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Article Title: Improved Series Z Source Inverter for PV System Using SVPWM Technique

Improved Series Z Source Inverter for PV System Using SVPWM Technique

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ABSTRACT

Voltage source (VSI) or current source power inverters were previously employed for DC-AC conversion (CSI). The major objective of this research is to enhance a number of impedance source inverter and converter characteristics. This incorporates the inverter's output gain, overall cost, complexity and dynamic responsiveness. By modifying modulation techniques, the suggested inverter system may also be efficiently regulated.

Keywords: THD current source inverters (CSIs), standard test conditions (STCs), voltage source inverters (VSIs)

1 Introduction

The two forms of power inverters that have historically been utilized for DC-AC conversion are current source (CSI) and voltage source (VSI) power inverters [1]. Regardless the fact that they are quite popular in commercial contexts like electricity distribution system, [2] hybrid electric vehicles (HEVs) and photovoltaic (PV) systems [3, they have some significant flaws, this lessens their appeal. Several important justifications for this, following are some examples of how VSIs are used: Maximum output voltage is restricted and isn't allowed to exceed input DC voltage [4]. VSI consequently requires a separate boost DCDC converter because it is a step down (buck) inverter [5-8] when a high o/p voltage is necessary for overdrive. For CSIs to operate, an inverter identical bridge's leg's switching components must overlap. Additionally, both VSIs and CSIs [9] suffer from the same flaws, such as the fact that they are either buck or boost power converters [10], requiring the usage of a separate dc-dc converter for a variety of output voltages. The end result is a two stage power conversion, it raises switching losses as well as costs for an entire power system. Furthermore, both are unreliable and susceptible to EMI [11] disturbances, which leads to subpar output waveform quality. Impedance source inverter (ZSI) [12] was suggested as a solution to these problems. Due to the removal of dead time and effective use of phase legs' shorting (shoot through) for increasing an output voltage, it affords a higher output waveform quality and allows for single stage power conversion.

2 Recent Works

Reddiprasad Reddivari *et al* [2020] proposed inverter is compared to previous MCIS networks, larger voltage gains can be achieved with fewer switching voltage spikes as well as minimal capacitor voltage strains. Additionally, the suggested inverter uses the fewest possible components in a circuit while drawing constant mains powered input current as well as sharing a commonality. Electrical along with magnetic domains are used to investigate the proposed NEDMZSI's operational principle. Utilizing a DC-DC converter arrangement, experimental evidence has been provided to support the suggested impedance network's ability to reduce voltage spikes.

Xinping Ding *et al* [2020] [14] presents a ZSI architecture that is expandable, abbreviated as EZSI. The substantial gain of voltage at low shoot through duty ratio of the suggested architecture improves an output quality of waveform. The benefits of steady input current along with lessened voltage of dc link overshoot are advantages it inherits from quasi ZSI. Modular construction techniques can be used to create the EZSI, a low voltage component based single stage inverter with great power.

Shri Prakash Sonkar *et al* [2020] [15] Two 3 quasi Z source inverters (qZSIs) with numerous ac outputs are advised to be employed. The proposed topologies are based on qZSI and are used to build 3 multi output inverters in parallel mode and series mode. An n number of parallel ac outputs with dissimilar load conditions, currents and voltages are produced by the topology in parallel mode. With identical load currents and voltages, the architecture generates n number of series ac outputs in the series mode. The suggested topologies meet several load needs simultaneously without the need for an extra adapter or regulator.

3 Proposed Work Explanation

This chapter examines the suggested inverter in detail and demonstrates how to create an improved ZSI with a clamping diode using a flow chart. The benefits of recommended inverter over the ZSI topologies that are currently in use that require transformers are then highlighted, use Matlab graphs to display the comparisons.

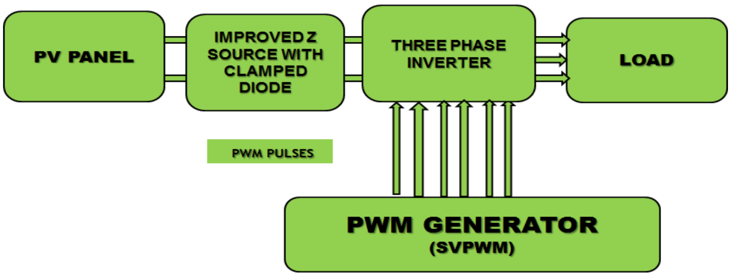

Figure 1: *Proposed system block diagram*

The key features of the suggested ZSI with clamping diode are outlined in the following list, which will be covered in more detail.

