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직류전압 퍼지 제어 기반의 3상 Z-소스 PWM 정류기

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Three-Phase Z-Source PWM Rectifier Based on the DC Voltage Fuzzy Control

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Abstract – This paper describes a fuzzy control method to control the output voltage of the three-phase Z-source PWM rectifier. A fuzzy control system is a control system based on fuzzy logic, and the fuzzy controller uses a single input fuzzy theory with its fuzzification. Analytical structure of the simplest fuzzy controller is derived through the triangular membership functions with its fuzzification. By setting the membership functions of the fuzzy rules, fuzzy control is achieved. The PI portion of the output DC voltage controller is controlled by fuzzy method. To confirm the validity of the proposed method, the simulation and experiment were performed, The simulation is performed with PSIM and MATLAB/SIMULINK. For the experiment, we used a DSP(TMS320F28335) controller to compute the reference value and generate the PWM pulses. For the transient state performance of the output DC voltage control of Z-source PWM rectifier, the PI controller and fuzzy controller were compared, also the conventional PWM rectifier and Z-source PWM rectifier were compared. From the results, the Z-source rectifier could allow to buck or boost of the output DC voltage. Through the analysis of the transient state, we could observe that the fuzzy controller has better performance than the conventional PI controller.

Keywords: fuzzy control, PI control, z-source PWM rectifier, output DC voltage control, sinusoidal input current, SPWM control

1. Introduction

With the development of the energy conversion technology, the PWM rectifier has much focus in the field of power electronics. The PWM rectifier can be used as an ideal network between equipment and power system.

According to the DC-link energy storage elements, PWM rectifiers are classified into voltage-source PWM rectifiers (VSR) and current-source PWM rectifiers (CSR). The DC side of the voltage-source PWM rectifiers (VSR) can use the capacitor to store energy, so that the DC side of the VSR shows a low impedance voltage-source characteristic. Although the DC side of the current-source PWM rectifiers (CSR) can use the inductor to DC energy storage. A conventional VSR is an AC-DC boost converter while a conventional CSR is an AC-DC buck converter. Their circuits are shown in Fig.1 and Fig.2 respectively. The conventional PWM rectifiers are only worked as a boost rectifier or a buck rectifier. But, the Z-source PWM rectifier[1] can generate any desired output DC voltage, greater or smaller than the line AC voltage. The Z-source rectifier can reduce the size of both the DC-link inductor and the capacitor compared to the conventional two-stage buck-boost rectifier. The conventional rectifiers are vulnerable to EMI noise in terms of reliability. However, the shoot-through state is allowed in a bridge leg, which increase the EMI noises resistance. It is possible that the Z-source rectifier can reduce the inrush and

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harmonic current, and make the unity power factor without any extra circuits. The Z-source rectifier structure has the reliability of the circuit which can be increased by adding the unique Z-source network.

A novel PWM rectifier named as Z-source PWM rectifier makes the shoot-through state which avoids the possibility of ruin by EMI noises. The Z-source network is coupled between the bridge and the load, with the unique control strategy. The shoot-though state allows the Z-source rectifier to buck and boost the output DC voltage.

Over the past few decades, a large number of inverters have been regulated using proportional integral (PI) controllers [2, 3]. The design procedures for these controllers are well defined and widely accepted by the control community. The conventional PI control is applied to establish a precise mathematical model for the deterministic control system. There is a nonlinear delay parameter variability and model uncertainty. Therefore, the conventional PI controller is difficult to obtain the satisfactory control effect. Furthermore, it is known that PI controller could not cope with system non-linearities and uncertainties satisfactorily [4].

Fuzzy logic control is one kind of the intelligent control, and it was firstly proposed by Lotfi A. Zadeh[5]. Fuzzy controller[6-12] is a non-linear controller that does not require precise mathematical model for its design[13]. It is obviously to obtain due to the complexity and uncertainties of the system. The most important advantage of this controller is high robustness and immunity for the external disturbances. Also fuzzy controller has shown an excellent dynamic performance and steady-state performance.

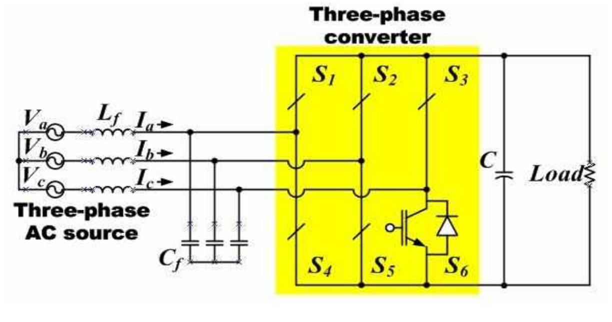

Fig. 1 Conventional voltage-source rectifier(VSR)

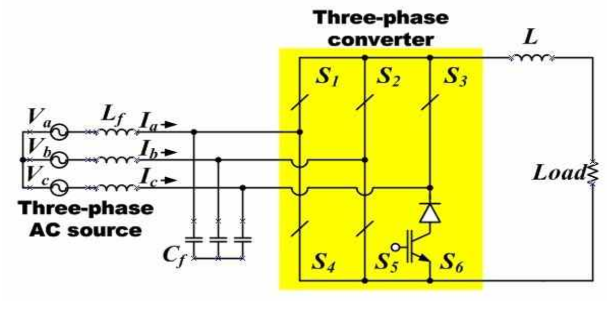

Fig. 2 Conventional current-source rectifier(CSR)

In this paper, the output DC voltage control method of the three-phase Z-source PWM rectifier using simplified fuzzy controller is proposed. To confirm the validity, simulation and experiment are performed. As a result, Z-source PWM rectifier can allow to buck or boost the output DC voltage. Each method is given the same the proportional value and the integral value. Comparing the transient state, we can observe that the fuzzy control reduce the computation time compared with PI control and is more stable than PI control.

