Active Power Control in Grid Connected Photovoltaic System

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Abstract

This paper proposes a design of grid connected photo-voltaic (PV) system through implementation of active power control & MPPT control using MATLAB/Simulink. In the present scenario of world energy sector renewable sources are growing their importance day by day. The overall system model consists of a PV array, MPPT controller, Inverter and a distribution system to deliver usable power to the end grid. However, the output of solar arrays varies due to change of solar irradiation and weather conditions. Therefore, the maximum power point tracking algorithm is implemented in DC/DC converter to enable PV arrays to operate at maximum power point. The Perturb & Observe (P&O) algorithm is employed to control the boost converter. Then the central inverter is controlled by using the PI controller for active power control, which is necessary to ensure that all maximum power is transferred to the grid. Active power control is cost effective & it improves the efficiency of the system. After the complete designing of the grid connected photovoltaic system, we analysed the performance results of the PV system in MATLAB.
Keywords: active power control, grid connected photovoltaic system, maximum power point tracking (MPPT), PI control, voltage source inverter

I. INTRODUCTION

In India, there is big challenge of supplying energy continuously, due to which there is many power crisis in our country. India is facing an acute scarcity which is hampering its industrial and economic growth therefore it is essential for us to use renewable sources of energy [17]. Thermal power is used mostly in order to generate energy and fulfil the energy requirement. Day by day, the demand of the energy is increasing and we are looking for various alternatives in order to fulfil the requirements [8-9]. Due to global concern on climate change and sustainable electrical power supply, renewable energy is increasingly becoming popular in the developed countries [18]. In [19] discussed, various kind on renewable energy sources which can be utilized to produce energy like wind, tidal, hydro, geothermal, solar etc. and they can play a key role in overcoming worldwide energy crisis.

PV system is a important and encouraging energy source in the recent years as PV installations are increasing day by day due to their environment friendly operation [20]. It is a step toward fulfilment of energy need. In India, there are various villages where the power for domestic use is not available. We can resolve these kind of problems with grid connected PV system. But there is drawback of using solar energy that if we do not control the power there will be variations in the output voltage and we will not get desired output. The outputs of the photovoltaic cell are nonlinear, so in order to obtain the maximum power, we need to track and control them which can be done by MPPT [10].MPPT is used to extract maximum power from PV arrays which helps in increasing the efficiency of the PV arrays. The MPPT sets voltage and current so that we can get maximum power. [21] proposed that, MPPT provides the reference for the outer dc-dc current loop. MPPT charge controller use smart technologies, such as microcontrollers, to compute the highest possible power output at any given time. In this scenario the voltage will be monitored and regulated without power loss. Therefore in the same conditions as above, where the input voltage is higher than the output voltage, the MPPT charge controller will lower the voltage and simultaneously increase the current to the batteries. This results in higher power transfer efficiencies, which means less solar power is lost during the storage process [11].MPPT has been shown to increase the efficiency of the system by approximately 30% over charge controllers that do not implement MPPT. There are various algorithm which are used in order to achieve maximum power like P&O, Incremental conductance etc. we have used P&O method here. [12]said, in P&O method the MPPT compares power at each instant , it compares the difference in new power and previous power if the difference is positive then it keeps comparing until the difference in power is negative.

The active power control is very important in the PV system, If the requirement of power in grid is less than the power we are generating from PV cell the we need to control the power by active power controller otherwise we will end up by giving more power to grid than it's requirement which is not good for us cause we have to manage the cost as well. In PV power conditioning system, current regulator is needed to control active power [16]. Therefore it is very beneficial if we use active power controller in PV system. In addition, the phase-locked loop (PLL) is also needed to receive the grid voltage and current information, such as the frequency, phase angle and amplitude, for controlling overall system [3]. In this research paper we are working on Active power control through PID controller. In this paper, the system is configured in section II. Section III includes the proposed control architecture of the grid connected PV system. Section IV includes the MATLAB/Simulink model of the above designed system. Simulation performances are discussed in the section V. The last section consists of conclusions.

