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"HIGH BOOST RATIO HYBRID TRANSFORMER BASED ON DC-DC CONVERTER FOR PV GRID APPLICATIONS"

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ABSTRACT

Integrating the power from the photovoltaic (PV) module into the existing power distribution infrastructure is achieved using power conditioning systems (PCS). The DC–DC conversion stage of the PCS requires a high efficient and high boost ratio DC–DC converter to increase the low DC input voltage from the PV panel to a higher DC voltage. In this work proposes, a high boost ratio hybrid transformer DC to DC converter and a full-bridge inverter to convert DC-AC, as the grid voltage is AC in nature. Total Harmonic Distortion is generated by inverter which is minimized by using a low pass filter so that the system is within its acceptable limits. A feedback loop is used in the boost converter to control the converter output voltage. Phase control circuit is required to maintain a constant output voltage at the load side since the PV system output voltage varies continuously in nature.

Key Words: *Hybrid transformer, High boost ratio DC-DC converter IGBT, Full-Bridge Voltage Source Inverter, PV array.*

I. INTRODUCTION

With increasing concern about non-renewable sources of energy, the steady increase in fossil fuel prices, global warming, environmental degradation and the ecosystem. Renewable energy is becoming increasingly popular and attracting more attention as an alternative to non-renewable energy sources. Among the renewable sources of energy, energy is considered to be the most important, most reliable and most sustainable energy source compared to other types of energy sources such as wind, tides, etc., by photovoltaic effects.

Solar energy is a kind of energy derived from the sun in the form of solar radiation and its converts into electricity. When the PV system is connected to grid is called Grid Connected PV System, it become more popular because of their applications in distributed generation and for more effectively using the PV array power.

II. SYSTEM DESCRIPTION

Fig.1 shows the components of the grid-coupled photovoltaic system with two stages for process automation and feed into the grid. The system consists mainly of a matrix of PV arrays that convert sunlight into direct current, a DC / DC boost converter to increase the PV array voltage to a higher level DC voltage and an inverter that is capable of

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converting the PV array voltage to a higher level DC power to alternating current. The generated alternating current supply is fed into the grid and / or is used by the local loads.

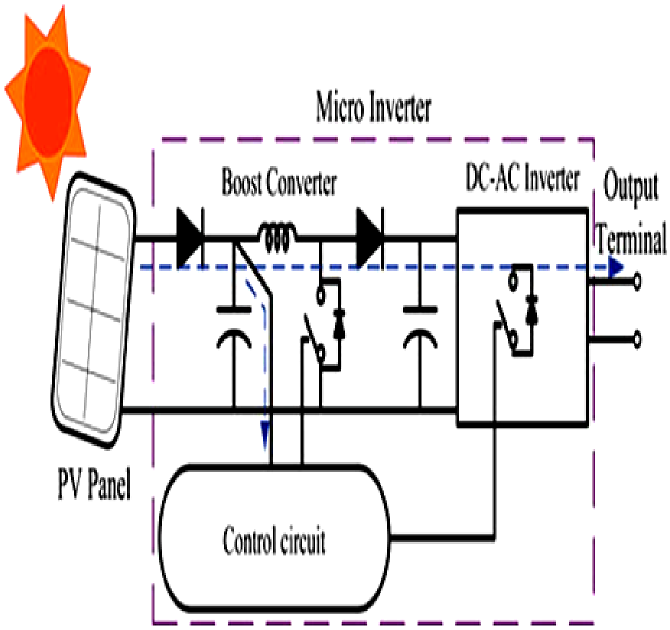

Fig. 1. Components of Grid connected PV systems

III. Operating Principle Of System Components

A. PV Array

PV array is composed of number of PV panels; While PV panel is a series as well as parallel combination of PV cells. A solar cell is basically a semiconductor diode whose p–n junction is exposed to light. A single solar cell can produce only up to 3 to 5 W output power and to increase the output power number of such cells is connected in series [1].

B. High boost ratio DC to DC Converter

It is a combination of flyback and boost converters. Flyback converter consists of L_1=L_2, C_r, D_r & L_r and a boost converter, which consists of L_1, S_1, D_1 & C_c. Hence the flyback output is nD/ (1- D) and boost output is 1/(1-D), the total output voltage is(1 +nD)/1- D).

