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Analysis of Impedance Inverter for Optimum Boosted Output

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ABSTRACT

When a PV module is required, an AC module that serves as a grid-connected inverter can be used. ZSI is being utilized to relieve VSI and CSI of a variety of problems. The use of renewable energy has increased noticeably in India, where a number of laws and programs have been proposed to focus on the renewable energy sector. Conventional voltage source inverters (VSIs) and current source inverters (CSIs) can only convert dc to ac via boost or buck methods. Consequently, VSI needs to install an extra DC-DC boost converter between the inverter bridge and the DC supply in order to get a higher AC output voltage..The triggering pulses are generated by bringing the input sinusoidal and triangular waves on the same graph. Maximum boosted output and constantly boosted can be achieved through this method just by adjusting its modulation index and shoot-through intervals. This work presents an impedance source inverter that is equipped with triggering pulses produced by maximum constant boost control modulation and maximum voltage boosting approach.

Keywords: *Inverter, Boosting, switching, transformer-less, shoot-through states, parametric fluctuations.*

1.0 Introduction

India has prioritized the use of green energy in recent years due to its heavy reliance on solar energy. India clearly increased its use of renewable energy, especially solar energy, between 2016 and 2022. Just 6.7GW of India's total installed capacity (TIC z) came from solar energy in 2016. These days, the number is over nine times higher, or closer to 56.95GW [1], A multi-phase motor outperforms a 3-phase motor under fault-tolerant settings. Furthermore, the primary issues pertaining to the system's dependability are the shoot-through problem in VSI and the open-circuit problem in CSI. The Z-source inverter (ZSI) [1], which has single-stage power conversion and buck-boost voltage capabilities in contrast to VSI and CSI inverters, is the primary cause of the aforementioned issues. Thus, a single-stage power conversion is used to provide buck-boost capabilities. In the event of a single-phase or dual-phase open circuit, a motor can use several states of health to keep operating without the need for extra hardware or controllers [2]. Table 1 displays the growing percentage of solar and renewable energy in India's installed capacity. In terms of the amount of electricity generated by solar power, India came in fifth place globally in 2018; but, after adding 7.3 GW of new solar power to the nation in 2019, India rose to third place. The possibility that the renewable energy sector may produce 363GW of power has led to the development of several initiatives and projects in India [4].

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Northern India may become a hub for renewable energy in the years to come. By 2022, MNRE intended to generate 175 GW of electricity from renewable sources, of which 100 GW would come from solar energy [3].

As of June 1, 2022, the latest updated statistics indicates that India's share of renewable energy is 166.72 GW, with 56.951 GW originating from solar energy. India was expected to have an installed power generation capacity of about 402.817 GW as of June 17, 2022, of which about 166 GW, or 41 percent [2] [5], comes from renewable energy sources 56GW, or 14% of India's total power generation, comes from solar energy [6]. The Indian government has implemented various financial efforts to enhance the nation's capacity to produce renewable energy, including the UDAY plan, rooftop program, and solar energy subsidy scheme. In an effort to improve ecological sustainability and allay concerns about energy security, the Indian government launched the National Sustainable Mission (NSM). India will also play a significant role in the worldwide effort to combat climate change.

PV systems' modular design makes it simple to boost installed power. In [8], [9], many layouts of an AC module have indeed been explored. The output of PV module which is mostly of lower range must be increased in able to link to the grid due to its inconsistent and fluctuating nature. Transformers are therefore used to achieve this boosting intent, however transformer-less layouts are greatly favored since they offer excellent efficiency, relatively inexpensive, and easy fabrication [10]-[13]. Transformer-less systems can be further classified into single step and dual step versions. Using DC-DC choppers, a PV module's low output can be increased in two stages before being reversed into AC for a three-phase load. By swapping the chopper or DC-DC boosting step with a straightforward 2-port network made of passive components, this layout is further optimized (L & C). Boosting and inversion can be accomplished via a Z-source inverter in a sole step. The constraints of traditional multi step layouts have been alleviated by ZSI. [15]. As demonstrated in Fig. 3 [14, 15], Many problems with VSI and CSI are resolved by ZSI, including the limited output voltage range and the requirement for double up and dead time to postpone the worry of malfunctioning devices and inductor disconnection. It is possible to use buck-boost functions without requiring any kind of transformer.