II. SYSTEM DESCRIPTION

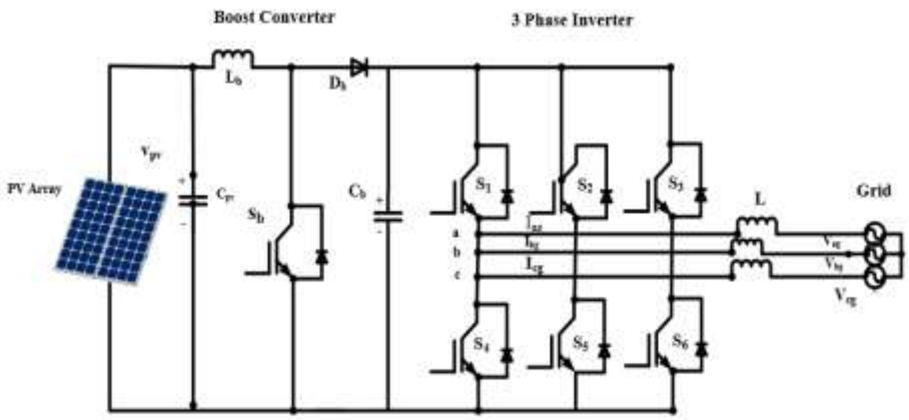

Fig. 1: Circuit Configuration of Grid Connected PV System

Fig 1 shows the circuit configuration of three phase grid connected photovoltaic system. The model of system is composed of PV array, DC-DC boost converter, DC link, DC-AC inverter & grid. The inverter transfers the active power to the grid. Also, the active power command is calculated from the PV array maximum power in order to ensure maximum power delivered to the grid.The parameters of the above discussed circuit are as:L= 1e-6 H; L_b= 0.287 H ;C_{pv}= 1000e-6 F ; C_b= 100e-3 F.

Now here are the parameters of the PV array module: Module Type= Sunpower SPR-305 WHT; No. of cells per module= 96; No. of series connected modules per string= 10; No. of parallel strings= 20; V_{oc}= 64.2 V; I_{sc}= 5.96 A; V_{mp}= 54.7 V; I_{mp}= 5.58 A. The irradiance on the solar panel is 1000 W/m^2, assumed to be fixed. The reference voltage is 415 V & the reference power is 2.5kW. Now, let's discuss the next step towards the designing of the system i.e. MPPT control, whose function is to maximize the output efficiency of a solar panel or solar array.

III. CONTROL ARCHITECTURE

A. *Mppt Control*

MPPT charge controller use smart technologies, such as microcontrollers, to compute the highest possible power output at any given time. In this scenario the voltage will be monitored and regulated without power loss. Therefore in the same conditions as above, where the input voltage is higher than the output voltage, the MPPT charge controller will lower the voltage and simultaneously increase the current to the batteries. This results in higher power transfer efficiencies, which means less solar power is lost during the storage process [1].The peak power point tracking techniques vary in many aspects, such as: simplicity, convergence speed, digital or analog implementation, sensors required, cost, range of effectiveness, etc. [2] There are many MPPT algorithms that can be implemented in the MPPT control such as Perturb & observe , incremental conductance, constant voltage method, fuzzy logic control, neutral network etc. But, we are implementing P&O algorithm in the MPPT control because it can be implemented simply and the MPPT controllers available in the market are mostly programmed with this algorithm.

Perturb & Observe (P&O) method of power point tracking follows the procedure of constantly checking the voltage (or current in some systems) and continuing to increase the voltage as long as the power continues to increase. After passing over the maximum power point (MPP) the power will begin to decrease which the algorithm will interpret as having gone too far and will start decreasing the voltage to compensate. This process continues to iterate until the MPP has been reached [14].

