

Design a High Quality Grid Connected PV Systems with Constant Power Generation and Input Output Linearizer Controller

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Abstract - With Increase in demand of clean electricity generation in many countries, the increasing techniques of new photovoltaic (PV) systems force the Distribution System for transmission and distribution of electricity. By considering this aspect, the distributors of electricity are focused to ensure fast and smooth transformation between maximum power point tracking and constant power generation so the maximum feeding power of PV systems must be limited. Optimum performance and stable operations are achieved in spite of solar irradiance levels by the new control technique which is proposed. In this strategy, PV output power can be regulated as per desired set point and force to operate the PV system at left side of maximum power point without any stability issues. This system consists of solar PV panel, boost converter, MPPT controller, inverter, LCL filter and Load. Here, PV system as energy source. The power generated from solar photovoltaic system is controlled by DC-DC boost converter. A modelling of this system is developed in MATLAB/Simulink. Constant power generation (CPG) control is much effective strategy in terms of stable transitions, high accuracy and fast dynamics which have been verified by experimental results.

Key Words: Active power control, constant power control, maximum power point tracking, PV systems, and power converters

1. INTRODUCTION

As the conventional energy sources produces air pollution, water pollution solid pollution, so this is very harmful to human beings. Hence the non-conventional energy sources like Solar PV panels and wind turbines are generally used. In general photovoltaic panels are used today in rural areas where the grid connected system is not convenient. Also photovoltaic panels are used in various applications such as water pumps, residential applications and many more. The photovoltaic system has many advantages as It is available freely in nature, no pollution but their installation cost is more due to the use of power converters like dc to dc or dc to ac, storage batteries and this system have low conversion efficiency hence to increase conversion efficiency various MPPT techniques can be used to compare the PV array voltage or current under specific atmospheric conditions [1]. Modelling of the Solar Cell.

Solar photovoltaic is a system to convert light energy into electrical energy. The solar photovoltaic system produces easy and clean energy. The solar systems can be installed on a house or big industry. The solar panels use the solar irradiance to generate electrical energy. The simple equivalent circuit of a solar cell is a photocurrent as a current source in parallel with a diode. The output of the photovoltaic panel depends on the light

falling on the cell. The circuit diagram shows the I-V characteristics of the Photovoltaic cell [2].

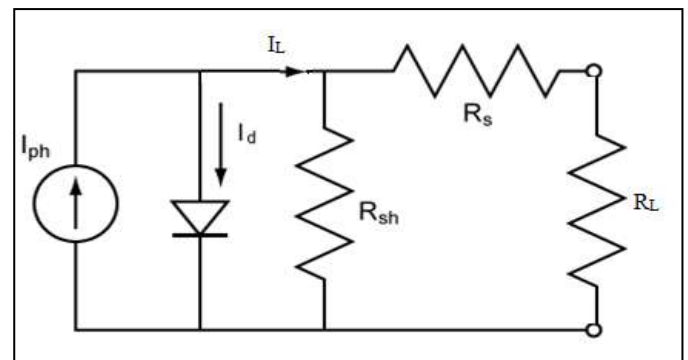


Fig. 1(a) Equivalent circuit of photovoltaic cell

The current flowing through the diode is

$$I_L = I_{ph} - I_0 \left(e^{A(V_L + I_L R_s)} - 1 \right) - \frac{V_L + I_L R_s}{R_{sh}}$$

Where:

I_L is the load current (A)

I_{ph} is the photocurrent (A) I_0 is the diode current q is the charge of electron = 1.6×10^{-19} coulomb.

K is the Boltzmann constant (j/K)

T is the temperature of cell (K)

R_s and R_{sh} are the series and shunt resistors of the cell, respectively

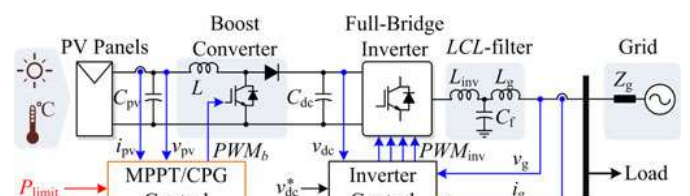


Fig. 1 (B). Hardware schematic and overall control structure of a two-stage singlephase grid-connected PV system.