2. Three-Phase Z-source Rectifier

Fig.3 shows the three-phase Z-source PWM rectifier. Z-network is coupled between the load and the rectifier circuit. The Z-network [14-15] is implemented using split-inductors (L1 and L2) and capacitors (C1 and C2) connected in X-shape. This Z-network allows the Z-source rectifier to buck or boost the output DC voltage.

The three-phase Z-source rectifier has nine permissible switching states (six active vectors, two zero vectors and one extra zero vector). When both the upper and lower devices of any one phase leg, any two phase legs, or all three phase legs are shortened through, the Z-source rectifier has one extra zero state. The shoot-through zero state provides a unique buck-boost feature to the rectifier. In a whole switching period, when the rectifier bridge

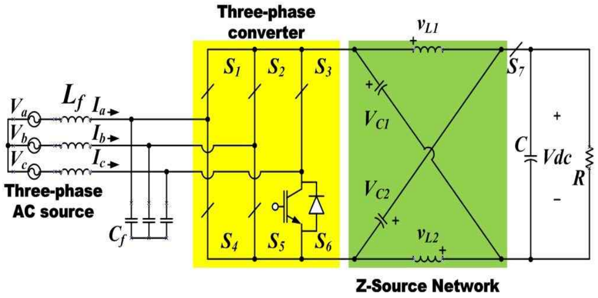

Fig. 3 Three-phase Z-source PWM rectifier

is in one of the eight non-shoot-through switching states and when in the shoot-through zero state respectively, the circuit comes through two equivalent circuits, which are shown in Fig.4 and Fig.5. How to produce the PWM extra zero state has been described in the reference [16].

From the symmetry and equivalent circuits, we have

$$V_{C1} = V_{C2} = V_C \ , \ V_{L1} = V_{L2} = V_L \tag{1}$$

where, the inductors L1, L2 and capacitors C1, C2 have the same inductance(L) and same capacitance (C) respectively.

When the rectifier bridge is given in the shoot-through zero state(T0) during a switching cycle T, vi is the input voltage of Z-network, we have:

$$v_i = 0 \ , \ V_L = - V_C \tag{2}$$

When the rectifier bridge is given in the non shoot-through zero state(T1), one have

$$V_L = V_C - V_{dc} \, , \, v_i = V_C + V_L = 2V_C - V_{dc} \tag{3}$$

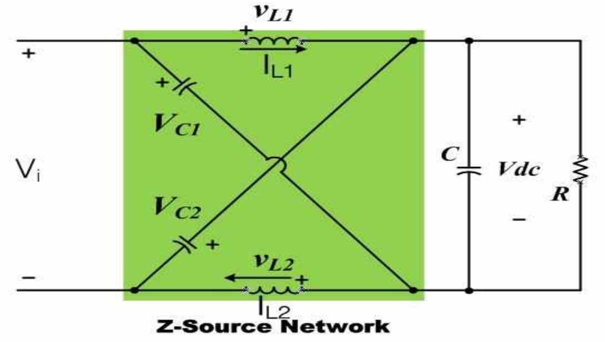

Fig. 4 Equivalent circuit of non-shoot-through switching state

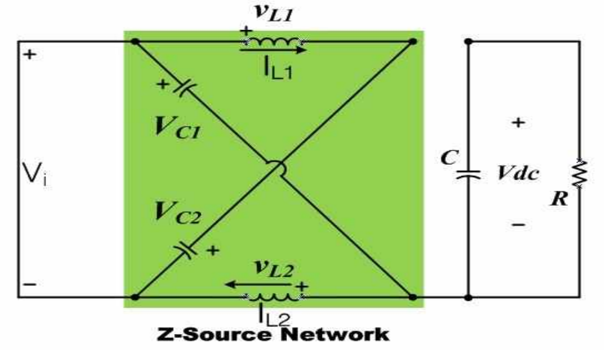

Fig. 5 Equivalent circuit of shoot- through zero state

where, T=T0+T1

From the analysis, the average voltage of the inductors per one switching period(T) should be zero in steady state, we have

$$V_L = \overline{v_L} = [T_0(-V_C) + T_1(V_C - V_{dc})]/T = 0 \tag{4}$$

or

$$\frac{V_C}{V_{dc}} = \frac{T_1}{T_1 - T_0} = \frac{1 - D_0}{1 - 2D_0} \tag{5}$$

where, D0=T0/T denotes the shoot-through duty cycle. The average DC link voltage across the load can be found as follows.

$$\begin{aligned} V_i = \overline{v_i} &= [T_0 \times 0 + T_1(2V_C - V_{dc})]/T \\ &= \frac{T_1}{T_1 - T_0} V_{dc} = V_C \end{aligned} \tag{6}$$

According to equation (3),(5) and (6), we can get

$$V_{dc} = (1 - 2D_0)\overline{v_i} = B\overline{v_i} \tag{7}$$

where, B is the buck factor.

