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Performance Analysis and Optimization of SVPWM Algorithm for Vienna Rectifier

Li Xujun

Gansu Mechanical &Electrical Vocational and College, Gansu, China, 741001

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Abstract: Vienna rectifier has high research value because of the advantages of large number of switches, high power factor and low current harmonic content, no dead time voltage of bridge arm switch, simple control circuit and so on. This paper first introduces the research status of Vienna rectifier, then analyzes the SVPWM strategy of Vienna rectifier, and finally analyzes the performance of the SVPWM algorithm of Vienna rectifier.

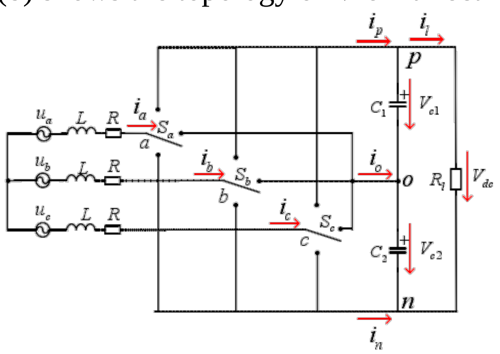
1. Introduction

Compared with two-level converter, Vienna rectifier has the advantages of low device stress, high power density and low current harmonic content. Compared with ordinary three-level converter, it has the advantages of simple structure, less power devices and high reliability. Because the number of Vienna rectifier switching devices is greatly reduced, and these switching devices only bear half of the output voltage, and do not need to set the drive dead time. Because of these advantages, it is of great practical significance to study the Vienna rectifier and its control method. Vienna rectifier has a wide application prospect in active power filter, uninterruptible power supply, AC / DC drive system, communication power supply, new energy field, industrial frequency converter and other fields.

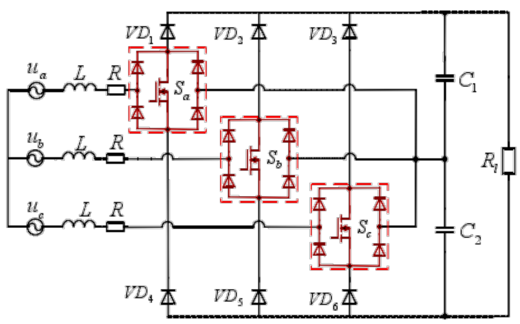
2. Characteristics and applicability of vortex flowmeter

2.1. Topology of Vienna rectifier

According to the circuit structure of Vienna rectifier shown in Fig. 1 (a), when the switch is on, the corresponding phase voltage is connected to the midpoint of the output voltage, causing the current of the corresponding phase to increase; when the switch is off, the diode connected to the same bridge arm will be on, and the current of the corresponding phase will decrease. If the on and off of the transistor can be well controlled, the current of each phase can become a sine wave. Figure 1 (b) shows the topology of Vienna rectifier.



(a)



(b)

Figure 1. Equivalent circuit and topology of Vienna rectifier

2.2. Modulation technology of Vienna rectifier

Most of the modulation methods of Vienna rectifier are based on the common diode clamped (NPC) three-level converter. The common modulation strategies are carrier modulation, space vector modulation (SVM) and discontinuous modulation (DPWM). Two different implementations of SPWM modulation are shown in Figure 2. Both of them have the characteristics of simple SPWM modulation, low voltage utilization and large fluctuation of neutral point current.

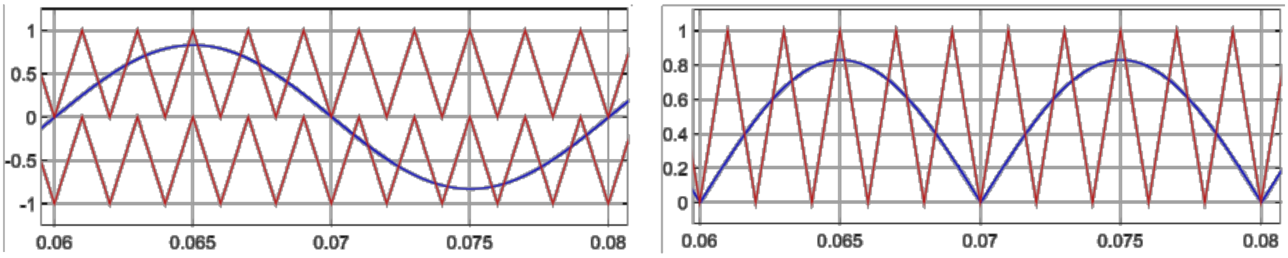


Figure 2. String carrier modulation

According to the principle of V-s balance, the three-level space vector modulation uses the basic vector to synthesize the target vector. Different from the two-level vector modulation, each bridge arm of the three-level converter can generate three levels, and more basic vectors can be selected. Figure 3 shows the space vector diagram of the Vienna rectifier. DPWM will clamp the bridge arm voltage to the positive, zero and negative level in time-sharing, and the modulation wave is discontinuous. In the clamping process, there is no switching process, and the switching loss is far less than other modulation methods. However, in this way, the neutral point current fluctuates greatly and the input current harmonics are high.

