Output Voltage Constant Control of Three-Phase Z-Source Inverter

Se-Jin Kim*. Young-Gook Jung+. Young-Cheol Lim*. Yan-Jun Wu*
*Chonnam National University, +Daebul University
Sj6129210@naver.com

***Abstract*- This paper proposes a new constant control method of the output voltage of a voltage-fed three phase Z-source inverter (ZSI), in case of the capacitor voltage variations in Z-source network or the heavy changes of load. The modulation index for the reference output voltage of the ZSI can be calculated by the basic definition of the ZSI, the input DC voltage and capacitor voltage in Z-source network. And, the output voltage of the ZSI is controlled by the modified SVM(space vector modulation) with the calculated modulation index. By the proposed method, the modulation index of the output voltage is closely following in the reference modulation index. To verify the validity of the proposed method, PSIM simulation was achieved and a DSP controlled 1[kW] three-phase Z-source inverter was manufactured. Despite the input DC voltage of the ZSI is heavily changed from 80[V] to 110[V] (or from 120[V] to 90[V]) and the load is changed into three-steps (20[Ω], 40[Ω], 80[Ω]), the capacitor voltage of Z-source network kept up 168[V], therefore, the output phase voltage could be controlled by the reference output voltage (68[V_{RMS}]) according to the capacitor voltage.**

I. INTRODUCTION

The most general way for obtaining the voltage boost capability of PWM inverter using renewable power source such as wind or PV power generation is to install a DC-DC boost converter as an extra circuit at the input stage of PWM inverter. These two-stage PWM inverter systems lead to the problem such as control complexity and increase of switching devices [1]. To overcome these problems, a new inverter topology so called Z-source inverter(ZSI) which is utilized a Z-impedance network with L-C lattice to replace the traditional DC Link has been presented [1-2]. The ZSI advantageously utilizes the shoot-through states to boost the DC-bus voltage by gating on both the upper and lower switches of a phase leg. Therefore, the ZSI can buck and boost voltage to a desired output voltage that is greater than the available DC bus voltage. The approaches to control constantly and stably the output voltage of the ZSI, many studies such as modified SVM (space vector modulation) method under d-q coordinate transformation [3] also the calculation method of the boost factor and switching duration time by using PID control [4-5] have been done. Although all of them have showed a good performance but there are still so many problems that requires the complex control algorithm and the circuit for sensing the three-phase output voltages.

Therefore, this paper proposes the output voltage control algorithm by using the detection of both Z-impedance network DC capacitor voltage and output voltage of the ZSI. The proposed method expresses the modulation index (M) using the voltage gain (G) which can presented by relationship between Z-impedance network capacitor voltage (V_C) with the input DC voltage (V_{IN}) of the ZSI. Control modulation index (M_C) for the output voltage control is calculated by the detected actual modulation index (M_A) and the reference modulation index (M_R). And, calculated control modulation index is applied to the modified space vector modulation (SVM) for control the output voltage of the ZSI.

To verify the validity of the proposed method, PSIM simulation was achieved and a DSP controlled 1[kW] three-phase Z-source inverter was manufactured. The simulation and experiment are performed under the condition that the load is heavily changed in case of the constant input DC voltage, and the input DC voltage is suddenly changed in case of the load is constant. As a result, we could know that the output phase voltage of the Z-source inverter nearly followed to the reference voltage 70[V_{RMS}] despite the load or the input DC voltage were suddenly changed.

II. PROPOSED SYSTEM

Fig. 1 shows the configuration of the proposed system. The proposed control algorithm can be divided into three-Steps.

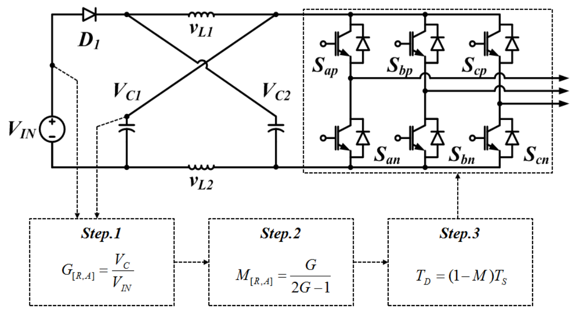

Fig. 1. Configuration of the proposed system

First, in Step-1 the two-voltage gains (G_R, G_A) are obtained through detection of the input voltage (V_{IN}) and the Z-impedence network capacitor voltage (V_C). Where, G_A refers to the actual voltage gain, and G_R denotes the reference voltage gain.

In Step-2, two modulation index (M_R,M_A) are determined by the voltage gains calculated in Step-1 and the control modulation index (M_C) which can constantly control the output voltage of the ZSI is calculated by using (M_R,M_A).

