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EXTREME POWER POINT TRACKER OF A LARGE PHOTOVOLTAIC SYSTEM BATTERY CHARGE CONTROLLER & REDUCING WEATHER EFFECT

Md. Hasibur Rahman[1], Md. Tanvir Yeasin[2], and Mohammad Alaul[3]

E-mail: md.rahman.hasib@gmail.com

Abstract: Photovoltaic cells have a complex relationship between their operating environment and the maximum power they can produce. It shows non-linear I-V characteristics and that vary with solar insolation, environmental situation, age of the cell. This paper describes an efficient way for real time tracking of the maximum power point (MPPT) of a solar panel charging a battery in a varying weather. To estimate the maximum power that a cell can provide with an optimal load under any weather condition, selection of a controlling method is imperative. MPPT performance will be evaluated through ORCARD and a Prototype to have simulation and experimental results respectively.

I. Introduction

World's energy from fossil fuel like diesel, petrol, coal or CNG is being finished gradually. Adversative result of those on the nature is also a matter of concern. So we, the most civilized creature in the world, have to look for more and more energy from the renewable sources. At the same time we need to take into consideration the weather as well. Because we've no control on it. And solar energy is the most likely solution of this energy crisis of the future world and weather condition is the integral part of it. The attractive aspects of solar energy are its availability all over the world than other forms of renewable energies. So for spreading the light of technology for industrial application is the need of the moment.

The output power of a solar panel depends on the amount of light projected on the panel, load connected to the panel. We easily can tune the load but not weather. So we have to find out a controlling strategy than can work independent of weather and suit perfectly for industrial activities.

II. Solar System and Maximum Power

For better understanding, we need to consider the electrical analogous circuit of a solar system which is shown in Fig. 1. It has a current source I_L, a diode and two resistors (R_S and R_{SH}). Upon incidence of light on the solar cell, current I_L is generated and part of the current can be delivered to load.

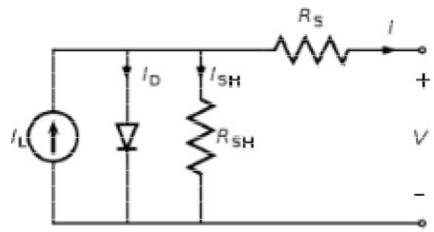

Fig. 1 Equivalent circuit of a solar cell.

The current output to load from a solar cell is given by

$$I = I_L - I_0\left\{exp\left[\frac{q(V+IR_S)}{nkT}\right] - 1\right\} - \frac{V+IR_S}{R_{SH}} \quad (1)$$

Where,
I = output current (amperes)
I_L = photo-generated current (amperes) I_D = diode current (amperes)
I_{SH} = shunt current (amperes)
V = voltage across the output terminals (volts) R_S = series resistance (Ω)
I_0 = reverse saturation current of diode (amperes)
n = diode ideality factor (1 for ideal diode)
q = elementary charge
k = Boltzmann's constant
T = absolute temperature
R_{SH} = *shunt resistance (Ω)*

The Current/Power–Voltage characteristic of a solar cell is shown in Fig. 2.

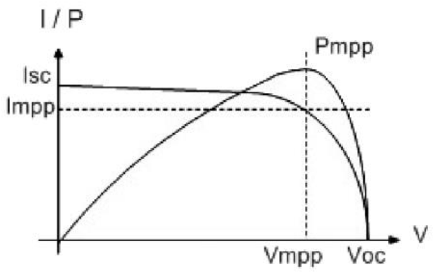

Fig. 2 I-V and P-V characteristics of a solar cell

A solar cell operates as an ideal current source over a range of load voltage. By increasing the resistive load of an irradiated cell continuously from zero (a short circuit) to a very high value (an open circuit) the maximum-power point can be determined The output power is zero in both the short circuit and open circuit extremes.