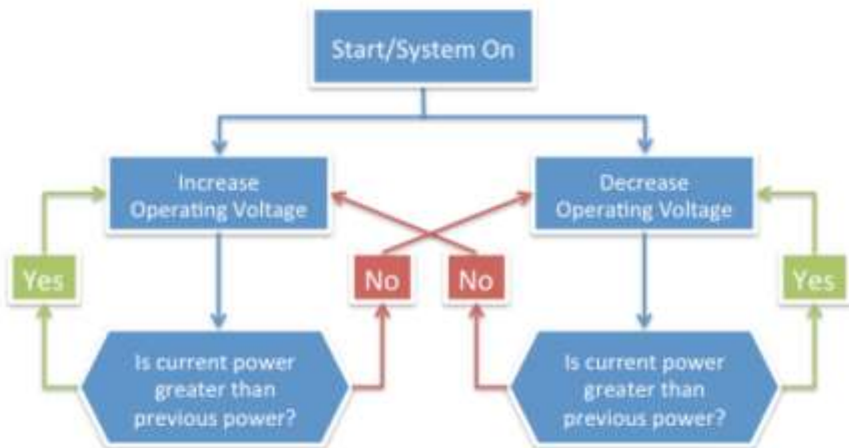

Fig. 2: Flow Chart of P&O Algorithm [15]

B. *Active Power Control*

Active power control is necessary to achieve the stable grid requirements. Inverter control in the grid connected photovoltaic system involves two major tasks. One is to ensure that the PV module(s) is operated using the MPPT mechanism. The other is to inject sinusoidal current into the grid [7]. The main advantage of active power control over passive power control is their small Non-Detecting Zone (NDZ). Also, active power control include slide-mode frequency shift and active frequency drift or frequency bias[14].For the requirements of stable grid voltage as compared to the solar panel output voltage, we have to design some control strategies in the inverter control. We are implementing active power control with controller such as PI controller. There are many control techniques that can be implemented in inverter control such as PI control, hysteresis control, proportional resonant control, repetitive control, modified ramp type control, delta modulated current control, dead beat control etc.

PI controller maintains output such that there is zero error between process variable and set point/desired output by close loop operations. It integrates the error over a period of time until error value reaches zero. [3] proposed a control strategy for inverter control such that the dc voltage is set by PI controller that compares actual DC bus voltage and reference generated by MPPT and provides I_d (active current reference). [4] imposed an inverter control in which the PI controller is fed with an instantaneous current error. The integral term in the PI controller improves the tracking by reducing the instantaneous error between the reference & the actual current. The resulting error signal forms two reference signal V_{ref1} and V_{ref2}.Now, these reference signals are compared with a triangular carrier signal & intersections are sought to produce PWM signals for the inverter switches. The author also discussed that, because the inverter is used in a grid-connected PV system, a proportional-integral (PI) current control scheme is employed in order to keep the output current sinusoidal and to have high dynamic performance under rapidly changing conditions & to maintain the power factor at near unity.

Here the voltage V_{abc} and current I_{abc} are the voltage & current across the inverter. $V_{dc}$is the dc bus voltage while I_d and V_d are the feedback current and voltage, obtained by the park transformation which are fed to the PI controllers. After the park transformation, a limiter is connected before the PWM generator to limit the magnitude of the signal within a certain band. At last, the PWM generate generates gate pulses to the inverter.

