An Approach to Implement Photo Voltaic System using Arduino

[1]Neeraj Vijay Kale, [2]Prashant Shivasharan Malge
[1,2]Dept. of Electronics Engineering, Walchand Institute of Technology, Solapur, Maharashtra, India

Abstract
Today, people are more concerned about fossil fuel exhaustion and environmental problems caused by conventional power generation and renewable energy sources than ever before. Among the renewable resources, photovoltaic panels are primary contenders. They have the advantage of being maintenance and pollution-free, but their installation cost is high and, in most applications, they require a power conditioner (dc/dc or dc/ac converter) for load interface. Photovoltaic modules (PV Modules) also have relatively low conversion efficiency. Overall system cost can be reduced using high efficiency power conditioners which are designed to extract the maximum possible power from the PV module using maximum power point tracking (MPPT) techniques. To maximize power output from the solar panels, one needs to keep the panels aligned with the sun. This paper will describe the Design and Implementation of PV system using Maximum Power Point Tracking and Sun Tracking technique for maximum power output with Power Monitoring using Arduino.

Keywords
Maximum Power Point Tracking, Sun Tracking, Battery Health Management, Monitoring, Overall System Design

I. Introduction
Solar power is an alternative technology that will hopefully lead us away from our petroleum dependent energy sources. The major problem with solar panel technology is that the efficiencies for solar power systems are still poor and the costs per kilo-watt-hour (kWh) are not competitive, in most cases, to compete with petroleum energy sources. Solar panels themselves are quite inefficient (approximately 30%) in their ability to convert sunlight to energy [1]. However, the charge controllers and other devices that make up the solar power system are also somewhat inefficient and costly. Hence paper will describe design of the PV system using Arduino that include MPPT, Sun tracking Techniques for getting maximum efficiency, monitoring and battery health management.

Maximum Power Point Tracking, frequently referred to as MPPT, is an electronic system that operates the Photovoltaic (PV) modules in a manner that allows the modules to produce all the power they are capable of [2]. MPPT is a fully electronic system that varies the electrical operating point of the modules so that the modules are able to deliver maximum available power. Additional power harvested from the modules is then made available as increased battery charge current.

Automatic sun tracking involves orienting the solar panel in the direction of maximum light. The conventional solar receiving devices are usually fixed, this installation is simple, structural stability, but because of the location of the sun in the sky is changing, most of the time the sun cannot direct solar receiver, the use of the sun inadequate. In order to maximize power output from the solar panels, one needs to keep the panels aligned with the sun. As such, a means of tracking the sun is required. This is a far more cost effective solution than purchasing additional solar panels. It has been estimated that the yield from solar panels can be increased by 30 to 60 percent by utilizing a tracking system instead of a stationary array [3].

Solar photovoltaic power generation system is a multipower system, mainly be consisted of the solar panels, batteries, power, inverter components [4], due to the special nature of solar energy resources, how to improve the utilization of solar energy resources has long been a topic of concern, and the overall optimization of solar power system is an important method to improve the utilization of solar energy resources, solar power monitoring is particularly important, the data must be able to meet the comprehensive, simultaneous and real-time requirements [5]. Real-time data, the validity is related to the entire power system security and uptime, reliable data communication is related to the practical significance and application value of .monitoring system. Compared with traditional monitoring system, the system with real-time high, reliable communications, no wiring, unattended, etc., and to achieve the network, intelligent, user-friendly goals of solar power system monitoring [4].

Arduino is an open-source electronics prototyping platform based on flexible, easy-to-use hardware and software. It's intended for artists, designers, hobbyists, and anyone interested in creating interactive objects or environments. The hardware consists of a simple open hardware design for the Arduino board with an AtmelAVR processor and on-board input/output support. .Official Arduinos has used the mega AVR series of chips, specifically the ATmega8, ATmega168, ATmega328, ATmega1280, and ATmega32u4, ATmega2560.

II. Maximum Power Point Tracking

A. Mathematical Model
The building block of PV arrays is the solar cell, which is basically a p-n semiconductor junction, shown in fig. 1. The V-I characteristic of a solar array is given by Eq. (1)(6).

