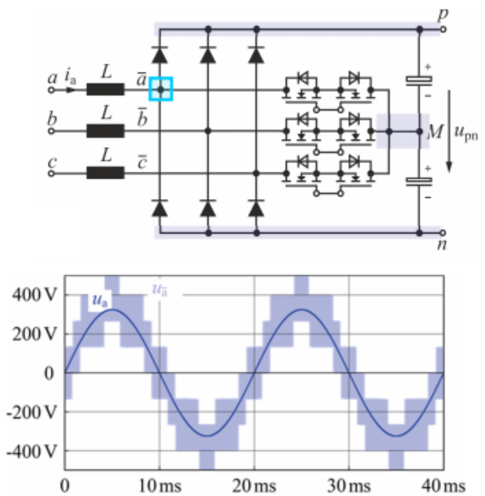
This paper provides a comparative analysis of three different switch realization in Vienna rectifier and efficiency of all the topologies have been computed over a varying voltage range. Sizing of the classical Vienna rectifier has been also provided. This paper comprises of three different subsections apart from introduction. In Section II, detailed analysis of Vienna rectifier has been provided. In section III, different topologies of Vienna rectifier have been provided along with results. Section IV concludes the paper.

2. Vienna Rectifier: Detailed Analysis

This section provides detailed analysis of Vienna rectifier and its operation.



(a)



(b)

Figure 1. (a) Standard PWM rectifier, (b) Vienna Rectifier

Figure 1 (a) provides the circuit diagram of a standard 3-phase PWM rectifier whereas Figure 1 (b) illustrates the circuit diagram of a Vienna rectifier. Vienna rectifier has a smaller number of switches and low total harmonic distortion. Vienna rectifier is a boost type rectifier, don't have any galvanic isolation. Vienna rectifier in basic form is unidirectional in nature which works on pulse width modulated waveform.

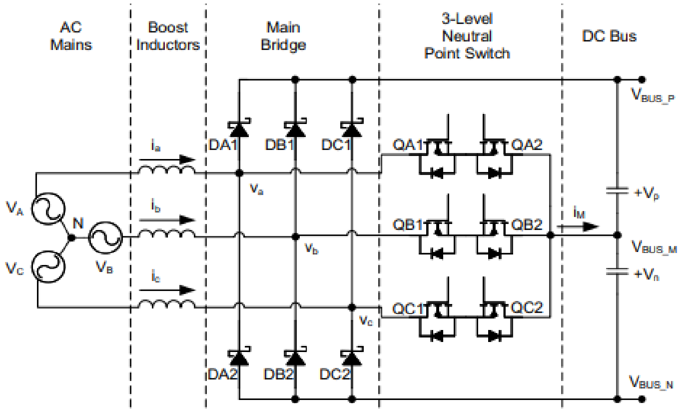


Figure 2. Vienna rectifier

Figure 2 shows the circuit diagram of Vienna rectifier having following specifications

1. Output DC power: 2 kW
2. Input 3-phase AC voltage: 360 V – 440 V (L-L)
3. Input frequency: 50 Hz (5% tolerance)
4. Output DC voltage: 750 V
5. Switching frequency: 20 kHz

Three-phase supply voltage can be represented as follows:

$$V_A(t) = V_m \sin(\omega_o t) \ldots\ldots(1)$$

$$V_B(t) = V_m \sin\left(\omega_o t - \frac{2\pi}{3}\right) \ldots\ldots.(2)$$

$$V_C(t) = V_m \sin\left(\omega_o t + \frac{2\pi}{3}\right) \ldots\ldots(3)$$

The peak value of input current of the Vienna rectifier is

$$I_{in(peak)} = \frac{\sqrt{2}P_{in}}{\sqrt{3}pfV_{in\_ll(RMS)}} \ldots\ldots(4)$$

Where;

