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Comparison of Design and Simulation of Step up Converters with Inverters for Solar Application

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Abstract: ***Now a days as per the present scenario lot of power shortages are there in all over the world especially country like India. Almost the electrical power from the fossil fuels is becoming so less some of the examples of the fossil fuels which are coal, oil and gases. So most of them looking in forward for the electrical power from green or renewable based energies like solar, biomass, wind, tidal which does not cause any pollution to the environment. This paper proposes a step up converter which is interleaved with voltage multiplier module with two types of inverter for photovoltaic power system. The main attribute of the step up converter with inverter topology is the fact which generates an AC output voltage which is larger than the DC input voltage. Operations, control strategy, modulation and experimental results are included in this paper. Firstly, step up converter interleaved with voltage multiplier module with full bridge inverter is compared with step up converter with voltage multiplier module with half bridge inverter is done in Matlab/ Simulink. The FFT spectrums for the outputs of the system are compared and presented to validate the proposed control strategy. Then step up converter interleaved with voltage multiplier module with inverter is compared with conventional step up converter with inverter for solar application.***

Keywords: Step up converter, Voltage multiplier module, PV system, MPPT model, Single phase full bridge inverter, Single phase half bridge inverter, Conventional step up converter

1. Introduction

Electricity which is the most essential part required for human survivor and for the growth of any nation. But the main fact is that, electricity is not available naturally and it has to be converted from other sources of energy. Also due to the rising costs and limited amount of nonrenewable energy sources, there is an increasing demand for the utilization of renewable energy sources such as photovoltaic system [1]. So the main focus of the engineers is to make use of the available PV energy and so to design and control of step up converter to step up output voltage of the PV system and an inverter which is suitable for such PV applications. The power electronics circuits with pulse width modulation (PWM) are mostly used in energy conservation system to achieve closed loop control [2][3].

Photovoltaic (PV) power generation is one of the main way to utilize the solar energy. The renewable energy source based distributed generation system which is normally interfaced to the grid through power electronic converters and inverters.

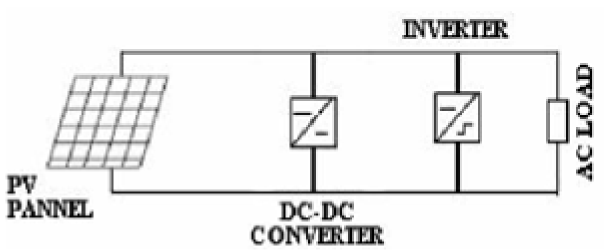

Figure 1: Typical Photovoltaic system

We know that renewable energy systems which generate low voltage output. Converters which may be designed to operate at a continuous current conduction mode for high power application and also at discontinuous current conduction mode for low power application. It is classified in to two categories, if the output voltage of the converter which is less than the input voltage then it is called as step down converter otherwise it is called as a step up converter [5].

2. Step up converter with voltage multiplier module

The proposed step up converter interleaved with voltage multiplier module which is shown in Figure 2. A conventional boost converter and also two coupled inductors are located in the voltage multiplier module, which is stacked on to the boost converter which forms an asymmetrical interleaved structure. The primary winding of the coupled inductors with Np turns are employed to decrease input current ripple, and also the same secondary winding of the coupled inductors with Ns turns are connected in series to extend voltage gain. Now the switching period can be subdivided in to six modes of operation. The modes 1-3 are same as the modes 4-6. Figure 2 shows the matlab simulation model for proposed step up converter which is interleaved with voltage multiplier module for photovoltaic system [1].

