

Modulation Control of Impedance Inverter to Achieve Simple and Maximum Boosted Output

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ABSTRACT

India has seen a notable increase in adoption of the renewable energy, Various policies and schemes had been proposed in India to focalize on renewable energy sector. For solar energy conversion, an AC module that functions as a grid-connected inverter after a PV module is needed. ZSI is being used to alleviate a myriad of issues that VSI and CSI have. An impedance source inverter provided with triggering pulses generated by maximum boost control modulation technique is presented in this paper. The shoot-through control approach that is utilized to generate pulses that are sent to semiconductor switches is directly related to the output voltage of the ZSI. Among the several techniques that can be used, the one that involves the least amount of complexity is the one that is used here. 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. This study compares and contrasts the modulation techniques used for 3-ZSI in order to highlight their fundamental differences. It then offers a practical method for obtaining high output voltage with minimal voltage stress on the inverter's switching components.

Keywords: *Inverter; Boosting; Switching; Transformer-less; Shoot-through States; Parametric Fluctuations.*

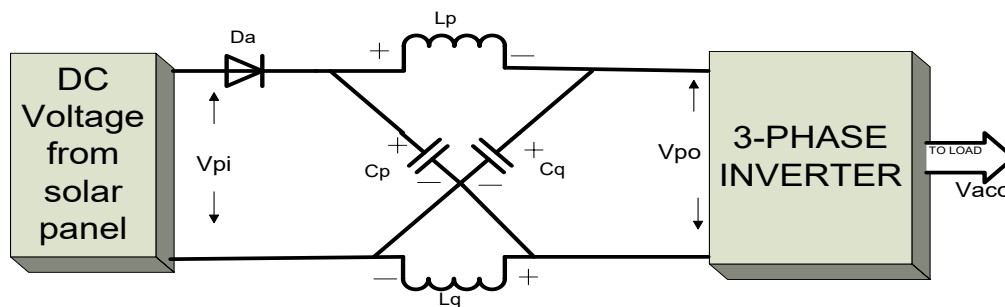
1.0 Introduction

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 also be subdivided into dual step and single step configurations. In a two-step layout, a PV module's low output is increased using DC-DC choppers before being inverted 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].

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Figure 1: One-stage Conversion



As demonstrated in Fig. 3 [14, 15], ZSI is being used to alleviate a myriad of issues that VSI and CSI have, such as the need for double up and dead time to put off the concern of device malfunction and inductor getting disconnected as well as alongside the restrictive output voltage range. It may be able to incorporate buck-boost capabilities without even employing a transformer. India places a great deal of reliance on solar energy, which has caused it to concentrate in recent years on using green energy. India has seen a notable increase in adoption of the renewable energy, primarily solar energy, from 2016 to 2022. Just 6.7GW of India's TIC z was devoted to solar energy in 2016, but today that number is closer to 56.95GW, or nearly nine times more [1], [2].

