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GRID INTERFACING OF PHOTOVOLTAIC VOLTAGE SOURCE INVERTER

[1]Mr. Dhaval Gohil, [2]Prof.Yashvi Parmar, [3]Prof.Hiren Sidhpuria

[1]*PG Student, Electrical Engineering Department, C.G.Patel Institute of Technolog,*
Bardoli, India

[2,3]*Assistant Professor, Electrical Engineering Department, C.G.Patel Institute of Technology,*
Bardoli, India

Author's Email: gohildhaval009@gmail.com, yashvi.parmar@utu.ac.in, hiren.sidhpuria@utu.ac.in

A*bstract*: The use of voltage source inverters (VSI) in grid integration of photovoltaic (PV) systems with Multi Megawatt have been research extensively and always be priority despite of the drawbacks of short lifespan of dc-link capacitor and inherent buck features. With regard to that, researchers continue to find feasible alternative topologies that may offer promising capabilities as in VSIs. Current source inverter (CSI) is one of the competitive options since it has inherent voltage boosting capability and continuous dc input current. These features are important requirements in PV application. This, study on the option of using VSI system to supply the ac grid with the required controlled active and reactive powers. The presented control strategy uses number of feedbacks loops to enable fast and accurate tracking of the desired set-points with minimum overshoot. The selection of feedback control variables are discussed using stability analysis. The proposed control strategy is verified by MATLAB/SIMULINK platform.

Keywords: PV, INVERTER, GRID, MATLAB , CSI, VSI.

1. INTRODUCTION

1.1 Inverter

The Inverter is the power electronic circuit, which converts the DC voltage into AC voltage. The DC source is normally a battery or output of the controlled rectifier. The output voltage waveform of the inverter can be square wave, quasi-square wave or low distorted sine wave.

The output voltage can be controlled with the help of drives of the switches. The pulse width modulation techniques are most commonly used to control the output voltage of inverters. Such inverters are called as PWM inverters. The output voltage of the inverter contain harmonics whenever it is not sinusoidal. These harmonics can be reduced by using proper control schemes.

1.2 What are the various types of Inverters?

Inverters can be broadly classified into two types. They are

1. Voltage Source Inverter (VSI)
2. Current Source Inverter (CSI)

When the DC voltage remains constant, then it is called Voltage Source Inverter(VSI) or Voltage Fed Inverter (VFI).

When input current is maintained constant, then it is called Current Source Inverter (CSI) or Current Fed Inverter (CFI).

Sometimes, the DC input voltage to the inverter is controlled to adjust the output. Such inverters are called Variable DC Link Inverters. The inverters can have single phase or three-phase output. A voltage source inverter (VSI) is fed by a stiff

DC voltage, whereas a current source inverter is fed by a stiff current source. A voltage source can be converted to a current source by connecting a series inductance and then varying the voltage to obtain the desired current. A VSI can also be operated in current-controlled mode, and similarly a CSI can also be operated in the voltage control mode. The inverters are used in variable frequency ac motor drives, uninterrupted power supplies, induction heating, static VAR compensators, etc.

The comparative study between VSI and CSI

VSI vs CSI

VSI is fed from a DC voltage source having small or negligible impedance’s is fed with adjustable current from a DC voltage source of high impedance. Input voltage is maintained constant. The input current is constant but adjustable. Output voltage does not dependent on the load. The amplitude of output current is independent of the load. The waveform of the load current as well as its magnitude depends upon the nature of load impedance. The magnitude of output voltage and its waveform depends upon the nature of the load impedance’s requires feedback diodes. The CSI does not require any feedback diodes.

The commutation circuit is complicated Commutation circuit is simple as it contains only capacitors. Power BJT, Power MOSFET, IGBT, and GTO with self-commutation can be used in the circuit. They cannot be used as these devices have to withstand reverse voltage.

2. RESEARCH WORK

After completion of this lesson the reader will be able to:

(i) Identify the essential components of a voltage source inverter.

(ii) Explain the principle behind dc to ac conversion.

(iii) Identify the basic topology of single-phase and three-phase inverters and explain its principle of operation.

(iv) Explain the gate drive circuit requirements of inverter switches.

