SOLAR PANEL CONTROL USING SLIDING MODE

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ABSTRACT

In this paper, a new sliding mode controller is proposed as the indirect control method and compared to a simple direct control method in order to control a buck converter in photovoltaic applications. The solar arrays are dependent power sources with nonlinear voltage-current characteristics under different environmental conditions. From this point of view, the DC/DC converter is particularly suitable for the application of the sliding mode control in photovoltaic application, because of its controllable states. Solar tracking allows more energy to be produced because the solar array is able to remain aligned to the sun. This method has the advantage that it will guarantee the maximum output power possible by the array configuration. Problems and possible improvements will also be presented.

KEYWORDS— *PV Model, Sliding Mode Controller, Buck Converter, LDR comparison, Maximum Power Point Tracker.*

I. INTRODUCTION

In remote areas the sun is a cheap source of electricity because instead of hydraulic generators it uses solar cells to produce electricity. While the output of solar cells depends on the intensity of sunlight and the angle of incidence. It means to get maximum efficiency; the solar panels must remain in front of sun during the whole day. But due to rotation of earth those panels can't maintain their position always in front of sun. This problem results in decrease of their efficiency. Thus to get a constant output, an automated system is required which should be capable to constantly rotate the solar panel. The SLIDING MODE CONTROL (SMC) was made as a prototype to solve the problem, mentioned above. It is completely automatic and keeps the panel in front of sun until that is visible. "The unique feature of this system is that instead of taking the earth as its reference, it takes the sun as a guiding source. Its active sensors constantly monitor the sunlight and rotate the panel towards the direction where the intensity of sunlight is maximum."

The rest of the paper is organized as follows: Section II explains the proposed system. Section III describes the analysis of system. Section IV explains the pertaining theory required for lucid understanding of the proposed system. Section V concludes the work with results and also throws a light towards the future work.

II. PROPOSED SYSTEM

Our proposed system for solar panel control using sliding mode is represented by the block diagram shown in Fig. 1.

The various stages of operation in our system are:

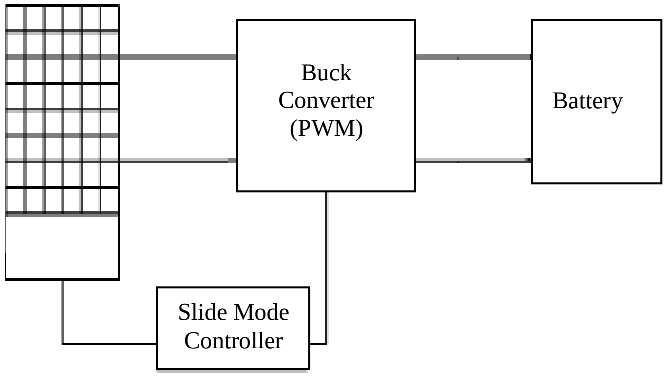
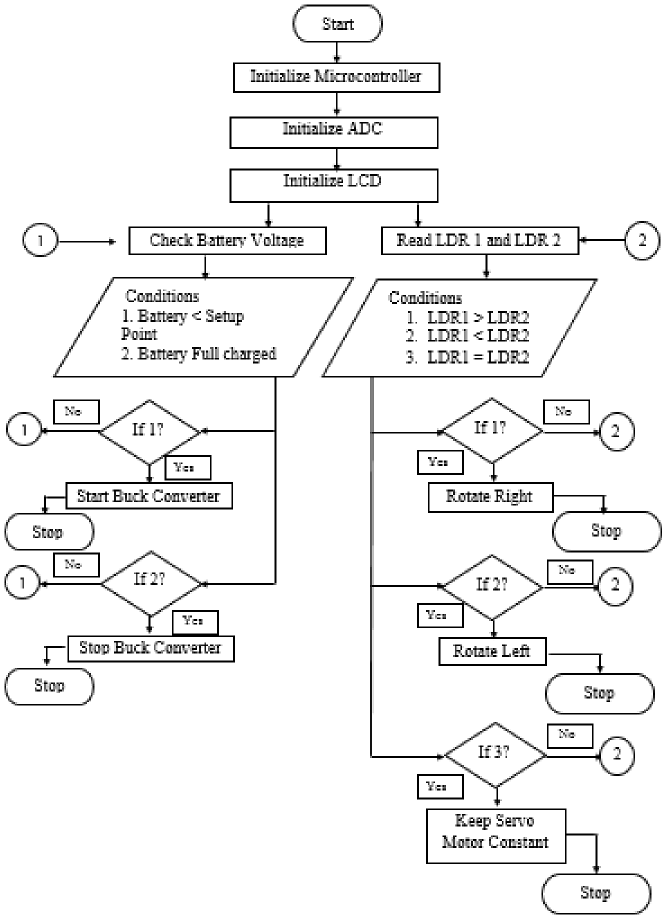


Figure 1. Block Diagram of the Proposed System

III. SYSTEM ANALYSIS



IV. THEORETICAL BACKGROUND

A. PV Model

This system use a PV system composed of N in series cells and P in parallel cells. It is connected to a converter in order to increase or decrease the desired voltage. After that, is connected directly to the load. The switching frequency is controlled by a sliding mode controller.