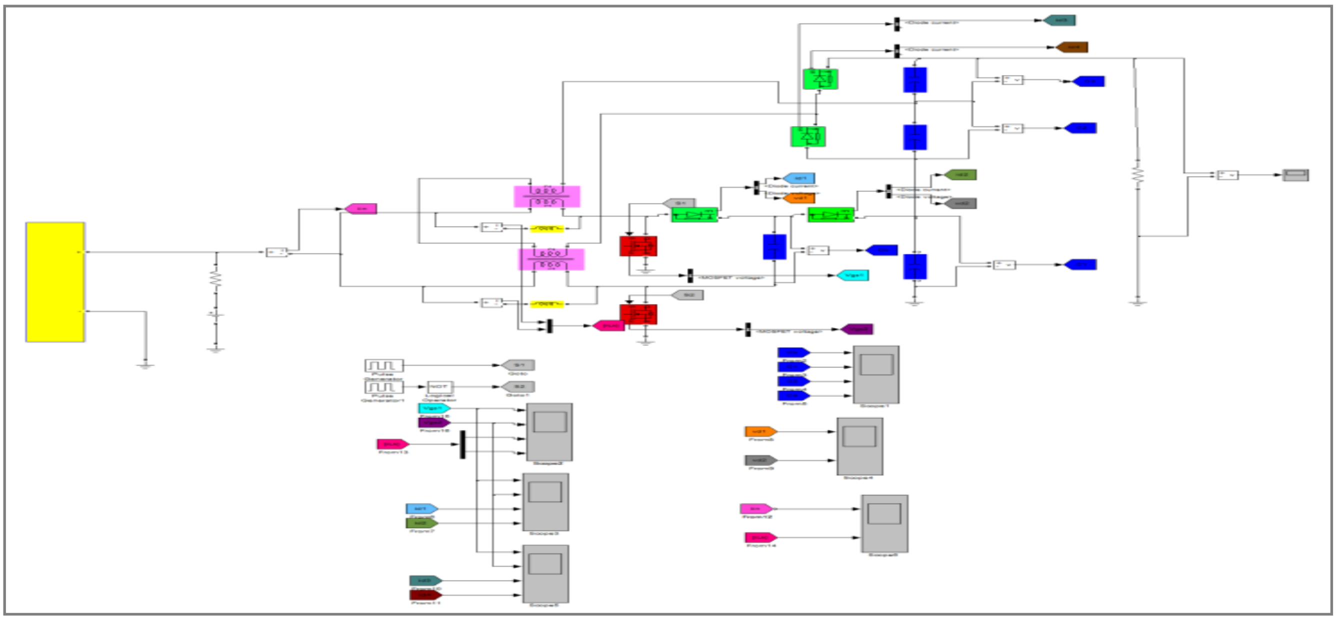

Figure 2. Matlab simulation model for step up converter

The MATLAB/ Simulink model for step up converter is shown in above figure in which the PV panel including MPPT is the input source which is 40V. The simulation is carried out by different six operating modes. According to this the simulink model works and gets output current and voltage waveforms. Then the system undergoes run command & after completion of the system run, the system behaviour is analyzed from the waveforms. The output of the system can be calculated as the sum of the voltages at the four capacitors and which is 380V. The output waveforms for the current & voltages at different stages are shown in following figures.

