Low Cost Maximum Power Point Tracking Method for Solar Battery Charging

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Abstract **- In this paper, we propose a low cost charger circuit with a maximum power point tracking method (MPPT) that is a key factor in photovoltaic systems. The solar panel output voltage, which is known to be generated by series connected solar cells (also called as photovoltaic cells), was adjusted to a constant voltage to maximize the transferred power even at different intensities of sunshine. By modifying the feedback circuit of a commercially available buck converter, we managed to constantly adjust the operating voltage of the solar panel to its point of maximum power being a different version of maximum power point tracker.**

***Keywords*–MPPT, Battery charging, Photovoltaic, Solar Power**

I. Introduction

Photovoltaic cells, founded by French physician Edmond Becquerel in 1839, produce electricity directly from sunlight [1].Series connected photovoltaic cells are used in solar panels that are used to produce direct current. A solar power system is a considerably inexpensive and practical solution for small-scale power requirements but requires an energy storage part that is generally charged during power generation (i.e. during a sunny day). Today's most common cell is a mass manufactured single p-n junction Silicon (Si) cell with efficiency up to 20 % [2].

The photovoltaic cells must be operated at a single operating point where the current and voltage of the cell yield maximum power output. Moreover, the impedance mismatching due to direct connection between solar panel and the load (battery) may reduce the output power level. For this purpose, DC-DC converter must be used between solar panel and the battery. In addition to impedance mismatching; light intensity dependent, non-linear current-voltage characteristic of photovoltaic systems require further tracking of maximum power transfer point. In the literature, the solution of this non-linearity problem is known as Maximum Power Point Tracking (MPPT) [3].

There are numerous MPPT techniques in the literature such as Perturbation and Observation, Incremental Conductance Method, Current Sweep Method and Constant Output Voltage Method. In these methods, the duty-cycle of the converter is modified. Some of them use sliding mode control, neural networks techniques to achieve them. They utilize digital signal processors or microprocessors with algorithms which of those require many calculations and may have stability problems, and most important of all, require additional power. All these methods are summarized and briefly described in [3, 4]. The ordinary MPPT methods that do not use any high performance processors may not work with higher efficiency but implementation is easier and more suitable for the low-cost systems. In low power photovoltaic applications such as police vest [5], traffic lights [6], parking payment kiosks, bus station lightening, ordinary MPPT methods are preferred.

A simple MPPT method is introduced in this paper. The method keeps constant the input voltage of a buck converter by using simple feedback circuit using a comparator. The proposed method is named constant input voltage (CIV) method by the authors of this paper. It can be easily implemented using low cost analog circuits with low implementation complexity. The method can easily be applied not only to the buck converter but it can also be applied to the other converters such as boost and buck-boost converters for many applications. The proposed method and circuit can be used to charge the battery of aforementioned systems and can be used in DC-DC converter circuit side of such low-power systems.

II. Photovoltaic Power Systems

Photovoltaic power systems mostly consist of the blocks shown in Figure 1. Either, the operating system is DC or AC (with a DC-AC inverter), they require an energy storage part which is mostly a rechargeable battery. Charging can be operated by a DC-DC (buck) converter.

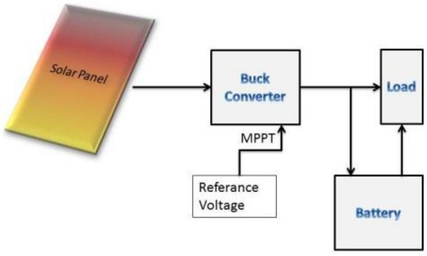

Figure 1. Photovoltaic Power System Blocks

As stated in previous section, photovoltaic cells have a low efficiency, that is, the ratio of maximum generated power and absorbed sun light density (W/m^2) is below 20%. Also the sun light density during a day cannot always be kept at a constant level. With these challenges, maximum power transfer must be ensured for any sun light density. To present the method, first the I-V characteristic of a single photovoltaic cell should be given.