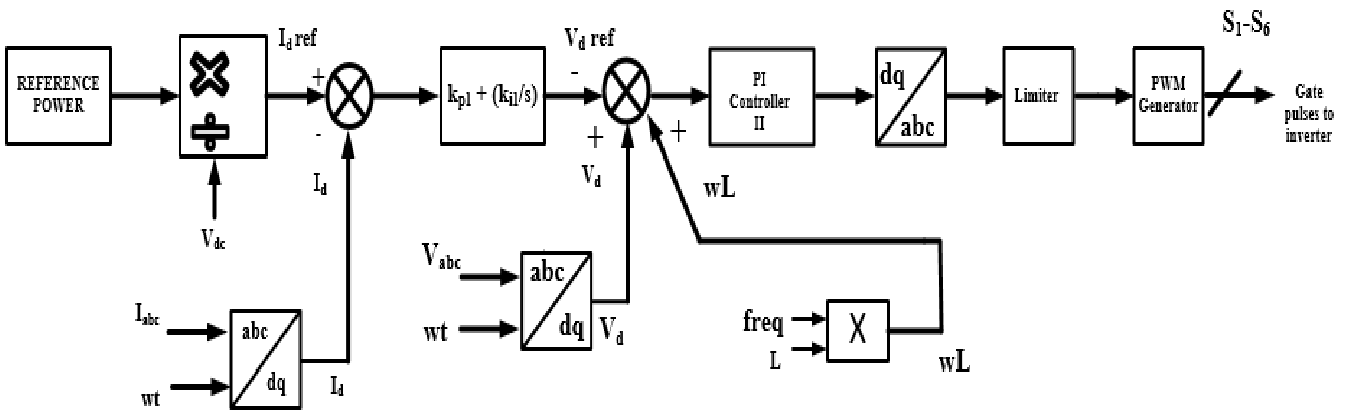

Fig. 3: Block Diagram of PI Controller

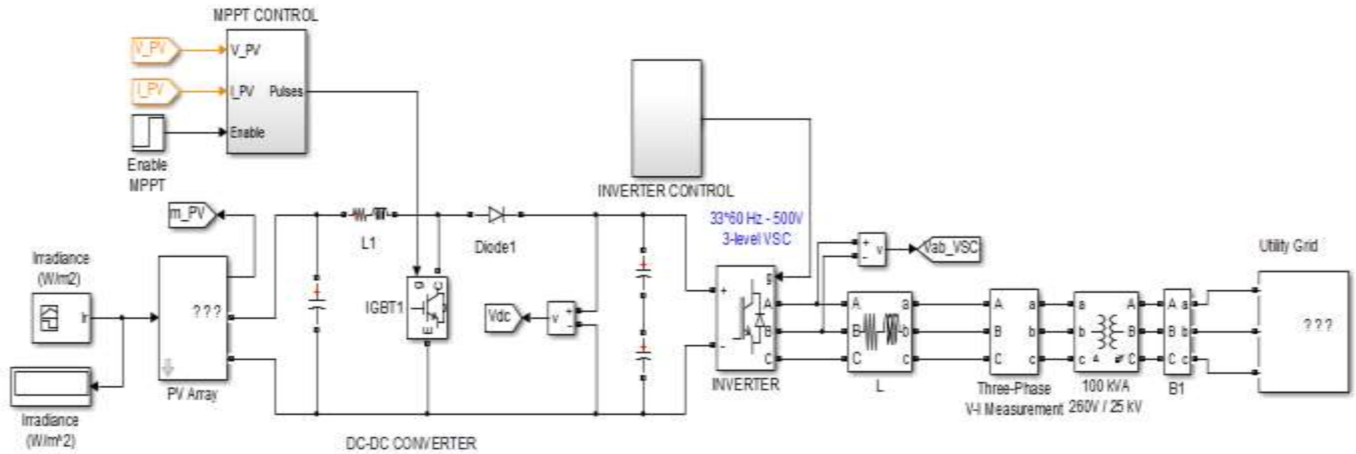

Fig. 4: Flow Chart of P&O Algorithm [15]

IV. RESULTS

After the implementation of MPPT control & Inverter Control in the above designed grid-connected PV system, now here are some of the graphs plotted which are as follows:

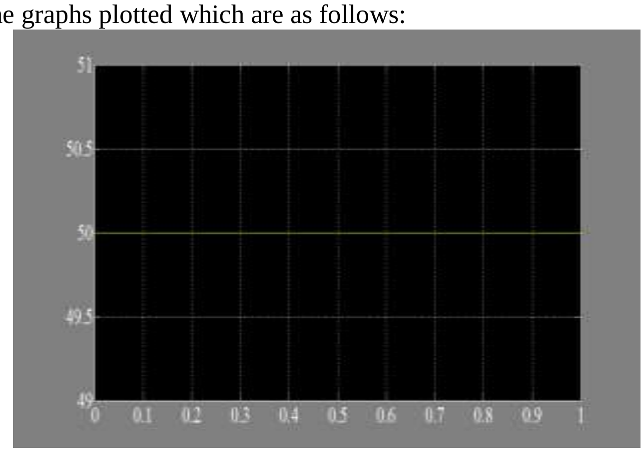

Fig. 5: Grid Frequency

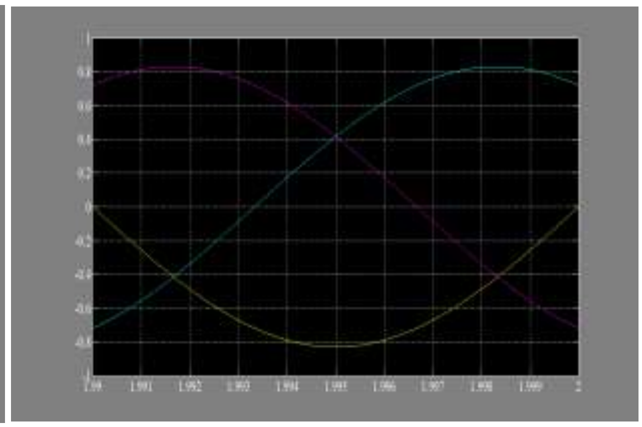

Fig. 6: Grid Current

Fig. 5 shows the graph plotted for grid frequency vs time. A grid frequency band of 49.5Hz to 50.05Hz should be maintained for stable grid frequency requirements. The current band is giving the frequency constantly i.e. 50 hertz with respect to the time which is desired for the whole system. Fig. 6, is the waveform of a grid current vs time which gives us information about the magnitude of current at each instant of time. The per unit value of the current is 0.71A.