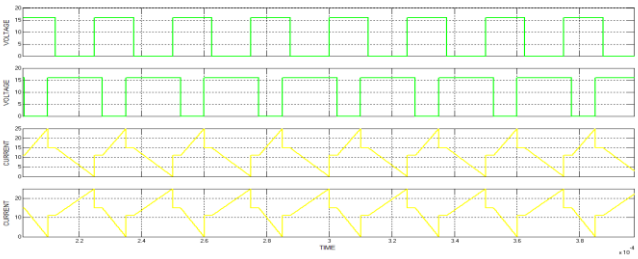

Figure 3: Voltage and current waveforms for Vgs1, Vgs2, Ilk1, Ilk2

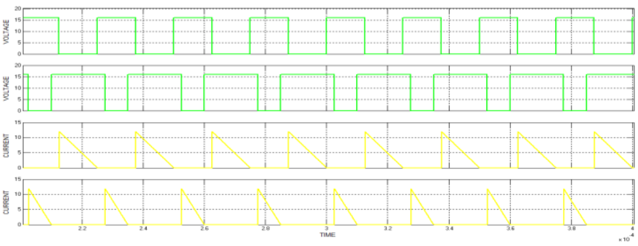

Figure 4: Voltage and current waveforms for Vgs1, Vgs2, Id1, Id2

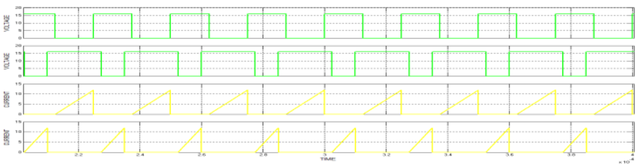

Figure 5: Voltage and current waveforms for Vgs1, Vgs2, Id3, Id4

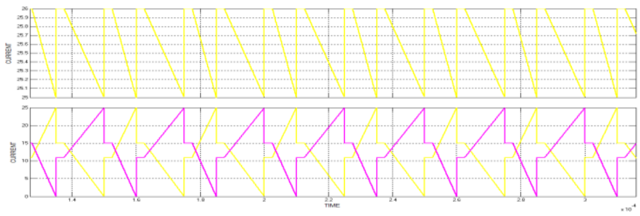

Figure 6: Results for current waveforms for Iin, Ilk

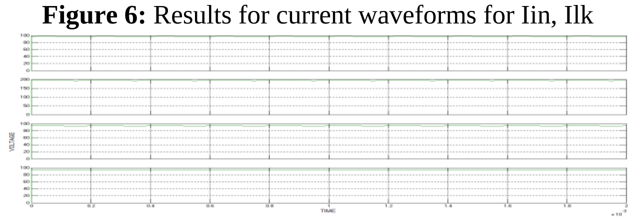

Figure 7: Results for output voltages Vcb, Vc1, Vc2, Vc3

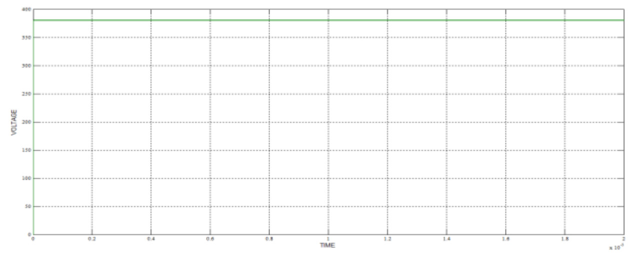

Figure 8: Output voltage for proposed step up converter

3. Proposed step up converter with 100W to 500W load variation

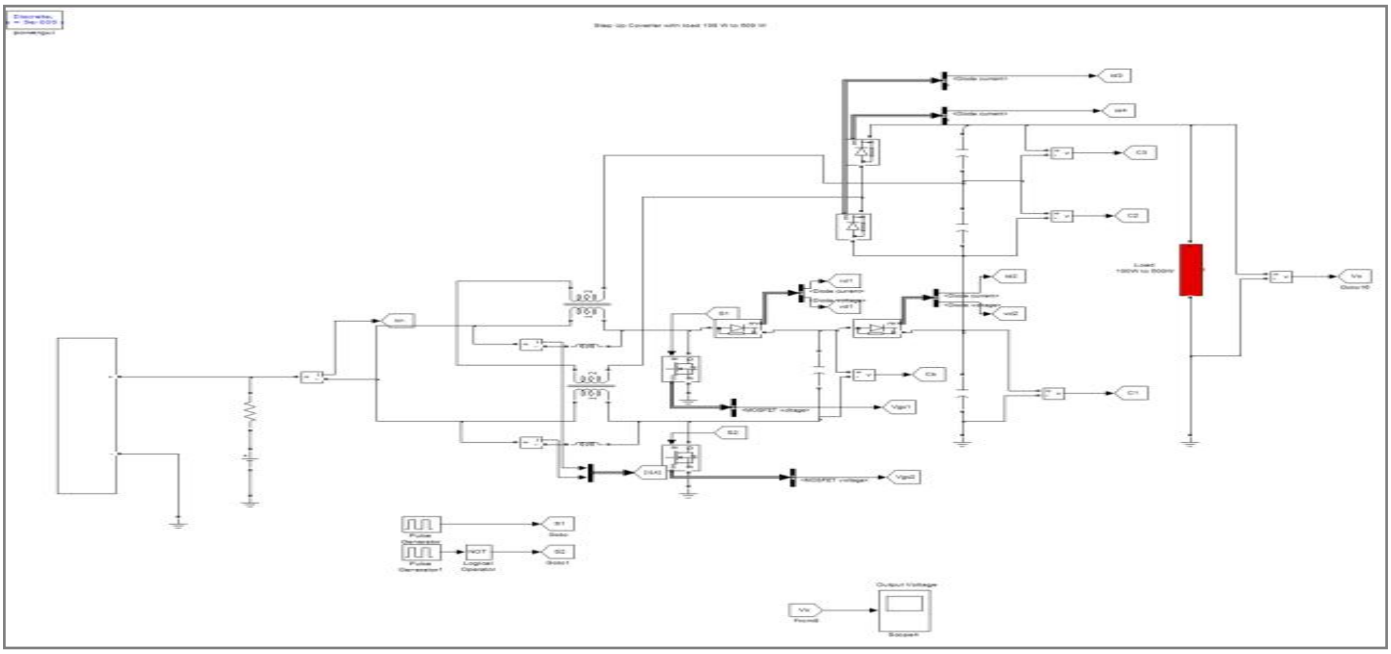

Figure 9: Matlab simulation model for step up converter with load variation between 100W and 500W

Above figure 9 shows the load variation between 100W and 500W for the proposed step up converter and the output waveform is shown in the following figure 10 which is 380V DC supply.

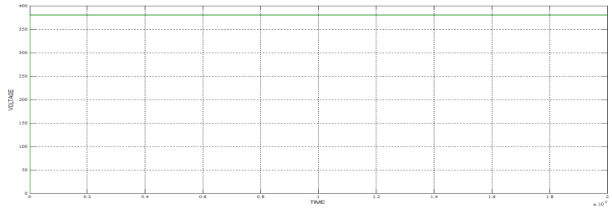

Figure 10: Output voltage for step up converter with 100W and 500W load variation