Where V and I represent the output voltage and current of the PV, respectively; Rs and Rsh are the series and shunt resistance of the cell; q is the electronic charge; ISC is the light-generated current; Io is the reverse saturation current; n is a dimensionless factor; k is the Boltzman constant, and Tk is the temperature in 0K.

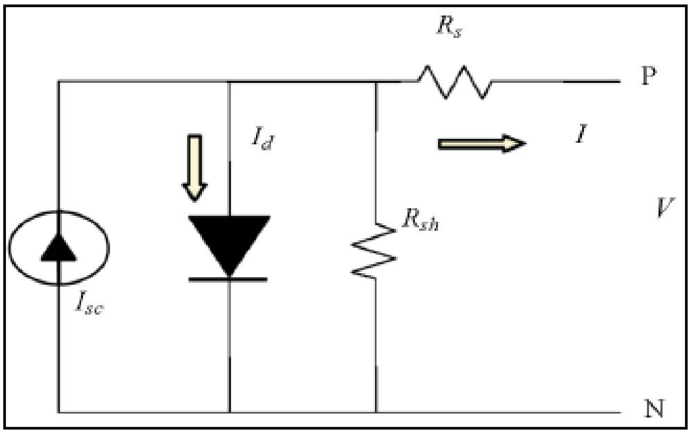

Fig. 1: Equivalent Circuit of PV Array

 ISSN : 0976-8491 (Online) | ISSN : 2229-4333 (Print)

The output characteristics of a solar cell, as shown in fig. 2. This curve clearly shows that the output characteristics of a solar cell are non-linear and are crucially influenced by solar radiation, temperature and load condition. Each curve has a MPP, at which the solar array operates most efficiently.

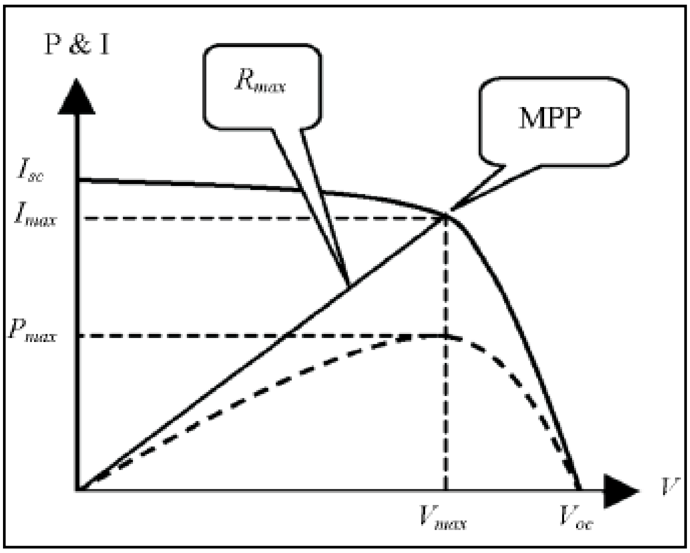

Fig. 2: V-I & P Characteristic of a Solar Cell

B. Maximum Power Point Tracking

MPPT is a technique that uses to get the maximum possible power from the PV array. Solar cells have a complex relationship between solar irradiation, temperature and total resistance that produces a non-linear output efficiency known as the I-V curve as shown in fig. 3.

It is the purpose of the MPPT system to sample the output of the cells and apply a resistance (load) to obtain maximum power for any given environmental conditions.