In Step-3, the ZSI are switched by modified SVM method adopting the control modulation index (M_C) calculated in Step-2. Using the input DC voltage (V_{IN}) and the Z-

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impedance network capacitor average value ($V_{C1}=V_{C2}=V_C$), peak output voltage (V_O) of the three-phase ZSI can be expressed by (1) [1]. Capacitor voltage (V_C) which defined by the input DC voltage (V_{IN}) and voltage gain (G) can be presented by (2) [1-2]. Where, D denotes the shoot- through duty ratio.

$$V_O = \frac{1}{\sqrt{3}} \cdot G \cdot V_{IN} \quad (\therefore V_C = GV_{IN}) \tag{1}$$

$$G = \frac{V_O}{V_{IN}} = \frac{1-D}{1-2D} \tag{2}$$

The proposed algorithm in this paper presents the control process of the modulation index (M) by the detection of the input DC voltage (V_{IN}) and the Z-source network capacitor voltage (V_C). The process for achieving the output voltage constant control of the ZSI can be realized by the following three- Steps.

1. Step - 1

The general relationship between the shoot-through duty ratio (D) with the modulation index (M) is shown in (3). Using (2) and (3), the modulation index (M) and the shoot-through duty ratio (D) can be rewritten as a function of gain (G) as shown in (4)[6] and (5)

$$M + D = 1 \tag{3}$$

$$M = \frac{G}{2G-1} \tag{4}$$

$$D = \frac{G-1}{2G-1} \tag{5}$$

Using the Z-network capacitor voltage (V_C) and the input DC voltage (V_{IN}), the actual voltage gain (G_A) can be induced. And we can determine the actual modulation index (M_A) by using the actual voltage gain (G_A). That is, the actual modulation index (M_A) is automatically determined according to the input DC voltage (V_{IN}) and load changes.

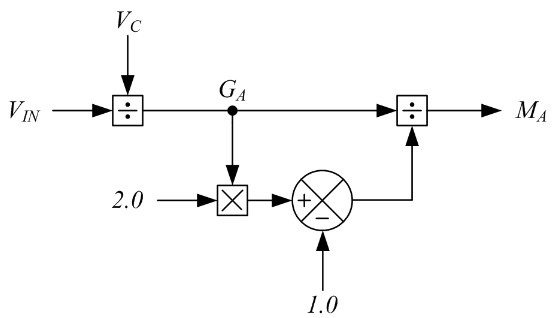

Fig. 2 The calculation process of the actual modulation index M_A by using V_{IN} and V_C

Fig. 2 shows the calculation process of the actual modulation index (M_A). In the other hand, in order to control the output voltage, the reference voltage gain (G_R) can be determined by the reference capacitor voltage (V_{CR}) and the input DC voltage (V_{IN}). Then we can take the reference modulation index (M_R) using the reference voltage gain (G_R) as shown in Fig. 3.

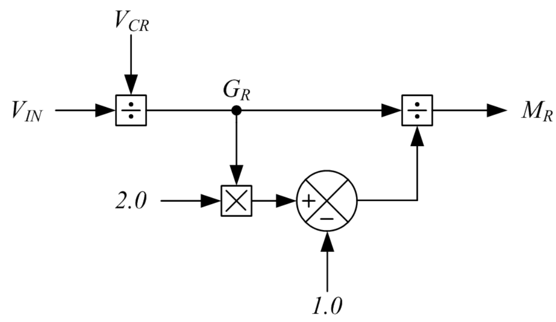

Fig. 3 The calculation process of the reference modulation index M_R by using V_{IN} and V_{CR}

In case that V_{CR} is always constant, the reference modulation index (M_R) will be varied according to V_{IN}.

$$V_{CR} = V_O \cdot \sqrt{3} \tag{6}$$

Therefore, the reference modulation index (M_R) according to V_{IN} can be determined to achieve the constant output voltage. V_{CR} is defined as (6) by using (1) [7].

2. Step - 2

The control modulation index (M_C) calculated by the actual modulation index (M_A) and reference modulation Index (M_R) in Step-1, can achieve the output voltage constant control.

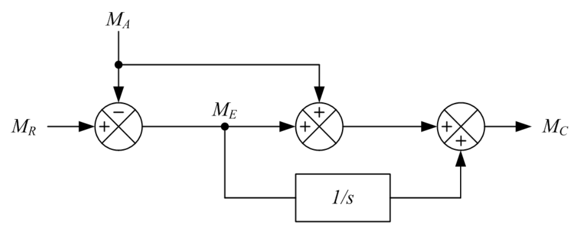

Fig. 4 The calculation process of M_C by using M_A and M_R

Fig. 4 shows the calculation process of the control modulation index (M_C) using M_A and M_R. First, M_A and the error M_E between M_R and M_A are summed. In theoretical, (M_A+M_E) is equal to M_R. But in practical, in order to prevent the error in the steady state, an integral control has set for M_E. Hence, M_C should be determined by all summation of M_A, M_E and the integral value of M_E.

3. Step - 3

The control modulation index (M_C) to achieve the output voltage constant control of the ZSI has been introduced in Step-2. The modified SVM applying MC has been presented and the duration time of each vectors have been modified as follows. In traditional SVM method, the duration time (T_A, T_B) of two-effective vectors adjacent to the reference vectors