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Simulation of Closed Loop Single Switch Quadratic Boost Converter and Cascaded H-Bridge Multilevel Inverter for PV Micro Grids using MATLAB/SIMULINK

Vishnu. S
Electrical and Electronics Engineering Department, BNM Institute of Technology, Bangalore, Karnataka, India.

Abstract: The major consideration in dc-dc conversion is usually related to low cost, high efficiency, reduced stresses involving semiconductors, high efficiency, simplicity and robustness of the involved topologies. The boost converter is one of the basic power electronics circuits used to set up the DC voltage.

A photo-voltaic micro grid is a standalone system wherein there is a need for efficient power conversion. The DC voltage obtained from the photovoltaic system is measured to be between 12.1V-18.9V DC for an irradiation variation 600-1500 W/m^2. The input voltage to the inverter must be maintained constant irrespective of load demand.

The main objective of this paper is to simulate a closed-loop single switch quadratic boost converter to maintain a constant input voltage for the inverter and also to simulate the five-level cascaded H-bridge multi-level inverter for small scale photovoltaic grid system. The quadratic boost converter and multilevel inverter are simulated using MATLAB/SIMULINK software package.

Keywords: Quadratic boost converter, multilevel inverter, PV micro grids, Cascaded H-bridge, closed-loop control.

I. INTRODUCTION

The utilization of the Maximum Power Point Tracking (MPPT) calculations has prompted to improve the capacity of the PV modules, and in this manner, it is important in the field of non-conventional vitality. Because of the variation in barometrical temperature and illumination, the voltage obtained from the module isn't steady. The test is to build up a proficient and modest system that would fill the need.

In the course of the most recent decades, Distributed network assets are centred incredibly around the photovoltaic framework as it holds huge potential in vitality extraction. The variables which lead to such an adjustment in government motivating force plan are because of the decrease of cost, rising power request, and upgrades in the PV system industry. The PV cell yield voltage and current are subject to ecological conditions, i.e., irradiation and temperature.

One of the issues in the age of power, from a sustainable power source is, for example, sun-powered cells is fluctuating yield voltage because of the impacts of illumination and temperature from daylight. So to have the option to gracefully the steady loads, it despite everything requires reconciliation with other electronic hardware, for example, DC-DC converter keeping this as a top priority. For high effective voltage change, the switch-mode power supply (SMPS) must have high on and off-speed. The switching losses should be minimum with this approach.

Loss of productivity is one of the limitations in high-voltage gain applications. Further, decreased efficiency is serious at overwhelming burdens. Many converter topologies, for example, the coupled inductor based circuits, quadratic boost converter (QBC), and other higher-request converters have been proposed as of late to beat a portion of the confinements forced by conventional boost converters.

In these topologies, the gadget stress, top voltage/current pressure, is the primary restriction as mentioned in [1]. As of late, a few higher-order improved execution dc-dc converters together with higher voltage-gains were accounted for. Exchanged inductor or capacitor arrangement is the prime part in these developments wherein other boosting circuits are fell (or) converged to shape a basic high-gain converter topology.

The dynamic and consistent state execution has equivalent significance to the new topological advancements. Taking into account, there is a need for an advanced single switch quadratic booster, which helps topologies with the more consistent state voltage increase and better productivity.

II. LITERATURE SURVEY

As mentioned in [2], the static gain increase of the traditional boost converter is constrained practically speaking in light of the fact that the high-yield voltage requests high duty cycle esteem, in this manner driving the change to stay on for long time interims. In the event that the current through the diode is high, genuine downsides with respect to the reverse-recovery will generally exist. Along these lines, it is significant that the static gain doesn't depend just on the duty cycle in high-voltage step-up requirements. The conventional boost converter appears in Fig. 1, where the characteristic arrangement opposition of the inductor is spoken to by RL. By utilizing the volt-second equalization guideline and considering the activity in CCM, it is effective to show that the static gain.

