SIMULATION OF MPPT FOR SINGLE STAGE PV GRID CONNECTED SYSTEM

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Abstract— **This paper presents a Simulation of Maximum Power Point Tracking (MPPT) control for Grid connected PV systems. The topology considered in this project is single stage system. The Single stage system consists of PV array fed to three phase Inverter synchronized with three phase Grid. Different MPPT algorithms reported in literature have been classified based on topology of Grid interface. In this work, Modified Incremental Conductance with δ control has been employed. Simulation of this single stage Grid tied PV Inverter is done using MATLAB/ Simulink. Different cases have been considered for simulation and validation under varying irradiation and temperature conditions. Also the MPPT control under varying grid parameters has also been analyzed. The Simulation results have been presented in detail and the results depicts that δ(delta) control modified Incremental conductance MPPT works for different values of Irradiations, Temperature and grid parameters variation and are presented in this work.**

Index Terms—**MPPT, Single Stage, Load angle(delta), Photovoltaics, Incremental Conductance.**

1. Introduction

Grid-connected Photovoltaic systems usually employs two stages, the first stage is a dc-dc boost converter for boosting the PV voltage, and achieving MPPT, and the second stage is a dc-ac inverter for conditioning the output power and synchronizing with the power grid. However, such systems have drawbacks as complexity in control, lower efficiency, lower reliability, higher cost, and larger size.

On the other hand, single-stage grid-connected systems provide many advantages such as simple topology, high efficiency, high power density, and lower cost. However, achieving MPPT, while conditioning the output power and synchronizing with the power grid, is a big challenge in such systems [1].

The inverters must guarantee that the PV module is operated at the MPP, which is the operating point where the maximum energy is captured. MPPT is an essential part of any PV system. Many Maximum Power Point tracking (MPPT) methods have been developed and implemented. The methods vary in performance indices, complexity, input sensors, convergence speed, cost, range of effectiveness, implementation complexity, and in other aspects.

The general requirements for MPPT are simplicity, low cost, quick tracking under changing conditions, and small output power fluctuation. Efficient methods to solve this problem become crucially important. This paper presents a MPPT controller that enables an efficient power control using a single-stage voltage source inverter (VSI)[2].

The paper is organized as follows, section II presents literature survey, the theoretical frameworks are described in Section III. Section IV describes Incremental Conductance MPPT scheme for grid connected PV Systems. Finally, conclusion and future work have been presented in Section V.

2. Literature Survey

About 135 IEEE Journal Papers have been studied to make a survey on the basis of the MPPT schemes employed in standalone and grid connected PV Systems. It is majorly segregated as grid connected system and standalone applications. Further, classified based on the topology used in the paper i.e. Single Stage and Double Stage. Figure 1 shows number of papers in the literature about MPPT schemes employed in grid connected PV systems.

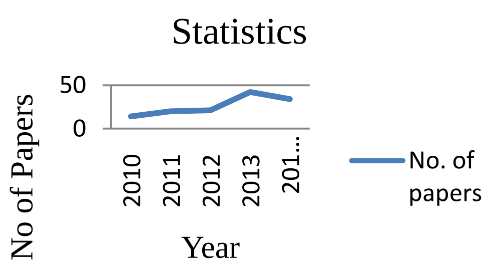


Fig. 1 No. of PV Grid Connected system Papers

Using a solar panel or an array of panels without a controller that can perform Maximum Power Point Tracking (MPPT) will often result in wasted power, which ultimately results in the need to install more panels for the same power requirement [3]. In short term, not using an MPPT controller will result in a higher installation cost. Based on the topologies used, that is single stage or double stage, the converter on which the MPPT is implemented is differs. In case of a double-stage conversion system, the MPPT technique is used to control the DC/DC converter, while in case of single-stage conversion system the

MPPT is included in the DC/AC converter control [4].

This survey gives a clear idea about the existing MPPT schemes employed in grid interfaced PV systems. Figure 2 shows the different types of MPPT schemes.