Conduction loss of diode $P_c = I_{avg}V_f$

Switching loss of diode $P_s = \frac{1}{2}CV^2 f_{sw}$

Conduction loss of MOSFET $P_c = I_{rms}^2 R_{ds(on)}$

Switching loss Turn on loss of MOSFET $P_{s1} = \frac{1}{2} V I_{rms} t_r f_{sw}$

Turn off loss of MOSFET $P_{s2} = \frac{1}{2} V I_{rms} t_f f_{sw}$

3. Different Topologies of Vienna Rectifier

Figure 3 shows three different switch realization and Figure 4 shows the Vienna rectifier using switch realization of topology-2 as shown in Figure 3. Figure 5 shows the Vienna rectifier using switch realization of topology-3 as shown in Figure 3. Figure 6 shows the efficiency of three different topologies for different voltage range.

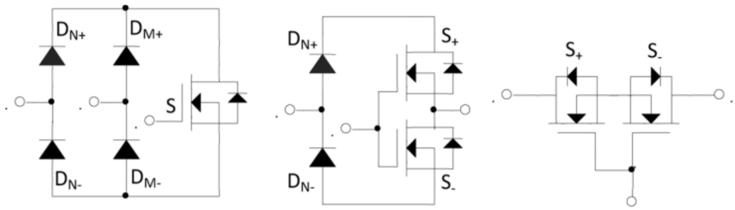


Figure 3: Different topologies of Vienna rectifier switching arrangement

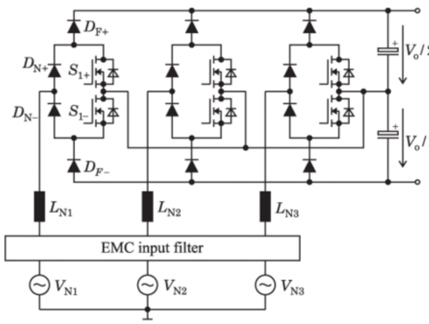


Figure 4: Complete circuit diagram of Vienna rectifier with switches shown in Topology-2

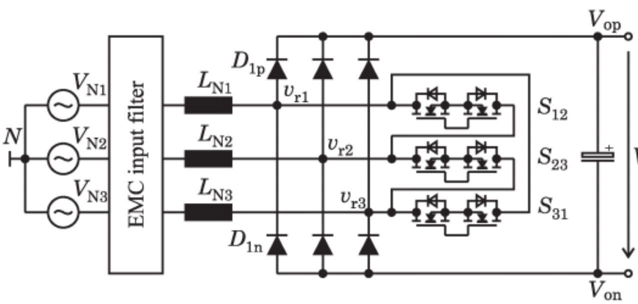


Figure 5: Complete circuit diagram of Vienna rectifier with switches shown in Topology-3

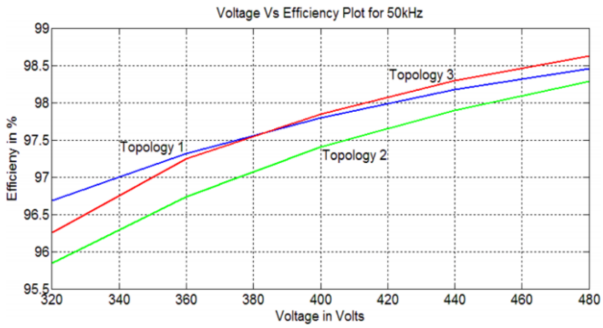


Figure 6. Efficiency curve of three different topology over different range of voltage

4. Conclusion

This paper provides the comparative analysis of different topologies of Vienna rectifier. Switching loss and conduction loss of the rectifier has been evaluated. Vienna rectifier is a very highly efficient rectifier widely used in more electric aircraft (MEA) and other applications due to its modular nature and compact architecture. Three-phase converters come in a variety of topologies. With a three-level power electronic converter, you can cut down on the number of switches, overall harmonic distortion, voltage stress, and AC side voltage ripple. The Vienna rectifier is a top-notch PFC circuit component for unidirectional power flow. Modularity and weight are kept to a minimum with the Vienna rectifier.

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