The word ‘inverter’ in the context of power-electronics denotes a class of power conversion (or power conditioning) circuits that operates from a dc voltage source or a dc current source and converts it into ac voltage or current. The ‘inverter’ does reverse of what ac- to-dc ‘converter’ does (refer to ac to dc converters). Even though input to an inverter circuit is a dc source, it is not uncommon to have this dc derived from an AC source such as utility ac supply. Thus, for example, the primary source of input power may be utility ac voltage supply that is ‘converted’ to dc by an AC to DC converter and then ‘inverted’ back to ac using an inverter. Here, the final ac output may be of a different frequency and magnitude than the input ac of the utility supply.

[The nomenclature ‘inverter’ is sometimes also used for ac to dc converter circuits if the power flow direction is from dc to ac side. However in this lesson, irrespective of power flow direction, ‘inverter’ is referred as a circuit that operates from a stiff dc source and generates ac output. If the input dc is a voltage source, the inverter is called a voltage source inverter (VSI). One can similarly think of a current source inverter (CSI), where the input to the circuit is a current source. The VSI circuit has direct control over ‘output (ac) voltage’ whereas the CSI directly controls ‘output (ac) current’. Shape of voltage waveforms output by an ideal VSI should be independent of load connected at the output.]

The simplest dc voltage source for a VSI may be a battery bank, which may consist of several cells in series-parallel combination. Solar photovoltaic cells can be another dc voltage source. An AC voltage supply, after rectification into dc will also qualify as a dc voltage source. A voltage source is called stiff, if the source voltage magnitude does not depend on load connected to it. All voltage source inverters assume stiff voltage supply at the input.

Some examples where voltage source inverters are used are: uninterruptible power supply (UPS) units, adjustable speed drives (ASD) for ac motors, electronic frequency changer circuits etc. Most of us are also familiar with commercially available inverter units used in homes and offices to power some essential ac loads in case the utility ac supply gets interrupted.

In such inverter units, battery supply is used as the input dc voltage source and the inverter circuit converts the dc into ac voltage of desired frequency.

The achievable magnitude of ac voltage is limited by the magnitude of input (dc bus) voltage. In ordinary household inverters the battery voltage may be just 12 volts and the inverter circuit may be capable of supplying ac voltage of around 10 volts (rms) only. In such cases the inverter output voltage is stepped up using a transformer to meet the load requirement of, say, 230 volts.

How to Get AC Output From DC Input Supply.

Figs. 1 and 2 show two schematic circuits, using transistor-switches, for generation of ac voltage from dc input supply. In both the circuits, the transistors work in common emitter configuration and are interconnected in push-pull manner. In order to have a single control signal for the transistor switches, one transistor is of n-p-n type and the other of p-n-p type and their emitters and bases are shorted as shown in the figures. Both circuits require a symmetrical bipolar dc supply. Collector of n-p-n transistor is connected to positive dc supply (+E) and that of p- n-p transistor is connected to negative dc supply of same magnitude (-E). Load, which has been assumed resistive, is connected between the emitter shorting point and the power supply ground.

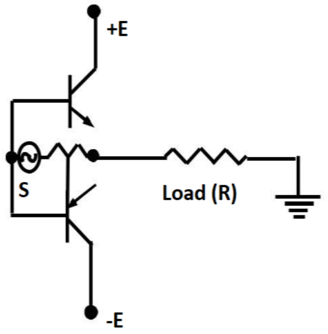

Figure 1: A Push – Pull active Amp. Circuit

In Fig. 1, the transistors work in active (amplifier) mode and a sinusoidal control voltage of desired frequency is applied between the base and emitter points. When applied base signal is positive, the p-n-p transistor is reverse biased and the n -p-n transistor conducts the load current. Similarly for negative base voltage the p-n-p transistor conducts while n-p-n transistor remains reverse biased. A suitable resistor in series with the base signal will limit the base current and keep it sinusoidal provided the applied (sinusoidal) base signal magnitude is much higher than the base to emitter conduction-voltage drop. Under the assumption of constant gain (hfe) of the transistor over its working range, the load current can be seen to follow the applied base signal. Fig. 3 shows a typical load voltage (in blue colour) and base signal (green colour) waveforms. This particular figure also shows the switch power loss for n-p-n transistor (in brown colour). The other transistor will also be dissipating identical power during its conduction. The quantities in Fig. 3 are in per unit magnitudes where the base values are input supply voltage (E) and the load resistance (R). Accordingly the base magnitudes of current and power are E/R and E2/R respectively. As can be seen, the power loss in switches is a considerable portion of circuit's input power and hence such circuits are unacceptable for large output power applications.

