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Design and Simulation of Grid Connected PV system with DC Boost Converter and Maximum Power Point Tracking MPPT

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Abstract Demand of the renewable energy resources is increasing nowadays, due to the fast economic growth of the nations across the world, environmental issues have been increased. To counter these ongoing problems in this research work, we have developed a grid-connected Photovoltaic (PV) model to produce clean energy with maximum efficiency. In this model an Electronic Controller (EC) for PV panels interfacing with the grid is designed, This EC model consists on a Maximum Power Point Tracking (MPPT) coupled with a DC boost converter connected with a line commutated inverter and the MPPT controller has been simulated. Subject upon that, the PV panel output is inconsistent. To supply constant DC voltages to the inverter circuit, it is necessary to adjust the duty cycle of PI controller. In this simulated modal a single phase grid is continuously fed by a Solar Array by extracting maximum power through the MPPT controller. The grid is fed through active power by altering firing angles at open and closed loop modes. The response of both cases has been compared and found that they are comparatively stable. This model has been simulated in Matlab/Simulink and found that the active power fed into the grid at different firing angles in both open and closed loop modes is stable.

***Index Terms*—Photovoltc module, Pi controller, Line commulated invertor, Boost convertor, MPPT.**

I. INTRODUCTION

FROM the past few years, renewable energy resources have become the alternative to conventional energy resources, countries on a national level are trying to implement a different type of renewable energy techniques to enhance their generation capabilities and to counter ongoing environmental issues. One of the most vastly availed renewable energy resource is Photovoltaic (PV) known as solar energy. PV energy is considered as modern energy resources and it is available almost everywhere in the world, the most promising advantage of PV energy is its pollution free feature it requires less maintenance. It is also used in satellites as an energy source. Furthermore, PV energy is used in many applications on a commercial level, e.g. PV energy is used for water heating. In domestic applications one of the major use of PV energy is battery charging at home to provide backup power, leading advantage of PV energy is free of cost unit production, One of the major disadvantages of PV energy is high installation cost which makes it expensive, and overall efficiency of PV panels is also a question mark, by countering these issues PV systems could be connected to the central grid to minimize unit production cost. Although PV panel's efficiency is not yet impressive, the efficiency of this system could be improved by using efficient controlling and converting equipment it may help to reduce installation cost and it can also improve the overall efficiency of the PV system, in this paper we have explained the MPPT technique with a boost converter capability, which extracts maximum power out of the PV panels. For the practical

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implementation of this concept, a highly accurate power interface between PV panels and grid is required with fast switching capabilities to respond abruptly to cope sudden variations of the grid power requirements [1] to even out load demands. In rural areas of Pakistan issue of electricity blackout is very severe, people living in rural areas face extreme electricity load shading throughout the day [2]. To cope load shading issue we have proposed that PV energy is the most suitable alternative; it may be implemented by improving the overall efficiency of PV system. For improving PV system efficiency, and to supply this produced energy into the grid, a solution of the line-commutated inverter is proposed. Therefore a controlling circuit is required in this system to transfer maximum power from PV panels to the grid as per requirement [3], [7].

II. PROPOSED SOLUTION

The schematic diagram of our proposed model is given in Fig 1,

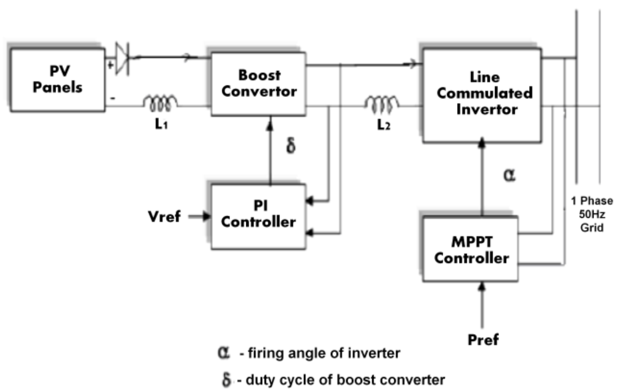

Fig 1. Schematic Diagram of Proposed Model

It includes the PV panels, DC boost converter, main grid, single-phase silicon control rectifier (SCR) circuit. The output DC voltages of PV panels are sensed in real time and a boost converter is used to step up generated voltages to a nominal conversion level. A PI Controller is used to control the duty cycle of the boost converter to maintain the output of PV panels on a constant level. The output of boost converter is then fed into silicon control rectifier circuit (SCR) circuit to convert it into AC to supply this generated energy to grid [3], [4].