III. Sunlight effect on I-V characteristics

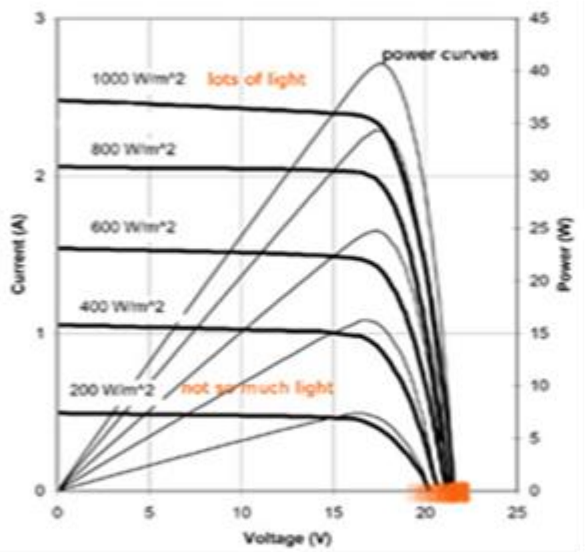

Fig. 3 Solar cell's I-V curve in varying sunlight

From basic circuit theory, the power delivered from or to a device is optimized where the derivative (graphically, the slope) dI/dV of the I-V curve is equal and opposite the I/V ratio (where dP/dV=0).[1] This is known as the maximum power point (MPPT) and corresponds to the "knee" of the curve.

A load with resistance(R=) V/I equal to the reciprocal of this value draws the maximum power from the device. This is a dynamic quantity which changes depending on the weather effect, one of sensitive factors. If the resistance is lower or higher than this value, the power drawn will be less than the maximum available, and thus the cell will not be used as efficiently as it could be. Fig. 3 clearly describes, solar power is decreasing with the light intensity counterpart. So the maximum power point trackers will be needed a control circuit or logic that can reduce weather effect.

IV. Control Algorithm

Several methods may be followed to attain MPPT such as Perturb and Observe(PO), Incremental Conductance(IC), Current Sweep Method, Constant Voltage etc. Both PO and IC are examples of "hill climbing" methods that can find the local maximum of the power curve for the operating condition of the array, and so provide a true maximum power point.[2][3]

The PO method can produce oscillations of power output around the maximum power point even under steady state illumination. The IC method has the advantage over the PO method that it can determine the maximum power point without oscillating around this value.[4] It can perform maximum power point tracking under rapidly varying irradiation conditions with higher accuracy than the PO method.[4]

In the constant voltage ratio (or "open voltage") method, the current from the photovoltaic array must be set to zero momentarily to measure the open circuit voltage and then afterwards set to a predetermined percentage of the measured voltage, usually around 76%.[5] Energy may be wasted during the time the current is set to zero.[5]

The IC algorithm shows better performance in terms of efficiency compared to the PO algorithm under adverse weather conditions.[6] Even a small improvement of efficiency could bring substantial savings if the system is large.[6]

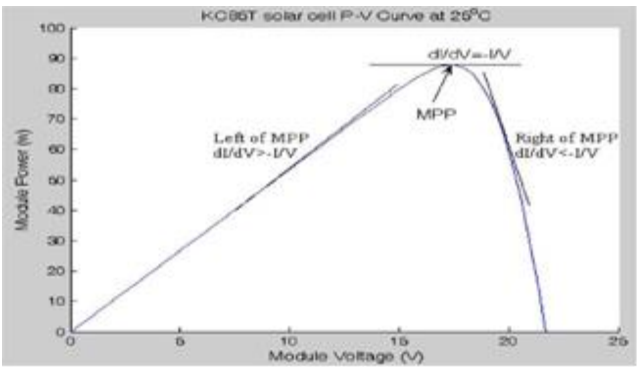

Fig. 4 IC method on a P-V curve of a solar module

Fig. 4 shows that the slope of the PV array power curve is zero at the MPP, increasing on the left of the MPP and decreasing on the right-hand side of the MPP. The basic equations of this method are as follows [7]:

$$\frac{dI}{dV} = -\frac{I}{V} \qquad At\ MPP \qquad (2)$$

$$\frac{dI}{dV} > -\frac{I}{V} \qquad Left\ of\ MPP \qquad (3)$$

$$\frac{dI}{dV} < -\frac{I}{V} \qquad Right\ of\ MPP \qquad (4)$$

Where I and V are the PV array output current and voltage respectively. The left-hand side of the equations represents the IC of the PV module, and the right-hand side represents the instantaneous conductance. From (2)–(4), it is obvious that when the ratio of change in the output conductance is equal to the negative output conductance, the solar array will operate at the MPP. In other words, by comparing the conductance at each sampling time, the MPPT will track the maximum power of the PV module. The accuracy of this method is proven in [8], where it mentions that the IC method can track the true MPPs independent of PV array characteristics.

Therefore, considering weather effect and all other factors IC algorithm is taken into account.

V. Power Converter Design & Simulation

For ORCAD simulation, solar system has to be represented by an equivalent circuit like Fig. 5 where an ideal current source (I1) and a resistance (R1) in parallel. Power MOSFET M2 controls the charging current to battery. The diode D4 resists the reverse current. The smaller resistance R4 accounts for the inner resistance of the battery. When M2 is off, Capacitor C1 stores the charge and delivers during pulse time.

