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# Comparative Study of Photovoltaic System Employing PI, PID and Sliding Mode Controller

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***Abstract*--The aim of this paper is to find the maximum power point of the photovoltaic system and to track it under varying atmospheric and load conditions. Here a fast and unconditionally stable maximum power point tracking method is proposed for the photovoltaic systems using sliding mode control. High tracking efficiency is ensured by the maximum power point tracking algorithm.**

***Keywords: Maximum power point tracking, MPPT, Sliding mode control, photovoltaic system,***

## I. INTRODUCTION:

Maximum power point tracking (MPPT) is a technique which inverters, solar battery chargers and similar devices use to get the maximum possible power from one or more photovoltaic devices like solar panels. Today, with the focus on greener sources of power, PV has become an important source of power for a wide range of applications. Enhancements in converting light energy into electrical energy as well as the cost reductions have helped create this growth. Even with higher efficiency and lower cost, the goal remains to maximize the power from the PV system under various lighting conditions. Solar cells have a intricate relationship between solar irradiation, temperature and total resistance that produces a non-linear output efficiency which can be analyzed based on the I-V curve. It is the purpose of the MPPT system to sample the output of the cells and apply the proper resistance (load) to obtain maximum power for any given environmental conditions. Compared to conventional power sources, it is advantageous to operate photovoltaic systems at their maximum power point (MPP). But depending on the photovoltaic arrays temperature and insolation intensity, the maximum power point varies over a wide range. Other factors that affect the maximum power point tracking are the clouding conditions, ageing of PV cells and variations in loads electrical characteristics

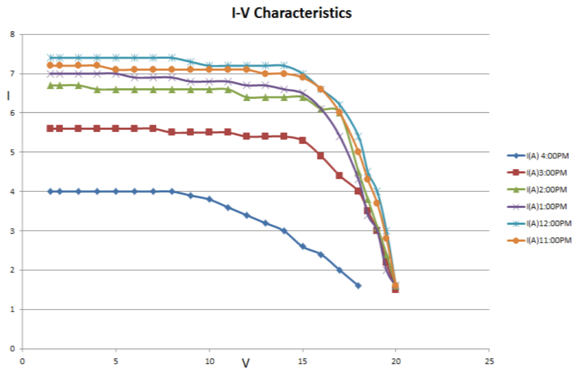
## II. SYSTEM DESCRIPTION:

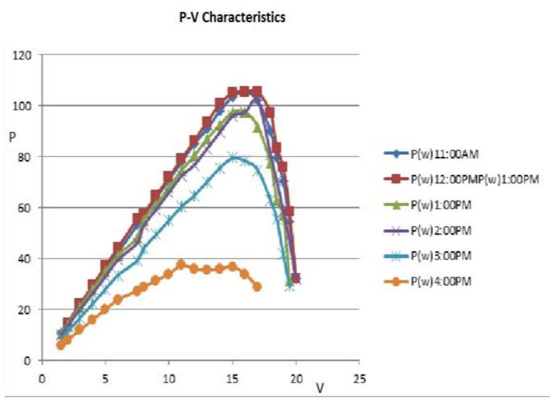
### *A. Photovoltaic system:*

A photovoltaic system (informally, PV system) consists of an arrangement of components designed to supply usable electric power for a variety of purposes, using the Sun (or other light sources) as the power source. The I-V and P-V characteristics of the photovoltaic panel are plotted at different insolation levels and the MPP at various insolation levels are found out.



Figure 1: Experimental Setup of a Photovolatic system



### 2.2 Block diagram:

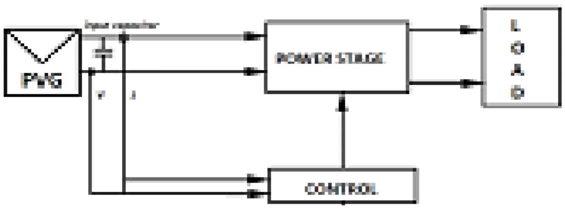



Figure 2: Block diagram

Compared to PWM based MPPT, here we propose a sliding mode controlled MPPT and is comparing with PI and PID based MPPT. This controller contributes three major advantages: by a proper choice of the switching surface, the reaction to variations in radiation is accelerated by an order of magnitude. The sliding mode controller operates as a voltage source or current source, thus providing stability from short circuit to open circuit.

## III. MATHEMATICAL MODELING OF PV CELL:

Figure 4 shows a simple model of a PV cell. RS is the series resistance associated with connecting to the active portion of a cell or module consisting of a series of equivalent cells.