The firing angle of the silicon controlled rectifier (SCR) circuit is kept more than 90 degrees and its operation is controlled by a line cumulated inverter. One of the outputs of the boost converter is going to PI controller input and (260V) is provided to the controller as a reference. According to these reference voltages, the duty cycle modulation is done. To provide generated power to the grid, an Ac inverter is connected to the controller, which fed power to the grid according to load demand by drawing a maximum power out of the PV panels. The input of PI controller is based on the comparison on real power Po and reference power Pref, the difference between both these powers is sensed and it is set as an input of the controller. To minimize the error the firing angle is modified on the controller output. In the proposed module two PV panels are taken as an energy source and rating of each PV panel is 80 Watts. 21volts, 5A, which are connected in series. For grid modeling, a grid of single phase 230V with 50Hz frequency is used which is connected to the output of inverter [6], [1].

A. *Circuit of Boost Converter*

The circuit of boost converter which is used in this proposed method is shown in Fig 2. In this circuit PV panels generated output is step up to 260Volts. The output of boost converter is given by the following equation

$$Vout = Vdc[1/(1-\delta)] \qquad (1)$$

Where Vo is the Converter output, V_{dc} = DC input, which is coming from PV panels [6], through this we can alter duty cycle, which helps to change the value of V_{dc}, and δ = boost converter duty cycle. One of the advantages of the boost converter is, it works as transformer alternative and helps in reducing overall unit cost and minimize the losses in the system.

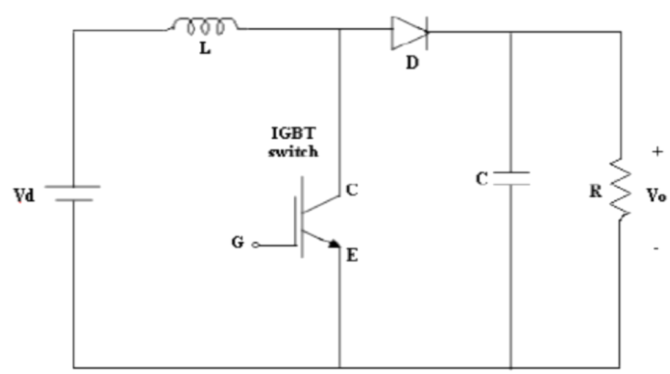

Fig 2: DC Boost Converter Circuit

B. *Designed Controller for Boost converter*

To maintain the output of the boost converter to a nominal 260Volts an automatic self-adjusted duty cycle for the converter is required which is achieved through PI controller. The main function of PI controller is to compare reference voltages (V_{ref}) with actual voltages (V_{act}) and change duty cycle according to error voltages (V_{error}).

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These error voltages, then fed into P.I controller, and the output (V_{out}) of P.I controller is compared in a comparator with a sawtooth wave of (500KHZ). After comparison, it generates gate pulses which are required for controlling boost converter operation [11]. The output of PI controller is

$$Vout = [Gp + Gi/S](Vref - Vact) \quad (2)$$

Where Gp and Gi are the representation of proportional gain and integral gain respectively for PI controller. In this proposed method the integral and proportional gain values are Gi = 1 and Gp = 0.250 for the achievement of desired output voltages 260V Volts from boost converter [14]. [13].