The DC output voltage of the traditional V-source PWM rectifier can be expressed as

$$V_{dc} = \frac{2V_i}{Mcos\varphi} \tag{8}$$

where, $\varphi = \tan^{-1}\frac{wL}{r}$

M refers to the modulation index, L refers to the input inductor, r is the equivalent input resistance, and Vi is the peak phase AC input voltage.

According to equation (7) and (8), we have

$$V_{dc} = \frac{B}{M}\frac{2V_i}{\cos\varphi} = B_B\frac{2V_i}{\cos\varphi} \tag{9}$$

where, BB is the buck-boost factor.

$$B_B = \frac{B}{M} \tag{10}$$

From equation (9), we can know that the output DC voltage and the input voltage have a certain ratio, by selecting a suitable boost/buck factor. The buck-boost factor BB is determined by the modulation index and buck factor B. The factor B can be controlled by duty cycle of the shoot-through zero state over the non-shoot-through states of the PWM rectifier.

3. Fuzzy Controller

Fig. 6 shows the control diagram of the proposed system. The PWM generator needs a kind of the input to create the gate switching signals. They are carrier waveform, modulation index(M) and shoot-through duty radio(D0) signal which were needed to be controlled.

Fig.7 shows the swiching method of the Z-source PWM rectifier. The switches of each phase leg is turned on or off through comparing the reference with the triangular carrier. The Z-source rectifier has a shoot-through time, and the shoot-through time is determined by the duty cycle D0. When the rectifier bridge is in the shoot-through state, the circuit comes through the equivalent circuits as Fig.5 and Fig.7.

The input voltages($V_{a,b,c}$) and currents($I_{a,b,c}$) are converted to d-q values through the abc-dqo transformation. By the calculation of these results, three-phase reference sinusoidal waveform($V_{ra,rb,rc}$) are obtained by the dqo-abc transformation. The difference between the output DC voltage(V_{dc}) and the output DC reference voltage(V_{ref}) in the voltage control loop is input to the fuzzy controller as an input variables.

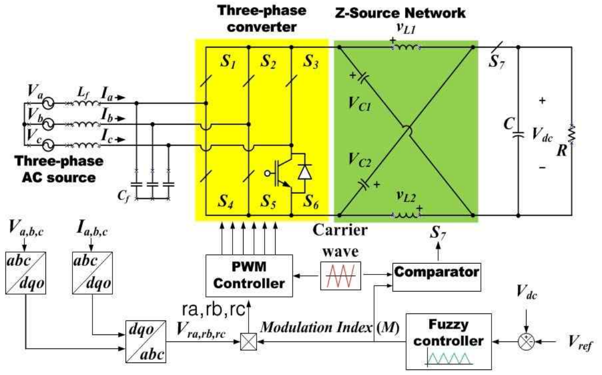

Fig. 6 Control block diagram of the proposed system

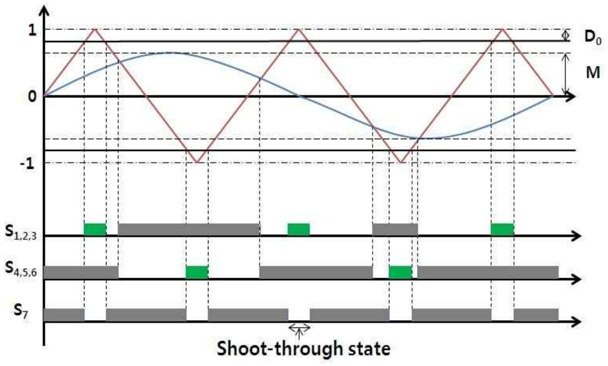

Fig. 7 The control strategy of Z-source PWM rectifier

In the fuzzy controller, membership functions are set. The relationship between the input variable and the output variable of the fuzzy controller are given as the control rules. The output value of the fuzzy controller is the modulation index(M), and M is obtained by fuzzy rules. The three-phase references for controlling the Z-source rectifier(ra,rb,rc) are produced by multiplying by modulation index (M) and three-phase reference sinusoidal waveform, such as equation (11). By comparing these reference with the triangular carrier, PWM pulses are generated as shown in Fig. 6.

$$\begin{aligned} ra &= M\times v_{ra} \\ rb &= M\times v_{rb} \\ rc &= M\times v_{rc} \end{aligned} \qquad (11)$$

Fig. 8 shows a d-q control system. First, the input voltage and current are converted to d-q values through the d-q transformation, and equations are expressed as (12),(13). There is a phase difference between voltage and current. Hence, in order to eliminate the its phase difference and also to implement the control to achieve the best results, we can do that the three-phase voltage and current are placed on the same d-q coordinate system. Vd and Id denote d-axis values, its phase angle is zero, therefore Vd is 0. Id rotates together with the Vd. Phase-coherent between the current and the voltage is achieved by the following control. Therefore, the difference between the Id and Vd is through a simple PI control as d value(equation 14), the square of the