1.1 Circuit framework & functional principle of ZSI

An impedance network is incorporated into the ZSI circuit layout to link with the circuit constituting inverter and the power supply in order to offer distinct features that are unavailable from standard CSI and VSI [16]. The impedance connection is made by an X-shaped connection between two capacitors (C_N& C_T) and a split inductor (L_N& L_T). After this impedance network, a 3-phase inverter is used to change the increased Direct Current voltage to Alternating Current. A certain input DC voltage is fed to the inverter, and by manipulating the on/off switch time period of the switches of inverter, a regulated output AC voltage could be derived from this. For such approach, a triangular carrier signal of high frequency and a three-phase sinusoidal wave as modulating signal with a 120-degree phase shift are selected, and the time between the meeting sites of these signals determines the pulsing or turning on period of modulated pulses and commutation. Unusually, ZSI permits continuous conduction of an inverter phase leg, that is made to happen only and only possible by tweaking the duty-cycle (T_0/T), leading to enhanced AC output voltage. [14].

Typically, there are 8 switching states in commonly used VSI and CSI, with 6 of them being actively functional states and the other 2 are null positions where shorting of end terminals occur). The 0- shoot through (ST) state, when sustained conductivity via up and down switches in different inverter legs is carried on, is one of the ZSI's supplementary switching states. ZSI has nine switching states altogether. Buck and boost features are permitted in ZSI inside this zone [16].ZSI consists of two components :- ST & NST. Power is delivered without a cessation to the load by the input DC voltage source and inductors throughout NST (Non-Shoot Through) phase as a continuous pathway is offered by a forward biased diode. Additionally, capacitors were being charged concurrently.

2.0 Mathematics Included in ZSI

Mathematical equations can be used to illustrate how ZSI parameters are interdependent, with $\hat{V}_{os}$ standing for the highest amount of DC link voltage, V_c for the capacitor attained voltage, and $\hat{V}_{os}$ for the output AC peak phase voltage.

So,

$$V_c = \frac{V_{is}}{1-D_z} \quad \dots 1$$

$$\hat{V}_{os} = B_z . V_{is} = \frac{V_{is}}{1-2D_z} \dots 2$$

$$\hat{V}_{os} = M_z . \frac{\hat{V}_{os}}{2} = M_z . B_z . \frac{V_{is}}{2} \quad \dots 3$$

$$B_z = \frac{1}{1-2D_z} \quad \dots 4$$

$$G_z = B_z * M_z \quad \dots 5$$

Where, B_z= boosting factor,

M_z= modulation index,

G_z= overall gain in ZSI

$D_z = \frac{T_{st}}{T_{sw}}$ is ST duty ratio,

T_{st} = time for shoot through,

T_{sw}= time for switching.

The relationships outlined above lead to the conclusion that altering M z and shoot-through time can control $\hat{V}_{os}$.

3.0 PWM Schemes for Shoot through Generation

Three legs make up a complete bridge, two of which have switches for each phase. EMI noise intrusion can activate switches on a single phase leg or multiple at once, resulting in ST pulses.

3.1 Maximum Boost Control Scheme (MBC)

Compared to the Simple Boost Control method, which severely strains the inverter switches' voltage, it performed better. By maintaining voltage gain within a certain range, it can be decreased. Therefore, to maintain their product at a desired value and reduce stress on the switches for a given voltage gain, we must limit the boosting factor and improve the modulation index [20]. The ST duty cycle is not continuous, therefore maximal exploitation of zero states yields additional boosting. But to obtain a greater degree of voltage gain, the boosting factor couldn't be too minimal.A separate method is used to create a new wave when the maximum boost control is in place. The greatest crest curve of each sinusoidal modulating wave is tracked to create the upper ST envelope, and the lower ST envelope is created in an analogous manner by joining the lower peak curves of each sine wave

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[18]. Rather than using straight lines, envelopes generated from the sine curves' peaks are utilized to generate shoot through, which transforms all of the null states into ST zero states without affecting the active states that are already present. In this case, any desirable output voltage can be obtained by using the maximum M_d. The ST duty cycle is not continuous, therefore maximal exploitation of zero states yields additional boosting.