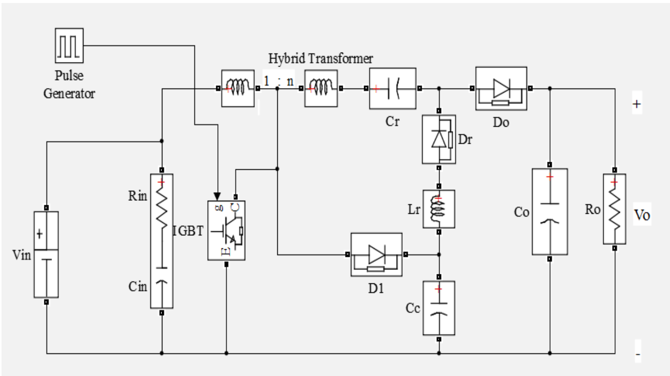

Fig. 2. High boost ratio DC to DC Converter

(i) Boost Converter

DC to DC Converters are used for converting one level of DC voltage (usually unregulated) to another level of DC voltage (regulated). This transformation is done with the help of a network consisting of storage elements like inductor and capacitor [1].

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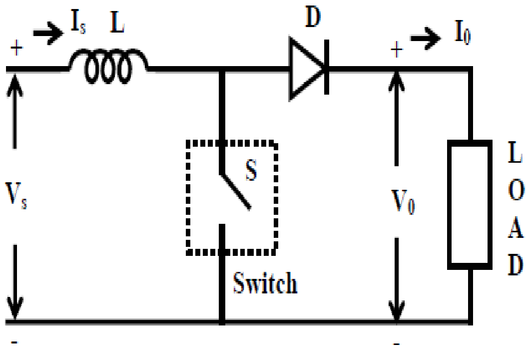

Fig. 3. Boost converter

The boost converter is the tendency of an inductor to oppose sudden changes in current. In a boost converter, the output voltage is always higher than the input voltage. A schematic of a boost converter is shown in Fig. 2. Here, IGBT is used as a switch. When the switch is turn-on, the current flows through the inductor (L) and hence energy $(\frac{1}{2}LI_s^2)$ is stored in it. When the switch is in turn-off, the stored energy $(\frac{1}{2}LI_s^2)$ in the inductor tends to fall and its polarity changes such that it adds to the input voltage. Thus, the voltage across the inductor and the input voltage are in series and together charge the output capacitor to a voltage higher than the input voltage.

(ii) Flyback Converter

It is suitable for both AC to DC and DC to DC conversion with galvanic isolation between the input and outputs. This is a type of buck-boost converter with the inductor split to form a transformer. Hence the voltage ratios are multiplied with an additional advantage of isolation.

The working principle of Flyback converter, when the switch is turned-ON, Transformer primary is directly connected to the input voltage source. So primary current as well as magnetic flux increases and storing energy in the transformer. The voltage induced in the secondary winding is negative.

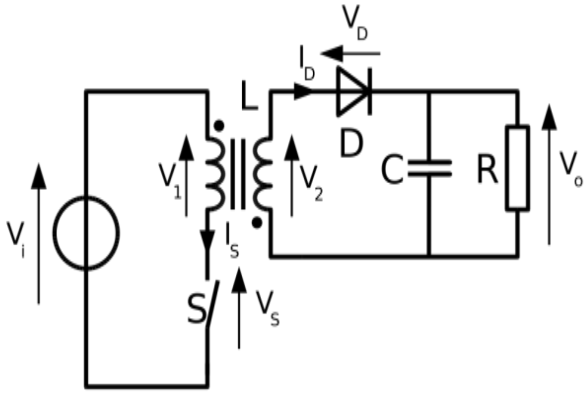

Fig. 4. Flyback converter

So the diode is reverse-biased i.e. blocked. The output capacitor supplies energy to the load. When the switch is turned-OFF, the primary current and magnetic flux drops, Then the secondary voltage is positive i.e. forward-biasing the diode, allowing current to flow from the transformer. The energy from the transformer charges the capacitor and supplies the load.

