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AC to DC Voltage Conversion of a Matrix Rectifier Topology by Using SPWM Control Strategy

Engineering

KEYWORDS: Absolute value logic SPWM, High frequency link, Matrix rectifier, MATLAB Simulink

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ABSTRACT

Matrix Rectifier has evolved from the traditional three phase to three phase Matrix Converter (MC) in recent years, and inherits merits of the traditional MC. Matrix Rectifier could be divided into isolated and non-isolated two types according to using high frequency transformer or not. A kind of isolated Matrix Rectifier topology, i.e., high frequency link Matrix Rectifier (HFLMR) has been selected as the study project. Space vector modulation is the mostly focused control strategy for the HFLMR, however its algorithm and its implementation are complicated and difficulty. So a novel straightforward absolute value logic SPWM control strategy based on De-Re-coupling idea has been proposed in this paper, which could realize unit power factor and DC voltage output, and made the transformer gain volt-second balance in a high frequency switching cycle. The validity and feasibility of the proposed control strategy have been well proved by the MATLAB simulation.

I. INTRODUCTION

Conventional diode rectifier and phase controlled rectifier have caused more serious harmonic pollution to the power grid, so high frequency PWM rectifiers have been paid more attention in recent years. PWM rectifiers can shape their input current as an approximate sine wave and they also can realize higher power factor, minor output voltage ripple, bidirectional flow of energy and better dynamic response synthesize a required wave by using of proper logic

However, neither voltage source kind nor current source kind of traditional PWM rectifier can be suitable for isolated single power conversion.Matrixconverter (MC), since proposed by L. Gyugyi and B. Pelly in 1976 has caused worldwide interest for merits of having no intermediate energy-stored link, realizing power factor in the mains side and adjustable amplitude and frequency of the output voltage.

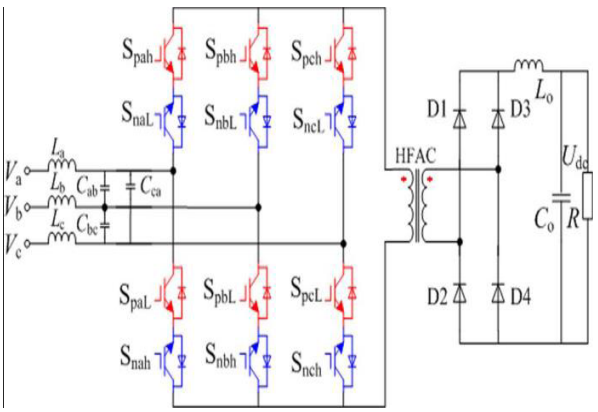


Fig 1.The Topology of High Frequency Link Matrix Rectifier

Matrix converter is a very flexible and universal power converter, and Matrix Rectifier has evolved from the traditional three phase to three phase Matrix Converter (MC) in recent years, and inherits merits of the traditional MC. It can be used in active power filter, wind power generation, motor drive systems, power factor correction, DC excitation, AC/DC switching mode power supply, etc. An isolated high frequency link MR (HFLMR) topology is shown in Fig. 1, it consists of several parts as input filter, MC, high frequency transformer, full bridge rectifier and output filter. According to the literature we could find, the isolating topology under virtual DC link modulation control was first proposed by Mr.Stefanos Manias in 1985. And then, more and more research working had been done on direct SVM or indirect SVM, but the modulation strategy is limited to SVM. To achieve SVM strategy not only needs sector partition, but also needs vector time calculation. Thus much resource is needed in DSP and SVM is not easy to be realized digitally. A novel absolute value logic SPWM (AVL SPWM) strategy based on De-Re-coupling idea has been proposed in the paper, which can control HFLMR to combination according to the absolute value of its input voltage. This modulation strategy has a plain idea and could be easily realized under the control of the modulation strategy, the HFLMR not only can get an input unit power factor and a steady output DC voltage, but also can contribute a maximum voltage utility and a reduced switching action within a high frequency period.