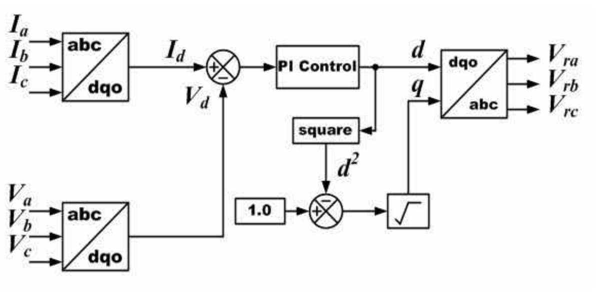

Fig. 8 the d-q control system for generating the three phase references d and q is equal to 1 which is (15), we can get the q value. As expressed in (16), the inverse d-q transformation using the resultant d and q values are performed to obtain three-phase reference sinusoidal waveform. Therefore, the input current of the system is to be sinusoidal, and unity-input power factor is achieved. The Z-source rectifier based on fuzzy controller has good dynamic response and vigorous rejection of the disturbance.

$$\begin{bmatrix} V_d \\ V_q \end{bmatrix} = \frac{2}{3} \begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & -\frac{\sqrt{3}}{2} & \frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} \cos\theta & -\sin\theta \\ \sin\theta & \cos\theta \end{bmatrix} \begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix} \tag{12}$$

$$\begin{bmatrix} I_d \\ I_q \end{bmatrix} = \frac{2}{3} \begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & -\frac{\sqrt{3}}{2} & \frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} \cos\theta & -\sin\theta \\ \sin\theta & \cos\theta \end{bmatrix} \begin{bmatrix} I_a \\ I_b \\ I_c \end{bmatrix} \tag{13}$$

$$d = K_p \times (I_d - V_d) + K_i \times \int_0^t (I_d - V_d)\,dt \tag{14}$$

where, t is the time constant of the integrator.

$$q = \sqrt{1 - d^2} \tag{15}$$

$$\begin{bmatrix} V_{ra} \\ V_{rb} \\ V_{rc} \end{bmatrix} = \frac{2}{3} \begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & -\frac{\sqrt{3}}{2} & \frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} \cos\theta & -\sin\theta \\ \sin\theta & \cos\theta \end{bmatrix}^{-1} \begin{bmatrix} d \\ q \end{bmatrix} \tag{16}$$

The input variables in a fuzzy control system are generally mapped by sets of membership functions similar to this, known as "fuzzy sets". The process of converting a crisp input value to a fuzzy value is called "fuzzification". The control system may also have various types of switch, or "ON-OFF", inputs along with its analog inputs, of course, such switch inputs will always have a truth value which is equal to either 1 or 0, but the scheme can deal with them as simplified fuzzy functions that happen to be either one value or another.

Fuzzy control has some advantages. In many cases, the mathematical model of the control process may not exist, or may be too "expensive" in terms of the computer processing power and memory, and a system based on empirical rules may be more effective. Furthermore, fuzzy logic is well suited to low-cost implementation based on cheap sensors, low-resolution analog-to-digital converters. Such systems can be easily upgraded by adding new rules to improve performance or add new features. In many cases, fuzzy control can be used to improve the existing traditional controller systems by adding an extra layer of intelligence to the current control method.

In this paper, the fuzzy control method can better respond to the complexity and uncertainty of the system. The advantage of the high robustness and immunity for the external disturbances can make the control more stable compared to PI control. Also, the fuzzy control reduce computation time, thus, the proposed system can produce the dynamic and stable response performance.

The processing stage is based on a collection of the logic rules in the form of IF-THEN statements, where the IF part is called the "antecedent" and the THEN part is called the "consequent". Typical fuzzy control systems have dozens of rules.

Fig. 9 and Fig. 10 show the input variable and the output variable of the fuzzy controller. The control rules:

(1) if input = "Small", then output = "Very Small".
(2) if input = "Msmall", then output = "Small".
(3) if input = "Zero", then output = "Middle".
(4) if input = "Mbig", then output = "Mbig".
(5) if input = "Big", then output = "Big".

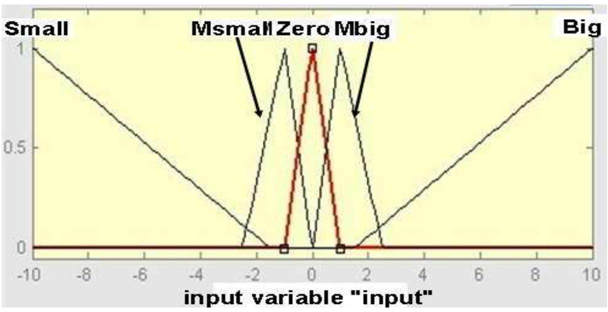

Fig. 9 The input membership functions

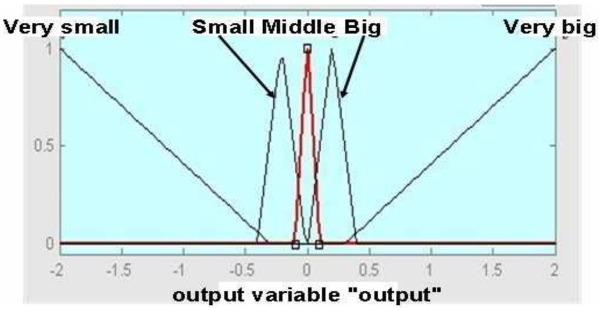

Fig. 10 The output membership functions

Such as rule (1), this rule uses the truth value of the input, which is some truth value of "Small", to generate a result in the fuzzy set for the output, which is some value of "Very Small". This result is used with the results of other rules to finally generate the crisp composite output. According to these parameters, fuzzy controller is designed and completed.