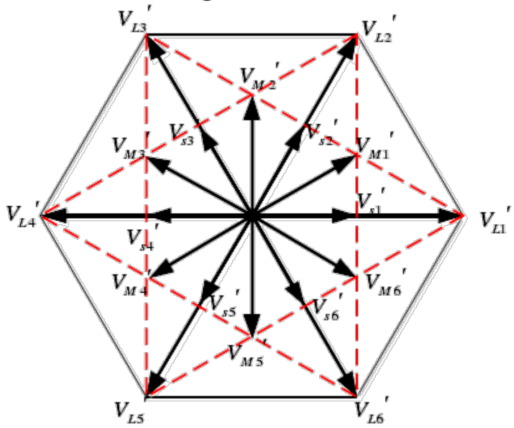


Figure 3. Virtual space vector map

2.3. Control strategy of Vienna rectifier

The control strategy of Vienna rectifier includes the hysteresis control in ABC natural coordinate, PR control in ABC coordinate, double loop control in d-q rotating coordinate system, etc. The PR control block diagram of the ABC static coordinate of the Vienna rectifier is shown in Figure 4. The whole control block diagram is composed of the output voltage outer ring and the input current inner ring. The voltage outer ring is used to stabilize the output voltage, and the output and input voltage phase information of the outer ring together get the current inner ring.

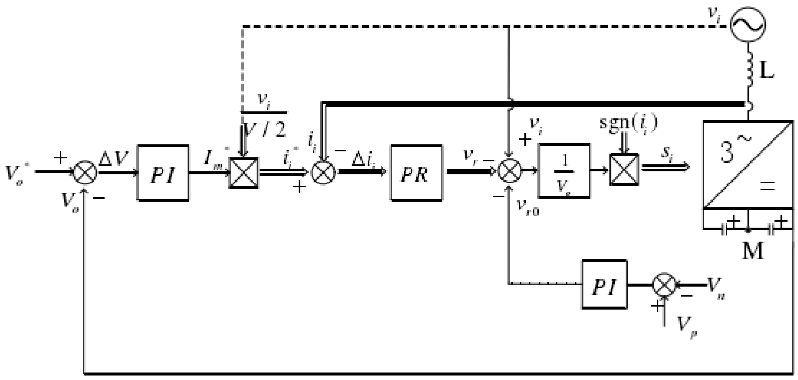


Figure 4. PR control block diagram in abc coordinate system

The control strategy of Vienna rectifier in d-q rotating coordinate system is widely used in three-phase PWM rectifier, also known as direct current control. The strategy has clear physical meaning, good robustness, can track the input current waveform well, and can use space vector modulation to further optimize the input current waveform.

3. Space vector modulation strategy of Vienna rectifier

3.1. Key problems of space vector PWM for Vienna rectifier

The key problems of SVPWM of Vienna rectifier are digital realization of vector modulation, complex algorithm of SVPWM and large amount of calculation, distortion of the rectifier when the input current is over zero under SVPWM, etc.

3.2. Space vector modulation strategy of Vienna rectifier

There are two kinds of space vector modulation strategies for Vienna rectifier: the traditional NTV method and the simplified three-level SVM method. Although the sector division and calculation process of the two methods are different, the basic vectors chosen are exactly the same. In essence, they are two different implementation methods under the same modulation strategy. Compared with the two methods, the simplified three-level SVM method is easier to program the SVPWM of Vienna rectifier.

4. Performance analysis of SVPWM algorithm for Vienna rectifier

Based on the principle of simplified three-level vector modulation, a vector modulation algorithm based on the principle of effective vector action time invariant is proposed. The algorithm does not need coordinate transformation and complex calculation. By establishing the relationship between carrier modulation and space vector modulation, only through the addition and subtraction of three-phase sinusoidal modulation wave, the sector of the target vector can be located and the last three basic vector action times can be obtained. By optimizing the distribution of the redundant vectors in the zero crossing sector of the input current, the midpoint of the bridge arm is clamped to the zero level in the zero crossing sector of the corresponding phase input current, avoiding the distortion of the zero crossing of the input current and reducing the THD of the input current.

The algorithm flow of SVPWM algorithm of Vienna rectifier based on the principle of effective vector invariance is as follows: first, judge the large sector of the target vector and obtain the target vector coordinates rotating to the first sector. Secondly, the sub sector of the target vector is determined. Finally, the working time of the basic vector is calculated. The algorithm only needs the addition and subtraction of sinusoidal modulation wave and logic operation from sector judgment to the calculation of basic vector time. It omits coordinate transformation and complex multiplication operation which takes a lot of time. It can reduce the time resources occupied by vector modulation algorithm and improve the accuracy of the algorithm. Compared with the traditional vector modulation algorithm, the implementation time of the algorithm is reduced by nearly half compared with the traditional algorithm, which shows that the algorithm can effectively reduce the time resources.

5. Conclusions

The advantage of the Vienna rectifier is the preferred topology of the front stage PFC of the high-power charging power supply. The SVPWM algorithm of Vienna rectifier described in this paper can effectively solve the shortcomings of traditional SVPWM and virtual SVPWM, but also increase the complexity of the algorithm. By adjusting the action time of the positive and negative small vectors and the current generated by the virtual vector to balance the neutral point potential, combining the neutral point potential balance problem and the switching loss problem, a discontinuous space vector PWM algorithm is studied to reduce the switching loss. The algorithm has a wide range of applications. It can reduce the current ripple nearby while restraining the distortion of the current zero crossing waveform. The validity of the modulation method and the correctness of the theoretical analysis are guaranteed.

Acknowledgement

Application of SiC MOSFET Device in VIENNA Rectifier and Research on Key Technologies.

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