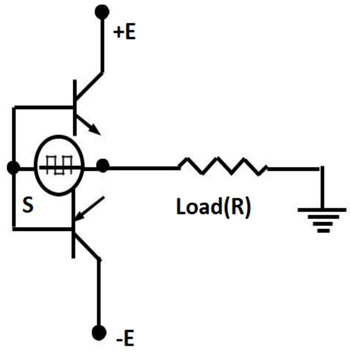

Figure 2: A Push– Pull Switched Mode Circuit

As against the amplifier circuit of Fig. 1, the circuit of Fig. 2 works in switched mode. The conducting switch remains fully on having negligible on-state voltage drop and the non-conducting switch remains fully off allowing no leakage current through it. The load voltage waveform output by switched-mode circuit of Fig. 2 is rectangular with magnitude +E when the n-p-n transistor is on and –E when p-n-p transistor is on. Fig. 4 shows one such waveform (in pink colour). The on and off durations of the two transistors are controlled so that (i) the resulting rectangular waveform has no dc component (ii) has a fundamental (sinusoidal) component of desired frequency and magnitude and (iii) the frequencies of unwanted harmonic voltages are much higher than that of the fundamental component. The fundamental sine wave in Fig. 2, shown in blue colour, is identical to the sinusoidal output voltage of Fig. 3.

