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Series Z-Source Inverter Fed Motor Drive

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Abstract: **The Z-source inverter (ZSI) has single state power conversion capability with buck-boost ability. Series Z-source inverter (SZSI) reduces inrush current, resonance between capacitor and Z-inductor and stress on capacitor. This paper presents a simple technique to increase shoot through in SZSI. The major benefit of this technique is improved performance of inverter in terms of boosting and harmonics profile. The validity of proposed technique is verified through simulation.**

Keywords: **series Z-source inverter (SZSI), inductor current, pulse width modulation (PWM).**

I. INTRODUCTION

Voltage source inverter (VSI) with sinusoidal pulse width modulation (SPWM) technique is matured technology and widely used for motor control in industries, flexible ac transmission system (FACTS) devices and non-conventional energy source with grid. In the application of non-conventional energy sources such as PV solar system requires boosting of dc voltage. This needs two converters, one for boosting dc voltage level and other to convert ac to dc, which has buck facility. ZSI, which was proposed in [1] combines the function of dc-dc boost conversion and VSI for dc to ac conversion with buck action. ZSI can handle PV voltage variation over wide range without over rating of inverter [2]. As a result, the component count and system cost are reduced with improved reliability due to allowed shoot through state. As described in [1], [3] the rms value of output fundamental component voltage of ZSI can be expressed as

$$V_{rms} = 0.612\ M\ B\ V_{dc} \quad (1)$$

Where V_{dc}, M, B, represents the input voltage or dc voltage, modulation index, boost factor respectively. Boost factor is a function of shoot through ratio, D and is given by

$$B = \frac{1}{1-2D} \quad (2)$$

and $$D = T_0 / T \quad (3)$$

Where T_o is shoot through time and T is time period of carrier cycle. shoot through employs a straight line equal to or greater than the peak value of the three phase references to control shoot through duty cycle. Maximum shoot through duty ratio, D of boost control is limited to $(1\text{-}M)$. In order to produce high voltage boost, M must be lowered. Lower M results in poor inversion ability at fundamental frequency, high total harmonics distortion value and consequently the final ac output performance will be degraded significantly [4], [5].

Many ZSI topologies have been published, which have been focused on improving boost factor. Transformer or coupling inductor used in T-Z source inverter [6], L-Z source inverter [7] and switched inductor ZSI [8] to boost voltage or minimize the part count. Quasi Z-source inverters [9],[10] were designed to overcome short coming of classical Z-source inverter. Recently two improved ZSI topologies have been presented called embedded [11] and series respectively [12]. The power source is in series connected with the Z-source inductor in embedded ZSI, shows the merits as continuous input current and voltage across the capacitor. In series ZSI, the power source is series connected with inverter bridge shows the reduced voltage across both capacitor with soft start capability. Compare to traditional ZSI, the improved ZSI can reduce the size and cost of capacitor in Z-source network with higher power density. On another side some approach have been presented to boost voltage includes maximum boost control [13],[14], which gives benefits in terms of implementation and harmonics performance.

In proposed scheme, series ZSI is used [15] as it reduces the size of capacitor and minimizes inductor current [16], control technique generates the signal for shoot through that employs instantaneous maximum voltage level amongs the reference signal. This reduces shoot through duty ratio and gives opportunity to increase modulating index. Increase in modulating index improves spectral performance. This paper presents the basic idea of drive system using SZSI in section II and then presents new PWM control technique. In section III, simulation results are included to demonstrate the idea and control scheme.

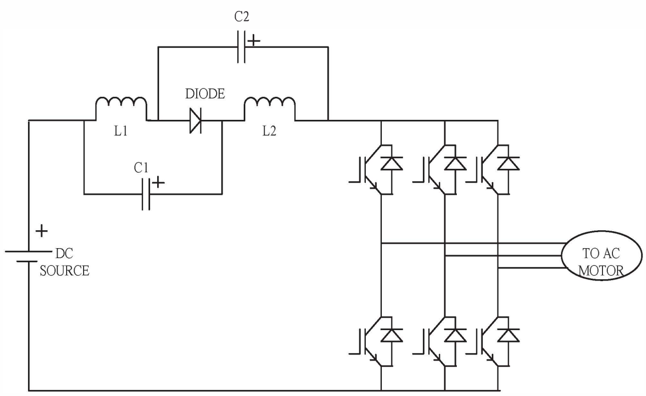

Fig.1 Series Z-source inverter fed motor drive

II .SERIES Z-SOURCE INVERTER

Fig.1 shows the circuit for SZSI. By controlling the shoot through ratio which is forbidden in VSI, the dc input voltage is boost and derive output can be obtained. Shoot through is the state where the upper and lower switches in the same phase legs are turn on simultaneously. Three phase VSI has six switches which makes eight switching combination states. Out of eight states, in two states, all upper or lower switches are on. Shoot through is achieved in these states by making other switches on in respective phase legs. To achieve this in conventional control scheme, four modulating signal are used as shown in Fig.2,these are V_a, V_b, V_c and V_t. V_a, V_b, V_c are sinusoidal and control the phase voltage. V_t is straight line and by changing its magnitude, shoot through ratio is changed resulting in boosting of dc bus voltage. The magnitude of V_t is equal or greater than peak value of V_a, V_b and V_c. Practically, there are two control signal of V_t, i.e. V_{t1} and V_{t2}. V_{t1} is with positive magnitude and V_{t2} is with negative magnitude (not shown in Fig. 2). The shoot through ratio can be calculated from Fig. 2

$$D = \frac{V_{cm} * V_t}{V_{cm}} \tag{4}$$

Where V_{cm} is amplitude of carrier signal. Shoot through ratio controls the capacitor voltage, V_c and is given by [12].