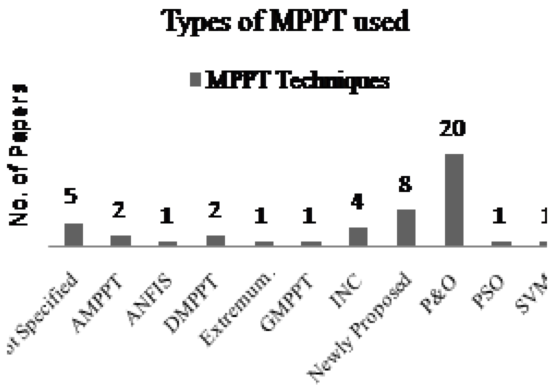


Fig.2 Types of MPPT used in Grid Connected PV systems

The main MPPT methods can be classified as Perturb and Observe (P&O), Incremental Conductance (INC). These algorithms are called “hill-climbing” methods. The P&O is one of the most used MPPT methods, because it can be easily implemented. But the advantage of Incremental conductance method is the fast and accurate tracking of the MPP without oscillations around the MPP, otherwise the complexity is increased, and hence it requires more computational time. In this paper, incremental conductance algorithm is employed

In the incremental conductance method [1], the controller must measure the incremental changes in array current and voltage to predict the effect of a voltage change. This method requires more computation in the controller, but can track changing conditions more rapidly than perturb and observe method (P&O) [5]. Like the P&O algorithm, it can produce oscillations in power output. This method utilizes the incremental conductance (dI/dV) of the photovoltaic array to compute the sign of the change in power with respect to voltage (dP/dV).

POWER TRANSFER BETWEEN TWO SOURCES

The primary objective of this PV fed Inverter synchronized with grid is to inject power from solar modules to grid. It is nothing but the power transfer between two sources. Circuit shown in fig.3 can be used to study the power transfer between two sources. The circuit consists of two ideal single phase sources of same magnitude and difference in phase angle connected in series along with a reactance.

According to the Maximum Power Transfer theorem [2], it is clear that the power flow takes places only when there is some load angle difference in the voltages. Let load angle be δ (delta). δ ranges from 0° to 180°.

$$P = 3\frac{V_1 V_2}{X}\sin\delta \qquad (1)$$

P- Maximum Power Delivered (W)

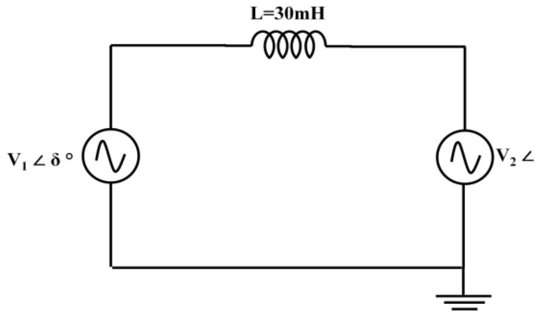


Fig. 3 Two Ideal sources in series

PV Voltage, $V_{pv}=V_1=230\ V\angle\delta°$, Load angle-δ
Grid Voltage, $V_g=V_2= 230\ V\angle 0°$, Frequency-f (Hz)
Reactance, X= 2ΠfL (L=30mH)

From equation (1), we know that the maximum power is a function of δ (load angle). Hence, Power can be controlled by varying the value of δ. The block schematic of single stage PV tied grid connected system is shown in figure 4. A set of PV array is connected in combination of series and parallel, which is interfaced with a three phase inverter through a dc link capacitor across it. The value of dc link capacitor is chosen appropriately. The output of the inverter is synchronized with three phase grid/utility. A line reactance is kept in between in the inverter and grid (L=30mH). Here, the inverter is controlled by Sine PWM technique in which δ is introduced in the three phase sine reference signal for power control.