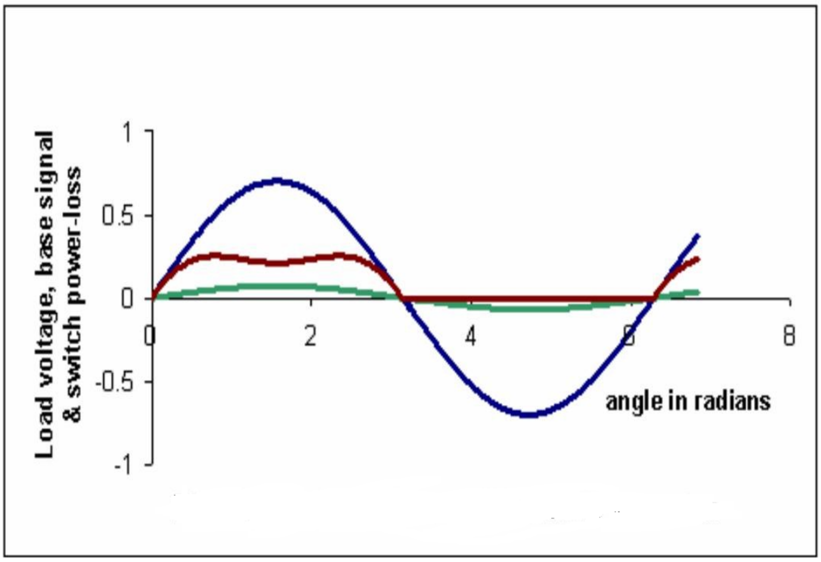

Figure 3: Switched in Amp. Mode

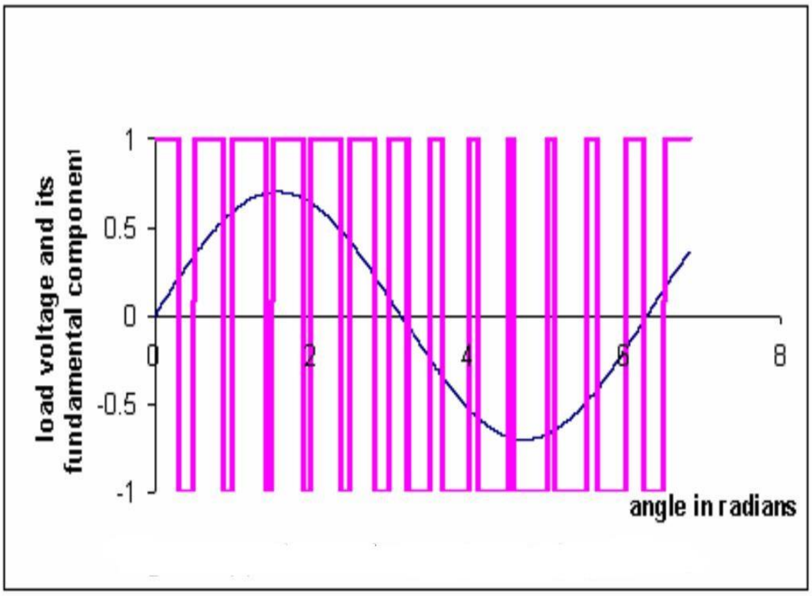

Figure 4: Switch in Operation

Both amplifier mode and switched mode circuits of Figs. 1 and 2 are capable of producing ac voltages of controllable magnitude and frequency, however, the amplifier circuit is not acceptable in power-electronic applications due to high switch power loss. On the other hand, the switched mode circuit generates significant amount of unwanted harmonic voltages along with the desired fundamental frequency voltage. As will be shown in some later lessons, the frequency spectrum of these unwanted harmonics can be shifted towards high frequency by adopting proper switching pattern. These high frequency voltage harmonics can easily be blocked using small size filter and the resulting quality of load voltage can be made acceptable.