The I-V characteristic of a solar panel is given by figure 2

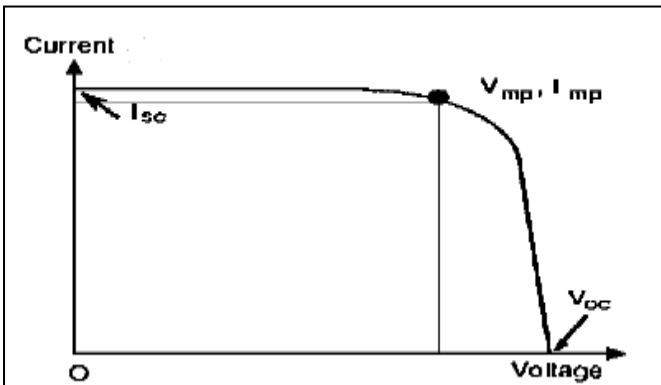


Fig. 2: I-V characteristic of a solar panel

The product of voltage and current characteristic shows power and we obtain the P-V characteristics of photovoltaic panel as shown in figure 3.

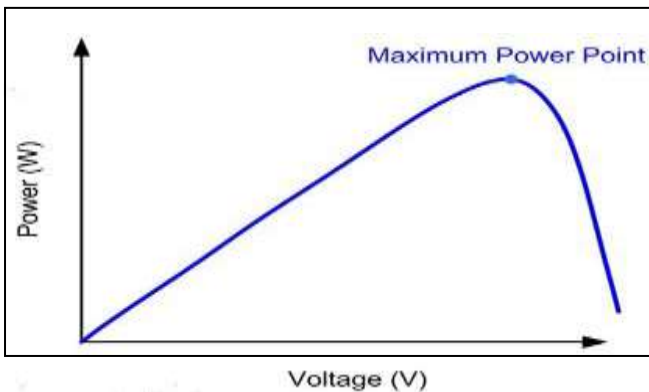


Fig. 3: P-V characteristic of a photovoltaic panel

II. COMMONLY USED MPPT TECHNIQUES

Constant Voltage Method

This method is the easiest method to achieve MPP. This method measures the photovoltaic panel voltage by using PI controller to adjust the duty cycle of the dc to dc converter in order to maintain the PV voltage near the MPP. The output voltage is regulated to a constant value under all conditions and one in which the output voltage is regulated based on a constant ratio to the measured open circuit voltage (VOC). [3]

A. Open Circuit Voltage Method

In this method the voltage of PV cell at maximum power point (V_{mpp}) is linearly proportional to the open circuit voltage V_{oc} . This V_{mpp} can be calculated as

$$V_{mpp} = K_1 V_{oc}$$

The value of K has always between 0.7 to 0.8 V_{oc} is updated as per the time for compensation of any temperature change.

Once the value of K_1 is known the maximum power point voltage (V_{mpp}) can be determined by measuring V_{oc} But when we measure V_{oc} the power converter has to be shut down for short time so more power loss will occurs. Another disadvantage

of this method is that it is unable to track the maximum power point and one more disadvantage is that the MPP reached is only an approximation. [4][5].

B. Short Circuit Current Method

This method explains the relationship between photovoltaic current (I_{ph}) to the corresponding maximum power current and short circuit current I_{sc} . And determines the current factor K by using the relation. $I_{mp} = K I_{sc}$ The value of K lies between 0.8 to 0.9

C. Incremental conductance method

The Incremental conductance method determines the MPP without disturbing the operating point. If this condition is not achieve the MPPT operating point must be perturbed can be calculated using the relation between dI/dV and $-I/V$.

At MPP the slope of PV curve is zero.

$$\begin{aligned} \left(\frac{dP}{dV}\right)_{mpp} &= 0 \\ \frac{d(VI)}{dV} &= 0 \\ I + V\left(\frac{dI}{dV}\right)_{mpp} &= 0 \\ V\left(\frac{dI}{dV}\right)_{mpp} &= -I \\ \left(\frac{dI}{dV}\right)_{mpp} &= \frac{-I}{V} \end{aligned}$$

The above equation represents the conductance of the solar PV panel at any instant. When this conductance equal to the conductance of solar cell then Mpp is reached. Here we are getting both the voltage and current simultaneously. Hence the error due to change in irradiance is reduced. the disadvantage of this method is that complexity increases as well as and the cost of implementation is unaffordable. So this method is used for highly complicated systems. Hence the perturb and observe methods are most widely used. [3]

D. Perturb and observe Method

This is simplest method of MPPT. In this method we use voltage sensor to sense the PV voltage. So its implementation cost is low. The algorithm of this method is very simple but it reaches very close to the MPP. But not at MPP. and keeps disturbing on both the direction. this algorithm has reached very close to the Mpp. and we can set an appropriate error limit. This is called as P&O method. It is mostly used due to its reliability.

