A Model Predictive Control Method to Reduce Common-Mode Voltage for Voltage Source Inverters

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***Abstract*—This paper presents a new model predictive control method without the effect of a weighting factor in order to reduce common-mode voltage (CMV) for a three-phase voltage source inverter (VSI). By utilizing two active states with same dwell time during a sampling period instead of one state used in conventional method, the proposed method can reduce the CMV of VSI without the weighting factor. Simulation is carried out to verify the effectiveness of the proposed predictive control method with the aid of PSIM software.**

***Keywords*— Model predictive control, common-mode voltage (CMV), voltage-source inverter (VSI).**

I. INTRODUCTION

Three-phase voltage source inverters (VSIs) have been widely employed in AC motor drive systems [1]. However, the common-mode voltage (CMV) generated by fast switching operation of the VSI is a main source of early motor-winding failure, bearing deterioration. Thus, the reduction of the CMV is important to increase the motor life time. Many researches have been presented to reduce the CMV based on the PWM strategies by avoiding the appearance of zero vectors in the switching sequences [2]. Due to the lack of using zero vectors, the performance of these PWM strategies become deteriorated. Recently, the model predictive control (MPC) method has received many considerable attention as an effective method because of its advanced characteristics such as simplicity and control flexibility.

Regarding to the CMV reduction, the cost function including a CMV constraint is designed and the amount of CMV reduction is decided by an appropriate weighting factor [3]. However, the selection of the weighting factor is not easy due to the lack of theoretical design procedure. In order to solve this problem, we apply the MPC method to reduce CMV without the effect of the weighting factor. The proposed method is based on the concept of virtual vector in the PWM strategy which uses two active states with same dwell time during a sampling period. Therefore, the proposed method can not only reduce the peak value of the CMV to 66.7% but also eliminate the effect of the weighting factor on the cost function. Simulation results are provided to validate the proposed method.

II. PROPOSED PREDICTIVE CONTROL METHOD

In general, the CMV of a three-phase VSI is defined as following:

$$v_{cm} = (\mathrm{v}_{ao} + \mathrm{v}_{bo} + \mathrm{v}_{co}) / 3 \quad (1)$$

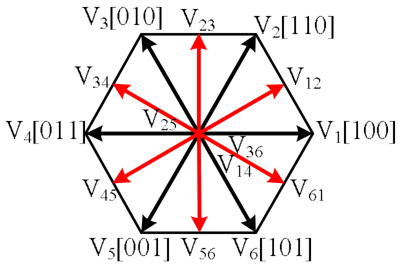

Fig. 1. Virtual space vectors and original space vectors

TABLE I
CONSTRUCTION of VIRTUAL VECTORS

Virtual vectors	Combined active states		Magnitude of CMV	Average of CMV
V_{12}	[100]	[110]	$V_{dc}/6$	0
V_{23}	[110]	[010]	$V_{dc}/6$	0
V_{34}	[010]	[011]	$V_{dc}/6$	0
V_{45}	[011]	[001]	$V_{dc}/6$	0
V_{56}	[001]	[101]	$V_{dc}/6$	0
V_{61}	[101]	[100]	$V_{dc}/6$	0
V_{14}	[100]	[011]	$V_{dc}/6$	0
V_{25}	[110]	[001]	$V_{dc}/6$	0
V_{36}	[010]	[101]	$V_{dc}/6$	0

where v_{ao} , v_{bo} and v_{co} are the output phase voltages with respect to the neutral point.

The concept of virtual vector, which has recently been introduced in [4], is an effective PWM technique to reduce CMV. The virtual space vector is a combination of two active vectors which can obtain the lowest instantaneous value and zero average value of the CMV as shown in Fig. 1. All the virtual vectors have the same characteristics of the magnitude and average values of the CMV as shown in Table I. In order to reduce CMV without considering the effect of weighting factor, the concept of virtual vector is applied to the proposed method.

Table I also shows the combination of two active states corresponding with each virtual vector. By applying two appropriate active states during a sampling period, the same performance can be obtained as the corresponding virtual vector. Fig. 2 shows the flow chart of the proposed method.