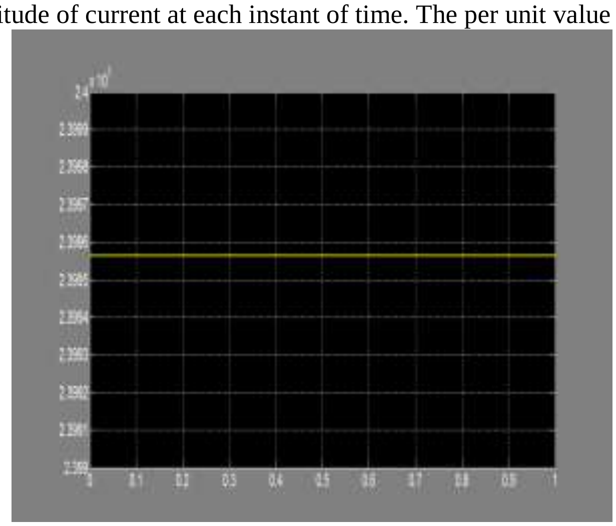

Fig. 7: Grid Power

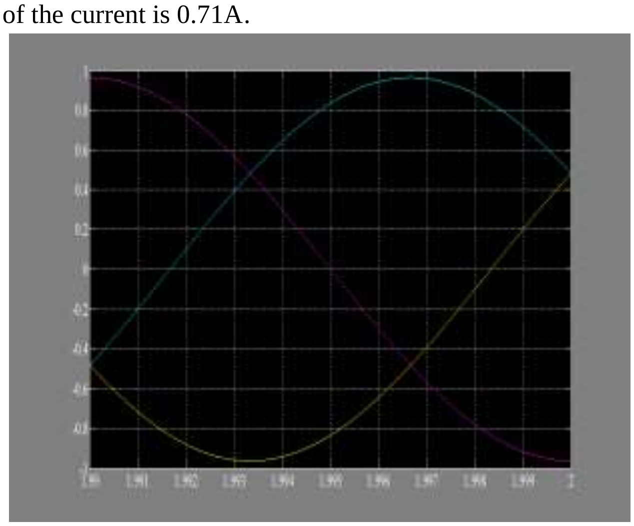

Fig. 8: Grid Voltage

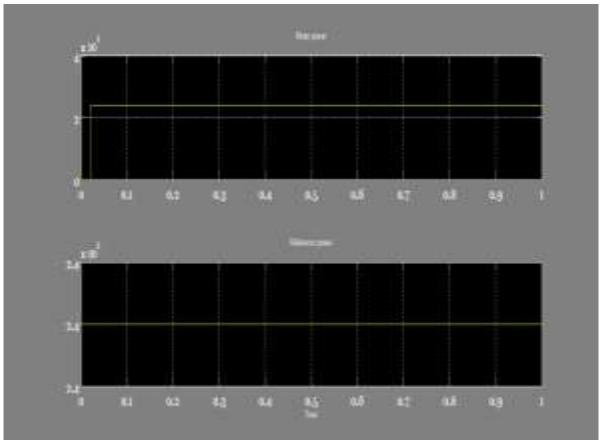
Fig. 9: Mean Power & Reference Power

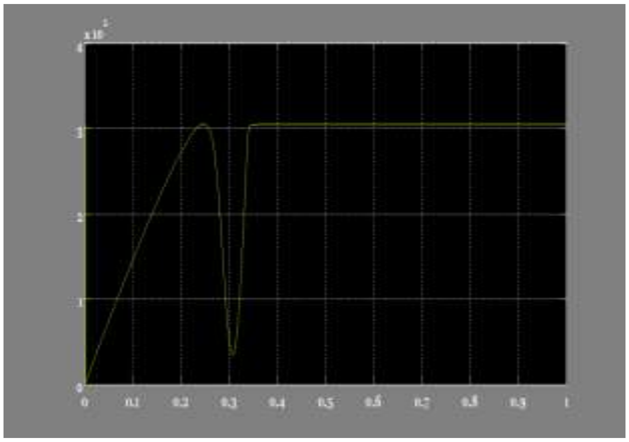
Fig. 10: PV Array Output Power

Fig. 7: is plotted as grid power of the system. As the reference power was 25 kW, but after the simulation when we checked the power available to the grid was around 23.994 kW, i.e. approx. 24 kW. So, the efficiency of the above designed grid connected system is approx. 93%. The wave form in fig. 8 shows graph between grid voltage and time, according to this graph we are getting per unit value of 0.95 V. Fig. 9 depicts the PWM duty cycle. Here, the mean power and reference power's waveform has been shown with respect to time, mean power is 24 kW and continuous after 0.02 interval the reference power should be 24kW continuously. The waveform is useful in checking the mean power at each instant of time. Finally, the wave form in fig. 10 shows the output power of the PV array, power is around 3.1 kW, which is constant after 0.3 sec.

V. Conclusion

DC-DC converters and their design remain an interesting topic and new control schemes to achieve better regulation and fast transient response are continually developed. A key challenge to design switching regulators is to maintain almost constant output voltage within acceptable regulation. In this paper, MATLAB simulink is preferred over other software for its enhanced designing, modelling & manipulating features. The block diagram of the converter system in MATLAB simulates the functionality of the system while providing specification for each individual block. We concluded that, the grid-connected PV system examined under PI control of inverter, delivers power to the grid of about 24 kW. As the reference power of our proposed system, was 25 kW, so the calculated efficiency of the system is approximately 93%. The discussed modeling technique can be extended to enhanced inverter control schemes with controllers such as dead beat controller, proportional resonant controller, repetitive controller, modified ramp type controller for the improvement of efficiency of the designed grid connected PV system .

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