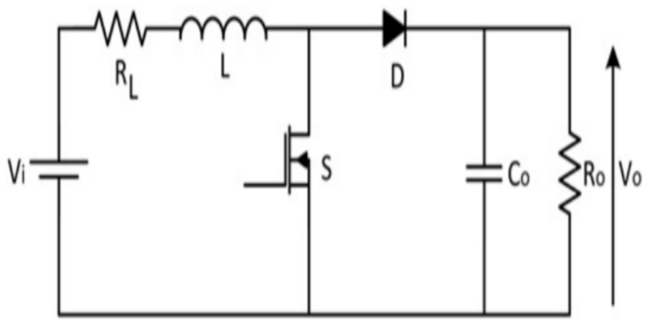

Figure 1. Conventional boost converter circuit

Where, V_o is the output voltage; V_i is the input voltage; R_o is the load resistance; D is the duty cycle.

According to [3], to acquire a consistent voltage reading, the DC-DC converter utilizes a controlling stage which comprises of two sorts: utilizing a linear regulatory framework and switching controllers. The linear regulatory framework utilizes a progression of transistors mounted in arrangement to change power from the input voltage to the output voltage ceaselessly. In this activity, the linear controller foresees the power was the more noteworthy the input and output voltage the more prominent the power dispersed with the goal that it will diminish the proficiency of the force flexibly itself. In switching guideline strategy, the power transistor is controlled with a switching signal obtained from the controller. This power transistor is utilized as a change to manage power and sent to the inductor and capacitor which is then provided to the load. The utilization of switching techniques working at a high recurrence frequency is more effective than a linear regulatory framework.

As mentioned in [4], The PV system is coupled to the boost converter so as to create the maximum peak power by tuning the electrical working point of the PV system.

The MPPT charge controller is, for the most part, a dc-dc boost converter. The converter modifies the working voltage of the PV board to allow and it is worked at a peak voltage to deliver maximum power. The yield voltage is controlled by differing the duty cycle of the boost converter. The PWM signal is given to the gate pin of the MOSFET in the boost converter and the control parameters are monitored continuously.

In India [5], individuals in remote zones don't have predictable access to power. The legislature had begun the procedure of electric establishment in rustic regions sometime before by advancing sustainable power sources and locally accessible assets. On one hand, individuals in semi-urban and country territories experience the ill effects of the absence of power. Then again, for individuals in urban zones, the issue is reliability, quality of the power. Because of the immense geological decent variety and differed client needs and prerequisites, the idea of miniaturized scale frameworks in India has a more extensive and more profound task to carry out to overcome any barrier and accomplish the various focuses of accomplishing fair, feasible, and fast financial development. A significant point with regards to India and the developing countries is that of financial aspects. The expense of power from a smaller scale framework must get equivalent if not less expensive than the expense of power from the grid. Evacuating motivating forces, for example, the endowments offered to the agribusiness divisions and lamp fuel for lighting, relocating to the utilization of intelligent meters that reduce power theft, and extending the size of microgrids may help make the smaller-scale network business increasingly maintainable. A firm promise to appropriate execution at the grassroots level is an absolute necessity for smaller-scale frameworks to get fruitful.

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III.SIMULATION

A. Single Switch Quadratic Boost Converter

DC-DC converter goes about as an intersection point between the load and PV system. By changing the duty ratio of the converter, the load resistance is balanced and coordinated to the pinnacle capacity to move the peak power. The traditional three-level boost converter isn't satisfactory for applications that request high-voltage gain. Wide change ratio and diminished current ripple can be accomplished if at least two-stage boost converters are connected in series. The input voltage is low and can be ventured up by the principal stage by utilizing high duty ratio signals. Then again, the subsequent stage can work with a decreased duty cycle, in this manner permitting the minimization of switching loss. Nonetheless, toughness is undermined as a result of the need for numerous dynamic switches, diodes, inductors and capacitors to accomplish extremely high-yield voltages, while the control circuit must be deliberately planned for this situation. With the use of a single switch, a quadratic boost converter with closed-loop control for low voltage boosting with limited source current is more efficient than the traditional boost converter.