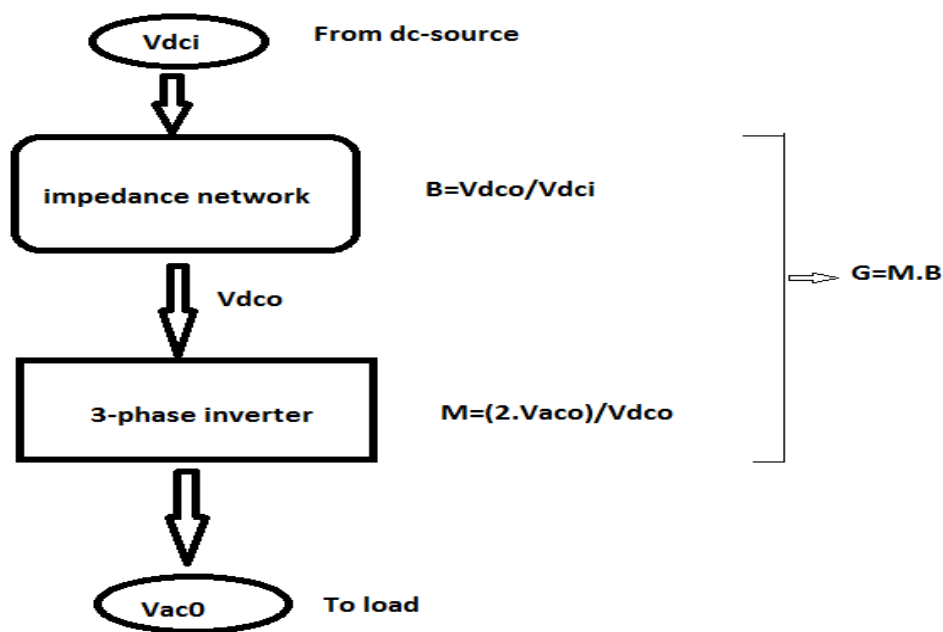
The overall installed capacity of the power generation in India, as of 17 June 2022, was estimated to be around 402.817 GW, with renewable energy accounting for roughly 166 GW, or about 41 percent of total utility power generation [2], [5]. 56GW, or 14% of India's total power generation, comes from solar energy [6]. The Indian government has enhanced the nation's capacity for renewable energy in recent years by introducing a number of financial programmes like the UDAY scheme, the rooftop scheme, and the solar energy subsidy scheme. The Government of India launched the National Sustainable Mission (NSM) as a significant project to promote ecological sustainability and address the country's energy security issues. Additionally, India's contribution to the global effort to address the concerns of changing climate would be significant.

2.0 Impedance Source Inverter

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. 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. To utilize the potential energy in solar AC block is needed that can function as an inverter which is directly connected to the grid, employed after the PV conversion structure. 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. The DC voltage source and inductors keep the power flowing to the load without interruption. throughout NST (Non-Shoot Through) phase as a continuous pathway is offered by a forward biased diode. Additionally, capacitors were being charged concurrently.

Figure 2: Flow Chart of Steady State Analysis



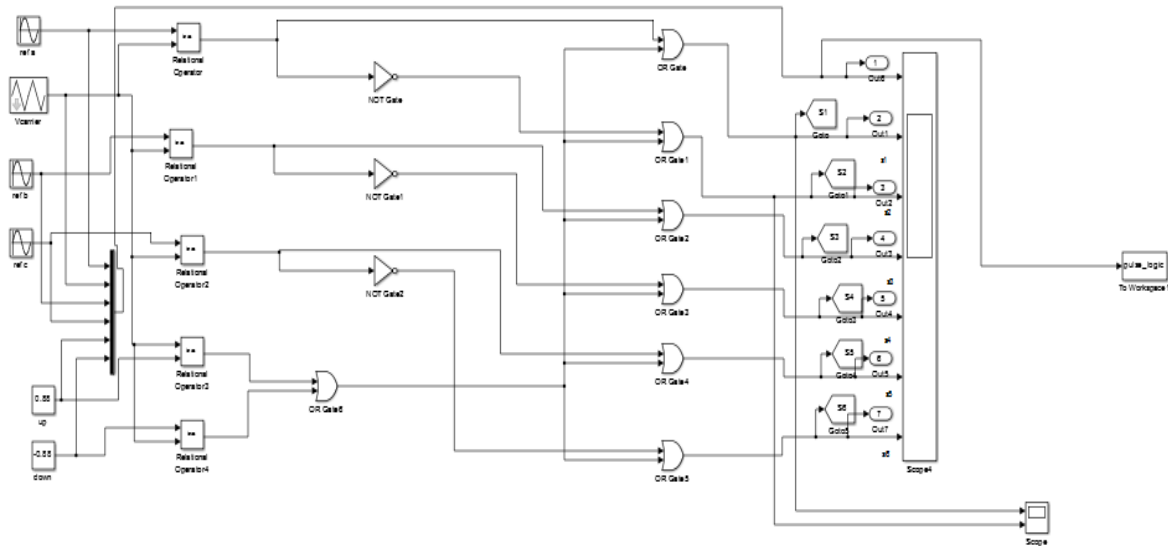
3.0 Generation of Triggering Pulses

A full bridge includes three legs, two of which are equipped with switches for every phase. ST pulses can be produced via EMI noise intrusion, which turns on switches on the single phase leg or several at once.

