Transient State Improvement of Three-Phase ZSI with the Input Feedforward and Fuzzy PI Controller

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입력 피드포워드와 퍼지 PI제어기를 갖는 3상 ZSI의 과도상태 개선

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ABSTRACT

This paper proposes a scheme of auto tuning fuzzy PI controller and input voltage feed forward to control the output voltage of a three phase Z source inverter (ZSI). The proposed scheme adjusts the ts (Kp and Ki) in real time in order to find the most suitable Kp and Ki for PI controller and to simplify the controller design. The proposed scheme is verified the validity by experiment and co simulation in PSIM and MATLAB/SIMULINK both load step change and input DC voltage variation in Z source inverter, and has compared with the conventional PID control scheme. The experiment results involve of three phase output voltage, Z network capacitor voltage and dc link peak voltage value. By those analysis and comparison, the availability of the proposed method in output voltage transient response quality improving has been verified. Compared with conventional PID method, the proposed method showed a more effective and robust control performance for coping with the severe disturbance conditions..

1. INTRODUCTION

The Z source inverter (ZSI) was introduced as a new kind of inverter topology and it has overcome some limitations of the conventional ones. ZSI can perform boost functions without transformer or chopper. as a result, Z source inverter has been used extensively in fuel cell application, wind power generation and photovoltaic generation. there is a same characteristic in this kind of power generating systems. DC power source is nonlinear and unstable, but the AC output power supply need to be stabled.

Z network capacitor voltage feedback control of Z source inverter has widely studied in recent years. But in this paper, the terminal voltages of 3 phase loads and input voltage have been taken sampling. With proposed control method, system has ability to compensate the load suddenly changing or input DC voltage changing. Proposed system recovers to the reference value after 0.03(sec). It shows that the proposed system has the compensation ability for the voltage variations.

In the practical applications, it is able to provide a safety environment for adjustable speed system (ASD) in commercial and industrial facilities

2. THE PROPOSED METHOD

2.1 ZSI topology

Traditional Z source inverter (ZSI) shown as Fig. 1 was proposed by Professor Peng in 2003 [1 2].

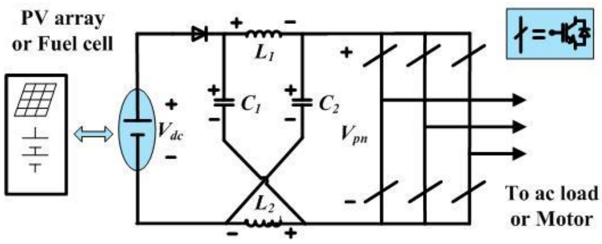

Fig. 1. 3 phase ZSI topolpgy

The ZSI operates have symmetrical L C lattice network which consists of two inductors L1, L2 and two capacitors C1, C2 and utilize the shoot through of the inverter bridge to boost voltage without dead time. To make shoot through states, several pulse width modulation (PWM) methods [3 4] have been developed with the attempt of increasing the voltage gain in the Z source network.

The shoot through duty ratio of ZSI is defined as follows;

$$D_0 = 1 - M \tag{1}$$

Where M means the modulation index, D0 is the shoot through duty cycle.

The boost factor B can be expressed as (2) is

$$\mathrm{B} = \frac{1}{1 - 2\frac{T_0}{T}} = \frac{1}{1 - 2\mathrm{D}_0} \tag{2}$$

And, the relationship between voltage gain (G) and modulation index (M) in the ZSI is.

$$\mathrm{G} = \mathrm{B} \times M = \frac{M}{1 - 2D_0} = \frac{M}{2M - 1} \tag{3}$$

By using the above results, the represented by (4) and And Z network capacitor voltage ($V_{Z\ C}$) expressed as (5).

$$\hat{V}_{ac} = \frac{MV_{\mathrm{dc}}}{2(1 - 2D_0)} = \frac{M}{2\mathrm{M} - 1} \times \frac{V_{dc}}{2} \tag{4}$$

$$V_{Z-C} = \frac{MV_{\mathrm{dc}}}{(1 - 2D_0)} = \frac{M}{2\mathrm{M} - 1} \times V_{\mathrm{dc}} \tag{5}$$

Then if we got the sampling voltage value of Vdc, we can calculate the reference modulation index (M_ref) as a feedforward output:

$$M_{\_ref} = \frac{2P_{\_ref}}{4P_{ref} - V_{dc}} \tag{6}$$

2.2 Close Loop Control

From the given formulas, we knew the boost factor is determined by the shoot through duty cycle in a half working period of ZSI.