4. Step up converter with full bridge inverter

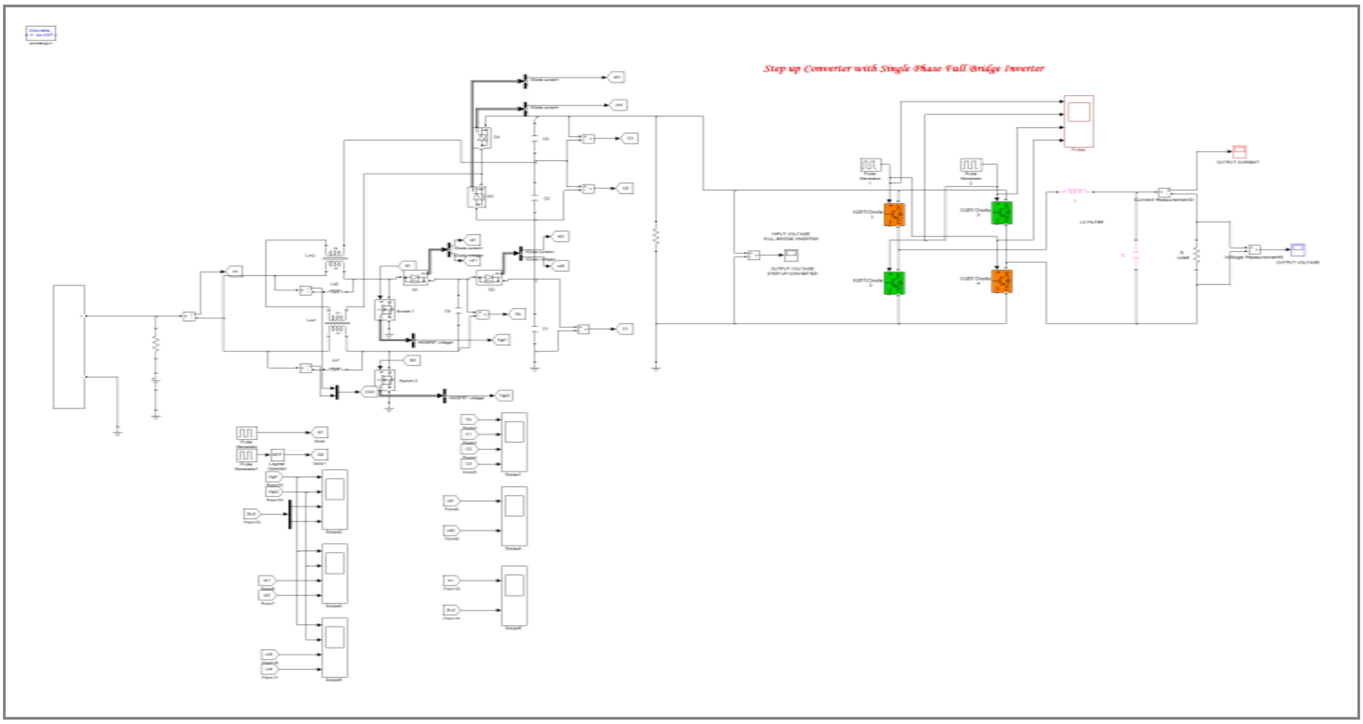

Figure 11: Proposed step up converter with single phase full bridge inverter

The above figure 11 shows the single phase full bridge inverter with input source as proposed step converter with photovoltaic system which converts the input 380V DC supply to the 380V AC supply as output. The LC filter is used in the system. Figure 14 which shows the output voltage of the full bridge inverter. The THD of the output voltage of the inverter is found to be 1.48%. The frequency spectrum is shown in the figure 16.