3.1 Simple boost control

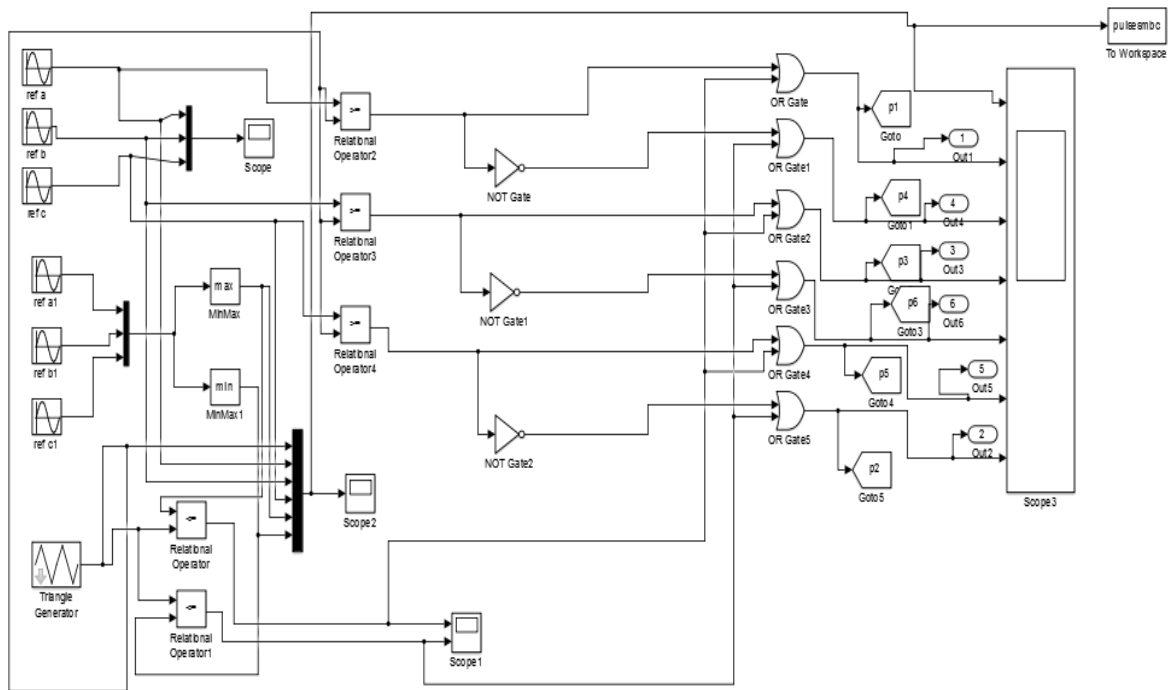
Two straight lines with values equal to the peak of the modulating sinusoidal signal are used to generate the ST standards in this manner. The values of these lines are equivalent to the signal's crest. OR gates serve as the connecting mechanism for merging these lines into the standard switching patterns. When the upper straight line is below the top triangular carrier waves or the lower straight line is higher than the bottom triangular carrier waves, the circuit enters ST mode; in all other circumstances, it operates as a conventional PWM circuitry [14]. ST mode is triggered when either Straight lines below or above the bottom triangle carrier waves are used to represent these two possible states of matter. Hiking is a phenomenon that occurs in an SBC system when in all switching devices there is an increase in voltage stress.

Figure 3: Matlab Model for SBC



3.2 Maximum boost Control

Figure 4: Matlab Model for MBC



It outperformed the Simple Boost Control method, which places considerable voltage stress on the inverter switches. By maintaining a certain range for voltage gain, it can be decreased. Therefore, to maintain their product at a target value and reduce stress on the switches for a specified voltage gain, we must improve modulation index and minimise boosting factor [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.