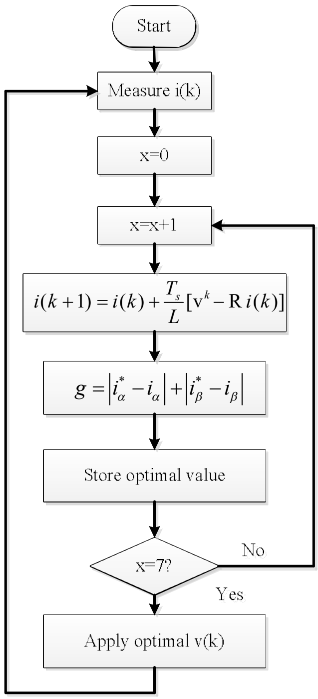

Fig. 2. Flow chart of the MPC method.

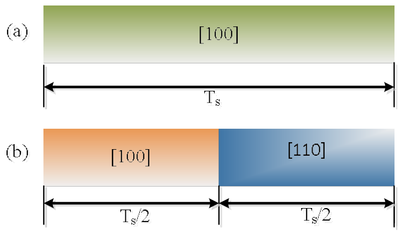

Fig. 3. Implementation of (a) conventional MPC method and (b) proposed MPC method during a sampling period.

The proposed method is implemented by using two active states with same dwell time during a sampling period instead of one state used in conventional method as shown in Fig. 3.

III. SIMULATION RESULTS

In order to evaluate the proposed method, simulation is carried out with a three-phase R-L load by using PSIM 9.0 software. The three-phase load currents and the CMV waveforms of the conventional and the proposed MPC method are shown in Fig. 4 and Fig. 5, respectively. As we can see, the peak value of the CMV in the proposed method is 33.33 V (corresponding with $V_{dc}/6$), whereas the peak value of the CMV in the conventional method is 100 V (corresponding with $V_{dc}/2$). However, the output current performance is not deteriorated with the proposed method; the total harmonics distortion of the conventional method and the proposed method are 2.54% and 2.35% , respectively.

IV. CONCLUSIONS

This paper proposes a MPC method for VSI to reduce CMV without the effect of the weighting factor. With the proposed MPC method, the CMV has the lowest instantaneous

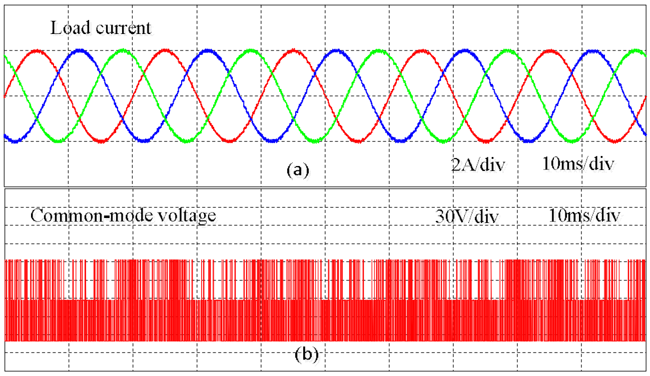

Fig. 4. Simulated results of: (a) three-phase load currents and (b) CMV in the MPC method.

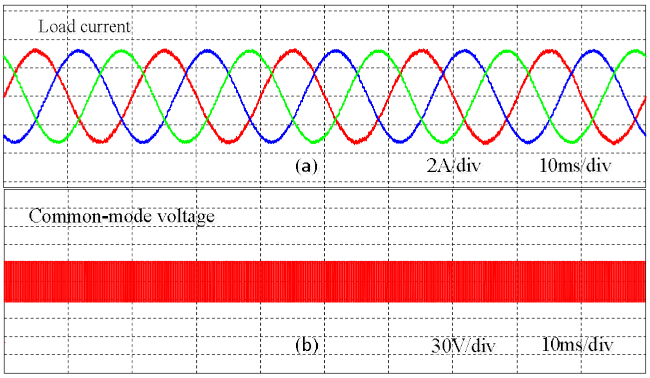

Fig. 5. Simulated results of: (a) three-phase load currents (b) CMV in the proposed MPC method.

value and zero average value without deteriorating the output performance. The simulation results verifies the effectiveness of the proposed method.

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