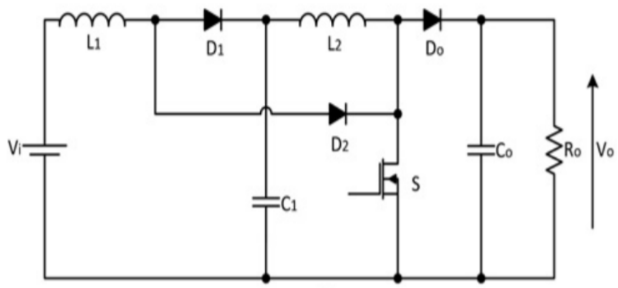

Figure 2. Single switch quadratic boost converter

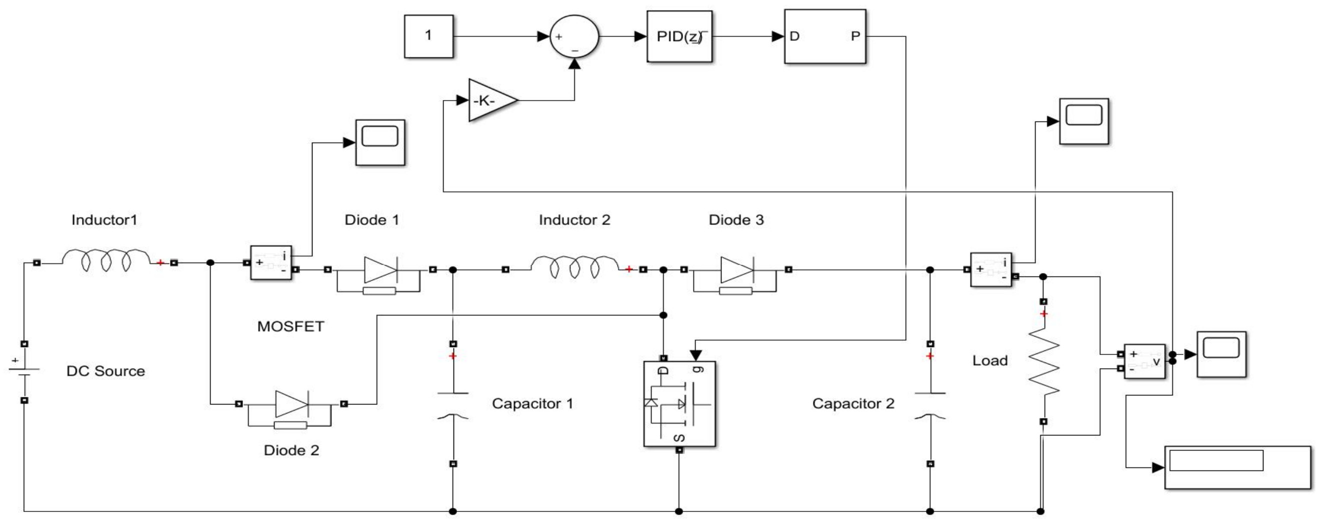

Figure 3. SIMULINK model of closed loop single switch quadratic boost converter

With the use of diode D2 in Fig.2 as this procedure can be applied to any number of stages to get a single-switch converter. Despite the fact that the ratio between the yield voltage and the input voltage in Fig.2 is equivalent to the product between the static gain of different traditional boost converters, some noteworthy drawbacks despite everything exist. Taking into account that numerous converters can be utilized, the worldwide proficiency of the subsequent topologies is essentially diminished, which doesn't make the previously mentioned topologies sufficient for high-power applications. In situations where the yield voltage is high, the voltage stresses over the power electronic switch and the boost diode in the last stage are apparent, that is, equivalent to the yield voltage, along these lines prompting the utilization of expensive parts and poor effectiveness. The reverse recovery issue in such diode and furthermore solidness are additionally of significant concern. But for the use of low voltage boosting to a medium voltage doesn't cause notable poor performance of the converter and efficiency. Thus, a single switched quadratic boost converter is simulated, refer Fig. 3 with input voltage ranging from 12.1V to 18.9V as per the PV module output over the irradiation it receives.