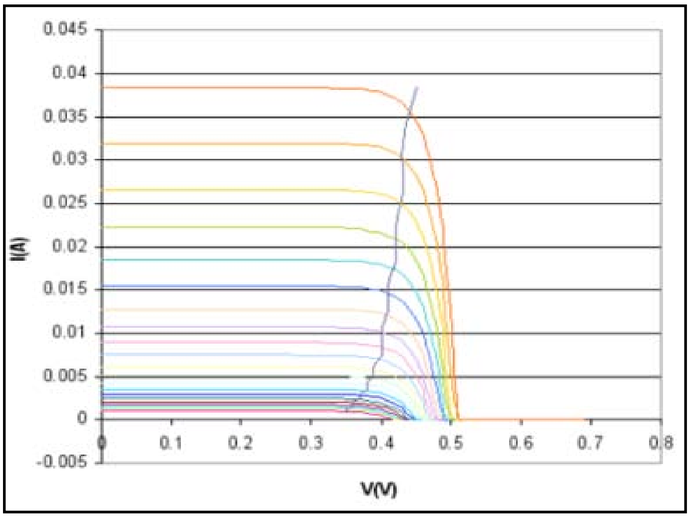

Fig. 3: Solar Cell I-V Curve for Varying Sunlight

Essentially, this defines the current that the inverter should draw from the PV in order to get the maximum possible power. For any given set of operational conditions, cells usually have a single operating point where the values of the current (I) and Voltage (V) of the cell result in a maximum power output. 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). This is known as the maximum Power Point (MPP) and corresponds to the "knee" of the curve.

A load with resistance R=V/I equal to the reciprocal of this value is the load which draws maximum power from the device, and this is sometimes called the characteristic resistance of the cell. Note however that this is a dynamic quantity which changes depending on the level of illumination, as well as other factors such as temperature and the age of the cell. 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. Maximum power point trackers utilize different types of control circuit or logic to search for this point and thus to allow the converter circuit to extract the maximum power available from a cell and MPPT techniques are classified into:

- Perturb-and-observe (P&O) method.
- Incremental conductance (INC) method.
- Constant voltage method.

III. Sun Tracking

Two Cadmium Sulphide (CdS) photo conductive cells and servo motor can be used for suntracking. The LDR changes from high resistance (>MΩ) in darkness to a low resistance <1kΩ) in very bright light. A voltage divider consists of two resistances R1 and R2 connected in series across a supply voltage Vs, as shown in fig. 4.

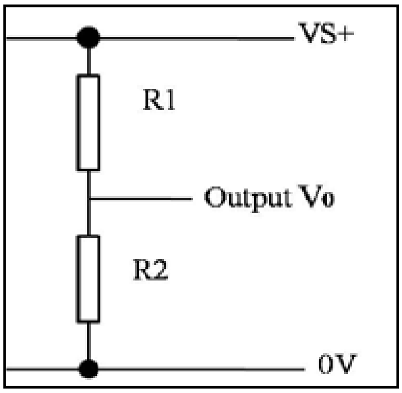

Fig. 4: Voltage Divider Circuit

The supply voltage is divided up between the two resistances to give an output voltage Vo which is the voltage across R2. If the LDR is placed on the top of the circuit in place of R1, as shown in fig. 5. Then as the light intensity decreases, i.e. as the resistance of LDR increases, then the output voltage will decrease and as the light intensity increases, the resistance of LDR decreases, then the output voltage will increase. can be used as input voltage to the A/D channel of the microcontroller.

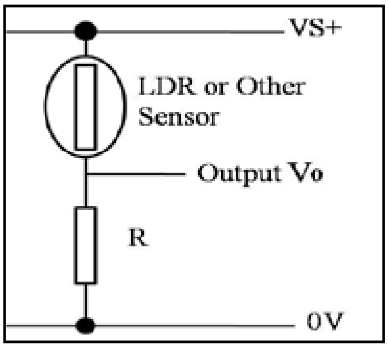

Fig. 5: Voltage Divider Circuit Containing LDR at Top

These cells are mounted at 90' to each other. When tracking the sunlight, e.g. for a solar panel, we would want the maximum sunlight intensity, to achieve this, both cells would therefore need

to see the same intensity of light.
Read both of the input cell values, and do a comparison, 0 difference means they are at the same light level, a -ve error value means the light is brighter to the right, and a +ve error value means the light is brighter to the left.
The servo is then sent up with a position value, and we simply increment or decrement the output on each scan to rotate the platform east and west to find the optimum balance light levels on the sensors again.

IV. Battery Health Management

Typically, the charging of the battery is carried out in 3 stages, also illustrated in fig. 6.