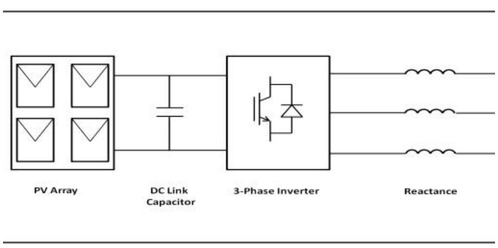


Fig 4. Block Diagram of Single Stage PV Grid Connected Systems

A. δ -Control

The load angle (δ) usually has a small value. In such band of angles, the sine function has a sharp slope, and the cosine function has a flat slope. Therefore, the active power (P_g) is deeply affected by changing δ than by changing the generator output voltage [6].

The above principle is usually used in case of conventional power generation systems. Moreover, it is applicable to grid connected PV systems [1]. This principle is applied to maximize the power produced by a grid connected PV system; as presented in [7]. Their investigations concluded that tracking with δ exhibits steady state oscillations around the MPP. Moreover, tracking with δ is made to be stable when it reaches state performance. On the other hand, the latter has a poor dynamic performance.

B. Simulation Of Single Phase PV Fed Grid with δ Control

The single stage PV grid connected system, is simulated in MATLAB/Simulink. The various simulation parameters are indicated in Table III (System Parameters). The maximum power delivered by the PV panels is $Power_{max}$ (P_m). P_m is given as the reference to calculate the value of δ (using Eqn. 2). Thus, the calculated δ is given to the sine PWM module to generate pulses to the inverter and the reference power is the maximum power, delivered to the grid. This is validated through calculations and the circuit is simulated for different values of irradiations (Q)(kW/m^2) temperature (T)(°C).

$$\delta = \sin^{-1}\frac{P\ X}{3V_1V_2} \qquad (2)$$

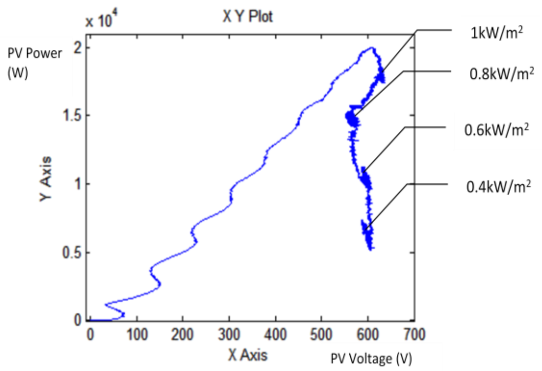


Fig .5 Array Power Vs Array Voltage

By varying the value of δ, which ranges from (0° to 180°), and the magnitude of the voltage kept constant.

Table. 1 Power for different Values of δ

δ	Irms	P	Q	S	pf
15°	6.327	1449	189	1462	0.9915
30°	12.58	2799	747	2897	0.9661
45°	18.62	3961	1636	4285	0.9243
60°	24.3	4846	2793	5594	0.8664
90°	34.36	5593	5587	7906	0.7075
120°	42.09	4838	8383	9679	0.4999
150°	46.43	2776	10420	10780	0.257
180°	48.72	-20.17	11210	11210	0.0018

The above table is taken by simulating the circuit shown in figure.6. The values of Real Power P, Reactive Power Q, Apparent Power S, Power factor (pf) are taken are the varying values of δ. Here, for analysis, δ has been considered from 15° to 180°. Because for 0 value of δ, the power flow will become zero. Hence it is omitted.

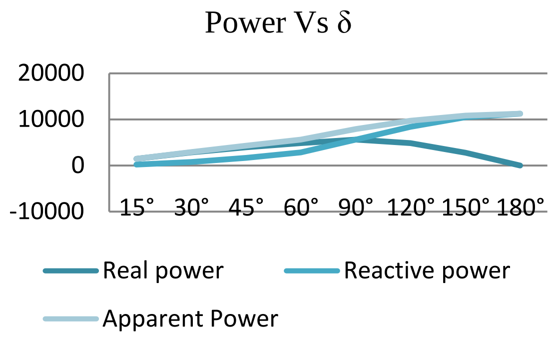


Fig 6. Power (P,Q,S) characteristics with respect to δ

From the above Figure 6, the characteristics of Real power, Reactive Power and Apparent Power are shown. For Real Power P, the value increases from its minimum value to maximum value till it reaches it maximum value at 90°. Beyond 90°, the value of real power decreases and also reaches negative value of power. Which means, the flow of power is reversed. That is the power flows from source-2 to source-1.