C. Control of DC to DC converter

The output voltage of DC to DC converter is controlled or regulated by switching ON and OFF the switch, in a periodic manner. The regulation is normally achieved by Pulse Width Modulation (PWM) technique at a fixed frequency. The constant switching frequency f_t is given by [1],

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$f_t = \frac{1}{T}$

Where Tis the time period of switching device and it is nothing but the addition of ON and OFF time of a switching device which is given by

$T=T_{ON}+T_{OFF}$

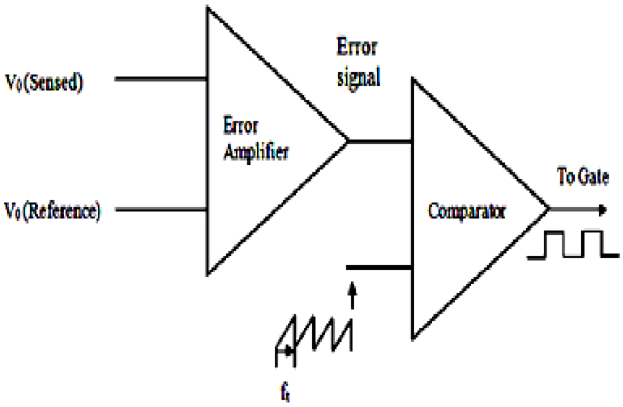

Fig. 5. Control circuit

As the ratio TON/T is duty ratio and as this duty ratio varies, the output voltage also varies. This is called constant frequency, variable duty ratio control.

Control circuit of boost converter is shown in Fig.5for regulation purpose, output voltage is continuously sensed Vo (sensed) and compared with a reference voltage Vo (reference).The resulting error signal is compared with a sawtooth waveform having frequency ft. The output of a comparator is fed to the switch or fed into the gate of a power IGBT [1]. Usually, frequency in kilohertz is selected so as to maximize the efficiency of a converter.

A full-bridge voltage source inverter (VSI) is used here, which consists of four switches. The function of the VSI is to convert DC voltage supplied by the DC-DC converter into an AC.

Two complimentary PWM pulses are generated by the sinusoidal PWM controller. G1 to G4 represents the gate pulses of switches. The basic principle in generating pulses with sinusoidal PWM is to divide the period of the desired sine wave output into number of intervals. In each interval, the control signal remains ON for part of the time and OFF for the other part of the time. The ratio of the “ON time” to “OFF time” at any given instant determines the amplitude of the desired output signal commonly known as duty cycle, which is fed to the switch of the VSI. One signal of gate pulse is sent to pair S1 and S2 while the other signal is sent to S3 and S4.

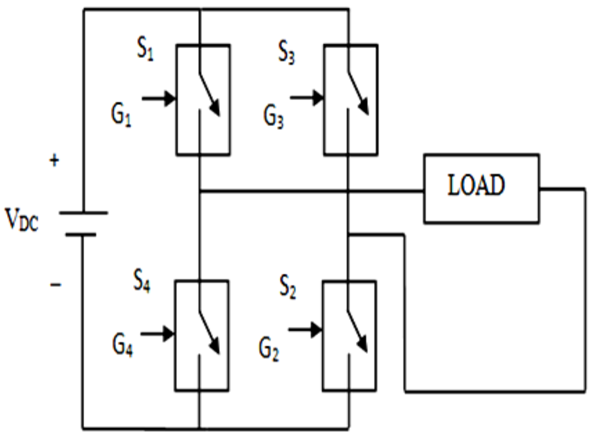

Fig. 6. Full-Bridge Voltage Source Inverter

The output signal from this full-bridge VSI is a square waveform which contains the desired output waveform along

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with frequency components at or around harmonics of the switching frequency. A low-pass filter is utilized here to extract the desired output voltage (50 Hz fundamental frequency) by separating it from the switching frequency [2].