- Constant Current Charge or the Bulk charge Stage
- Topping Charge Stage
- Float Charge Stage

Let us consider charging of a 12-volt lead acid battery. The voltage level of the battery is monitored continuously with the help of a built-in ADC module in the MCU. If the battery voltage is less than its nominal value, then a suitable charging voltage called “Accept Voltage” is applied to the battery which varies with temperature. The Accept Voltage which is applied to the battery is switched using a power transistor driven by a PWM, from the DC-DC converter output. During this period, the charge current is constant. In the case of a lead acid battery, we can call this the Bulk charge phase. Once the battery voltage reaches its nominal value, the battery is then 70% full. It now has to be charged further until the charge current drops to about 3% of the rated current of the battery. This is achieved by continuing the PWM charge method as before. This phase of charging is called the Topping Charge stage. When the charge current drops to 3% of the rated current, then the battery is completely charged. The Topping Charge stage is essential to keeping the battery healthy. If the topping charge is not applied, the battery will gradually lose its ability to hold a full charge. After charging is complete, to maintain the charge level, the battery is applied with a suitable voltage known as the Float voltage in the form of a PWM waveform. The Float Voltage is generally applied to compensate for self-discharge through the leads and other parasitic effects. Both the Float Voltage and Accept Voltage of a battery vary with temperature. The MCU continuously reads the output of the temperature sensor and determines the Accept Voltage and Float Voltage. Their value is controlled by a PWM waveform generated using a MCU.

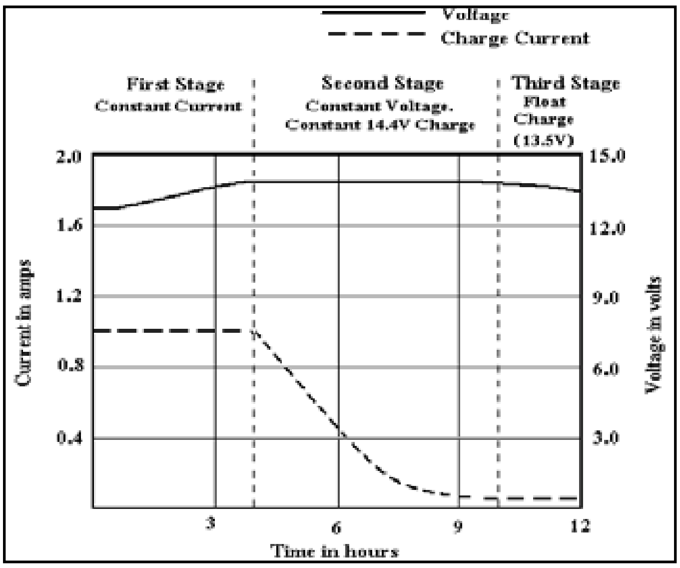

Fig. 6: Charging States of Battery

V. Monitoring

A data-acquisition system used for monitoring the performance of photovoltaic System an A/D converter on to a microcontroller records a set of sensors signals and the voltage levels. Monitoring includes collection of the input voltage, input current, Battery charging current, battery voltage, Output voltage, output current, and temperature of battery. Collected data is first stored in on chip EEPRO memory.
The data collected by the microcontroller are transmitted to a PC, with an RS-232 serial connection, where they are stored for further processing. The monitoring software on PC used to further process, display and store the collected data in the PC disk.