1) There is no need for an extra filter because the input current is continuous.
2) Because no current enters the main circuit at startup, unlike the ΓZSI, Trans ZSI and Tzsi, it offers start up inrush current suppression.
3) In different Z source topologies based on transformers, Voltage spikes are brought on by the transformer's accumulated energy, a new high frequency loop made up of C2-D2-C1 is formed by the clamping diode in the upgraded ΓZSI inverter. The dc link voltage is clamped at ($Vc1 + Vc2$), which prevents the inverter bridge's voltage spikes.
4) matching the requirements for the input and output and the rotational speed of the transformer, Compared to the original Γ ZSI and the aforementioned topologies, In comparison to the original ZSI, the revised ΓZSI features a shorter shoot through duty cycle and a larger voltage gain thanks to the clamping diode, This produces an output power quality improvement and a higher modulation index.

3.1 Modes of Operation

There are six active states in addition to the standard two zero states, an improved clamping diode equipped Γ-ZSI inverter has single additional state with shoot through, similar to any other impedance source inverter in use right now. For analytical purposes, a non-shoot through state are separated into two categories (state 2) and the shoot through state (state 1). Figures 2(a) and (b) depict an analogous circuits of revised ZSI inverter in various operational states (b).

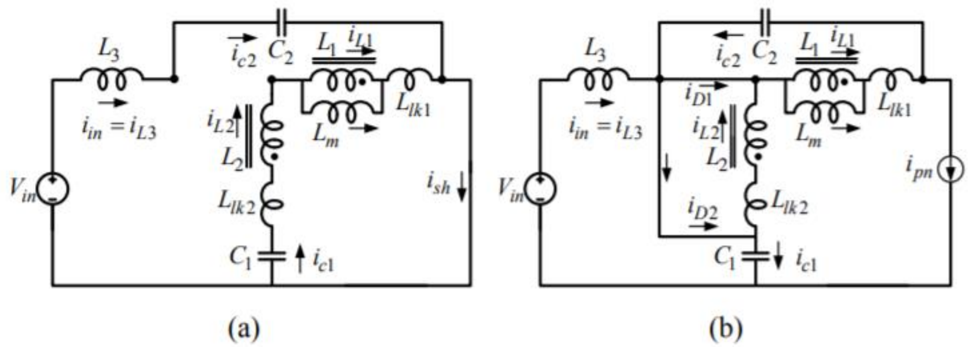

Figure 2: *Operating modes of the proposed inverter (a) State 1: Shoot through mode (b) State 2: Non-shoot through mode*

3.2 PV System

The output of Photovoltaic panel under varied electrical loads needs to be predicted, in this section, we will use the manufacturer's specification to determine the exact electrical properties of the PV panel or module, both on the power voltage plane and the current voltage plane.

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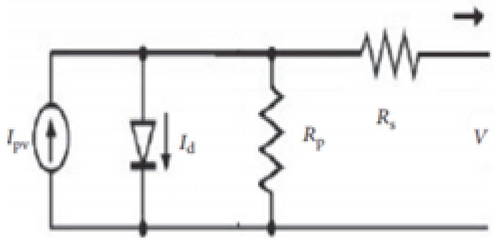


Figure 3: *PV Panel*

Additionally, the fundamental equation from semiconductor theory that uses mathematics to describe the properties of the perfect PV cell is

$$I = I_{pv,cell} - I_{0,cell}\left[\exp\left(\frac{qV}{a\text{K}T}\right) - 1\right]$$

$$I_d = I_0\left[\exp\left(\frac{qV}{a\text{K}T}\right) - 1\right]$$

These variables are monitored in relation to the cell temperature and sun irradiation standards test conditions (STCs).

3.3 SVPWM Technique

Many Power Electronics have employed Sinusoidal PWM as a typical PWM approach. Applications, particularly in the control of AC induction motors using V/F control. This chapter will demonstrate that Space Vector PWM, a different PWM method, is superior to Sinusoidal PWM. Compared to sine PWM, SV-PWM utilises the DC bus voltage by 15% more.

4 Results and Discussion

The suggested idea developed using Matlab simulation uses SVPWM to manage three phase VSI.