IV. CONSIDERATION OF PROPOSED CONVERTER

During the turn-off period, Secondary reflected voltage of the transformer is equal to nV_{in}.
Therefore V_{cc} can be given as

$$V_{cc} = V_{in} + \frac{DV_{in}}{1-D} \quad (1)$$

$$V_{cc} = V_{in}\left[1 + \frac{D}{1-D}\right] = \frac{V_{in}}{1-D} \quad (2)$$

During the turn-on period with V_{cc} constant, V_{cr} can be given as

$$V_{cr} = V_{cc} + nV_{in} \quad (3)$$

$$V_{cr} = \frac{V_{in}}{1-D} + nV_{in} = V_{in}[\frac{1}{1-D} + n] \quad (4)$$

After calculating voltage across the capture capacitor and resonant capacitor, now we can calculate the output voltage V_o.

$$V_o = V_{cc} + V_{cr} + \frac{nV_{in}D}{1-D} \quad (5)$$

$$V_o = V_{in}[\frac{1}{1-D} + \frac{1}{1-D} + n + \frac{nD}{1-D}] \quad (6)$$

Boost converter output $= V_{in}\frac{1}{1-D}$ (7)

Flyback converter output $= V_{in}\frac{nD}{1-D}$ (8)

Voltage across the resonant capacitor

$$V_{in}(\frac{n}{1-D} + n) \quad (9)$$

Hence the output voltage of the proposed converter is the sum of outputs of Boost converter, Flyback converter and the voltage across the resonant capacitor.

$$V_o = V_{in}[\frac{2}{1-D} + \frac{n-nD+nD}{1-D}] \quad (10)$$

$$V_o = V_{in}[\frac{2+n}{1-D}] \quad (11)$$

The output current can be calculated as,

$$I_o = \frac{V_o}{R_o} \quad (12)$$

The Boost conversion ratio can be calculated as,

$$M_{b=}\frac{V_o}{V_{in}} = \frac{2+n}{1-D} \quad (13)$$

TABLE-I SPECIFICATION OF PARAMETERS

Single Stage Proposed Converter								
Para-meter	V_{in} V	R_{in} Ω	C_{in} µF	C_r µF	$L_{r\mu}$ H	C_c µF	C_O µF	V_O V
IGBT	35	10	5	0.5	2.2	20	2	360

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V. MODELING AND SIMULATION RESULTS

A. Modeling of High Boost ratio DC-DC Converter

Fig. 7 shows the model of a boost converter developed in MATLAB/Simulink. This is the model developed from Fig. 2 of high boost ratio converter using the parameters given in Table II. In this model R represents the load resistance whose value is 50 Ω.

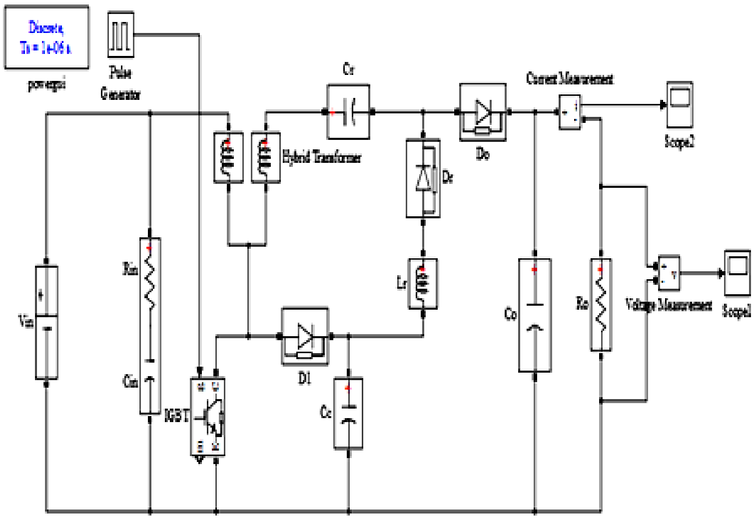

Fig. 7. Model of High Boost ratio DC-DC Converter

Fig. 7 represents Simulink model of proposed high boost ratio hybrid transformer dc to dc converter. In this input voltage = 35V given to this converter. The voltage is stepped up using a hybrid transformer and due to the capacitance Co the ripples will be reduced and the fine DC voltage is obtained at the output side of the circuit.