In the past, there have been different types of models to estimate the non linear equations of the photovoltaic module. Models like Anderson's, Blesser and the most common the one diode model. All these models present a good approach into estimating the solar cell voltage and currents but most of them need too much computational power or need information not available in the manufacturer's sheet. A more suitable equation will be used where all the information needed can be found in the manufacturer's sheet. The PVM model is the following four equations.

$$I(V) = \frac{Ix}{1 - \exp\left(\frac{-1}{b}\right)} \cdot \left[1 - \exp\left(\frac{V}{b \cdot Vx} - \frac{1}{b}\right)\right] \quad (1)$$

$$P(V) = \frac{I_x}{1 - \exp(-1/b)} \cdot \left[1 - \exp\left(\frac{V}{b \cdot V_x} - \frac{1}{b}\right)\right] \quad (2)$$

$$Vx = s \cdot \frac{Ei}{Ei_N} \cdot TCV \cdot (T - T_N) + s \cdot V_{max} - s(V_{max} - V_{min}) \exp\left(\frac{E_i}{E_{iN}} \ln\left(\frac{V_{max} - V_{op}}{V_{max} - V_{min}}\right)\right) \quad (3)$$

$$Ix = p \cdot \frac{E_i}{E_{iN}} \cdot [I_{sc} + TC_i \cdot (T - T_N)] \quad (4)$$

The first two equations (1) and (2) describe the relationship of the current and power with respect to the voltage. The PVM model takes into consideration temperature, *T*, and effective irradiance, *Ei*, over the PVM and the Standard Test Conditions, STC, i.e. *TN* is 25ºC and *EiN* is 1000 W/m2. The manufacturer data sheet will provide the temperature constant for the voltage, *TCV*, the temperature constant for the current, *TCi*, the open circuit voltage under STC, *Voc*, short circuit current under STC, *Isc*, and the PVM characteristic constant, *b*. Also, most of the manufacturers will provide the open circuit voltage, *Vmax*, when *Ei* is more than 1200 W/m2 and *T* is 25 o C and the open circuit voltage, *Vmin*, when *Ei* is less than 200 W/m2 and *T* is 25 o C[1] *Vmax* is approximately *1.03***.***Voc* and *Vmin* is approximately *0.85***.***Voc*.This model considers the useful data given by the manufacturer while no additional parameters are required, i.e. thermal voltage, diode reverse saturation current, band gap for the material, etc. Also, the PVM model is continuous and differentiable with respect to the voltage. The open circuit voltage at any *T* or *Ei*, *Vx* is given by (3) and is calculated when the current of operation is zero. *Ix*, the short circuit current at any *T* or *Ei*, is calculated when the voltage of operation is zero and is given by (4).

B. Sliding Mode Controller Surface

A sliding mode controller is a variable structure control where the dynamics of a non linear system is altered via the application of a high frequency switching control. In sliding mode control, the trajectories of the system are forced to reach a sliding manifold of surface, where it exhibit desirable features, in finite time and to stay on the manifold for all future time. It is achieved by suitable control strategy. To apply sliding mode control we have to know if the system can reach the sliding manifold. Once the systems reach the sliding manifold, the controller has to force the system to stay in the manifold for all future time. To design the sliding mode controller we have to select the desired surface. We want to obtain the maximum power that can be extracted from the PV module at the given factors. A typical P-V curve for a PVM is given by Fig. 2.