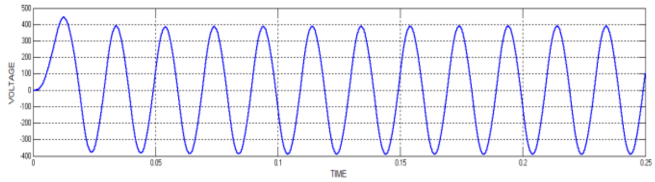

Figure 14: Waveform for output voltage of full bridge inverter

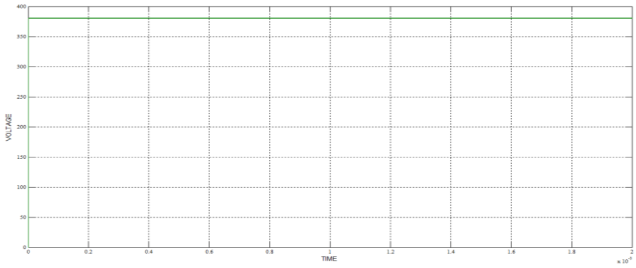

Figure 12: Input voltage of full bridge inverter

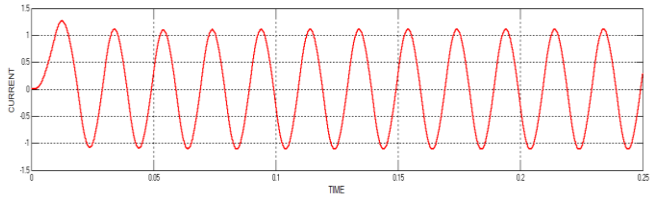

Figure 15: Waveform for output current of full bridge inverter

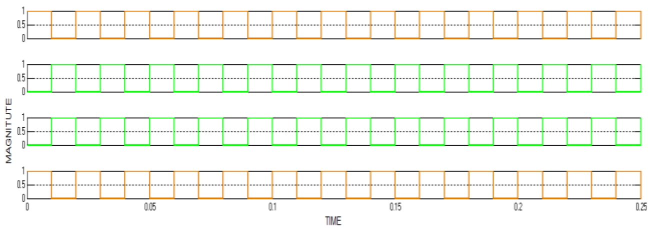

Figure 13: Pulses given to IGBT/Diode 1 to 4

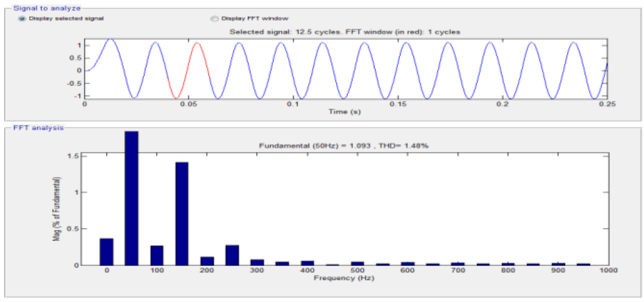

Figure 16: FFT and THD analysis for full bridge inverter

5. Efficiency calculation for step up converter with full bridge inverter

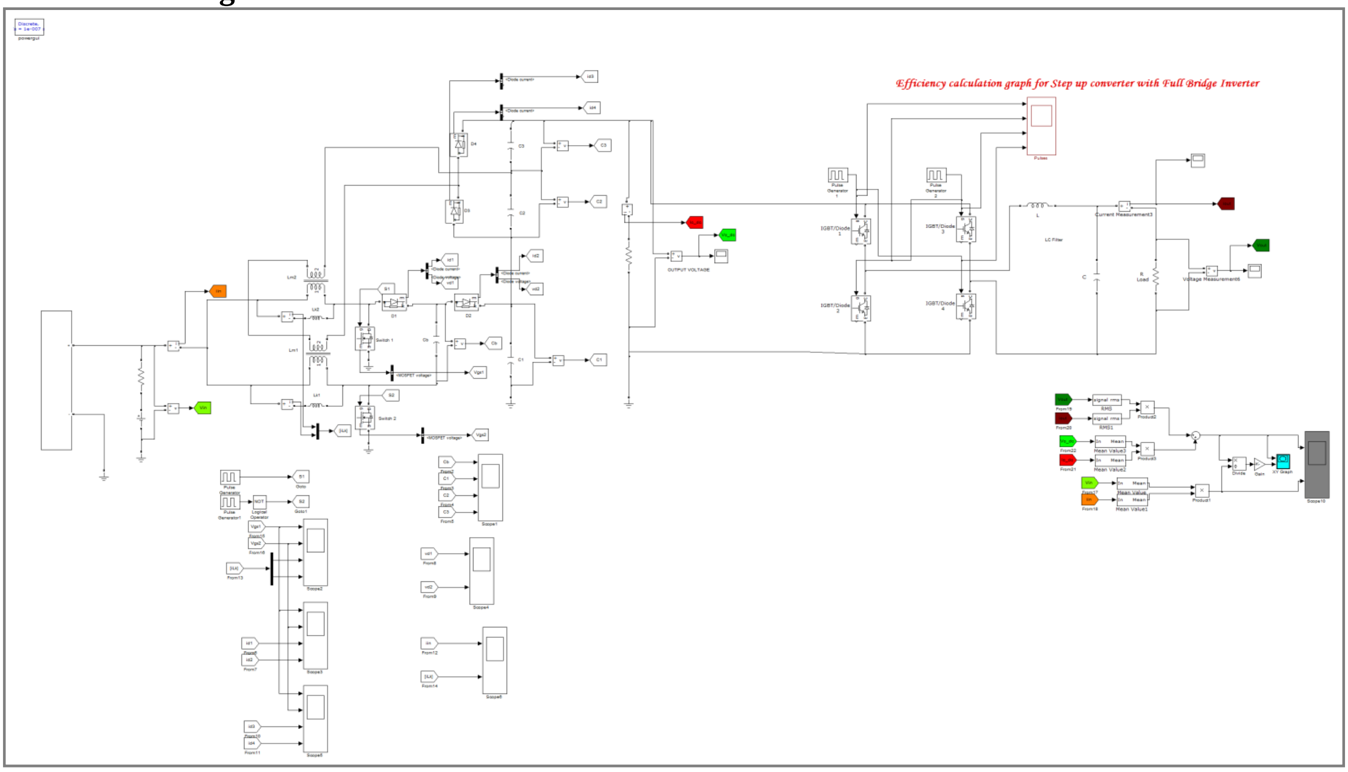

Figure 17: Matlab simulation model for efficiency calculation for step up converter with full bridge inverter

Above figure 17 shows for efficiency calculation for step up converter with full bridge inverter and the efficiency versus power graph is shown in the following figure 18.