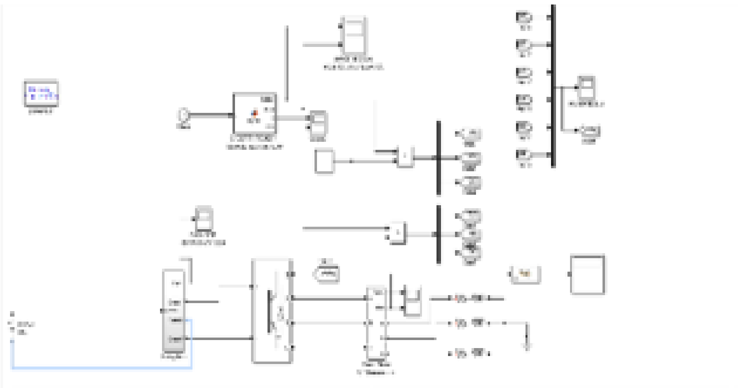
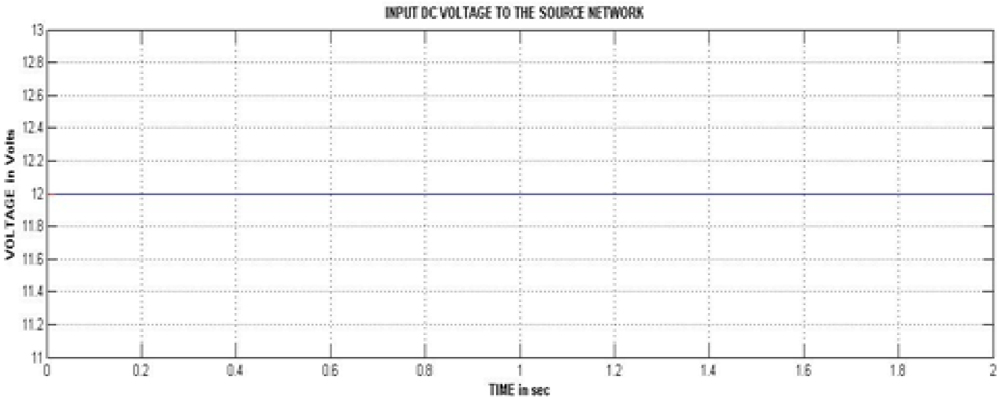
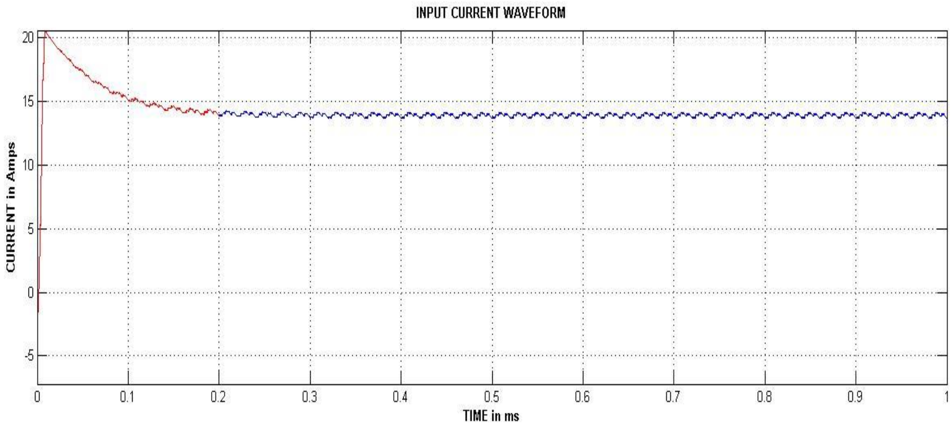


Figure 4: *Proposed system simulation view*



(a)



(b)

Figure 5: (a) *Input DC voltage to the Z source network* **(b)** *Input DC current in the Z source network*

After the input DC voltage has been applied, Figure 5 (a) shows an impedance source network. The circuit's current will continue to flow without interruption thanks to Z source network's reduction of ripples. The input current of Z source network has been displayed in Figure 5. (b). The usage of shoot through mode by Z source network has increased an output voltage.