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B. Cascaded H-Bridge Multilevel Inverter

The three basic topologies for multi-level inverters are as per the following: 1) diode clamped (neutral clamped) 2) capacitor clamped (flying capacitors) and 3) cascaded H-bridge inverter [6]. What's more, a few adjustments and control procedures have been created or developed for multilevel inverters, including the accompanying: multilevel sinusoidal modulation signal (PWM), multilevel specific harmonic elimination, and space vector technique. A single-stage three-level inverter embraces full-bridge arrangement by utilizing an approximate sinusoidal modulation method as the power circuits. The yield voltage at that point has the accompanying three qualities: zero, positive (+Vdc), and negative (−Vdc) flexibly dc voltage (expecting that Vdc is the graceful voltage). The harmonic segments of the yield voltage (output voltage) are dictated by the carrier recurrence frequency and switching variables. Along these lines, the harmonic content decrease is restricted in a specific way to conquer this confinement, hence a five-level PWM inverter whose yield voltage can be spoken to in the accompanying five levels: zero, +1/2Vdc, Vdc, −1/2Vdc, and −Vdc. As the quantity of yield levels expands, the total harmonic distortion can be decreased.

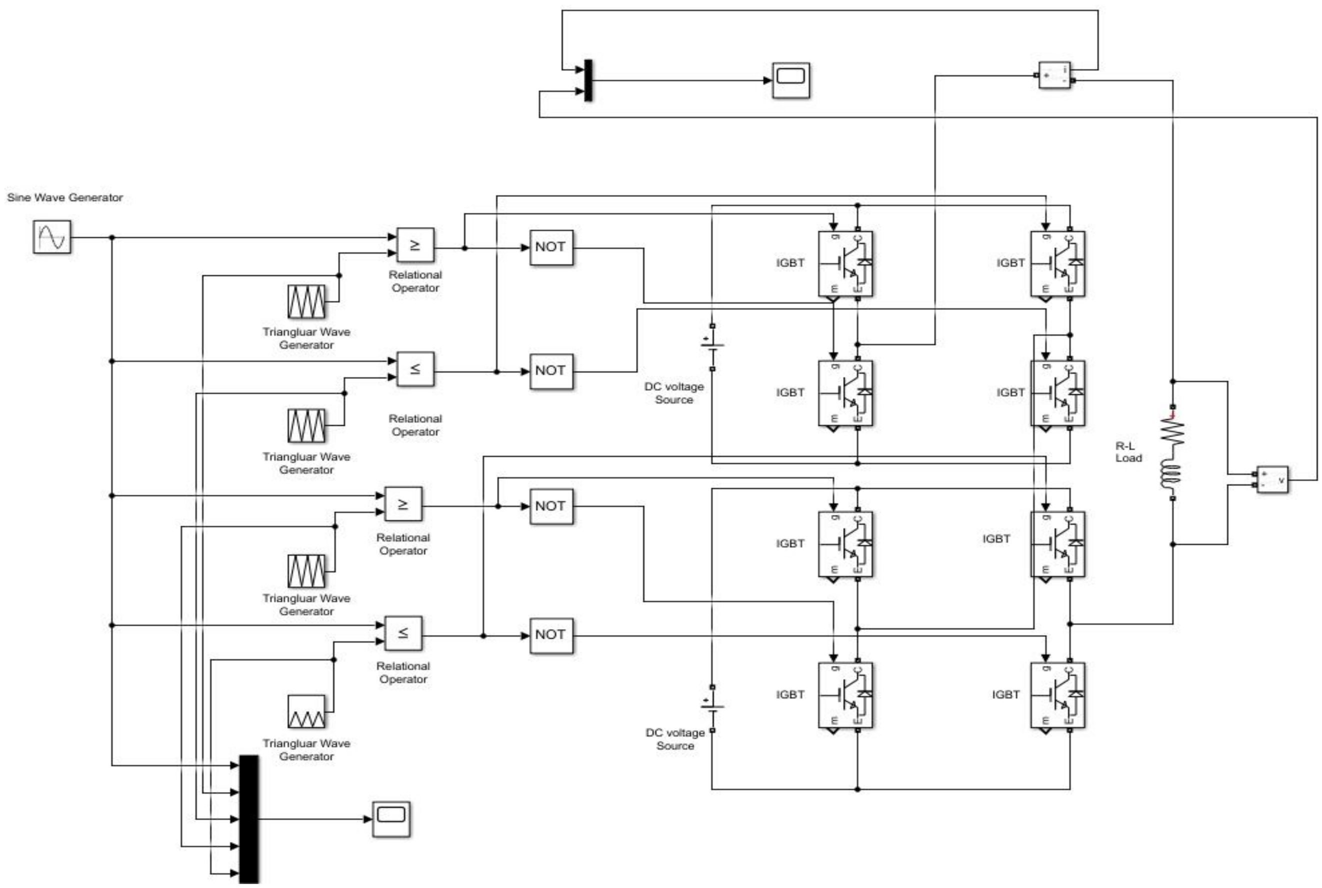

Figure 4. SIMULINK model of cascaded H-bridge multilevel inverter

A crucial period in Fig. 7 comprises of p beats whose widths fluctuate sinusoidally all through the cycle to give the basic part of the fundamental frequency. The premise of comparability between the ideal sinusoid and the real beat waveform is taken to be volt–seconds. The single-stage five-level inverter topology appears in Fig. 4. The inverter receives a full-bridge design with an assistant circuit. PV systems are associated with the inverter by means of a