A. Solar Cell Model

To characterize a solar panel, cell must be modelled mathematically which is similar to the diode equation because of solar cell's p-n junction. Referring to the circuit in Figure 2, one may write

$$I_0 = (I_1 - (I_S e^{v_D/V_T}) - \frac{V_0}{R_P})/(1 + \frac{R_S}{R_P}) \qquad (1)$$

where V_D is the forward diode voltage, V_T is the thermal voltage at 25^{0}C and it is 25mV, V_o is the output voltage, I_S=1.10^{-11} A,R_P and R_S represent the shunt and series resistors that are empirically set, respectively. Typical values are R_P =600Ω and R_S =0.01Ω. The generated current I_1 only depends on the intensity of sunlight.

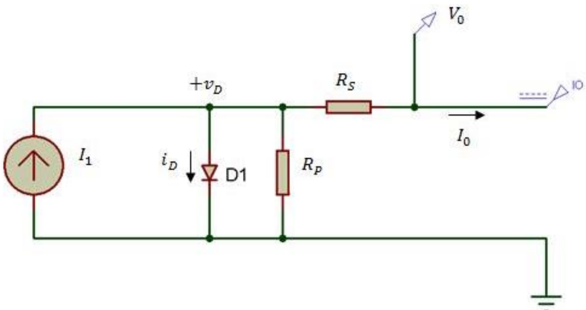

Figure 2. Basic model of a photovoltaic cell

A typical I-V characteristic curve is shown in Figure 3. Each of the curves corresponds to different intensities of sunlight. For each of the currents, the maximum power point is located close to a common vertical line which can be said to be at V=0.6V for a single cell. Thus, for a solar panel of N photovoltaic cells, this theoretical voltage value converges to N*0.6V (i.e. for a solar panel with 36 cells, we have 18 V).

B. Maximum Power Point Tracking

There exist many methods in literature for MPPT. The Perturbation and Observation Method [7] operates by periodically perturbing the array terminal voltage and comparing the solar panel's output power that of the previous perturbation cycle. Incremental Conductance Algorithm [7] uses the source incremental conductance method as its MPP search algorithm. Dynamic Approach Method [8] employs the ripple at the array output to maximize the array power by dynamically extrapolating the characteristic of the photovoltaic array. In Constant Voltage Method, the photovoltaic panel voltage is compared with a constant reference voltage that corresponds to the MPP voltage under specific ambient conditions [9]. The error signal is used to change the duty-cycle of a DC-DC converter between the solar panel and the load (or battery), so as to make the solar panel voltage equal to the MPP voltage.

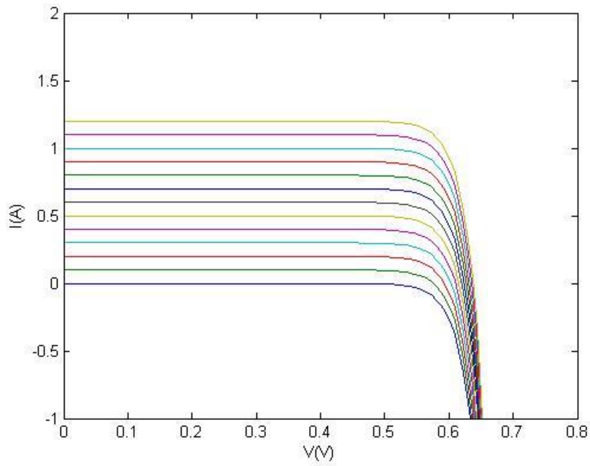

Figure 3. Characteristic I-V curves of a solar cell.

If the maximum power point is more likely to stay at the same voltage level theoretically as in Figure 3, it would make sense to adjust the solar panel to that voltage for each current, which are 0.5 V for a single cell and 18V for a solar panel with 36 cells as used in our experiments.