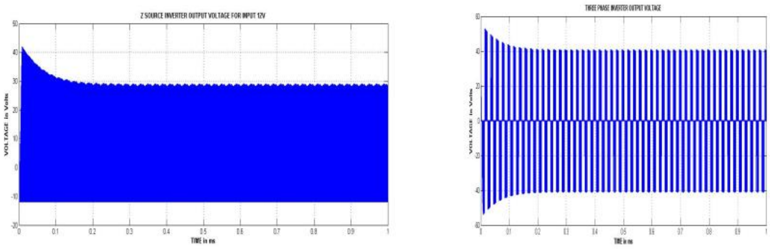


Figure 6: a) *Output voltage of Z source network* **b)** *Output voltage of VSI*

Figure 6 displays Z source network's output voltage (a). An output voltage has risen as a result of Z source network's use of a shoot through mode. Additionally, Z source provides good voltage stability thanks to source inductors. Figure 6 displays an output voltage of 3ϕ VSI employing SVPWM (b).

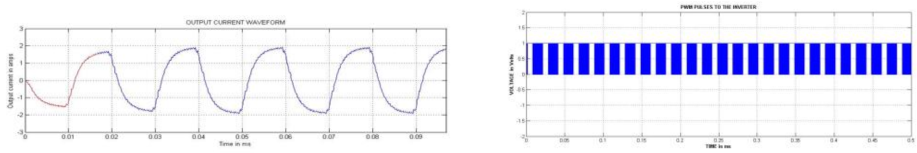


Figure 7: a) *Output load current waveform* **b)** *PWM pulse waveform to the ZSI*

The three phase Z source inverter's output current waveform simulation outcomes have been presented in Figure 7(a). Figure 7 displays the PWM pulse that was delivered to the three phase voltage source inverter (b). It was produced with a switching frequency of 10 KHz and was developed employing SVPWM technique.

	Trans-ZSI	Improved trans-ZSI	TZSI	ΓZSI	Improved ΓZSI with clamping diode
v_{pn} V_{sw}	$\overline{S_D}\cdot\left[\frac{V_{in}}{1-(1+n)D}\right]$	$\overline{S_D}\cdot\left[\frac{V_{in}}{1-(2+n)D}\right]$	$\overline{S_D}\cdot\left[\frac{V_{in}}{1-(2+n_1+n_2)D}\right]$	$\overline{S_D}\cdot\left[\frac{V_{in}}{1-\left(1+\frac{1}{n-1}\right)D}\right]$	$\overline{S_D}\cdot\left[\frac{(n-1)V_{in}}{n(1-2D)-1+D}\right]$
V_c	$V_{c1}=\frac{(1-D)V_{in}}{1-(1+n)D}$ $V_{c2}=NA$	$V_{c1}=\frac{(1-D)V_{in}}{1-(2+n)D}$ $V_{c2}=\frac{(1+n)V_{in}}{1-(2+n)D}$	$V_c=\frac{(1+n_1+n_2)DV_{in}}{1-(2+n_1+n_2)D}$ $V_c=V_{c1}=V_{c2}$	$V_{c1}=\frac{(1-D)V_{in}}{1-\left(1+\frac{1}{n-1}\right)D}$ $V_{c2}=NA$	$V_{c1}=\frac{(n-1)(1-D)V_{in}}{(n(1-2D)-1+D}$ $V_{c2}=\frac{(nD)V_{in}}{(n(1-2D)-1+D}$
V_D	$S_D\cdot\left[\frac{nV_{in}}{1-(1+n)D}\right]$	$S_D\cdot\left[\frac{(1-n)V_{in}}{1-(2+n)D}\right]$	$S_D\cdot\left[\frac{(1+n_1+n_2)DV_{in}}{1-(2+n_1+n_2)D}\right]$	$S_D\cdot\left[\frac{V_{in}}{n-1-nD}\right]$	$V_{D1}=S_D\cdot\left[\frac{nV_{in}}{n(1-2D)-1+D}\right]$ $V_{D2}=S_D\cdot\left[\frac{(n-1+D)V_{in}}{n(1-2D)-1+D}\right]$
G MB	$\frac{M}{1-(1-M)(1+n)}$	$\frac{M}{1-(1-M)(2+n)}$	$\frac{M}{1-(1-M)(2+n_1+n_2)}$	$\frac{M}{1-\left(1+\frac{1}{n-1}\right)(1-M)}$	$\frac{(n-1)M}{n(2M-1)-M}$