3.2 Maximum Constant Boost Control scheme(MCBC)

In MCBC, the majority of the blank states are used to provide ST, hence the width of the zone encircled by ST envelopes is maintained almost constant throughout the basic period to ensure maximal boosting and a stable ST duty cycle. ST envelope is created in an analogous manner by joining the lower peak curves of each sine wave [18]. Rather than using straight lines, envelopes generated from the sine curves' peaks are utilised to generate shoot through, which transforms all of the null states into ST zero states without affecting the active states that are already present. Dz is kept constant in this fashion. Dz determines the boosting factor, yielding as in maximum constant boost.This method fixes the line frequency-related ripple issue, allowing for the use of smaller L & C.

Table 1: Overall Gain, Boosting Factor, Voltage Stress & Duty Ratio for Different Control Schemes

	MCBC	**MBC**
Boost factor	$\frac{1}{\sqrt{3}M_z - 1}$	$\frac{\pi}{3\sqrt{3}M_z - \pi}$
Duty ratio	$\frac{2 - \sqrt{3}M_z}{2}$	$\frac{2\pi - 3\sqrt{3}M_z}{2\pi}$
Modulation index	$\frac{G_z}{\sqrt{3}G_z - 1}$	$\frac{\pi G_z}{3\sqrt{3}G_z - \pi}$
Voltage stress	$(\sqrt{3}G_z - 1).V_{is}$	$(\frac{3\sqrt{3}\,G_z - \pi}{\pi}).V_{is}$

4.0 Simulated Results

Table 2: Calculated Parameters

PWM method	**Vc**	**V_{os}**	**V_{rms}**
MBC	568.2	**198.8**	**243.5**
CBC	423	**148.3**	**181.6**

5.0 Conclusion

The ZSI output is affected by the modulation index and input voltage. As a result, parametric fluctuations are examined with a fixed input voltage and modulation index. As a result, MBC emerges as the most effective modulation method for attaining the highest possible output AC voltage. To achieve the highest enhanced output, one can modify the shoot-through intervals and modulation index of this method. This study specifies and illustrates the operation of a Z-source inverter with two modulation approaches using MATLAB modeling. Numerous factors, including the modulation index (Mz), the boosting factor (Bz), and the overall gain (Gz), affect the ZSI's output. To study the previously indicated parametric fluctuations while maintaining constant input and output voltage levels, an appropriate modulation method needs to be selected.