II. BASIC IDEA OF ABSOLUTE VALUE SPWM

The book (static Power Frequency Changer) [1], narrated by L. Gyugyi and B. Pelly in 1976, showed that three-phase to three-phase matrix converter can realize output function from the amplitude and frequency of one input to another, and can output random frequency waves in theory, which was called high frequency synthesis theory. Based on this theory, in three-phase-to-single-phase matrix converter, the input three phase sine wave with low frequency can be chopped into a series of high frequency AC waves. So the absolute value logic (AVL) SPWM idea for could be proposed, first we can get three absolute values of the three phase input voltages, and judge the relation among their values. Then according to the absolute value and suitable logic, the principle of the phase voltage conduction can be determined as: in a high frequency switching period, the phase with the maximum absolute value should be always in a conduction state both in former and latter half period; and the phase with the intermediate value should firstly be in a conduction state to match the phase with the maximum absolute value in a time slicing of the period; and then the phase with the minimum absolute value should secondly be conducting to match the phase with the maximum absolute value. For instance, see "section 1" in Fig. 5, A-phase voltage has the maximum absolute value, B-phase voltage value is lesser, and C-phase voltage value is minimum. Then the switches Connected to A-phase are on all in a high frequency period, B-phase switches firstly prefer to synthesize the output voltage with A-phase's, and then C-phase switches to be the second synthesizer. Because switching frequency is much higher than the grid voltage frequency, the input voltage amplitude could be approximately considered as a constant in a high frequency switching period. Then in the former half high frequency period, A phase and B phase voltages firstly synthesize the line voltage Vab (seeing Fig. 6), after that A phase and C phase secondly synthesize the line voltage Vac . Similarly, in the latter half period, A phase and B phase voltage firstly synthesize the minus line voltage -Vab, A and C secondly synthesize the minus line voltage -Vac.So a high frequency AC voltage meeting the volt-second balance has been gained at the output port of MC

III. ANALYSIS OF WORKING STATES UNDER AVLSPWM CONTROL

The main circuit of HFLMR is shown in Fig. 1, in which every bidirectional switch cell is composed of two unidirectional switches. As all switches have four-quadrant conduction ability, the matrix converter can output either plus or minus voltage and current, i.e., a kind of single phase high frequency AC square-wave voltage could be achieved by MC from the three phase AC grid mains. The specific working states are analyzed in the following by assuming A- phase voltage has the maximum absolute value, B-phase voltage has an intermediate absolute value, and C-phase voltage has the minimum absolute value.

1) State 1: The current flows from A-phase, through the bidirectional switch cell "Sah" in the upper of MC A-phase leg, then to the transformer's primary side, and pass by the bidirectional cell "SbL" in the lower of MC B-phase leg, finally the current flows back into B-phase.Thus, the plus voltage, which was shown as "Sta1" in Fig. 2, is formed in the primary side. At the same time, the current of second side flows through diode VD1, the output filter, and the load.
Finally, it flows back into the transformer second side by VD4.

So the state meets the equation:

Vab=Va-Vb=Ria+Ldia/dt+Lpσdia/dt

Where R is the total resistance that includes resistances in the inductance, the switches and wires; is the current in phase A,L is the primary inductance of the high frequency transformer; is the total inductance that includes the primary side leakage inductance of the transformer and parasitic inductance of wires.

2) State 2: The current flows through from A-phase, through the bidirectional switch cell "Sah" in the upper of MC A-phase leg, then to the transformer's primary side, and pass by the bidirectional switch cell "ScL" in the lower of MC C phase leg, finally the current flows back into C-phase. Thus, the plus voltage, which was shown as "Sta2" in Fig.2 is formed in the primary side. The secondary side current is as same as state 1. The state meets the equation:

Vac=Va-Vc= Ria+Ldia/dt+Lpσdia/dt

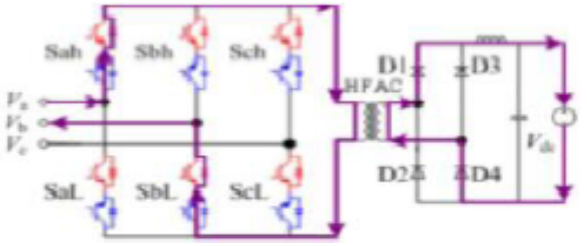
3) State 3:The current flows from A-phase, through the bidirectional switch cell "SaL" in the lower of MC A-phase leg, then to the transformer's primary side, and pass by the bidirectional switch cell "Sbh" in the upper of MC B-phase leg, finally the current flows back into B-phase. Thus, the minus voltage, which was shown as "Sta3" in Fig. 2, is formed in the primary side. At the same time, the current of secondary side flows through diode VD3, the output filter, and the load.Finally,it flows back into the secondary side by VD2. The state meets the equation:

-Vab= Vb-Va =Ria+Ldia/dt+Lpσdia/dt

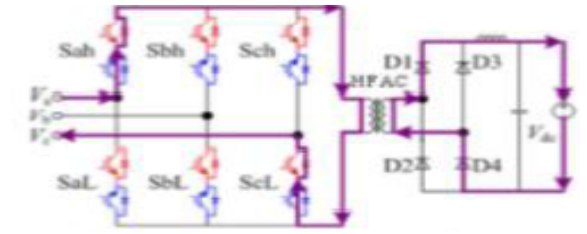
4) State 4: The current flows from A-phase, through the bidirectional switch "SaL" in the lower of MC A-phase leg, then the transformer's primary side, and pass by the bidirectional switch cell "Sch" in the upper of MC C-phase leg, finally the current flows back into C-phase . Thus, the minus voltage , which is shown as "Sta4" in Fig. 2, is formed in the primary side. The circulating of secondary side current is as same as state 3. The state meets the equation:

-Vac= Vc-Va = Ria+Ldia/dt+Lpσdia/dt

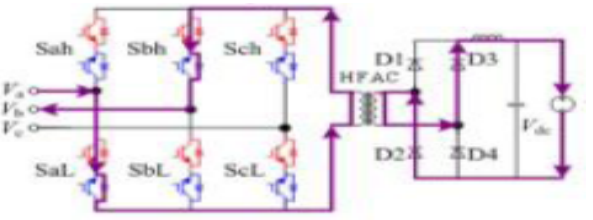
From the above working states, we can see the high frequency single phase AC voltage at the secondary side was rectified and filtered to be a DC voltage, this means that the high frequency link matrix rectifier has achieved the desired converting function.



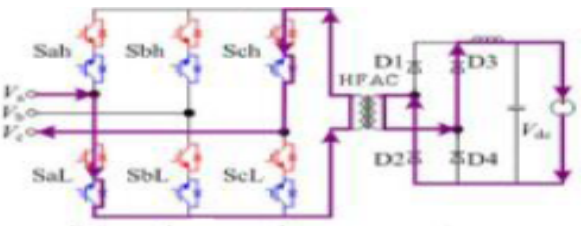
1) State1: the synthesis voltage Vab



2) State 2: the synthesis voltage Vac



3) State 3: the synthesis voltage –Vab



4) State 4: the synthesis voltage -Vac

Fig 2. The working states of matrix rectifier in a switching period

IV. SIMULATION AND EXPERIMENTAL RESULT

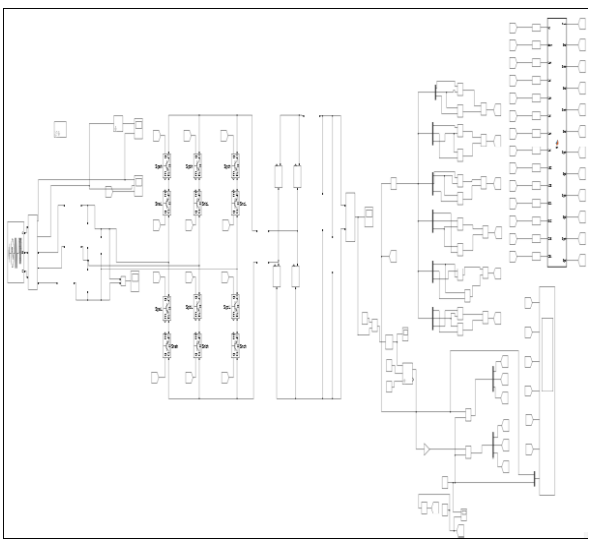


Fig 3:Simulated figure of feedback loop given to matrix converter

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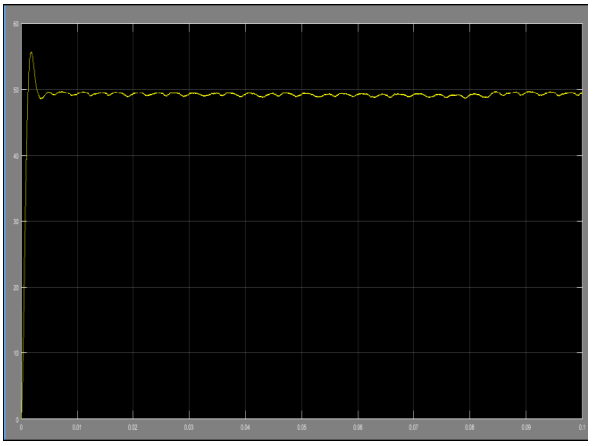


Fig 4 DC output voltage of matrix converter topology

IV. CONCLUSION

A kind of absolute value logic (AVL) SPWM strategy based on DE-RE-coupling idea has been proposed for HFLMR. Compared with the direct and indirect SVM control strategy proposed by the references, the AVL SPWM control strategy is simple and easy to implement. Some results of simulation and experiment have all proved the validity and feasibility of the new kind of AVL SPWM control strategy

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