3. RESULT

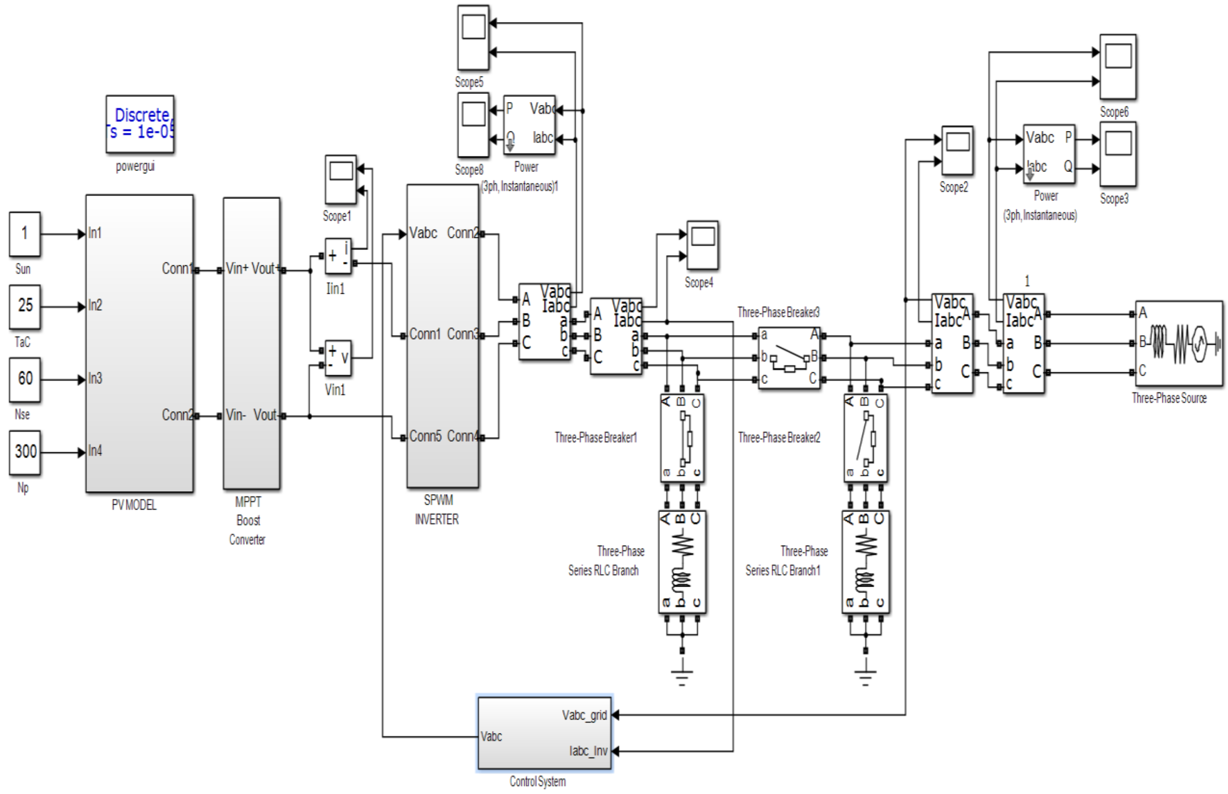

Figure 5: Inverter with MPPT & PV Model and Grid System

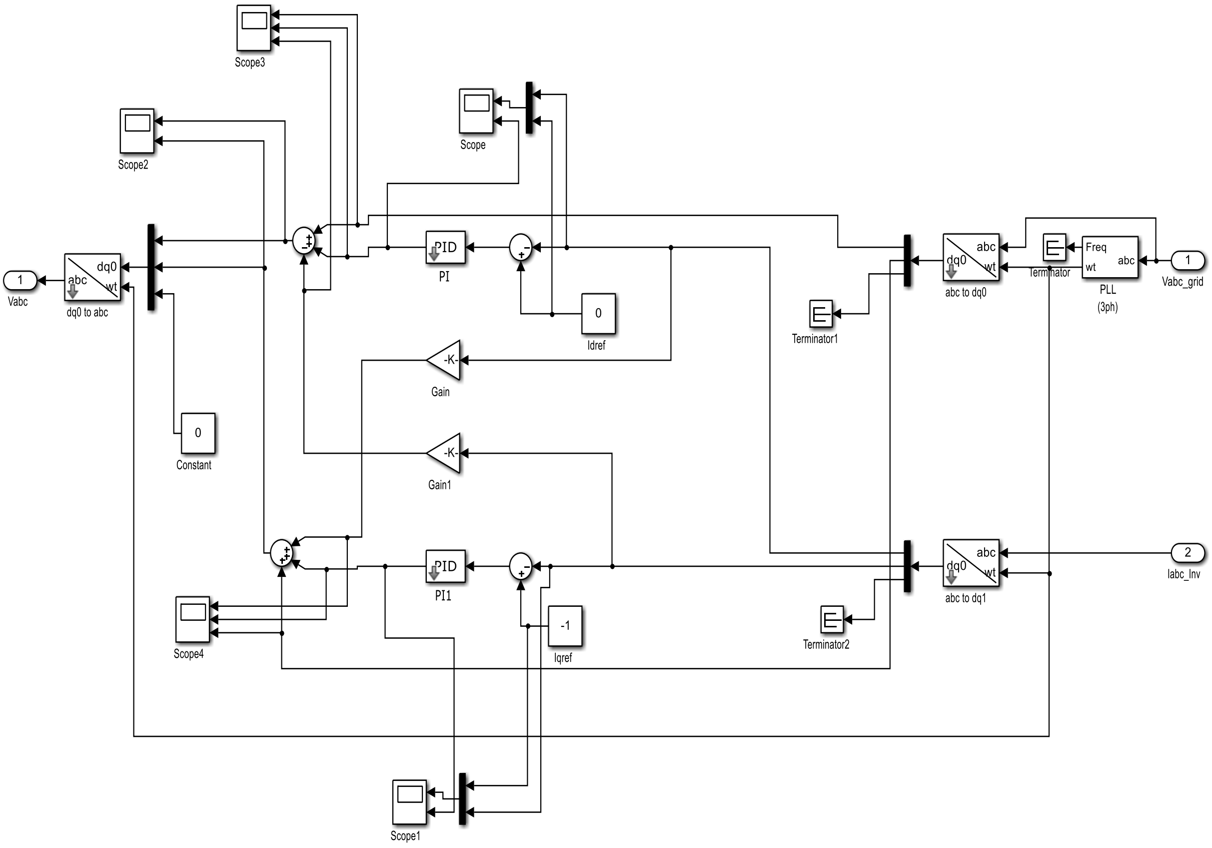

Figure 6: Control Circuit for Grid Operation

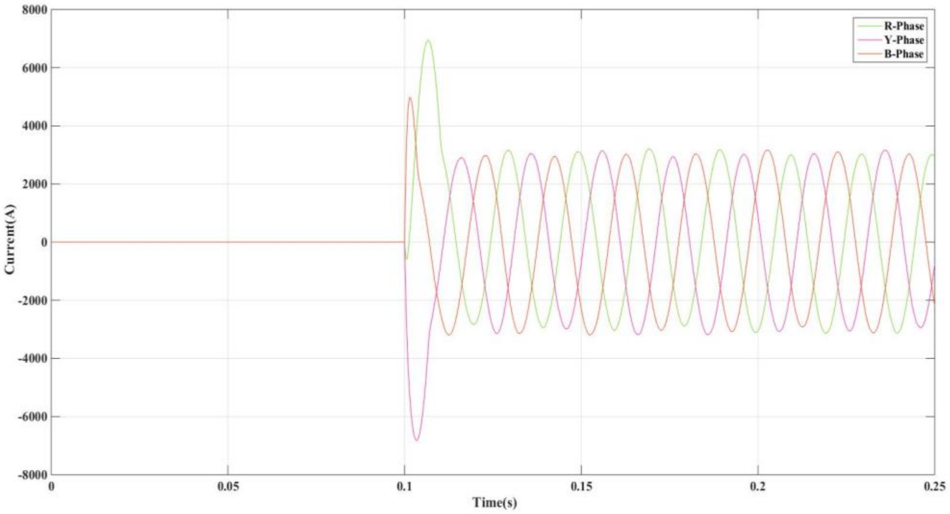

Figure 7: Result of current (Grid side)