Fuzzy controllers are very simple conceptually, They consist of an input stage, a processing stage, and an output stage. The input stage maps the sensor or other inputs to the appropriate membership functions and truth values. The processing stage invokes each appropriate rule and generates a result for each, then, combines the results of the rules. Finally, the output stage converts the combined result back into a specific control output value. The most common shape of the membership functions is triangular, although trapezoidal and bel curves are also used, but the shape is generally less important than the number of curves and their placement. From three to seven curves are generally appropriate to cover the required range of an input value.

4. Simulation Results

The simulation is performed with PSIM and MATLAB/SIMULINK. Main circuit is simulated in PSIM, Firstly, we can design of a loop in the PSIM. The difference between the instantaneous DC voltage and the reference DC voltage is input to the MATLAB. The SIMCOUPLE module gets the input port from PSIM to MATLAB as one sensor. By designing a fuzzy controller in the MATLAB, after transmission and operation, the obtained value is defined as the modulation index (M). The modulation index will be give back to the only one output port, and return to the PSIM. It is used in SPWM control. At the same time, this value is used to control the shoot-through duty radio (D0) signal. In the PSIM, this value and the reference voltage which is obtained by the d-q control are executed PWM control. The input voltage and current will change by d-q control. After setting up a closed-loop control, the input current of the system is to be sinusoidal, and unity-input power factor is achieved.

The error of the output DC voltage and the reference DC voltage is input to the MATLAB. Though a non-linear controller does not require the precise mathematical model for its design, the obtained value is defined as the modulation index (M). This value will be used in SPWM control.

Table 1 System Parameters

Parameter	Value	Parameter	Value
C_1=C_2	1,000μF	Load(R)	40Ω
L_1=L_2	1,500μH	Output capacitor(C)	1,000μF
V_i	70V	Input inductance(L_f)	1,500μH
frequency	6kHz	Input resistance(r)	0.2Ω
V_{ref}(PI control)	190V,150, 130V,60V	V_{ref}(fuzzy control)	130V,60 V

Table 1 shows the system parameters used in this study under the condition of the input voltage 70Vpeak, and both the simulation and the experiment are used the same values. The simulation and experiment results are provided to test and verify the validity of the proposed fuzzy controller.

A conventional rectifier(VSR) is an AC-DC boost converter. However, the Z-source rectifier can produce any desired output DC voltage greater or smaller than the input AC voltage, because of an AC-DC buck-boost rectifier. As shown in Fig.11, the following simulation results shows an AC-DC boost characteristics of the conventional VSR.

Fig.11 and Fig.12 show the output DC voltage control performance of the PI control based on the conventional VSR and Z-source PWM rectifier. Simulation results show the output DC voltage in transient state, and a phase difference between the input voltage and current nearly zero by d-q control scheme, so that the input power factor reaches unity. As shown in Fig.11, it is clear that the output DC voltage was boosted to between 190V and 150V under the condition of the input voltage 70Vpeak. We make sure that a conventional PI controlled VSR has a long transient state, also it shows an AC-DC boost characteristics without buck capability.

Fig.12 shows the simulation results of the PI controlled Z-source PWM rectifier. In case of Z-source rectifier, the DC output voltage is buck to 60V and is boosted to 130V. The shoot-though state allows the Z-source rectifier to buck and boost the output DC voltage.

Fig.13 shows the simulation results of the three-phase Z-source rectifier by fuzzy control. As shown in Fig.13, we can observe that the buck-boost characteristic of the three-phase Z-source rectifier can obtain by simulation results. Comparing Fig.12 and Fig.13, the transient state time of the fuzzy control is faster half a second and more stable than the PI control. Also it is able to completely eliminate the steady state error and reduce computation time.

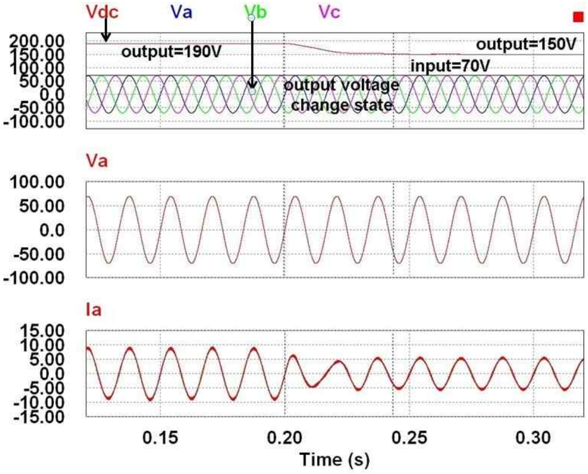

Fig. 11 Simulation waveform of the conventional VSR using PI control : (Top) waveform of the output DC voltage, (Middle) waveform of the A-phase input AC voltage, (Bottom) waveform of the A-phase input AC current