Duty cycle sweeping in ORCAD SPICE is achieved by comparing a triangular wave and a variable dc source with an Op-Amp operating as voltage level crossing detector, and the output is then rectified to get the desired variable duty cycle pulse to regulate the power drawn from the solar panel.

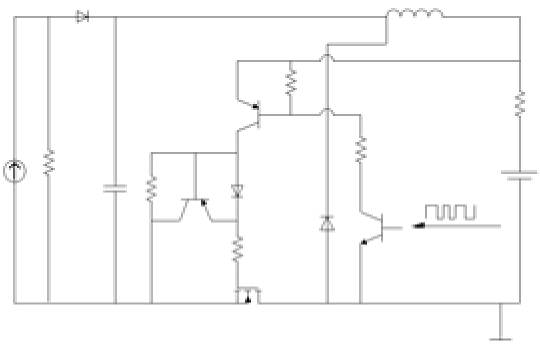

Fig. 5 Circuit for ORCAD SPICE Simulation

Simulation result is shown in Fig. 6. Time in horizontal axis corresponds to variable duty cycle. The duty cycle is kept at 100% up to 13ms to allow for the transient response due to the inductance. After then it is gradually decreased to 0% at 60ms. Power delivered to the battery is in vertical axis. At beginning, power increases with the decreasing duty cycle up to a certain point, then it gradually decreases to zero. Maximum 47W power is attained at nearly 54% duty cycle for this simulation.

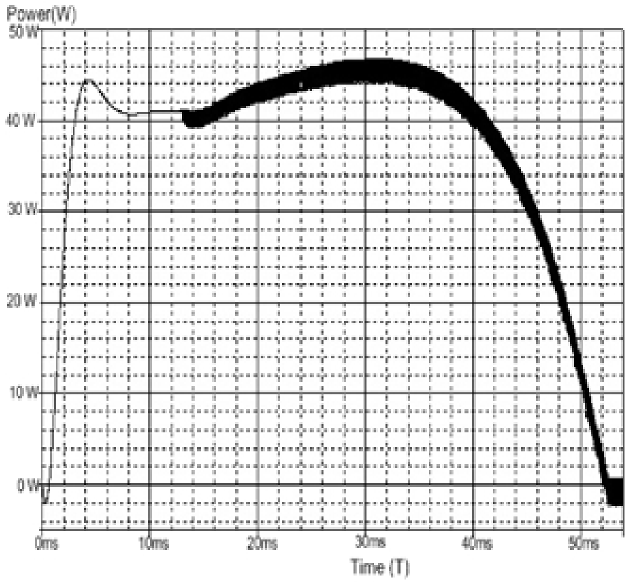

Fig. 6 Simulation result for finding the MPP

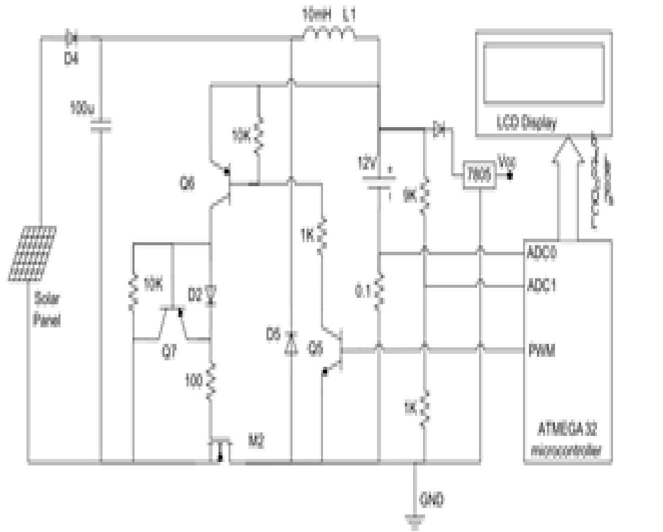

Fig. 7 Circuit Diagram of Implemented Prototype of the MPPT controller

VI. Hardware Implementation

A microcontroller (ATmega 32) with on-chip multi-channel Analog-to-Digital Converter (ADC) and a Pulse Width Modulation (PWM) module is used. A small current sensing resistance is put in series with the battery to measure the charging current. The microcontroller utilizes the ADC to sample battery voltage and charging current to calculate the power being delivered. The PWM switching frequency is chosen to be 4 kHz. The prototype circuit built over a Printed Circuit Board (PCB) is shown in Fig. 8.

