Novel of Indirect Matrix Converter with a Boost-up Chopper in Control of Neutral Point Load Voltage

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This paper proposes a novel control strategy for an indirect matrix converter based on the control of neutral point load voltage between a motor and a boost-up chopper. The proposed method is capable of direct AC/AC power conversion and it does not require any uses of reactor or capacitor. The basic operation of the proposed method is confirmed with the experiment results.

(Keywords: AC/DC/AC Converter, Indirect Matrix Converter, Boost-up Chopper, Zero Vectors)

1. Introduction

Increasing price of oils along with highly concerned about environment impact has lead to rapid development in new energy source system such as HEV (Hybrid Electric Vehicle). These systems require compact size, high efficiency and low cost power converter among AC and DC sources. A conventional AC/DC/AC power typically consists of a diode rectifier, a DC link and an inverter [1]. The DC link section usually consists of electrolytic capacitor to have high voltage withstanding capability for DC bus. However, a large capacitance electrolytic capacitor has a relatively limited operating lifetime.

This paper proposes using an indirect matrix converter [2] as a main circuit in AC and DC power sources [3]. One advantage of the proposed circuit is, it does not require DC link electrolytic capacitor to achieve a high DC link voltage. Further, a conventional design boost-up reactor can be replaced with a motor. A boost up chopper is included in the circuit to gain control of zero vectors period in the inverter. Control over zero vectors allows the control of the battery current in the proposed method. Experiment results are obtained to support the theory.

2. Circuit topology

For a conventional power converter system in HEV, battery is working as a secondary power supply. The operation of battery regeneration progress is based on power module which consists of energy storage components such as capacitor and reactor. A reactor is used to boost up the battery voltage. Electrolytic capacitor is used to smoothing energy. The requirement of a reactor and a capacitor in a conventional method caused the circuit is bulky and costly.

Fig.1 shows the proposed circuit diagram. Indirect matrix converter is a main circuit in this design. It is a direct power conversion system since it does not require large energy storage components between source and load. Thus, it features bidirectional power flows. For the proposed design, a DC battery is connected within the neutral point of the motor load and the neutral point of the dc link in the circuit. A boost up chopper is added between rectifier and inverter and operates as a fourth leg of the inverter. In the proposed method, it takes advantage of motor neutral point and result battery regeneration occurs in a more effective way.

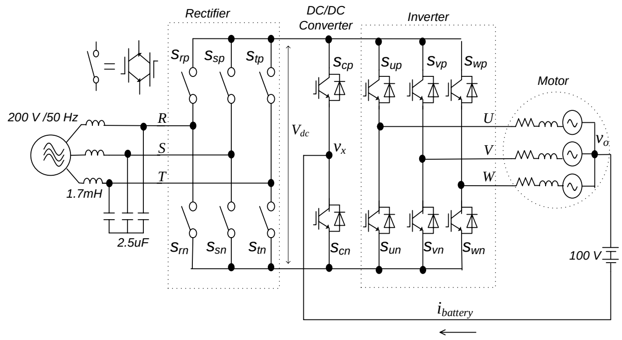

Fig.1. Proposed circuit diagram.

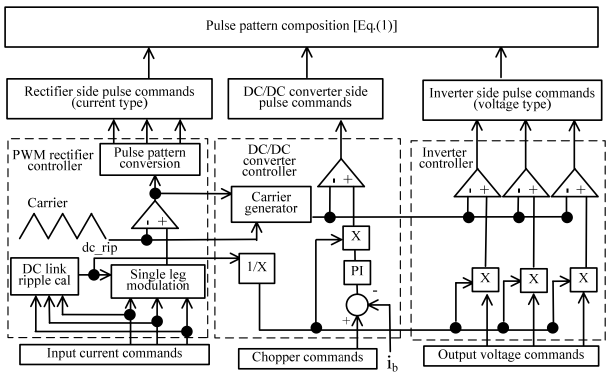

Fig.2. Control block diagram of the proposed method.

3. Control block diagram

Fig. 2 shows the control block diagram of the proposed method. The circuit operation is divided into two stages, rectifier and inverter. Both rectifier side and inverter side have its own control respectively. Control is performed by a virtual AC/DC/AC carrier comparison method [4]. A single leg modulation is designed in rectifier side to obtain a high DC link voltage. For the inverter side, a lean controlled carrier modulation of the inverter is designed. The leans of triangle carrier are controlled by the duty ratio of the rectifier side pulse. This carrier comparison method is able to obtain switching pulses for rectifier, chopper and inverter. Boost-up chopper works along with inverter side operates as a four-phase voltage source inverter voltage as expressed as

$$\begin{bmatrix} v_u \\ v_v \\ v_w \\ v_c \end{bmatrix} = \begin{bmatrix} s_{up} & s_{un} \\ s_{vp} & s_{vn} \\ s_{wp} & s_{wn} \\ s_{cp} & s_{cn} \end{bmatrix} \begin{bmatrix} s_{rp} & s_{sp} & s_{tp} \\ s_{rn} & s_{sn} & s_{tn} \end{bmatrix} \begin{bmatrix} v_r \\ v_s \\ v_t \end{bmatrix}. \quad (1)$$

where s_{xy} stands for the switching function of the switches shown in Fig.1. When S_{xy} is turned on, s_{xy} =1 and when S_{xy} is turned off, s_{xy} =0.