C. *Single Phase Line Commutated Inverter*

The circuit of line cumulated inverter is based on bridge converters, it is shown in Fig 03, it could operate in two functioning modes, and the first function is rectification and second is an inversion. The firing angle for rectification mode is selected in-between (0 to 90) degrees and for inversion mode, firing angle is selected in-between (90 to 180) degrees. In this proposed work the converter is used in an inversion mode [5]. [4]. The triggering firing angle of silicon controlled rectifier (SCR) T1 and T2 are α, and the triggering firing angle for SCR T3 and T4 are (α + 180) degree. In the following case power flow could be inverted by altering the DC voltages and the direction of current remains unchanged. For inversion mode, the angle of α must be higher than 90 degrees. By using SCRs no additional work or circuitry is required for maintaining output frequency according to grid requirement [8], [10], which is considered as an advantage of this circuit. The average output voltages E_{de} is given as.

$$\frac{1}{\pi}\int_{\alpha}^{\alpha+\pi} Em \times ln\theta d\theta = \frac{2}{\pi}\int_{a}^{b} Em \cos\alpha$$

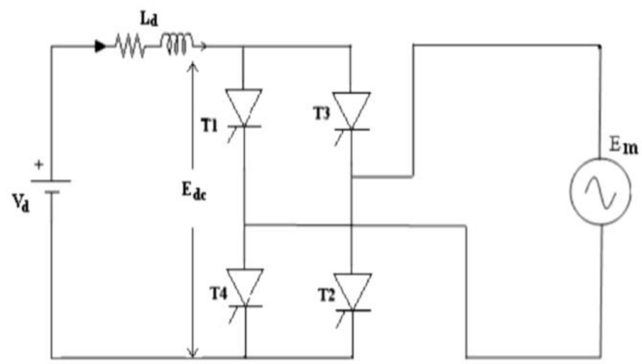

Fig 3: Controlled converter for single phase

III. MAXIMUM POWER POINT TRACKING (MPPT)

For extracting desired maximum power out of the PV Panels, the inverters firing angle in a closed loop is adjusted for achieving maximum power efficiency [7]. The PV panels reference power P_{ref} is given as

$$P_{ref} = V_{mp} \times I_{mp} \quad (3)$$

But here

$$V_{mp} = G_1 \times V_{oc} \quad (4)$$

$$I_{mp} = G_2 \times I_{sc} \quad (5)$$

Where G1 and G2 are the constants with the values of 0.76 and 0.8. And V_{oc} is the open circuit voltages and Isc is the short circuit current respectively.

The firing angle α of inverter is adjusted by comparing the reference power P_{ref} with the grid power P_{grid} divergence between both these powers helps to adjust firing angle "Alpha"

$$\alpha = (P_{ref} - P_{real}) \times [G_p + G_I/S] \quad (6)$$

The gains which are selected for PI controller are 0.3 and 7.0 accordingly [9].

IV. MATLAB SIMULATIONS AND RESULTS

The virtual model of proposed simulation methods has been simulated in MATLAB/Simulink 7.1 software, the schematic of the proposed method is shown in Fig. 04.

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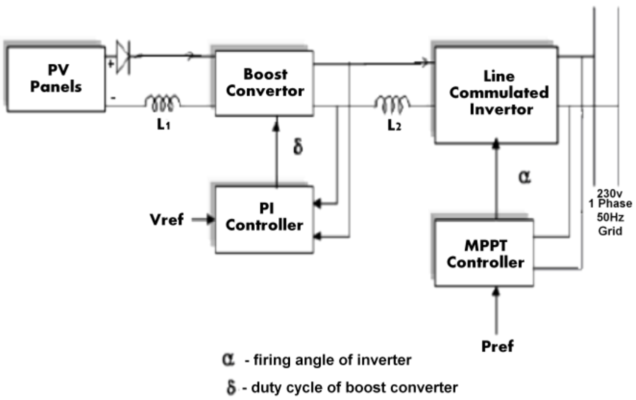

Fig 4. Schematic Diagram of Proposed Model

The MATLAB schematic of the proposed model consists of a PV Panels, closed loop controller, Line commutated inverter, DC boost converter and consumer grid. The values of PV Panels voltages and currents which is used in this model are following.

'Voc' = 21.2Volts
'Isc' = 5.14Amps
` 'L1' = 3.4mHinery

Boost Converter values
'L = 1mH'
'C = 1000mF'
'R = 50W'

Values of DC link components
'R2 = 0.2W'
'L2 = 20mH'

The value of α for MPPT was determined through the SCR triggering in open loop mode at different triggering angles [12]. These values on different triggering angles were noted and compared with closed loop values. And these values are given in Table. 01.