dc-dc boost converter. Since the proposed inverter is utilized in a framework associated PV framework, the domestic load is represented using R and L values rather than the grid system. The infused current must be sinusoidal with low harmonic content. So as to produce sinusoidal current, sinusoidal PWM is utilized in light of the fact that it is one of the best techniques. Sinusoidal PWM is acquired by contrasting a high-frequency recurrence carrier and a low-frequency sinusoidal signal, which is the regulating or reference signal. The carrier has a steady period; accordingly, the switches have a consistent switching frequency. The switching moment is resolved from the intersection of the carrier and the regulating signal.

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IV. SIMULATION RESULTS

The simulation is carried out by modelling the circuit in Simulink. The close loop control is achieved with the help of the PI controller. The following are the parameters of the proportional integer controller.

k_p =0.7 and k_i=100

Output upper limit=1 and Output lower limit=0.1

A part of the output is sampled with the input to generate the error signal. The error signal is amplified with a high gain block to obtain the amplified signal which is fed to the gate terminal of the MOSFET. Based on the input voltage and the error signal generated the duty cycle are increased or decreased. Thus, with the help of a PI controller closed-loop control is achieved.

The output voltage of a PV model varies from 12V to 18.9V DC. For the mentioned voltage range, the output of the converter remains constant at 30V DC with a tolerance of +/-0.95V. The Fig.5 represents the output voltage waveform of the boost converter. For the simulation of the converter, the following parameters were considered.

L_1=L_2=Inductor 1&2 = 1e-3 H.

C_1=C2=Capacitor 1&2= 10e-6 F.

f_s= switching frequency=50kHz.

R_o=400ohms.