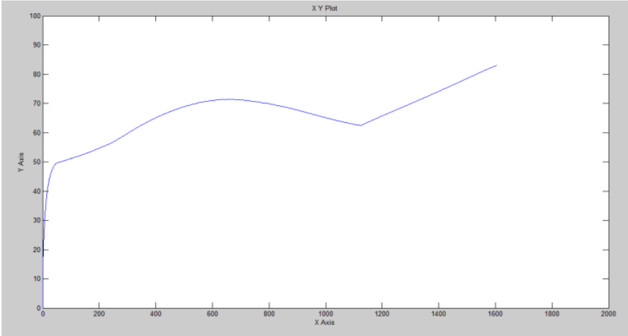

Figure 18: Efficiency calculation graph for full bridge inverter

6. Step up converter with half bridge inverter

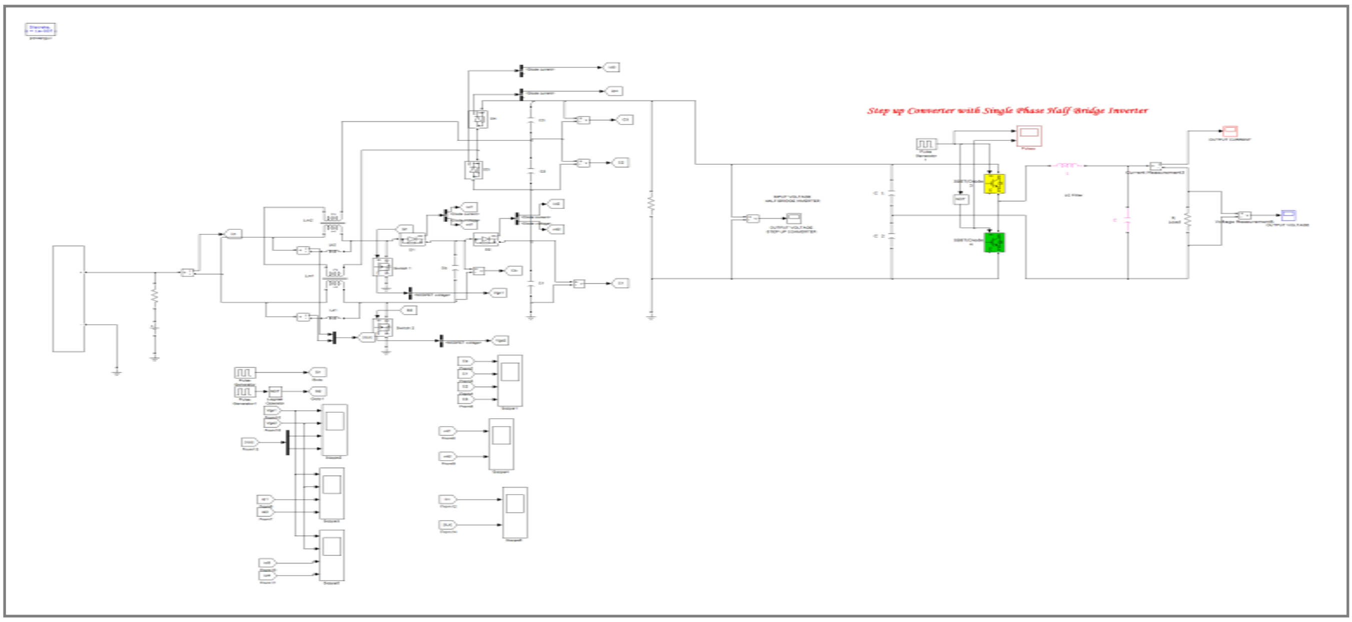

Figure 19: Matlab simulation model for proposed step up converter with single phase half bridge inverter

The above figure 19 shows the single phase half bridge inverter with input source as proposed step converter with photovoltaic system which converts the input 380V DC supply to the 190V AC supply as output. The LC filter is used in the system. Figure 22 which shows the output voltage of the full bridge inverter. The THD of the output voltage of the inverter is found to be 3.76%. The frequency spectrum is shown in the figure 24.