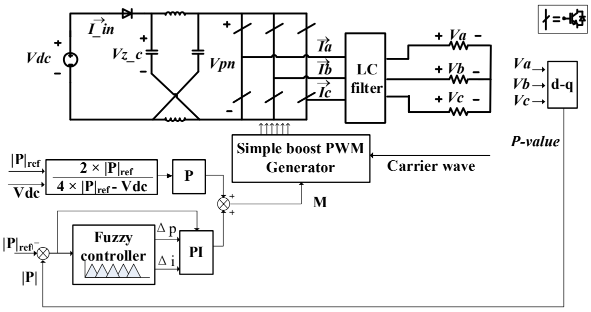

Fig. 2. Control block diagram of the proposed system

The SIMCOUPLE module gets four input ports from PSIM to MATLAB as four sensors. After transmission and operation in MATLAB, the duty cycle D0 will be give back to the only one output port, and return to the PSIM.

3. EXPERIMENT AND DISCUSSION

In order to verify the controller algorithms, a 5kW Z source inverter structure have been made. Fig. 3 shows the transient state performance of PID controller without feed forward as comparison result. which setting time is about 0 2(sec).

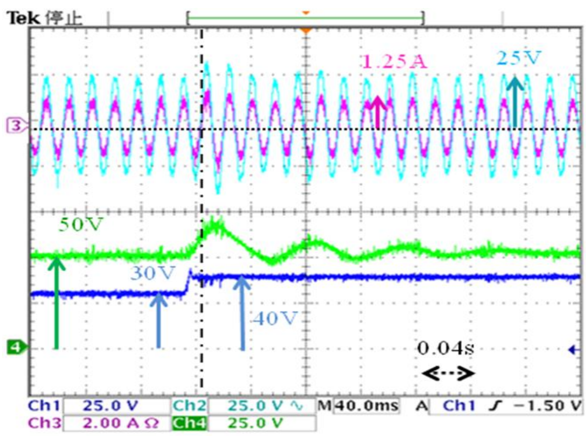

Fig. 3. System performance of the traditional PID controller without feedforward.

As shown in Fig. 3, waveform in green is the Z network capacitor voltage(50V), blue is the step changing input DC voltage(30V 40V), and pink is the output phase current(1.25A) and light blue is the phase voltage(25V).

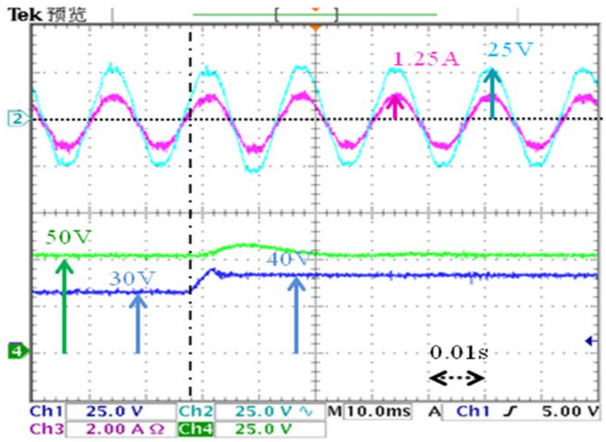

Fig. 4. System performance of proposed fuzzy PI controller with feedforward.

Fig. 4 shows the system control performance under input DC voltage swell condition with proposed fuzzy PI controller. The modulation index (M=1 D0) changed from 0.714 to 0.833 in about 0.03 (sec) as the setting time is.

4. CONCLUSIONS

In this paper, the goal is to control the DC voltage boost and AC output voltage of a 3 phase Z source inverter. Paper proposed the control strategy base on the self auto tuning fuzzy PI control and input voltage feed forward. For the conventional PID control scheme and the proposed fuzzy PI control scheme, the experiment has been built to compare their control performances by means of interposing two kinds of disturbances (unstable DC source and load change) to the system to study their transient behavior. As a result, the proposed controller can constantly control the output voltage under an unstable DC power source or load changing environment, also it has rejected the disturbance with speedy response. The voltage control stability of the ZSI system can be improved by the auto tuning fuzzy PI controller.

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