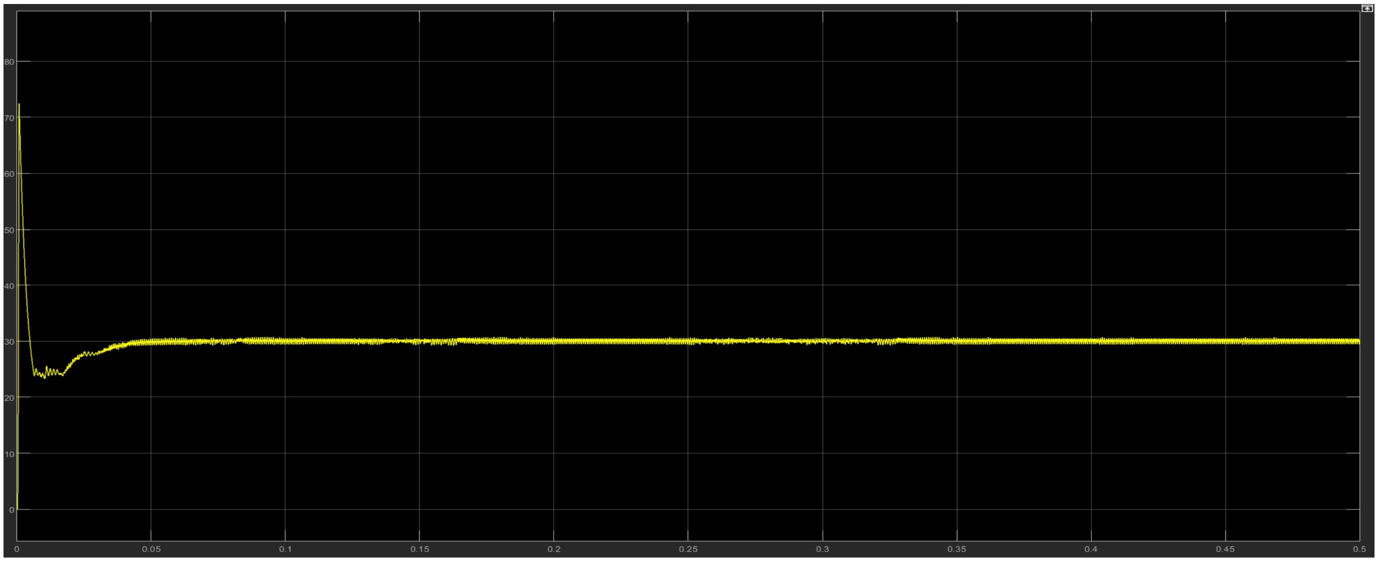

Figure 5. Output waveform of the closed loop single switched quadratic boost converter