VI. Overall System Design

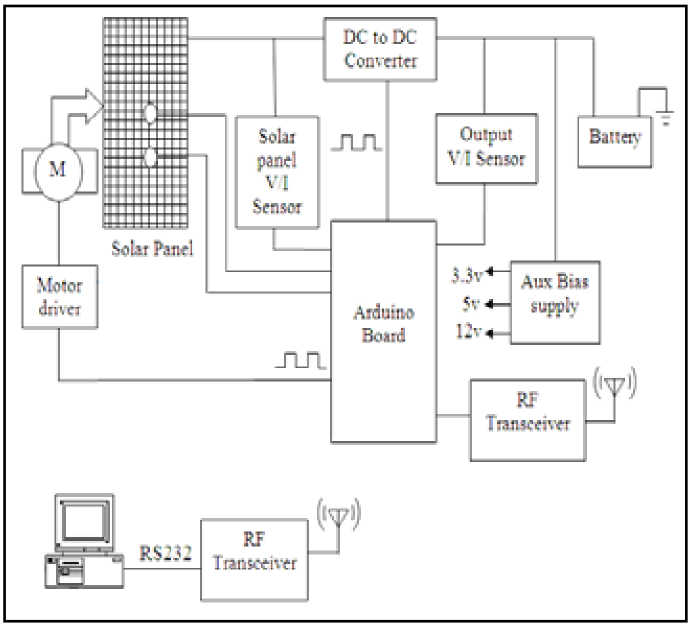

Fig. 7: Overall System Block Diagram

Fig. 7 shows the block diagram of complete PV system using Arduino. MPPT algorithm can be implemented through a microcontroller. The controller executes the very precise algorithms required to keep the panel at the maximum power extraction point while adjusting the dc-dc conversion to produce the output dc voltage required for the string. The PV maximum output power is dependent on the operating conditions and varies from moment to moment due to shading,, cloud cover, and time of day so tracking and adjusting for this maximum power point is a continuous process. The controller contains advanced peripherals like high precision PWM outputs and ADCs for implementing control loops. The ADC measures variables, such as the PV output voltage and current, and then adjusts the DC/DC converter by changing the PWM duty cycle depending on the load.
Two sensors are used for sun tracking. The output voltages are digitized using an on-chip ADC .The servo motor is driven by a PWM signal generated by the MCU. Battery voltage is scaled down and digitized using on chip ADC. Output of sensor can be digitized using on chip ADC. This data is used for monitoring. Solar panel output voltage, current, battery voltage all these voltages can be digitized and stored in on chip EEPROM memory. These collected data can be transmitted using UART to the monitoring Software that can be developed on PC.RF transceiver are used for wireless transmission.

 ISSN : 0976-8491 (Online) | ISSN : 2229-4333 (Print)

VI. Conclusion

It is possible to implement the MPPT, Sun tracking Technique, and Power monitoring using Arduino. The only external components required would be a diode and inductor for the DC-DC converter, and resistors to scale down the battery and the PV module voltage.

References

[1] Dr. Nirmal-Kumar Nair,Yen-Jung Mark Tung, Dr. Aiguo Patrick Hu,"Evaluation of Micro Controller Based Maximum Power Point Tracking Methods", Dept. of Electrical and Computer Engineering University of Auckland, New Zeland, 2006.

[2] Roberto Faranda, Sonia Leva,"Energy comparison of MPPT techniques for PV Systems", Department of Energy Politecnico di Milano Piazza Leonardo da Vinci, 32 – 20133 Milano, ITALY, July 2008.

[3] A.K. Saxena, V. Dutta,"A versatile microprocessor based controller for solar tracking, in Proc. IEEE, [1990]

[4] Lian Peng, Hua Fang, Ming Tang,"Solar power wireless monitoring system based on ARM7", Department of Electronic Information and Control Engineering Guangxi University of Technology, 2010.

[5] Reinhard Haas,"The Value of Photovoltaic Electricity for Society", Solar Energy.

[6] Bose, B. K., Szczeny, P. M., Steigerwald, R. L. "Microcomputer Control of a Residential Photovoltaic Power Conditioning System", IEEE Transactions on Industrial Electronics, Sept. /Oct.,Vol. IA-21, pp. 1182-1191.

[7] [Online] Available: http://www.arduino.cc/en/Main/Hardware

[8] [Online] Available: http://www.en.wikipedia.org/wiki/Arduino

[9] [Online] Available: http://www.en.wikipedia.org/wiki/File:Solar-Cell-IV-curve-with-MPP.png.

Neeraj Vijay Kale received his B.E. degree in Electronics & Telecommunication from Bharat Ratna Indira Gandhi College of Engineering, Solapur, Maharashtra, India in 2011. Pursuing M.E. degree in Electronics from Walchand Institute of Technology, Solapur, Maharashtra, India. Currently, He is teaching assistant, with Walchand Institute of Technology, Solapur, Maharashtra, India. At present, He is working on the project Design and Implementation of Photo Voltaic System: An Arduino approach.

Prashant Shivasharan Malge received his B.E. and M.E degree in Electronics Engineering from Shivaji University, Kolhapur, Maharashtra, India in 1990. and 2007 respectively. Currently, He is an Associate Professor, with Department of Electronics Engineering, Walchand Institute of Technology, Solapur, Maharashtra, India. At present, pursuing Ph.D from Deparment of Electronics & Telecommunication Engineering SGGSIE&T, Nanded, Maharashtra, India. His research interests include VLSI architectures for Image processing and Signal Processing.