4.0 Results

A MATLAB/SIMULINK-based virtual model has been constructed for the purpose of validating the theoretical study. In order to demonstrate the distinct behavior of VSI and ZSI, Fig. 7 utilizes two distinct values for the input and output variables. The panel's output voltage is 220 volts for the first half second and a half of the test. Boosting isn't necessary at this time, thus the converter circuit's typical VSI action, which has eight switching states, can deliver the desired output voltage

Table 1: Specifications for Components

Parameters	Values
X- connected capacitors(Cp&Cq)	1000e-6 F
Split inductor(Lp & Lq)	5e-3 H
Fundamental frequency (fo)	50 Hz
Input DC voltage from solar panel	90V
Output Voltage (L-L RMS Vaco)	106V

Table 2: Calculated Parameters

PWM Method	When $V_{pi}=90V$ and $\hat{V}_{aco}=86.7V$	
	Voltage stress (\hat{V}_{po})	Modulation index (M_i)
Simple Boost	256.6 V	0.676
Maximum Constant Boost	210 V	0.823
Maximum Boost	196 V	0.88

4.1 Simple boost control result

Figure: Voltage Stress in Simple Boost Control

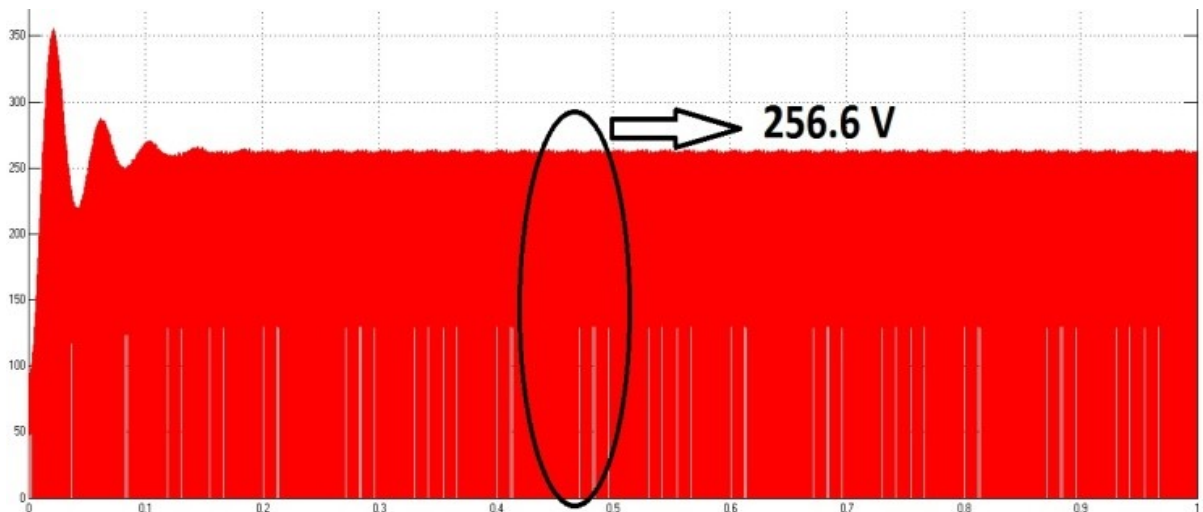
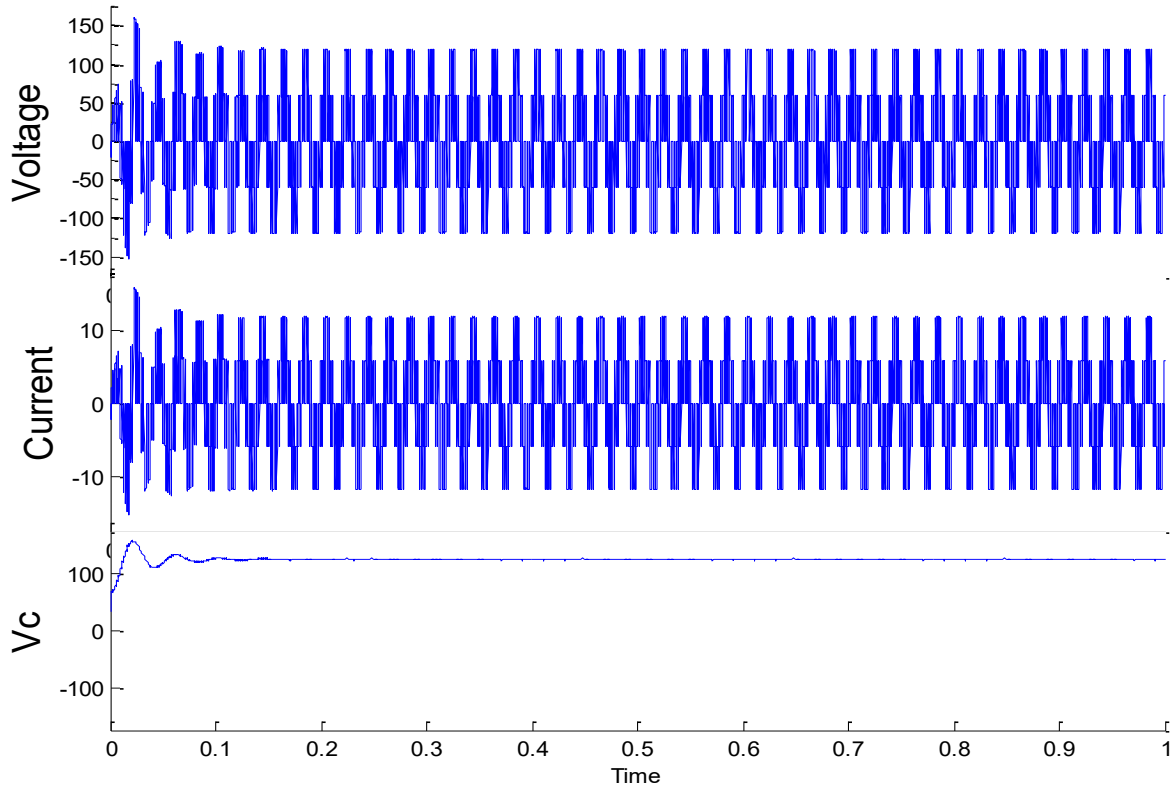