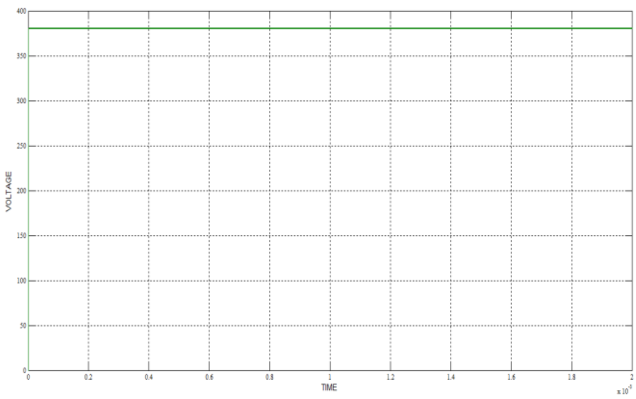

Figure 20: Input voltage of half bridge inverter

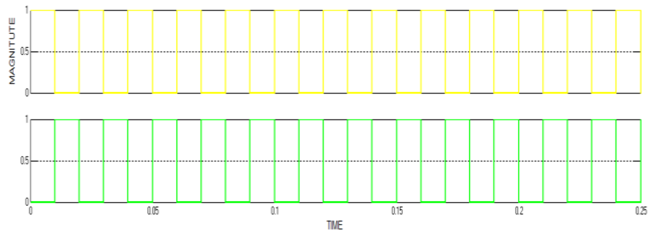

Figure 21: Pulses given to IGBT/ Diode switch 1 and 2

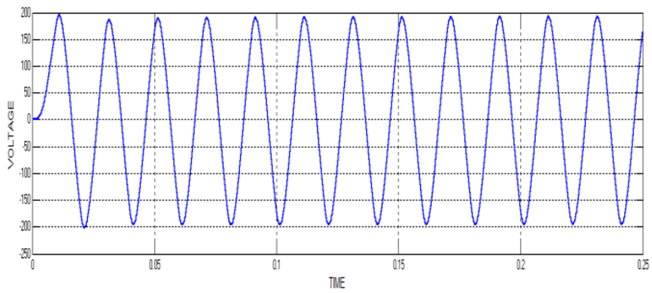

Figure 22: Waveform for output voltage of half bridge inverter

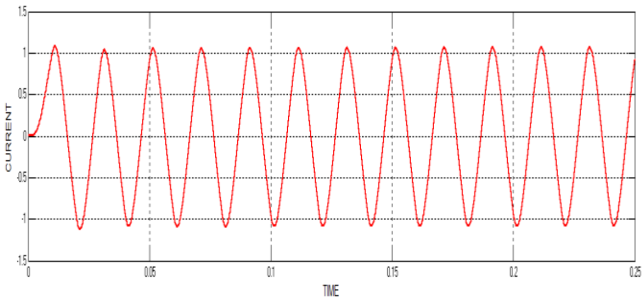

Figure 23: Waveform for output current for half bridge inverter

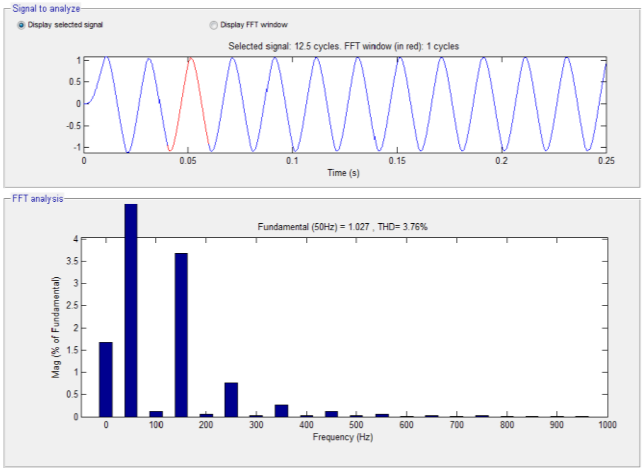

Figure 24: FFT and THD analysis for half bridge inverter

7. Efficiency calculation for step up converter with half bridge inverter

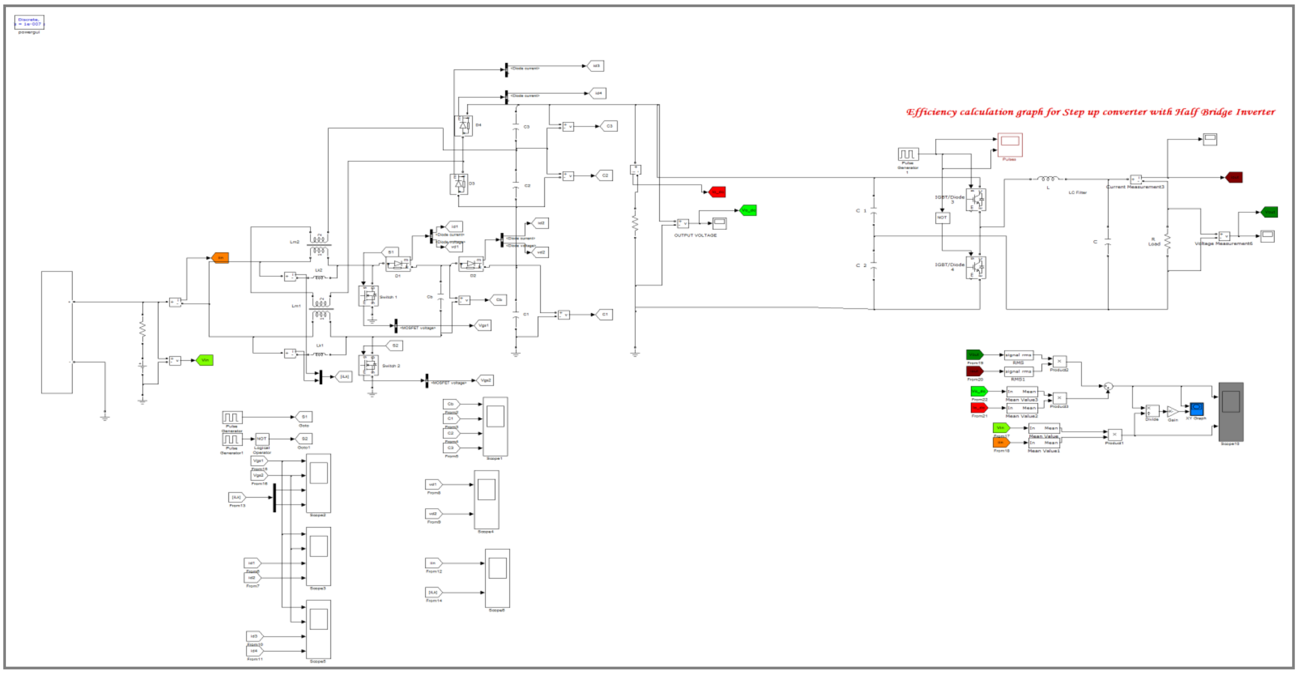

Figure 25: Matlab simulation model for efficiency calculation for step up converter with half bridge inverter

Above figure 25 shows for efficiency calculation for step up converter with full bridge inverter and the efficiency versus power graph is shown in the following figure 26.