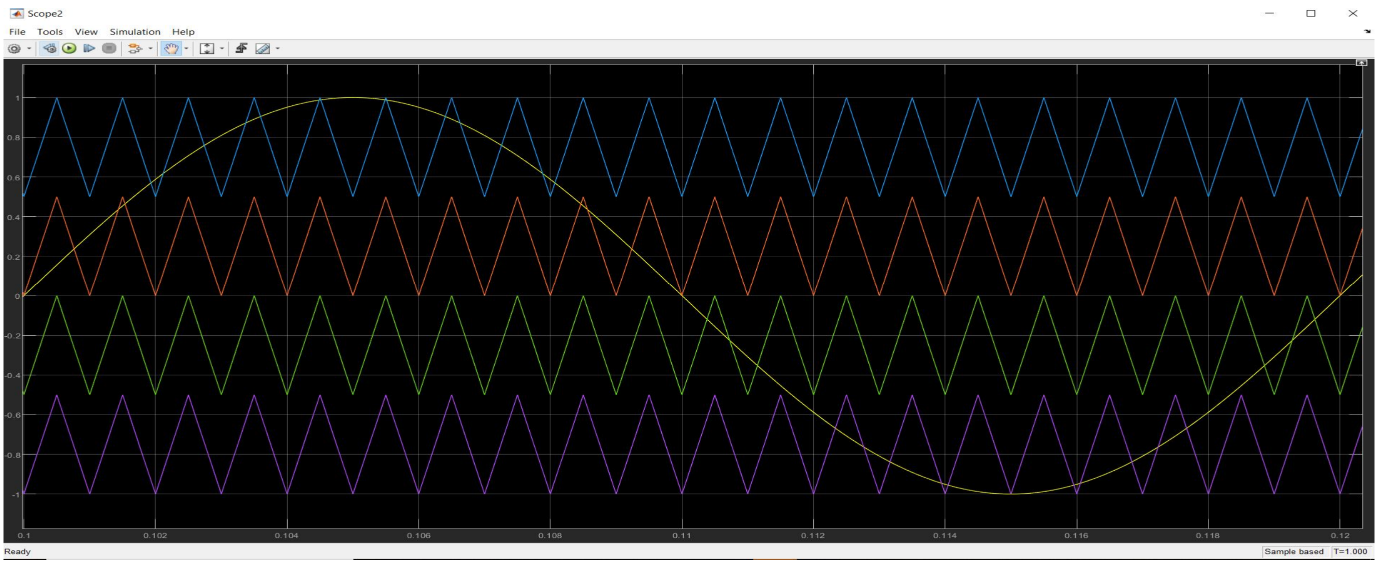

Figure 6. Gate pulse generated with sine wave as reference

The inverter simulated is a five-level cascaded H-bridge multilevel inverter with IGBT semiconductor switches. The control signal is generated by sampling pure sine wave with a triangular wave with the help of a relational operation block. The non-inverted signal is given to the first leg of the H-bridge and the inverting signal is given to the second leg of the H-bridge and the second H-bridge is also connected in a similar manner. The relational operation block parameters are tuned to generate the switching pulses for the IGBT switches which are shown in Fig 6.
The following parameters are considered for the simulation of a five-level cascaded H-bridge multilevel inverter.
Fundamental Frequency of Sine wave=2*pi*50 rad/sec.
Load, R_o=1ohm and L_o=5e-3 H
IGBT switch R_{on}=1e-3 Ohms

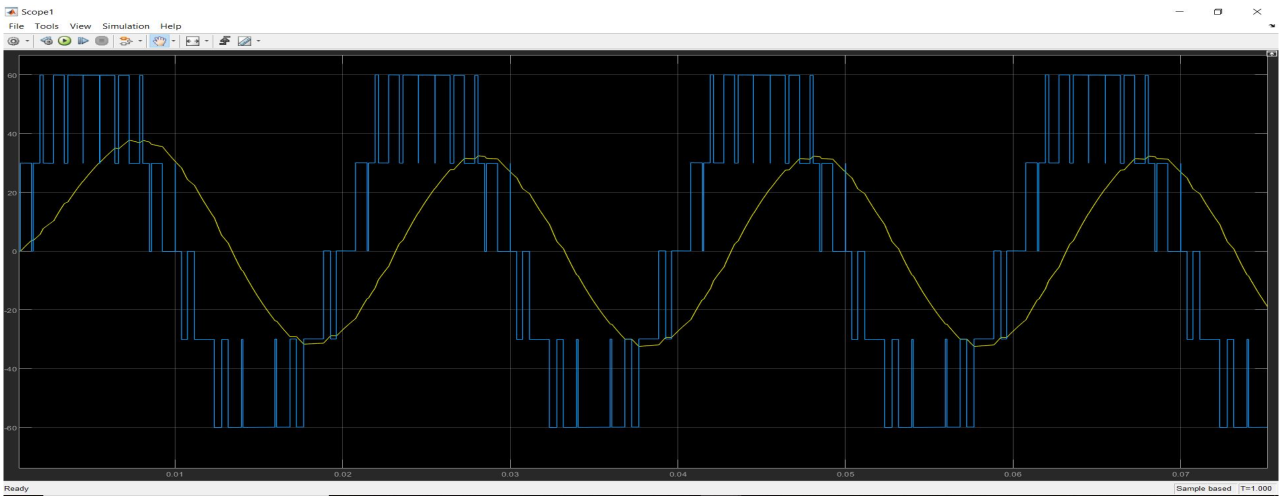

Figure 7. Cascaded H-bridge multilevel inverter output waveform

The IGBT switches are turned on and off as per the switching frequency to obtain the output voltage and current waveforms with fundamental frequency as 50Hz. Fig. 7 represent the sinusoidal switched pulse width modulated signals seen at the output side. The output voltage obtained can be stepped up with the help of a set-up transformer to meet the voltage value of 230V AC.

V. CONCLUSION

The closed-loop control is achieved with the help of the PI controller; this maintains the output voltage constant with a tolerance of +/- 0.95V with the input voltage ranging from 12V to 18.9V for a small scale photovoltaic system. The voltage remains constant irrespective of current drawn within the rating of the converter. With the help of a boost converter, the input voltage to the inverter can be maintained constant without much voltage fluctuations. With the use of cascaded H-bridge on the AC side, low harmonic distortion can be achieved along with medium voltage operation. Thus, with the use of closed-loop quadratic boost converter the DC voltage can be stepped up and maintained constant and with the help of five levels cascaded H-bridge multilevel inverter, the conversion from DC to AC can be done with the lower harmonic distortion which is suitable for a standalone PV micro-grid system.