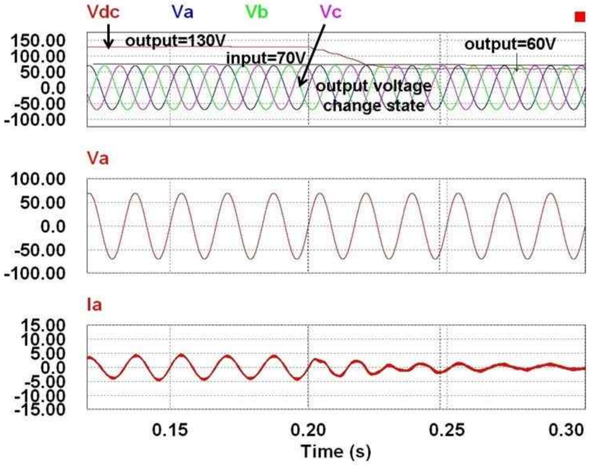

Fig. 12 Simulation waveform of the three-phase Z-source rectifier using PI control : (Top) waveform of the output DC voltage, (Middle) waveform of the A-phase input AC voltage, (Bottom) waveform of the A-phase input AC current

Fig.14 and Fig.15 show that two control methods are given the same output voltages. First of all, Fig.14 shows the waveform by the PI control. From the top trace, we can observe that the output DC voltage has a long transient state during the three references 60→70→130V. Fig.15 shows results under the condition of the fuzzy control. Comparing with the PI control, we can find that the fuzzy control is more stable and faster.

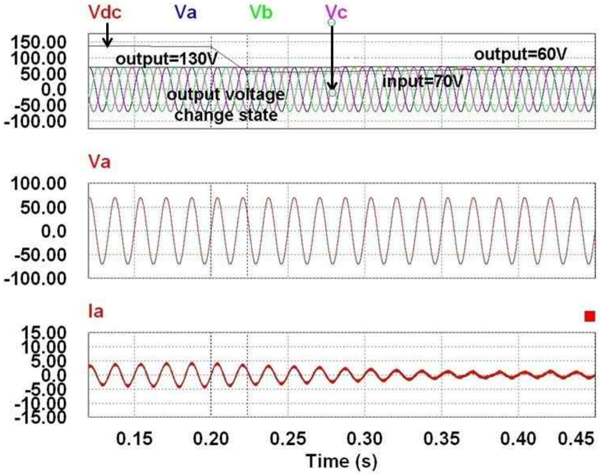

Fig. 13 Simulation waveform of the three-phase Z-source rectifier using fuzzy control : (Top) waveform of the output DC voltage, (Middle) waveform of the A-phase input AC voltage, (Bottom) waveform of the A-phase input AC current

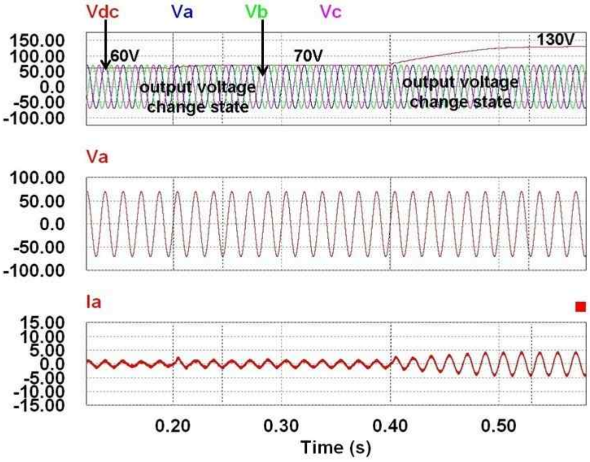

Fig. 14 Simulation waveform using the PI control : (Top) waveform of the output DC voltage, (Middle) waveform of the A-phase input AC voltage, (Bottom) waveform of the A-phase input AC current

Fig.16 shows the transient state performance of the PI control and fuzzy control for the output DC voltage. From this result, we can observe the fuzzy control is more faster and stable than PI control.

5. Experimental Results

Fig.17 shows the experiment system. The experiment are performed to verify the feasibility of the three-phase Z-source PWM rectifier based on fuzzy control. Experiment requires the voltage and current sensors for connection with a DSP(digital signal processor) input ports, in order to detect the input voltage and current values. Z-network is coupled between the load and the rectifier circuit. Output terminal is connected to a sensor, it is used to receive the output voltage and to complete the output voltage control.

In the experiment, we used the DSP (TMS320F28335) controller to compute the reference value and to generate the PWM pulses. The DSP controller can compute the data in high speed and be operated in 32bit variables. Moreover, the circuits (as HRPWM, eCAP, eQEP) and 6CH's PWM, 12 bit 16CH's ADC are integrated in one board.