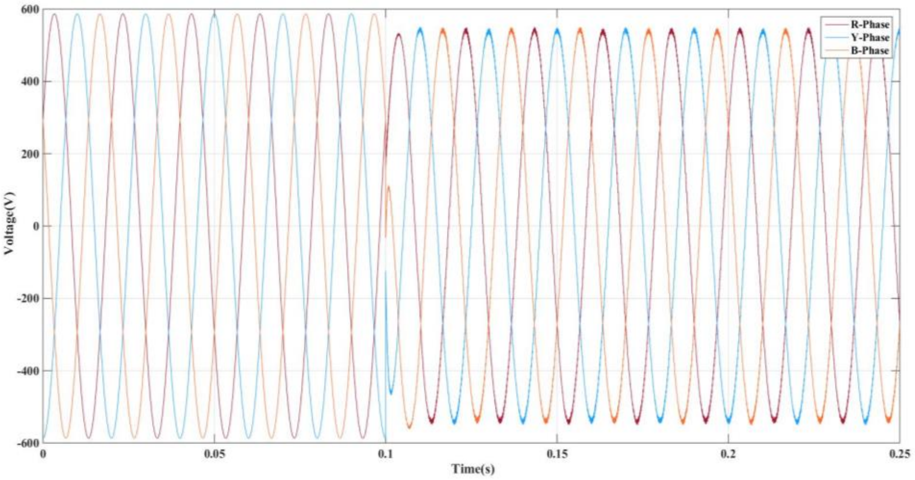

Figure 8: Result of voltage (Grid side)

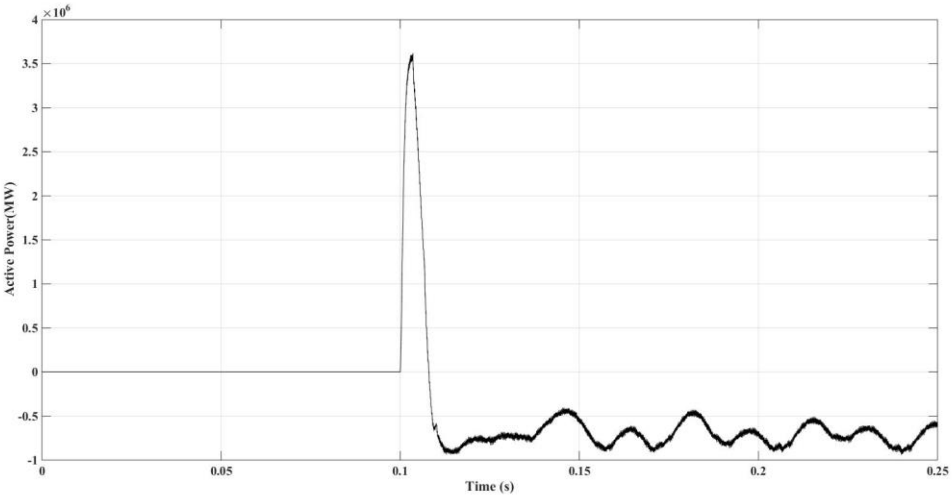

Figure 9: Result of Active power (Grid side)