1) Advantages:

P&O is most commonly used in practice because

- 1) Its algorithm is simple.
- 2) Easy to implementation.
- 3) It has better accuracy than others methods.

E. Drawbacks:

There are some limitations of P&O method are

1. This algorithm cannot determine the actual MPP. The output power always oscillates around the MPP but cannot reach at Mpp. This oscillation problem can be decreased by using various minimization techniques. [3]

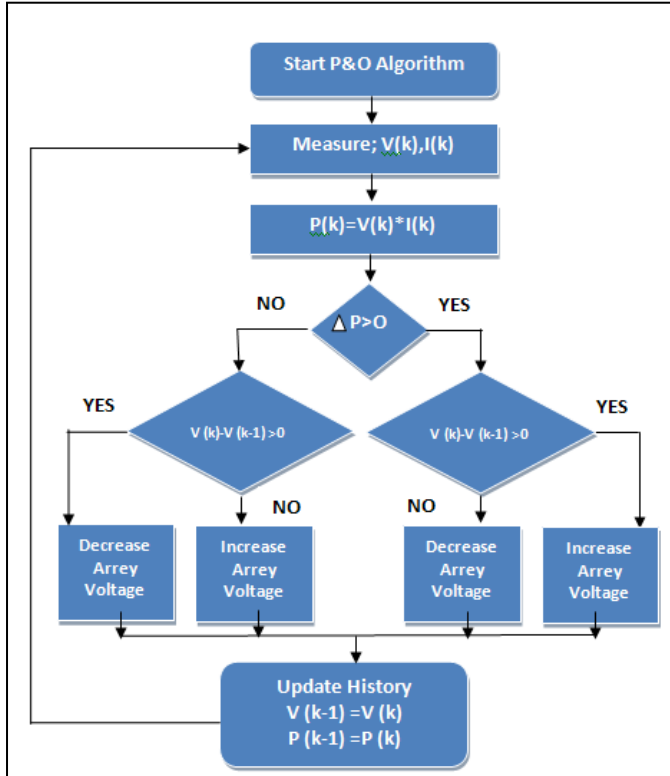


Fig. 4: Algorithm of P & O Method

III. BLOCK DIAGRAM OF PROPOSED SYSTEM

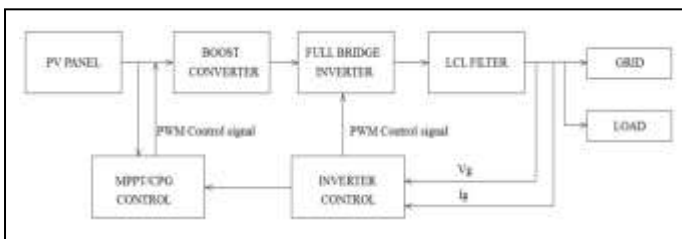


Fig. 5: Block diagram of a two-stage single phase grid-connected PV system.

A. Boost converter

PV module is connected to output resistive load through DC-DC boost converter. For switching in boost converter MOSFET is used. The duty ratio of boost converter is controlled by pulse generated via MPPT technique. These pulses are generated by comparing a carrier wave to control signal. Elements, inductor (L) and capacitor (C), values are selected through following equations provides very high impedance at fundamental frequency hence draws negligible current.