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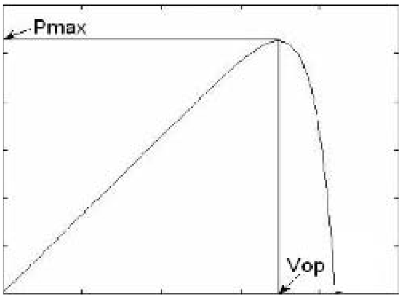

Figure 2. Power vs. Voltage

Clearly, Fig. 2 shows that the maximum power occurs at a given optimal voltage, *Vop*, which it smaller that the open circuit voltage, *Vx*. If we derivate the power with respect to the voltage we obtain the following equation [1]:

$$\frac{\partial P(V)}{\partial V}=\frac{Ix-Ix\cdot exp\left(\frac{V}{b\cdot Vx}-\frac{1}{b}\right)}{1-exp\left(\frac{-1}{b}\right)}-V\cdot\frac{-Ix\cdot exp\left(\frac{V}{b\cdot Vx}-\frac{1}{b}\right)}{b\cdot Vx-b\cdot Vx\cdot exp\left(\frac{-1}{b}\right)} \quad (5)$$

At the knee of the P-V curve is the maximum power of the PVM. Also at the knee, the derivative of power with respect to voltage is zero. Solving (5) for *V* we obtain the optimal voltage, *Vop*. Unfortunately, (5) is a transcendental function that cannot be solve for *V*. To solve this problem the Linear Reoriented Coordinates Method will be used to approximate the optimal value for the voltage to obtain the maximum power as given by (6).

$$Vop = Vx + Vx*b*\ln(b - b*\exp(-1/b)) \quad (6)$$

Where *Vx* is the open circuit voltage, *b* is the characteristic constant for the PVM. To obtain the optimal current, *Iop*, (6) is substituted by (1). Finally, knowing that we can formulate our sliding manifold as the following:

$$S=1/2 -1/2sign\ (Vop-V) \quad (7)$$

C. Buck Converter

The buck-converter is similar for both the AT90S4433 and the ATtiny15. They consist of one P-channel MOSFET switching transistor driven by the AVR via one bipolar NPN transistor. The switching transistor is connected to an inductor, a diode and a capacitor (see Figure 3). An additional diode prevents the battery from supplying voltage into the microcontroller when the power is disconnected. When the switching transistor is on (illustrated by a switch on the figures below) the current will flow like Figure 3(A) illustrates. The capacitor is charged from the input via the inductor (the inductor is also charged up). When the switch is opened (Figure 3(B)), the inductor will try to maintain its current-flow by inducing a voltage. The current flows through the diode and the inductor will charge the capacitor. Then the cycle repeats itself. If the duty cycle is decreased, by shorter on time, longer off time, the voltage will decrease. If the duty cycle is increased (longer on timer, shorter off time), the voltage will increase. The buck-converter is most efficient running on a duty cycle of 50%.

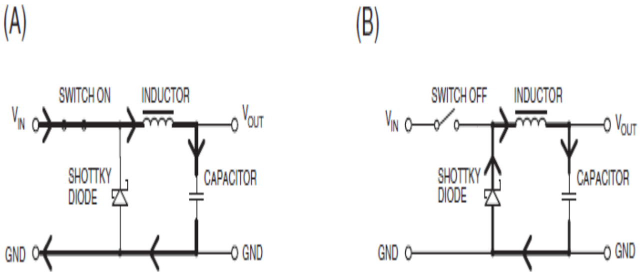

Figure 3. Buck Converter Switching Principle

V. CONCLUSION AND FUTURE SCOPE

The proposed algorithm uses a non-inverting Buck converter in order to easily change the operation mode of the converter that can be necessary if the optimal voltage of the PV module is lower than the battery voltage. The proposed algorithm is capable of calculating the optimal voltage with little error. The proposed controller only requires the array output voltage and the optimal voltage which is continuously computed.

From the simulation results is evident that a maximum power is tracked and achieved by the proposed sliding mode controller under constant and varying ambient temperature and solar irradiance and delivered, with the losses in the converter, to the battery increasing the current that is charging the battery which, eventually, will reduce the charging time.

Solar power improves energy efficiency and is therefore very beneficial for Third World countries. Solar power electricity reduces the costs of conventional power for built up cities, and is cheaper for industrial and commercial purposes

to run their operations. This leaves the use of PV systems to generate power for most of the developing world's population in rural areas.

1. RTC Based:-Interfacing RTC will automate the project. The street lights will turn ON at the specified time set in it.
2. All DC operating device can run on solar power.

This project will be beneficial in:-

1. Conserving Non Renewable Energy Resources.
2. Reduction of Energy usage.
3. Perfect for supplying power to remote radio and communication posts and water pumps.
4. Perform well as mounts for residential PV system.

ACKNOWLEDGMENT

We would like to thank the support centre of MathworksInc and all its bloggers for their prompt support to answer our questions and doubts unconditionally. We would also like to thank our teacher and guide Prof. Mr S. L. Chavan for his continuous help regarding our paper. Furthermore, we also thank the IEEE associates for providing a large collection of papers based on image processing, which were of great help in studying, analysing and selecting the right path towards our goal in the project.

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