Fig.18 show the experiment waveform of the conventional VSR using PI control. As shown in Fig.18, we can observe that the output DC voltages are controlled to 190V and 150V under the condition of the input voltage 70Vpeak. This means that conventional

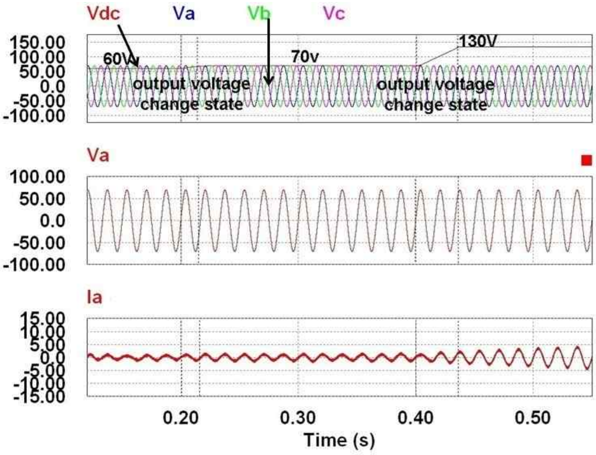

Fig. 15 Simulation waveform using the fuzzy control : (Top) waveform of the output DC voltage, (Middle) waveform of the A-phase input AC voltage, (Bottom) waveform of the A-phase input AC current

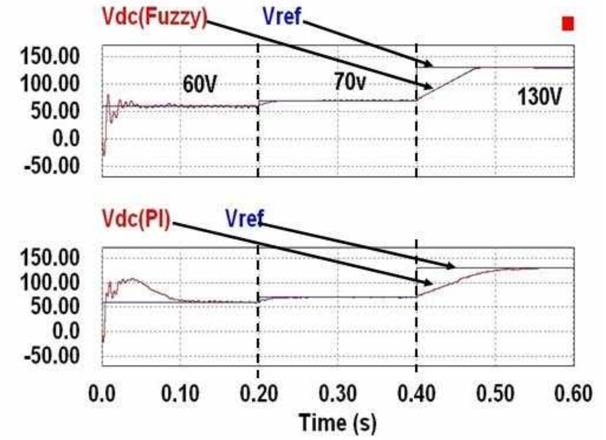

Fig. 16 Comparison of the transient state performance of the PI control and fuzzy control : (Top) the fuzzy control and (Bottom) the PI control

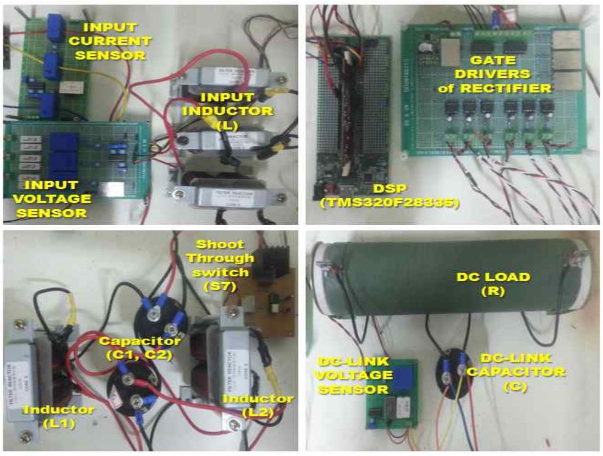

Fig. 17 Experiment system

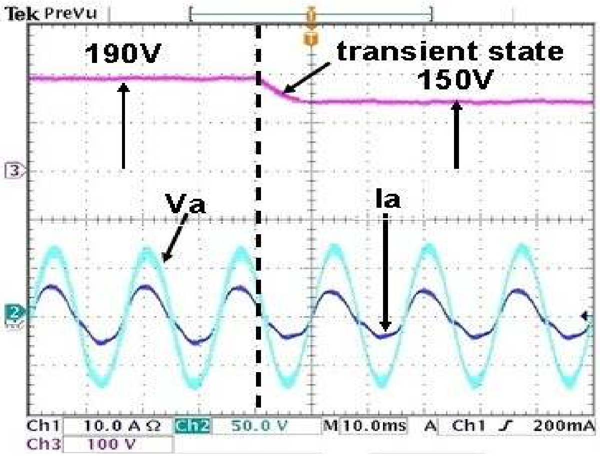

Fig. 18 Experiment results of the conventional VSR using PI control : (Top) waveform of the output DC voltage, (Bottom) waveform of the A-phase input AC voltage and current

VSR has an AC-DC boost characteristics. Therefore, the output DC voltages are greater than the input voltage. The phase angle between A-phase input voltage and current are almost consistent.

Fig.19 shows the experiment results of the three-phase Z-source rectifier using PI control. Under this shoot-through state, the output DC voltage is 130V which is greater than the input voltage, and it is 60V which is smaller than the input voltage. Comparing the output voltage of Fig.18 and Fig.19, we can know that the shoot-though state allows the Z-source rectifier to buck and boost the output DC voltage. The experiment and the simulation results are essentially the same.

Fig.20 shows the experiment results of the three-phase Z-source rectifier by fuzzy control. As shown in the output voltage waveform, it shows the characteristic of Z-source rectifier which can buck and boost the output DC voltage. The dotted lines of Fig.19 and Fig.20 mean the change point of the output DC voltage. We can see that transient state performance of the fuzzy control shows faster and more stable than PI control. Fuzzy control can reduce the computation time, also it show a good control effect. Through the response performance in the transient state, we can get faster to the desired output DC voltage. The phase angle of the input voltages and currents are nearly same, therefore the input power factor of the system is nearly unity.