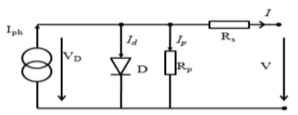



Figure 4: pv cell

Simple PV output current:

$I = I_{ph} - I_d$

$I = I_{ph} - I_s * [\exp([V+IR_s]*q/m*k*T) - 1]$

where

Is = saturation current (in the order of 10-10 A to 10-5 A)

m = diode factor

q = electron charge

k = Boltzmann constant=1.38*10-23 J/K

$I_{ph} = [I_{sc} + K_I (T-298)] * (\lambda/1000)$

where

KI - 0.0017 A/o C is cell's short-circuit current temperature coefficient

Isc - cells short circuit current at 25oC

λ - the solar insolation in kW/m2

T - the cell's temperature in K

$I_s = I_{rs}[(T_k/T_{ref})^3 \exp(qE_g(1/T_{ref}-1/T))] * A_k$

$I_{rs} = I_{sc}/[(\exp(qV_{oc}/N_s kAT)-1)]$

where

Is Saturation current

Irs Reverse saturation current

Eg bang gap energy of the semiconductor

## IV. CONTROLLER DESIGN:

PI controller will exclude forced oscillations and steady state error resulting in operation of on-off controller and P controller respectively. The speed of the response and overall stability of the system I s negatively affected with introduction of integral mode. Hence the speed of the controller is not increased by the PI controller. PI controller does not have the ability to forecast what will happen with the error in near future

By instigating derivative mode which has the ability to forecast what will happen with the error in near future, we can decrease reaction time of the controller. PID controller has all the necessary dynamics: fast reaction on change of the controller input (D mode), increase in control signal to lead error towards zero (I mode) and suitable action inside control error area to eliminate oscillations (P mode) Derivative mode improves stability of the system and enables increase in gain K and decrease in integral time constant Ti, which elevates the speed of the controller response

The SMC is a nonlinear control approach which act in accordance with the nonlinear characteristic of a boost converter. Such control mechanism is resilient even against the plant parametric variation and can compensate the modeling approximations. Also, it is characterized by a good dynamic response. In addition, the SMC is easy to implement. The first step to design a sliding mode control is to determine the sliding surface with the desired dynamics of the corresponding sliding motion.



## V. RESULTS AND DISCUSSION:

The Simulink block diagram of the PI controller is shown in Figure 5. Here a solar panel with boost converter of 15V to 30V is constructed. The output voltage of the converter is compared with the desired voltage that is the reference voltage. The resulting error is fed to a PI control which does the necessary controlling actions and the corresponding output is provided to a PWM to generate the required pulses to drive the MOSFET.

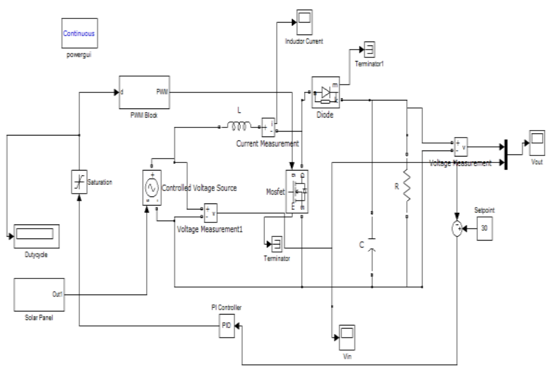


Figure 5: Simulink block diagram for maximum power point tracking of photovoltaic system using PI controller

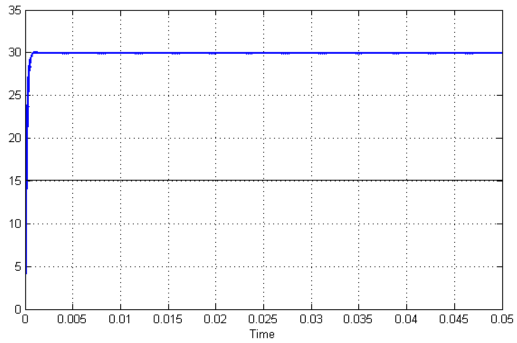



Figure 6: Simulink response for maximum power point tracking of photovoltaic system using PI controller

The responses for the output voltage was plotted which shows that the output voltage of the boost converter is maintained at the desired voltage level that is 30V which is shown in Figure 6.

The proportional gain $K_p$ was selected as 0.09 ant the integral gain $K_I$ was selected as 109.09 on trial and error basis. It was found that PI controller did not respond well to significant changes in operating points.