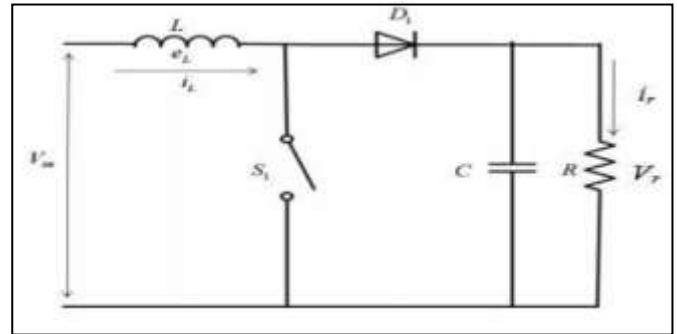


Fig. 6: DC-DC boost converter

IV. DESIGN AND DEVELOPMENT OF TWO-STAGE SINGLE PHASE GRID-CONNECTED PV SYSTEM

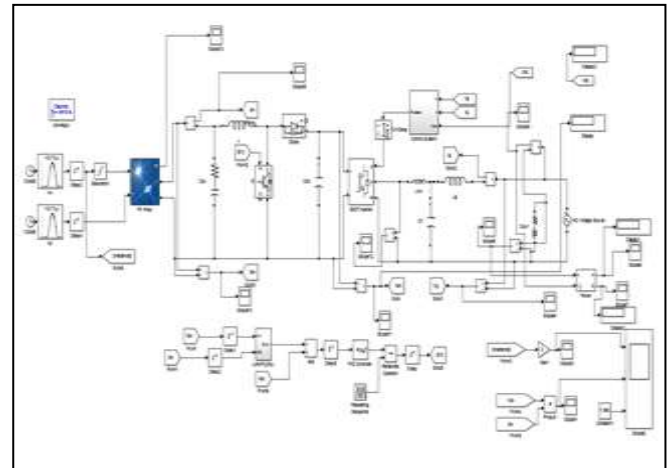


Fig. 7: Simulation model of two-stage single phase grid-connected PV system.

The PV Array block implements an array of photovoltaic (PV) modules. The array is built of strings of modules connected in parallel, each string consisting of modules connected in series. The PV Array block has two inputs that allow you to supply varying sun irradiance (input I_r in W/m^2) and temperature (input T in deg. C) data. The PV Array consists of one string of 40 BP SOLAR BP365TS 10 modules connected in series. At 25 deg. C and with a solar irradiance of $1000 W/m^2$, the string can produce 1500 W. PV array output Voltage is 110V.

The output of the solar panel is a DC voltage of very low magnitude. Hence a boost converter is required for boosting the voltage to higher level without use of the transformer. The primary parts of a support converter are an inductor, a diode and a high recurrence switch Pv panel is connected to boost converter. The P & O Algorithm CPG control is implemented in the boost converter. Then DC voltage is applied to the full bridge inverter where DC supply is converted into AC. Output of an Inverter is controlled through PWM control system. Then output of inverter is fed to LCL filter where output signals are filtered and then fed to the grid. Single phase load is connected at the load end.

V. SIMULATION RESULTS & DISCUSSION

Fig. 8 (a & b) shows the performance of the conventional P&O-CPG method and Fig. 9 (a & b) shows the proposed high performance P&O-CPG method with two daily conditions. The overshoots and power losses are significantly reduced by the proposed solution and a stable operation is also maintained. The algorithm also has a selective behavior to only react, when the fast irradiance condition is detected.

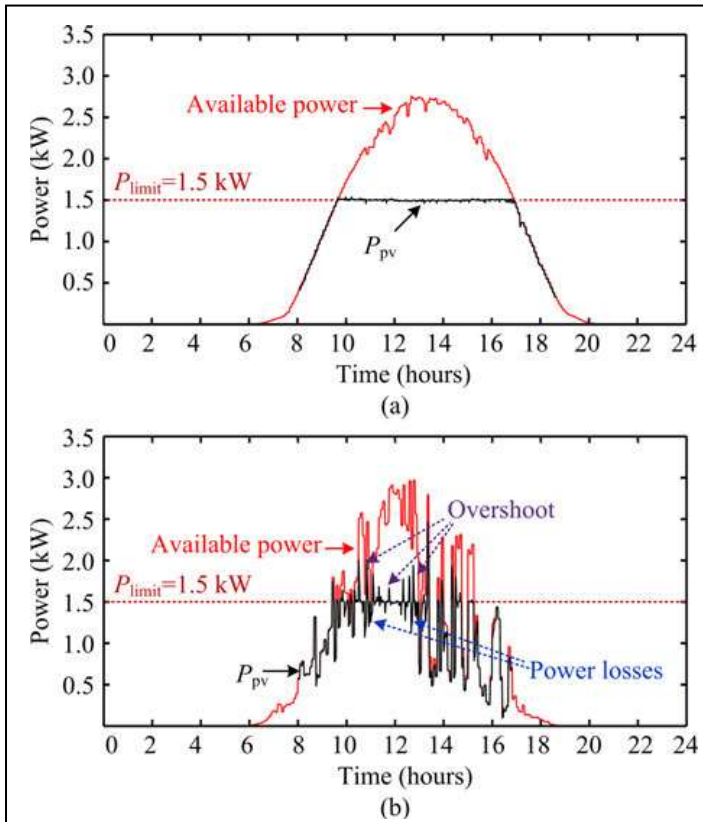


Fig. 8: Results of the P&O-CPG algorithm under two daily conditions: (a) clear day and (b) cloudy day.