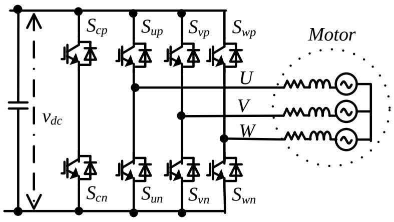

Fig. 3. Positive-phase sequence equivalent circuit.

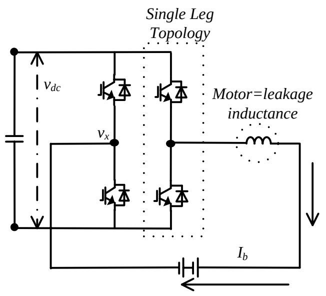

Fig. 4. Zero-phase sequence equivalent circuit.

4. Battery current control

Boost up chopper is an important design in this circuit. It combines with a three-phase inverter, operates as a fourth leg of an inverter, to control the zero vectors of the inverter. It is possible to use zero vectors to control the battery current, (i_s) in this circuit design. During zero vectors period, two individual sequences will occur at one carrier cycle, known as positive-phase sequence and zero-phase sequence.

Fig. 3 represents the positive-phase sequence. Inverter is operating as normal. On the other hand, Fig. 4 shows the zero-phase sequence, the motor is considered as a leakage inductance and the inverter can be regarded as a single leg topology. The circuit functions same as a boost up chopper. This result the battery current has bidirectional current flows. Battery can be charged or discharge during this period. An ACR is designed to control the battery current.

5. Experiment results

Fig. 5(a) shows battery charge mode experiment result and Fig. 5(b) shows the simulation result. The switching frequency is 10 kHz, the output frequency is 30 Hz and no load is connected. Table 1 shows the tested motor parameter. The experiment waveforms show good sinusoidal waveforms for both input current and output current respectively. Notice there is a distortion in i_b is caused by the dead time in inverter modulation.

Fig.6 shows the neutral point voltage of the proposed circuit in charge mode and its harmonics analysis. The neutral point voltage keeps at a constant around zero. One reason for the ripple happened in V_L could be the unbalanced motor speed due to the motor internal structure.

Table 1 Rating of Tested Induction Motor

Power	750 W	Rated current	3.6 A
Frequency	50 Hz	Rated voltage	200 V
Motor Speed	1420 r/min	Leakage inductance	4.42 mH

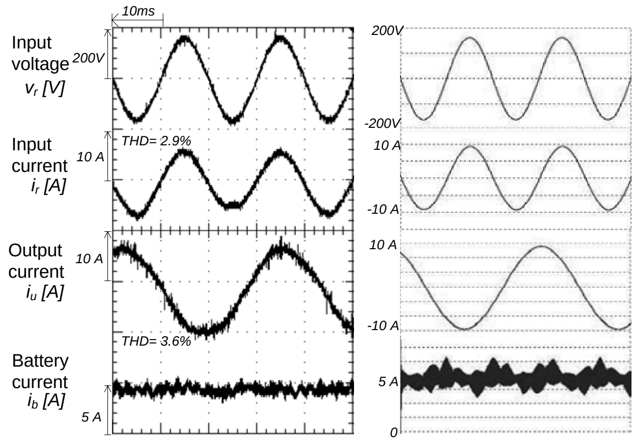

Fig. 5. (a) Experiment result. Fig.5. (b) Simulation result.

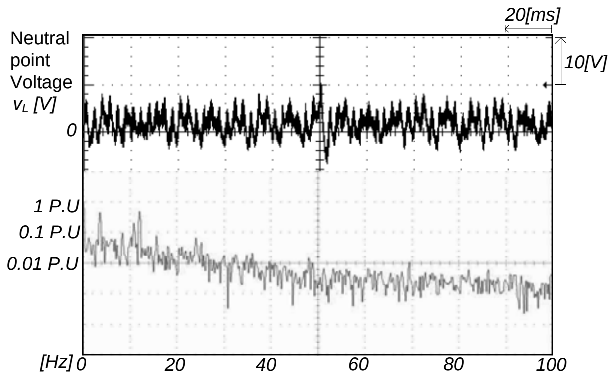

Fig. 6. Neutral point voltage and its harmonics analysis.

6. Conclusion

This paper proposed a control method to achieve zero vectors based on the control of a boost-up chopper in an indirect matrix converter. Experiment results have proved the validity of the proposed concept.

References

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