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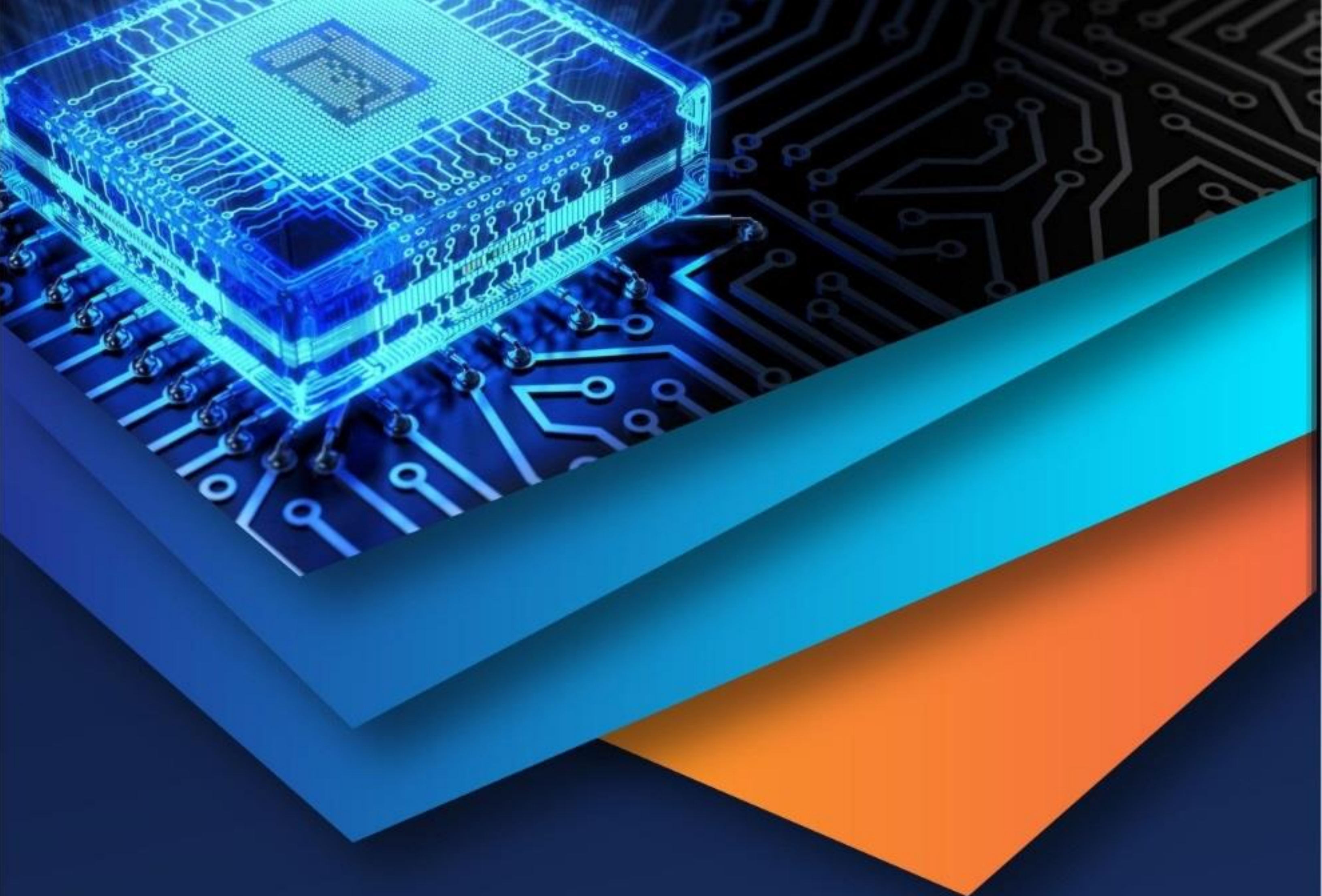

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