C. Experimental Verification

Solutions to improve the dynamic performance of the P&OCPG algorithm have been discussed previously. Parameters of the proposed high-performance P&O-CPG algorithm are designed as: $\gamma = 10$, $k = 0.715$, $\epsilon_{inc} = 50$ W, $\epsilon_{dec} = 100$ W, and $\epsilon_{ss} = 30$ W. Experiments are carried out referring to Fig. 1(B), and the system parameters are given in Table I. In the experiments, a 3-kW PV simulator has been adopted, where real-field solar irradiance and ambient temperature profiles are programmed.

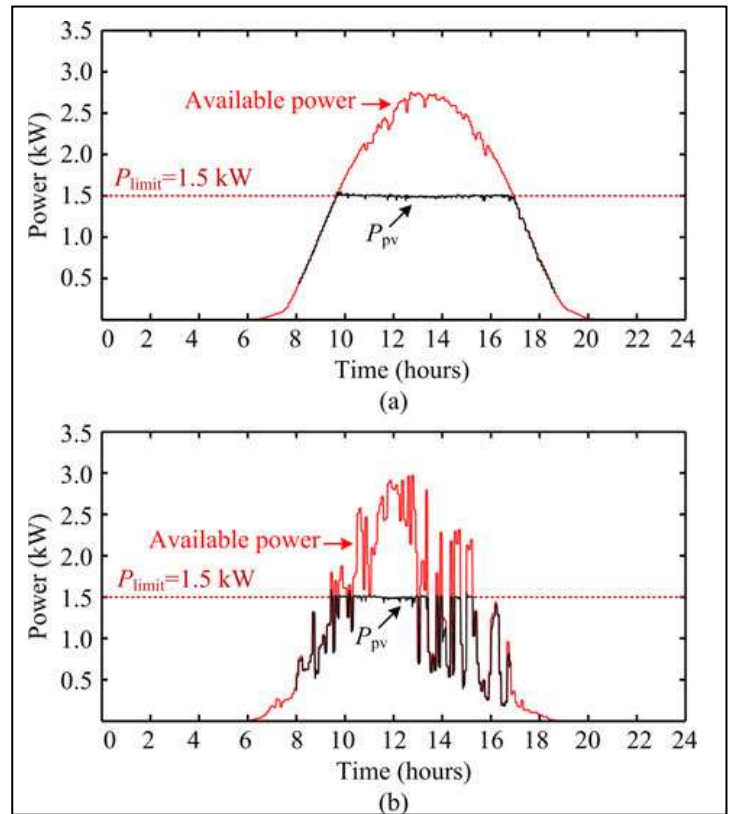


Fig. 9: Results of the proposed high-performance P&O-CPG algorithm under two daily conditions: (c) clear day and (d) cloudy day.

VI. CONCLUSION

A high-performance active power control scheme by limiting the maximum feeding power of PV systems has been proposed in this paper. The proposed solution can ensure a stable constant power generation operation. Compared to the traditional methods, the proposed control strategy forces the PV systems to operate at the left side of the maximum power point, and thus it can achieve a stable operation as well as smooth transitions. Experiments have verified the effectiveness of the proposed control solution in terms of reduced over-shoots, minimized power losses, and fast dynamics. Notably, for single-stage PV systems, the same CPG concept is also applicable. However, in that case, the PV voltage operating range is limited and minor changes in the algorithms are necessary to ensure a stable operation.

APPENDIX

Parameters	Specification
PV Panel	3 KW, 110 V, 3.73 A
Boost converter inductor	$L = 1.8$ mH
PV-side capacitor	$C_{pv} = 1000$ μ F
DC-link capacitor	$C_{dc} = 1100$ μ F

LCL-filter	$L_{inv} = 4.8 \text{ mH}$, $L_g = 4 \text{ mH}$, $C_f = 4.3 \mu\text{F}$
Switching frequency	Boost converter $f_b = 16 \text{ kHz}$ Full-Bridge inverter $f_{inv} = 8 \text{ kHz}$
DC-link voltage	$V_{dc} = 450 \text{ V}$
Grid nominal voltage (RMS)	$V_g = 230 \text{ V}$
Grid nominal frequency	$\omega_0 = 2\pi \times 50 \text{ rad/s}$

Table 1: Simulation Parameters

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