Fig.21 shows the phase relationship between the input voltage and current waveforms. We can observe that the phase angle of the input voltage and current are the same.

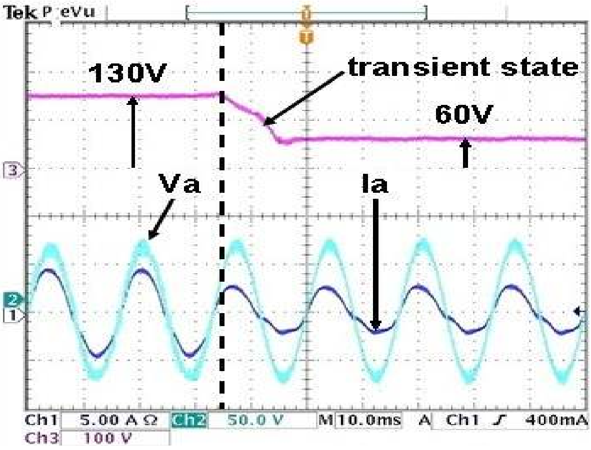

Fig. 19 Experiment results of the three-phase Z-source rectifier using PI control : (Top) waveform of the output DC voltage, (Bottom) waveform of the A-phase input AC voltage and current

From the above analysis, using the equation (9), we can get the following calculations.

1) When M is 0.7, D0 is 0.18, we have

$$V_{dc}=\frac{1-2D_0}{M}\frac{2V_i}{\cos\psi}=\frac{1-2\times 0.18}{0.7}\frac{2\times 70}{0.99}\cong 129.3\,V$$

2) When M is 0.6, D0 is 0.37, we have

$$V_{dc}=\frac{1-2D_0}{M}\frac{2V_i}{\cos\psi}=\frac{1-2\times 0.37}{0.6}\frac{2\times 70}{0.99}\cong 61.3\,V$$

Obviously, we can know that the measured value is consistent with the calculated value. Also, both the

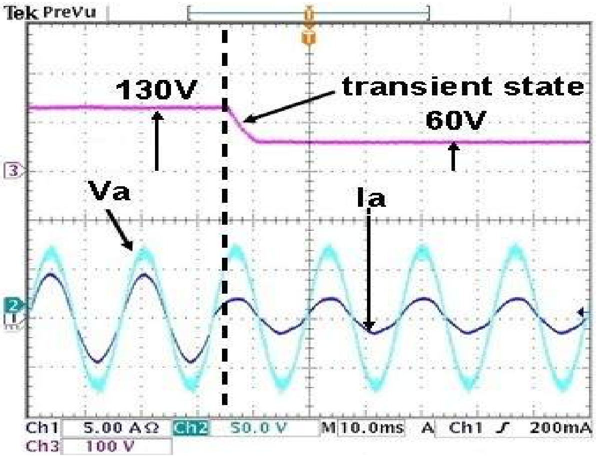

Fig. 20 Experiment results of the three-phase Z-source rectifier using fuzzy control : (Top) waveform of the output DC voltage, (Bottom) waveform of the A-phase input AC voltage and current

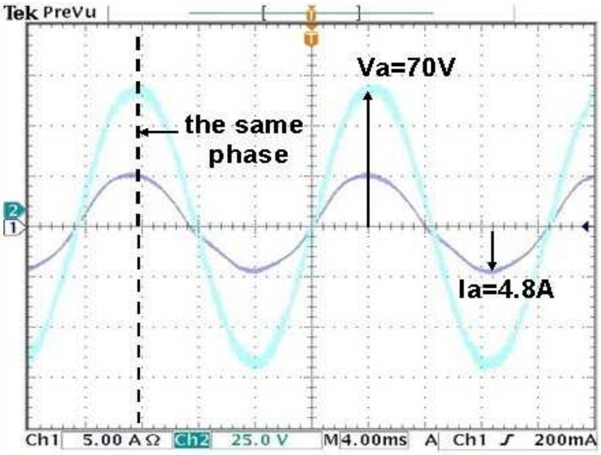

Fig. 21 Experiment results of the enlarged A-phase input voltage and current

output DC voltage and Z-source capacitor voltage of the proposed system show a fast response effect and a small overshoot.

6. Conclusions

The goal of this paper is to control the output DC voltage of the three-phase Z-source PWM rectifier by fuzzy controller. Based on discussion of the equivalent circuit and control strategy, the relationship between the output DC voltage and the input voltage has been discussed. To confirm the validity of the proposed system, simulation and experiment were performed. Both the simulation and the experiment were used the same system parameters. The phase angle of the input voltage and current in each method were the same, the input power factor was nearly unity.

We could know that the conventional VSR has an AC-DC boost characteristics without buck capability. On the contrary, the Z-source rectifier based on PI control could buck or boost the output DC voltage by using a shoot-through state. The Z-source rectifier based on the fuzzy control can constantly control the desired output DC voltage for the output reference voltages. We can find that the fuzzy control is faster and more stable in the transient state than PI control. It is shown that the proposed system have the dynamic and stable response performance compared with the conventional system. The voltage control stability of the Z-source PWM rectifier can be improved by the fuzzy controller, and also can reduce computation time.

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