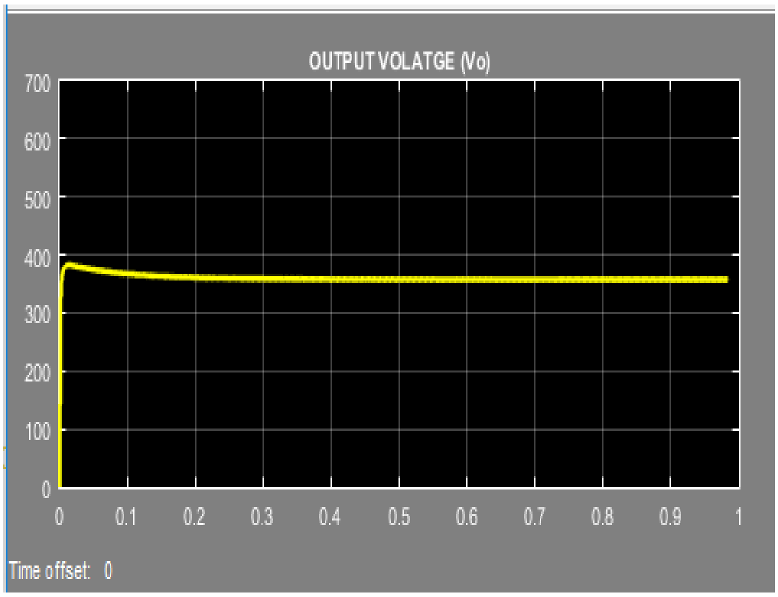

Fig. 8. Output voltage at input voltage = 35V

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B. Modeling of Voltage Source Inverter

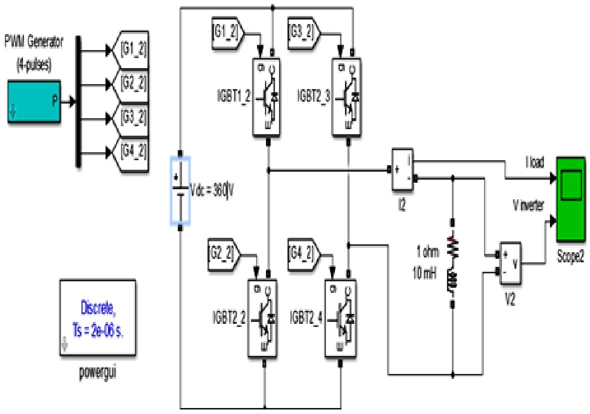

Fig. 9. Model of Voltage Source Inverter (VSI)

Model of a single phase full-bridge voltage source inverter is as shown in Fig. 9. Input signal to the inverter is DC voltage of 360 Volts, which is the output voltage of boost converter and output voltage is 230 Volts. Design parameters of inverter are shown in Table III. In this model, RL represents the load resistance and inductance respectively whose values are 1 Ω and 10 mH.

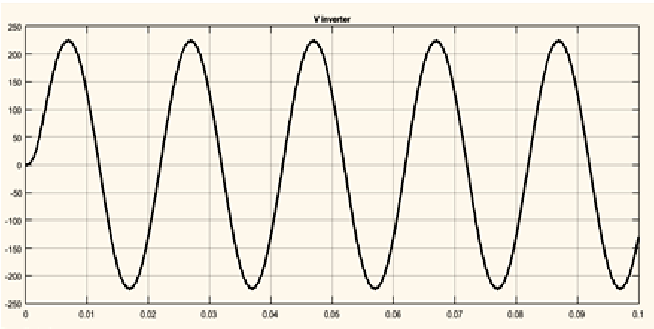

Fig. 10. Output Voltage of Inverter

VI. CONCLUSION

Designing of single phase grid connected solar PV system is carried out in this work. System parameters are calculated and from these parameters model is formulated and simulation results are presented. Simulation results shows that the proposed control technique regulates the output voltage of high boost ratio DC-DC converter. Load voltage is sinusoidal of 230 Volt, having frequency 50 Hz same as grid voltage and frequency.

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