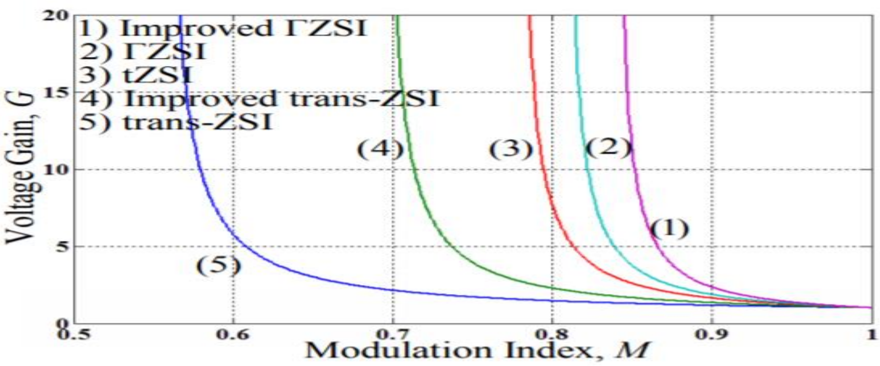


Figure 8: *Comparison of M.I and voltage gain*

Fig. 8 displays a curve of switch voltage stress vs. voltage gain. A greater modulation index along with lower shoot through duty cycle are used by the updated Γ-Z source inverter with

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clamping diode, to get same voltage gain, less voltage stress must be applied across the switching devices.

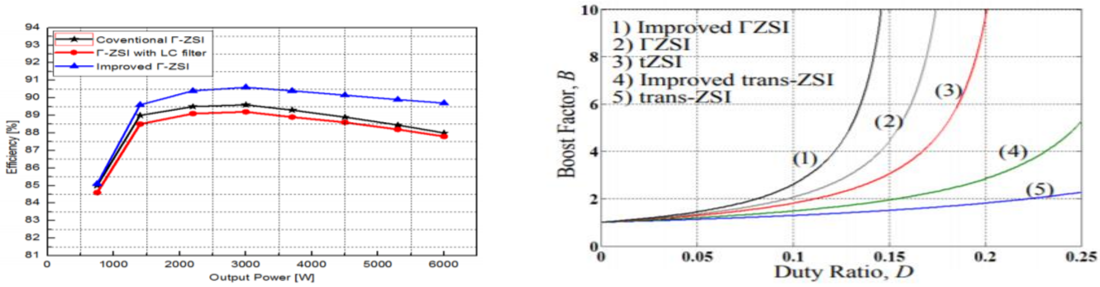

Figure 9: a) *Efficiency Comparison* **b)** *Plot of boost factor versus duty cycle with n=1.24*

It is necessary for demonstrating the benefits of an updated clamping diode Z source inverter, in this section, topologies that have previously been proposed are compared. Figure 9(a) illustrates an improved TZSI, Trans ZSI, ΓZSI, ΓZSI as well as enhanced duty cycle D vs. Trans ZSI boost factor B graphs. A ratio of transformer turn has been modified to 1.24 for each of the inverter topologies so that they can be compared. The plot shows that compared to alternative topologies with a same number of turns, an upgraded ΓZSI with clamping diode has a significantly larger boosting capacity. Figure 9(b) illustrates a voltage gain vs modulation index graph for Trans ZSI, enriched Trans ZSI, ΓZSI, tZSI, ΓZSI.

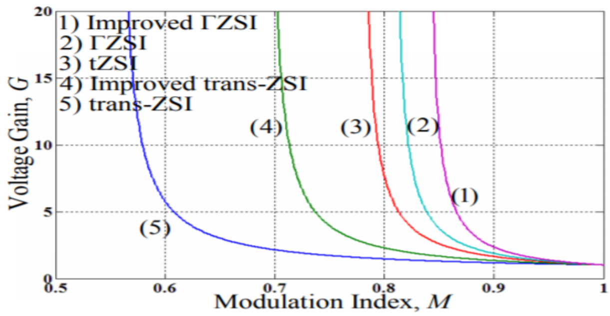

Figure 10: *M.I Vs Gain of the converters*

Figure 10 depicts that the voltage gain increases as modulation index decreases.

5 Conclusions

A brand new Z source inverter topology has been revealed by this project. A revised topology has a number of benefits over the prior Z source inverter. 1 To maintain the same boost capability, the voltage stress on the Z source capacitor is considerably reduced; thus, you can use low voltage capacitors to cut the system's cost and size; 2) The DC utilization and losses are reduced via the space vector PWM approach. The advantages of the suggested topology are supported by simulation and experimental data.

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