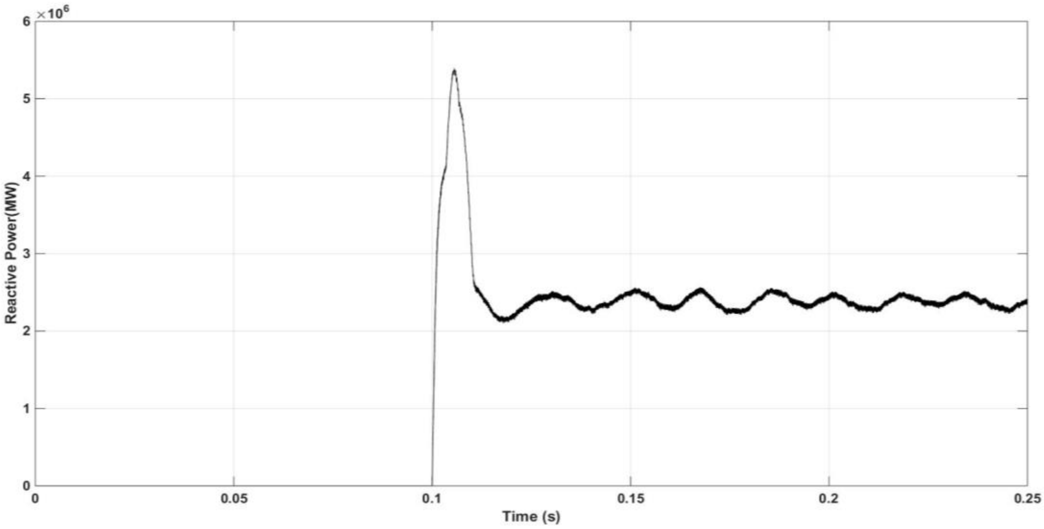

Figure 10: Result of Reactive power(Grid side)

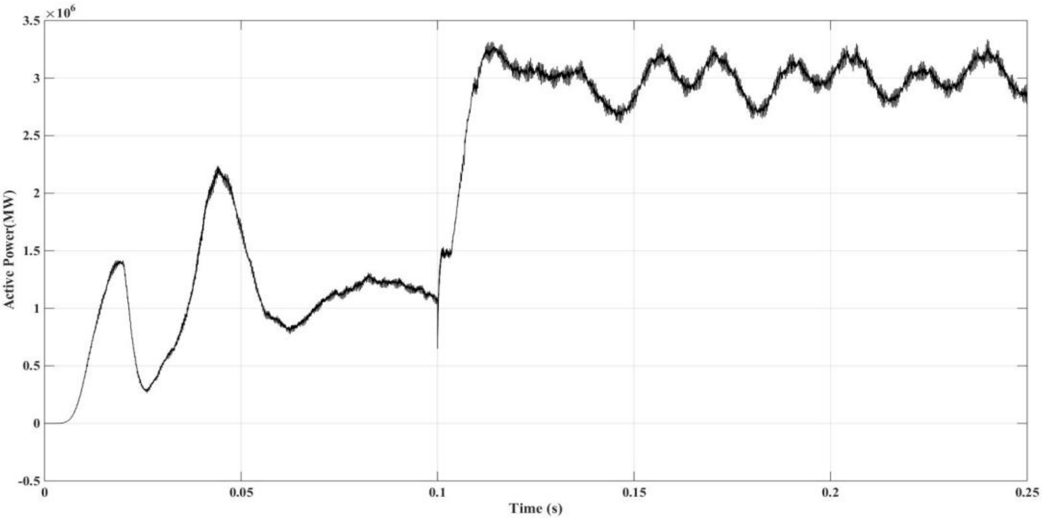

Figure 11: Result of Active power (inverter side)

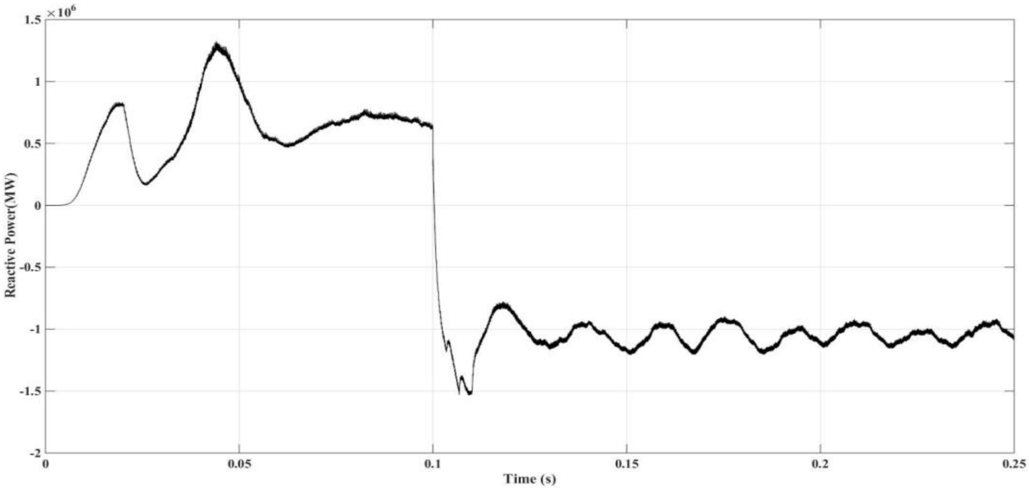

Figure 12: Result of Reactive power (inverter side)