B. Simulation

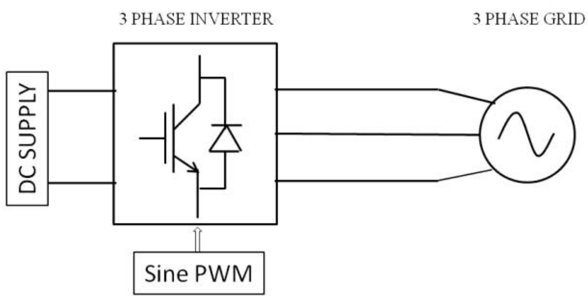
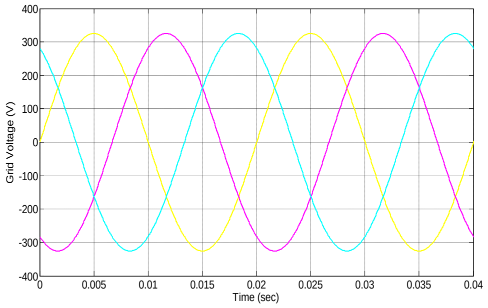


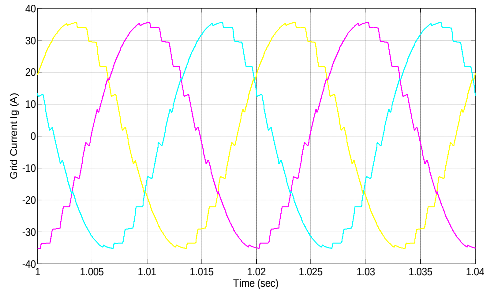
Fig 7 Block diagram single stage PV grid connected system

The load angle (δ) usually has a small value. In such band of angles, the sine function has a sharp slope, and the cosine function has a flat slope. Therefore, the active power (P_g) is deeply affected by changing δ than by changing the generator output voltage.

In fig 7, the block diagram of single stage grid connected system is shown .The above principle is usually used in case of conventional power generation systems. Moreover, it is applicable to grid connected PV systems. This principle is applied to maximize the power produced by a grid connected PV system. Their investigations concluded that tracking with δ exhibits steady state oscillations around the MPP. Moreover, tracking with δ is made to be stable when it reaches state performance. On the other hand, the latter has a poor dynamic performance.



(a)



(b)

Fig 8. Grid voltage and grid current using delta control MPPT

The different values of irradiation and temperature used for the simulation of PV fed grid. The simulation reaches its steady state at 0.2 seconds for each change in value of Q and T. In fig 8, the grid voltages and currents are shown.

As irradiation reduces, power delivered reduces. Array power with respect to array voltage is shown in Figure 5. For each change in value of irradiance and temperature, the power delivered varies accordingly. Different maximum power point of different values of irradiations are indicated in the graph above. (Fig.5). Table II gives the specifications considered for the simulation.

Table. 2 System Parameters

S.No	Parameter	Symbol	Value
PV Parameters			
1	Maximum Power of a Module	P(W)	80W
2	Standard Temperature	T(°C)	25°C
3	Standard Irradiance	$Q(kW/m^2)$	$1\ kW/m^2$
4	Open Circuit Voltage	$V_{oc}(V)$	21.29V
5	Short Circuit Current	$I_{sc}(A)$	4.72A
6	No. of strings in parallel		7
7	No. of panels in series		35
Grid Parameters			
8	Grid Voltage	$V_g(V)$	415V, 3 φ
9	Line Inductance	L(mH)	30mH
PWM			
10	Switching Frequency	f_s (Hz)	1050Hz
11	Modulation Index	M_i	1

Conclusion

A delta control MPPT is presented for single stage grid connected PV Inverters. It employs load angle control to deliver maximum power. Power is very sensitive to the change in load angle(δ). (Power is a function of Load angle, δ). The simulation results proved its efficient performance and applicability to track the MPP in a grid connected PV energy systems.

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