Figure 1: Output Obtained from the End Side of MBC Scheme

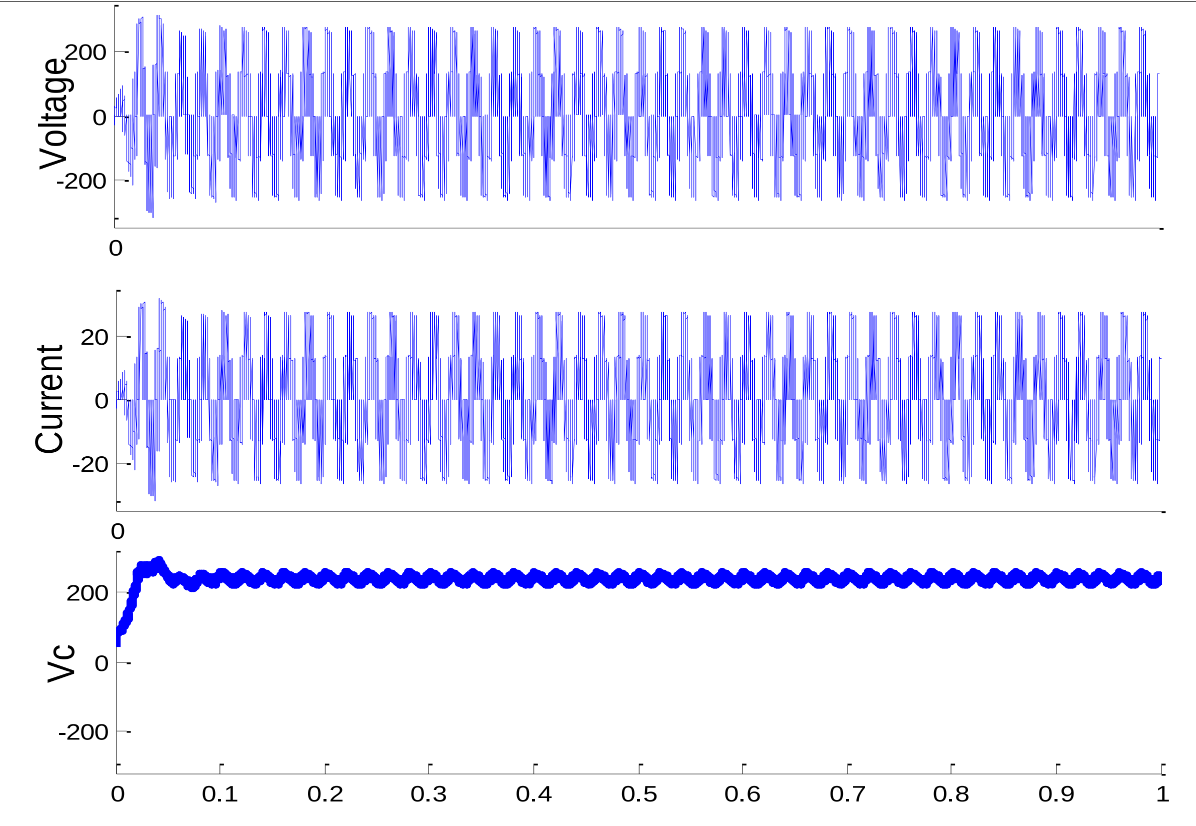
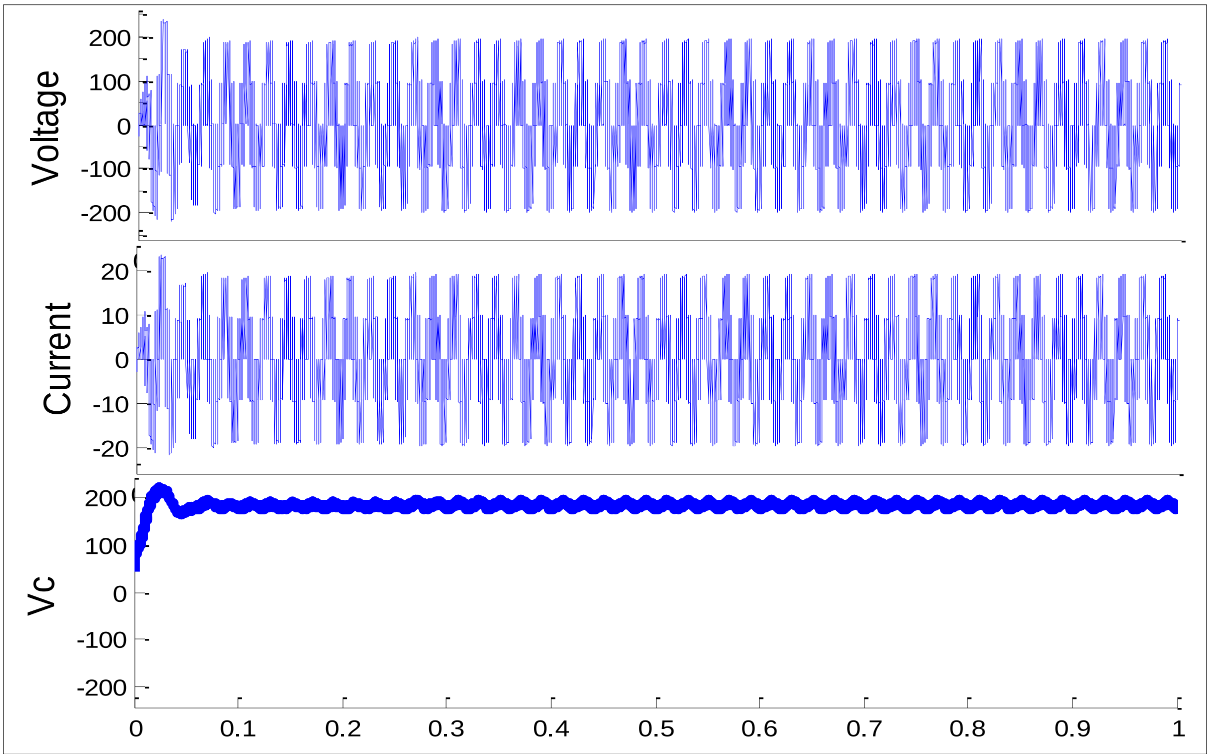


Figure 2: Output Obtained from the End Side of MCBC Scheme



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