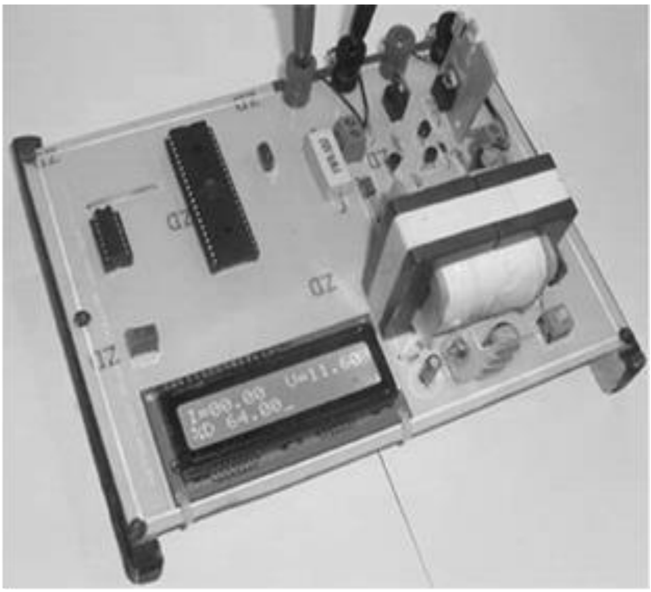

Fig. 7 Photovoltaic MPPT battery charge controller

VII. Solar Panel Specification

Solar Panel: SIEMENS SP70
Battery: 70 Ah, 12V Sealed Lead-Acid Battery
Experimentation Date: May 23, 2013
Place: BUET Campus (23°43′34″N, 90°23′33″E)
Panel Orientation: 24.6° w.r.t North-West horizontal

Below table shows the maximum power point achieved at different light intensities.

Table: *Current, Voltage & Power stat in varying sunlight*

Light Intensity (W/m2)	Current (Amp)	Voltage (Volt)	Max Power (Watt)
95.75	1.61	12.05	19.4005
150.85	2.14	12.11	25.9154
180	2.21	12.18	26.9178
328.55	2.45	12.32	30.184
337.5	2.48	12.35	30.628
369	2.52	12.36	31.1472
378	2.54	12.37	31.4198
381.15	2.55	12.38	31.569
387.45	2.57	12.41	31.8937
388.85	2.59	12.42	32.1678
391.52	2.6	12.45	32.37
392.4	2.65	12.46	33.019
396	2.82	12.48	35.1936

Above table shows the reduction of weather effect at low light intensity (95.75 W/m^2) and output power varies moderately with the light intensity. Experiment is done with smaller system but the result could be totally aligned in case of large counterpart.

Conclusion

Employing an application driven design philosophy, this work describes an approach to the design of photovoltaic power system, especially for industrial application, which will reduce the weather impact to a great extent. It will be enough resourceful for third world countries where power crisis is a usual case.

References

[1] Dr. Simon Min Sze, "Physics of Semiconductor Devices" 2nd Edition, Page-796

[2] D. P. Hohm and M. E. Ropp, "Comparative study of maximum power point tracking algorithms", Progress in Photovoltaics: Research and Applications Volume 11, Issue 1, pages 47–62, January 2003

[3] Yen-Jung Mark Tung, Dr. Aiguo Patrick Hu and Dr. Nirmal-Kumar Nair, "Evaluation of Micro Controller Based Maximum Power Point Tracking Methods Using dSPACE Platform", Australian University Power Engineering Conference 2006

[4] "Maximum Power Point Tracking", zone.ni.com., Retrieved 2011-06-18

[5] Yu, Z., Texas Instruments, Ogboenyira, K., Texas Instruments, "Renewable Energy Through Micro-Inverters", Power Electronics, April 1, 2009

[6] Arjyadhara Pradhan, Dr S.M Ali and Ritesh Dash, "A Comparative Study of Perturb-Observance(PO) Method and Incremental Conductance(IC) Method", Indian Journal of Applied Research(IJAR), Volume: 3, Issue: 5, May 2013

[7] D. Sera, T. Kerekes, R. Teodorescu, and F. Blaabjerg, Improved MPPT Algorithms for Rapidly Changing Environmental Conditions. Aalborg, Denmark: Aalborg Univ. /Inst. Energy Technol., 2006.

[8] T. Esram and P. L. Chapman, ―Comparison of photovoltaic array maximum power point tracking techniques,‖ IEEE Trans. Energy Convers., vol. 22, no. 2, pp. 439–449,Jun. 2007.