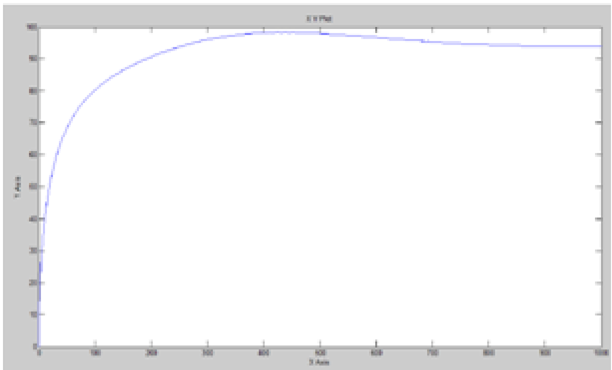

Figure 26: Efficiency calculation graph for half bridge inverter

8. Conventional step up converter with full bridge inverter with efficiency calculation

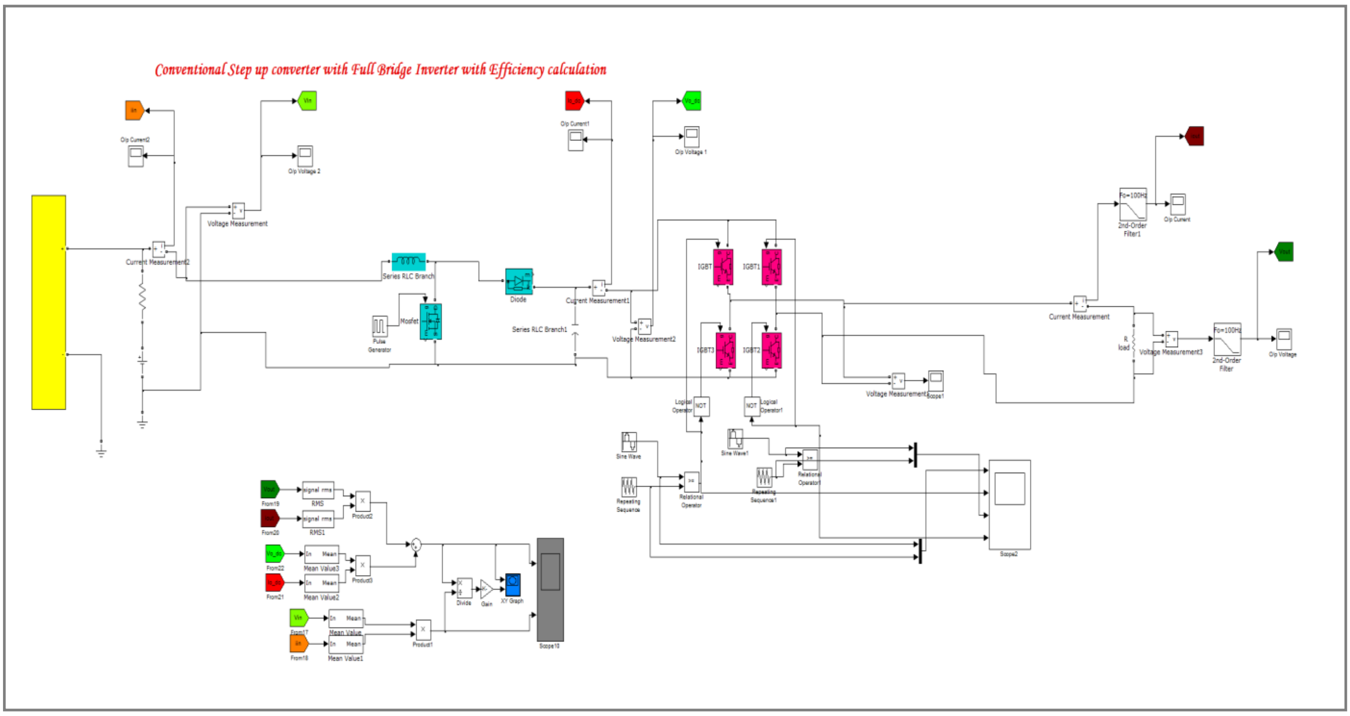

Figure 27: Matlab simulation model for conventional step up converter with inverter

The above figure 27 shows the conventional step up converter with full bridge inverter with photovoltaic system. The step up converter converts the input 40V DC supply to the 140V DC output supply and then the inverter converts this DC 140V to the AC 140V output supply which are shown in the following figures. Figure 24 which shows the output voltage of the conventional PV system. Figure 30 shows the efficiency versus power graph for conventional step up converter with full bridge inverter.

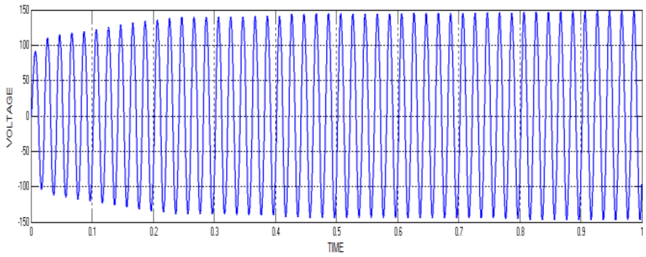

Figure 28: Waveform for output voltage of inverter

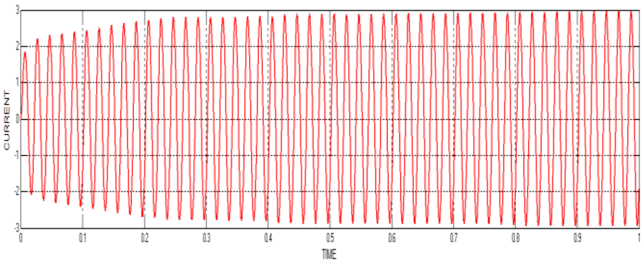

Figure 29: Waveform for output current of inverter

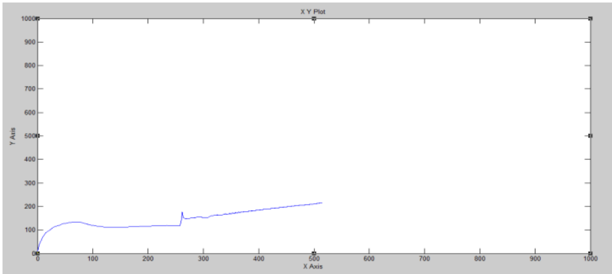

Figure 30: Efficiency calculation graph for conventional step up converter with inverter

9. Conclusion

The control system of a power converters is one of the most important part of the photovoltaic power generation system. In the paper, proposed step up converter interleaved with voltage multiplier module with single phase full bridge inverter and single phase half bridge inverter using solar power source is simulated using Matlab/Simulink and compared with conventional step up converter with inverter for solar system. The proposed step up converter interleaved with voltage multiplier module which converts the DC 40V input supply to 380V DC output. The output voltage of proposed converter with full bridge inverter is obtained as 380V AC supply with a THD of 1.48%. The output voltage of proposed converter with half bridge inverter is obtained as 190V AC supply with a THD of 3.76%. The conventional step up converter which converts the 40V DC input supply to the 140V DC supply and then inverter converts 140V AC output supply. Thus the proposed step up converter is more suitable than the conventional step up converter for the photovoltaic power generation system.

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