$$V_c = \frac{D}{1-2D} V_{dc} \tag{5}$$

DC link voltage is pulsating because in shoot through state, dc link voltage is zero and in non-shoot through state, dc link voltage is given by

$$V_i = 2V_c + V_{dc} \tag{6}$$

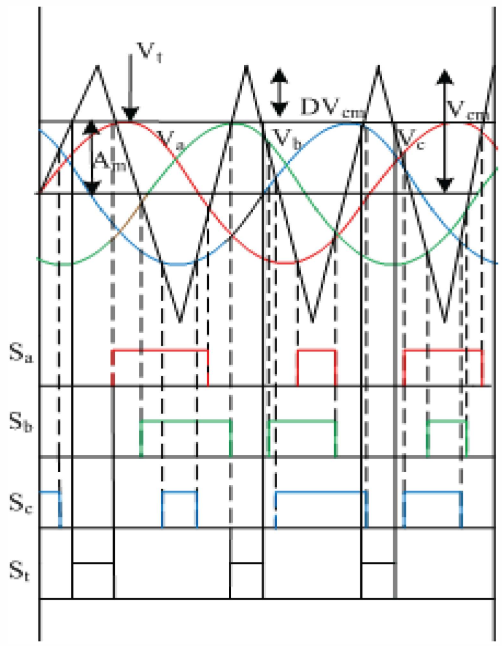

Fig.2 Traditional PWM control

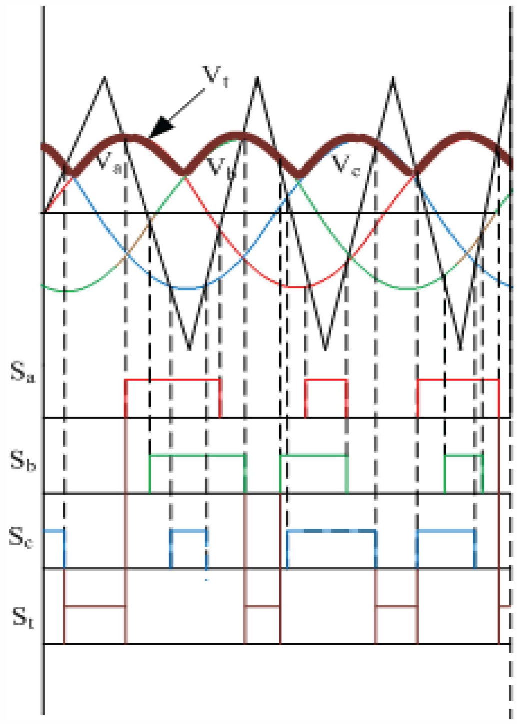

Fig.3 Proposed PWM Control

In conventional control, if modulating index is increased, V_t level must be increased, which results in reduction in D and V_c therefore voltage boost also reduces. To increase boosting, D must be increased, which results in reduction of the modulating index. It is well known that for lower magnitude of modulating index, THD in output voltage of inverter is higher. Magnitude of modulating index, V_t, shoot through ratio, D depends on each other. In proposed control scheme V_t is equal to or greater than instantaneous value of V_a or V_b or V_c which is higher as shown in Fig. 3. In this technique, shoot through ratio is variable, when modulating signal has maximum value, D is minimum and when instantaneous value of modulating signal reduces, D increases. Boosting ratio changes from *(1-M)* to *(1-0.5M)*. Therefore boosting of dc bus voltage increases as compare to conventional control technique. Shoot through can be achieved in positive carrier signal with V_{t1} as well as negative carrier signal with V_{t2} as shown in Fig. 4.

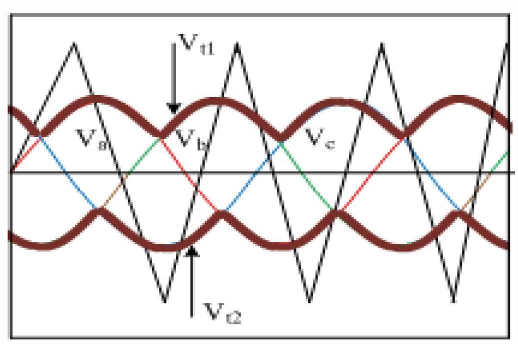

Fig.4 Actual sketch map of proposed control