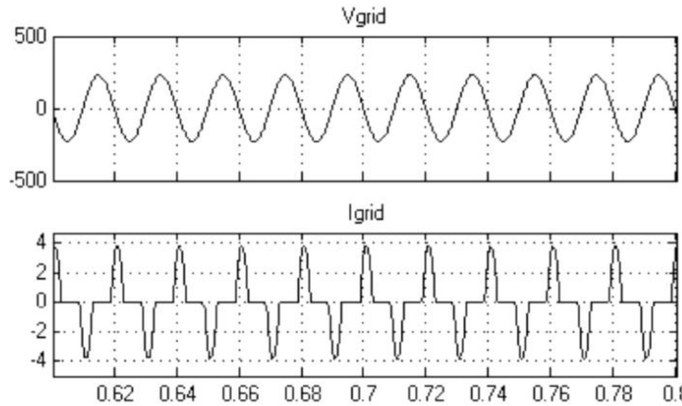

Fig. 5: Utility Grid Voltages & Current

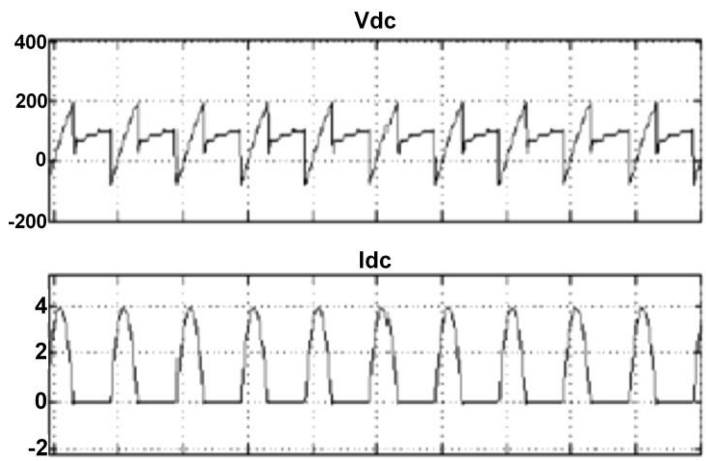

Fig. 6: DC Voltages and DC Currents

TABLE I
VALUES AT DIFFERENT TRIGGERING ANGLES

Scale	Open Loop Mode	Close Loop Mode
DC Current	0.9 Ampere	1 Ampere
DC Voltage	-108V	-119V
Utility Grid Current	`1 Ampere	0.4 Ampere
Grid Active Power	-70.5W	-72.62W
Firing Angle α	160 Degrees	162.2 Degrees

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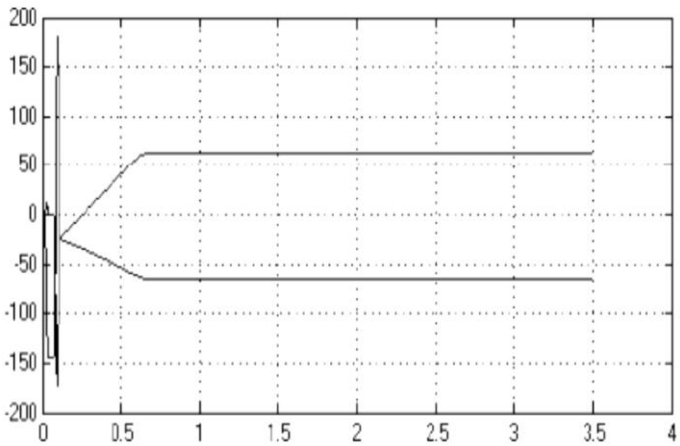

Fig. 7: Active Power and Reactive Power Supplied to Grid

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V. CONCLUSION

According to the results of this study line cumulated inverter and boost converter is very convenient for the practical implementation of PV system with single-phase grid. The simulation results proofed that our proposed method has many advantages that are verified through different curves. The final simulation results show that there are some losses in the circuit due to inductors presence, so the resultant power supplied to the grid is comparatively less. This problem could be solved through proper selection of inductors rating with less internal losses.

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