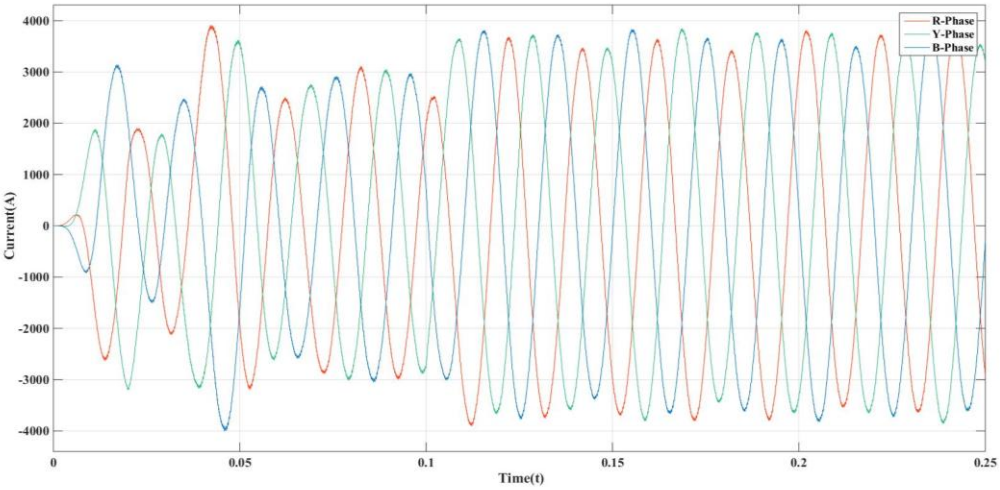

Figure 13: Result of current (inverter side)

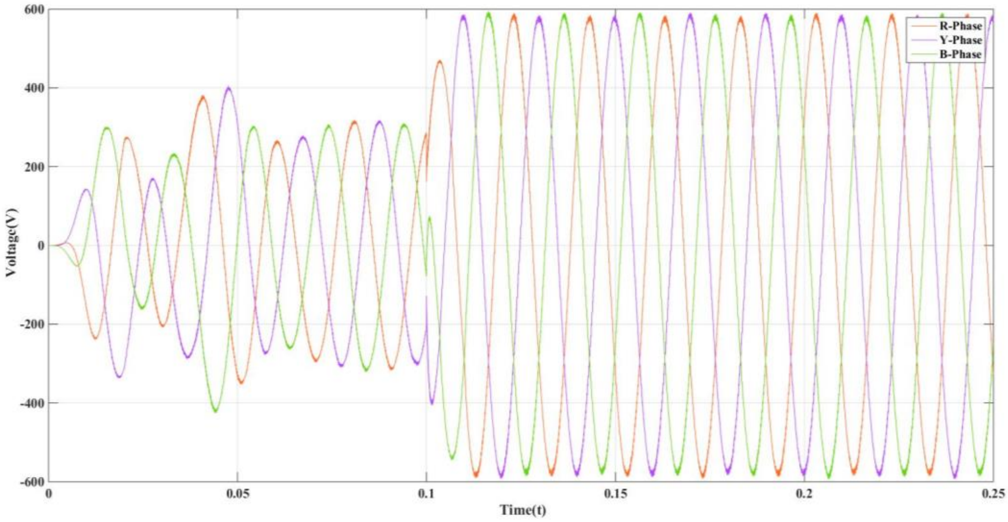

Figure 14: Result of voltage (inverter side)

4. CONCLUSION

This project has demonstrated a design procedure for a medium-voltage multi-MW inverter with MPPT boost converter. The procedure sought to ensure that the full specified output power and the limits for maximum injected harmonic currents and peak inverter ripple current could be met given the constraints on the inverter dc-link voltage and maximum switching frequency. The procedure centered on minimizing the most costly component, the inverter-side inductor, and attempted to achieve the smallest, lightest, and most efficient design by placing the resonant frequency as high as possible, minimizing the maximum store energy and maximum inverter current and this type of system can be easily interface out with Grid system. Dq transformation is used for controlling purpose in this topic.

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