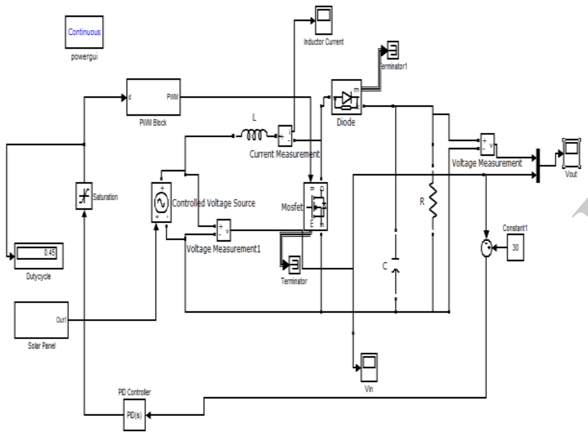



*Figure 7: Simulink block diagram for maximum power point tracking of photovoltaic system using PID controller*

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The response of the PID is (shown in Figure 8) was compared to that of the PI controller response and the corresponding results are shown in Table 1. We can see that the settling time and rise time of PID is less than that of the PI controller.

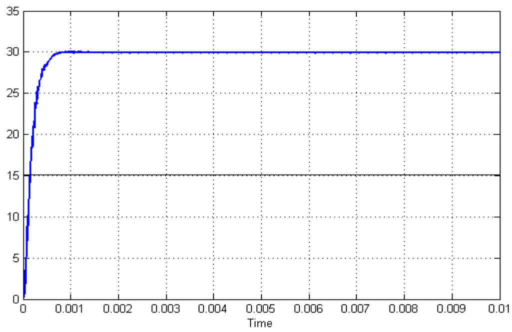


Figure 8: Simulink response for maximum power point tracking of photovoltaic system using PID controller

| Controller | Rise Time(sec) | Settling Time(sec) |
|---|---|---|
| PI | 0.0005 | 0.001 |
| PID | 0.00034 | 0.0008 |

Table 1: Comparison of PI and PID controllers

As the response of the boost converter with PI and PID controller did not respond well to the significant changes in the operating points, a SMC was designed in Simulink SimPower Systems toolbox in MATLAB. The Simulink model of the boost converter with SMC control is shown in Fig. 9. The PVG voltage and current constitute all the converter's state variables, effecting in the switching surface given by

S(v,i) = (a*i-b*v+ref)

S < 0: ON state, S > 0: OFF state

where i and v are inductor's current and input voltage and a, b and ref specify the switching surface. a and b set the slope of the PVG i-v plane, and are chosen to be non-negative, and offset is set by ref.

The response of the SMC is (shown in Figure 10) was compared to that of the PI and PID controller response and the corresponding results are shown in Table 2 from which we can see that the settling time and rise time of SMC is less than that of the PI and PID controller.

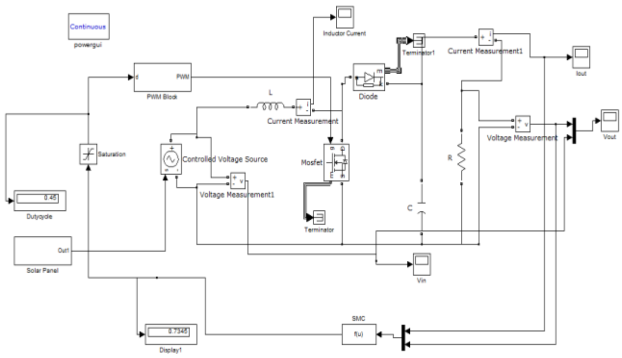

Figure 9: Simulink block diagram for maximum power point tracking of photovoltaic system using PID controller

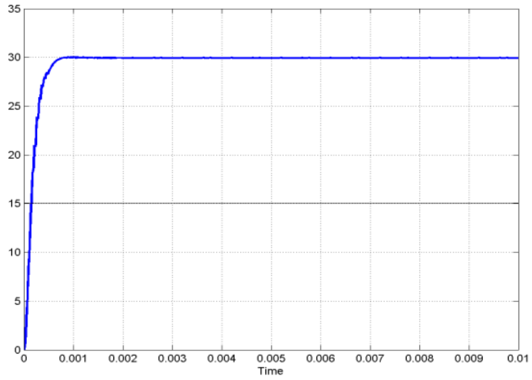


Figure 10: Simulink response for maximum power point tracking of photovoltaic system using PID control

## VI. Explanation:

| Controller | Rise Time(sec) | Settling Time(sec) |
|---|---|---|
| PI | 0.0005 | 0.001 |
| PID | 0.00034 | 0.0008 |
| SMC | 0.00029 | 0.0006 |

The results show that SMC offers better controlling action than that of conventional PI and PID

## VII. Conclusion and Future Work:

The conventional energy resources are not enough to fulfill the needs of society, that's the reason for going alternative energy sources like renewable energy sources. Renewable energy is the energy generated from natural resources.. Solar energy is the radiant light and heat from the sun, which can be converted directly into electrical energy by using photovoltaic effect. As the temperature and insolation changes the output power will change.

SMC gives a faster response when compared to PI, PID and FLC controllers. SMC provides reduced rise time and settling time. Real Time implementation of SMC for maximum power point tracking of photovoltaic systems can be done.



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