III. BUCK CONVERTER AND PROPOSED MPPT

A switching converter consists of capacitors, inductors, and switches. All these devices ideally do not consume any power, which is the reason for the high efficiency of switching converters. The switch is realized with a switched mode semiconductor device, usually a MOSFET. If the semiconductor device is in off-state, its current is zero and hence its power dissipation is zero. If the device is in on-state (i.e. saturated), the voltage drop across it will be close to zero. Thus, the dissipated power will be very small [10].

In our experiments, operating at maximum power point is controlled by chosen buck converter integrated circuit. It is a buck converter that gives a regulated constant output voltage by means of a feedback from the output voltage.

Buck converter's 4th pin is normally connected to output voltage as feedback.In our proposed method, the feedback taken from output voltage is disconnected and replaced with a zener diode instead, to make the feedback voltage constant. With this modification, buck converter's duty-cycle is fixed to a specific value. As a property of buck converter, in this state, the variation of D(duty-cycle) value changes the input voltage value, which is also the voltage across the terminals of the solar panel. By this way, we are able to adjust each single cell terminal voltage to 0.5V or 18V for our panel, and thus can ensure maximum power transfer. It yields to a modified version of the constant voltage method; namely, Constant Input Voltage (CIV) method.

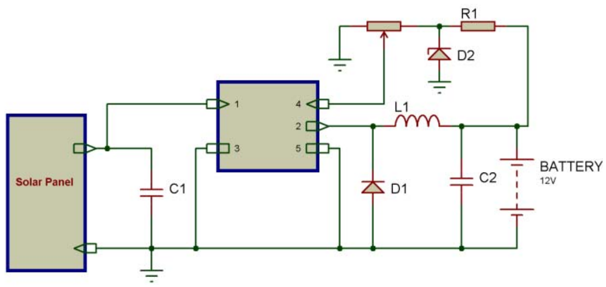

Figure 4. The charger system

Since the buck converter's feedback signal can now be adjusted independently from the output, the battery voltage can be adjusted up to 14.7V which is the full charge voltage of the battery. However, without the modification of the circuit, the buck converter would act as a simple voltage regulator and the battery voltage would stay at the same level. But it is observed that the solar panel voltage stays constant due to our proposed method when the battery voltage changes from 12V to 14.7V.

IV. Experimental Results

An experiment was made in a sunny day, at 120000Lux while getting maximum current from the solar panel. The I-V characteristic is as shown in Figure 5.

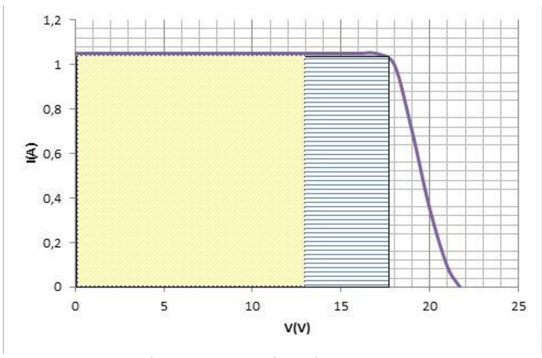

Figure 5. Transferred power

Referring to Figure 5, at the maximum solar panel current, the solid area represents the power transferred when connecting the battery directly to solar panel, whereas the dashed area represents the gained power transfer by using the buck converter and the proposed MPPT method.

V. Conclusion

In this paper, simulation and realization of a solar battery charger circuit was made with an MPPT method that is very simple to set and has very low cost. The feedback terminal of the integrated circuit is usedfor the MPPT and such implementation forces the buck converter's duty-cycle to transfer maximum power from solar panel. To do that, instead of output voltage of buck converter, the input voltage is adjusted to the constant maximum power voltage. The proposed CIV method brings simplicity and low cost control to small scale systems, which does not require any microcontroller that increases the consumed power of the whole system.

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