Figure: Output Voltage, Current and Capacitor Voltage



4.2 Maximum boost control result

Figure: Voltage Stress in Maximum Boost Control

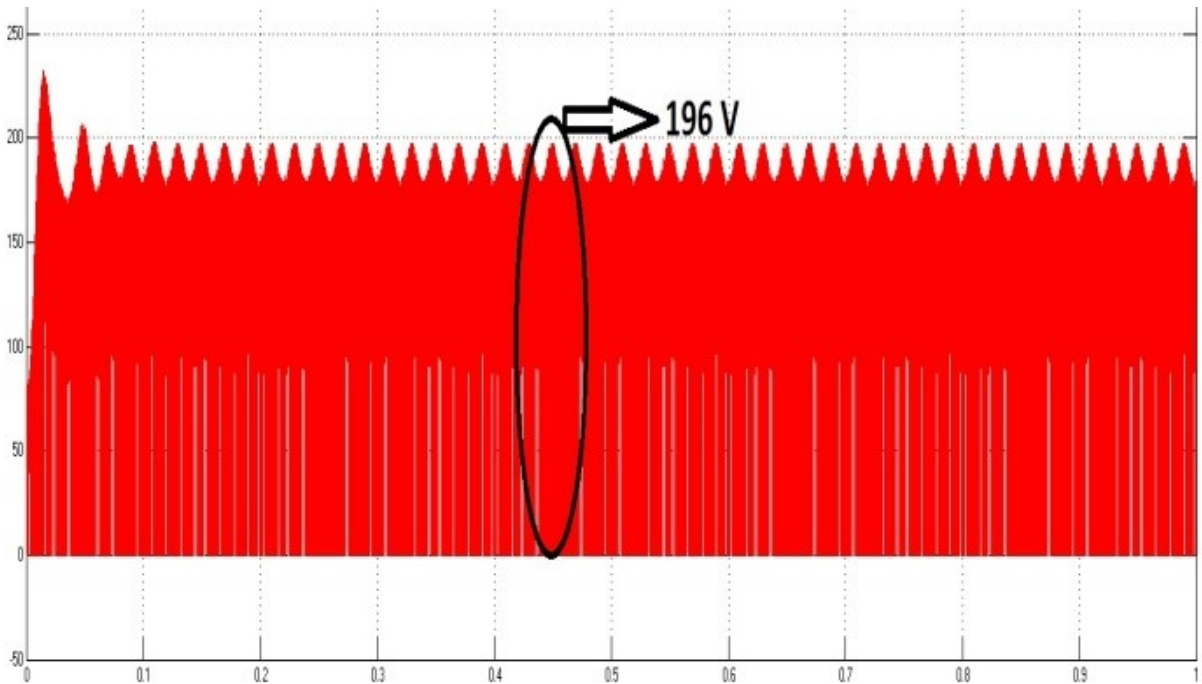
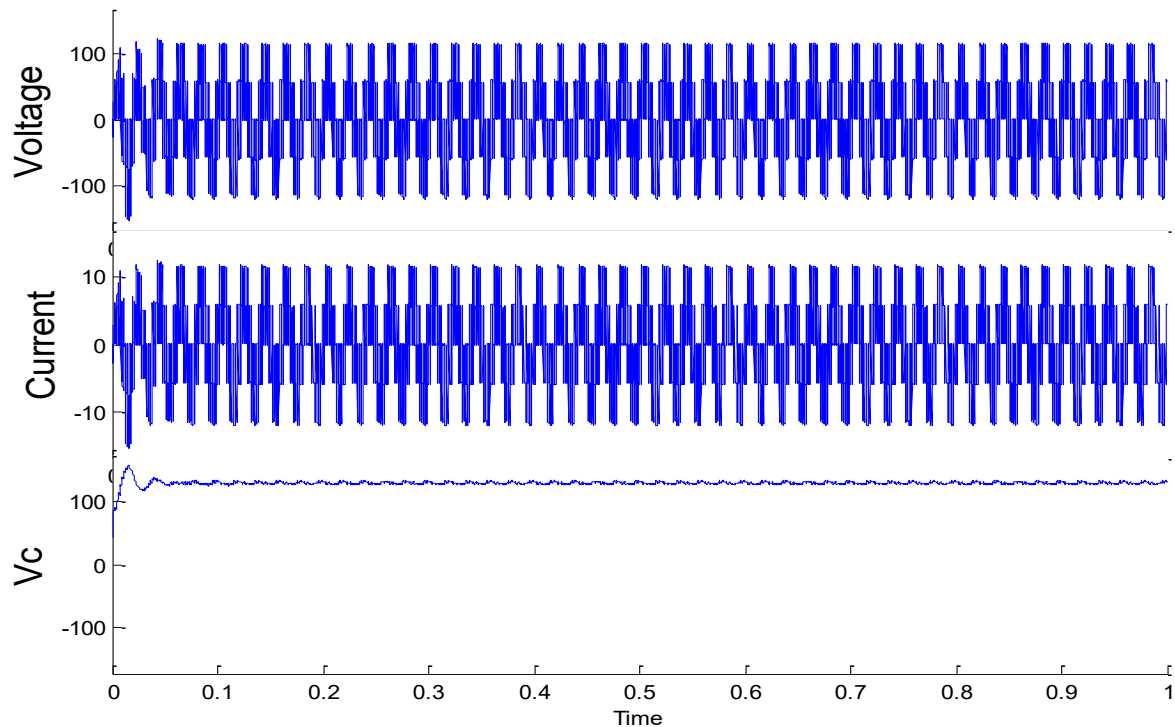


Figure: Output Voltage, Current and Capacitor Voltage

5.0 Conclusion

ZSI output is influenced by modulation index and input voltage. Thus, while maintaining a fixed input voltage and modulation index, parametric fluctuations are investigated. As a result, MBC proves to be the most effective modulation approach for producing the highest possible output AC voltage. Maximum boosted output can be achieved through this method just by adjusting its modulation index and shoot-through intervals. This study describes and illustrates the operation of a Z-source inverter with two modulation methods using MATLAB modelling. Numerous factors, including the modulation index (M_z), the boosting factor (B_z), and the overall gain (G_z), determine the ZSI's output. In order to explore the aforementioned parametric fluctuations while maintaining constant input and output voltage levels, an appropriate modulation approach must first be identified.

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