

Implementation Of MPPT Solar Charge Controller Using MSP430 Ultra Low Power Microcontroller

Vennila D A¹, Dhanush P S², Sachin³, Rangappa⁴, SyedaMaazia Tabreen⁵

EEE Dept, SriSairam College of Engineering, Bangalore

Vennila.eee@sairamce.edu.in

Abstract—The need for renewable energy sources is on the rise because of the acute energy crisis in the world today. Solar energy is a vital renewable resource for the power. In this project, we examine a method to extract maximum obtainable solar power from a Photo Voltaic (PV) module. This project investigates in detail the concept of Maximum Power Point Tracking (MPPT) which significantly increases the efficiency of the solar photovoltaic system by using interleaved buck topology. The MPPT is responsible for extracting the maximum possible power from the photovoltaic and feed it to the battery or load via the interleaved buck converter which steps down the voltage to required magnitude. The main aim will be to track the maximum power point of the photovoltaic module so that the maximum possible power can be extracted from the photovoltaic module. The algorithms utilized for MPPT is Perturb and observe method which is easy to model or use as a code. The interleaved buck converter is controlled through ultra low power MSP430 Microcontroller and photovoltaic full bridge driver.

Index Terms— MPPT, Interleaved Buck Converter, Photovoltaic full bridge driver, PV cell, Pulse width modulation.

I. INTRODUCTION

One of the major concerns in the power sector is the day-to-day increasing power demand but the unavailability of enough resources to meet the power demand using the conventional energy sources. Demand has increased for renewable sources of energy to be utilized along with conventional systems to meet the energy demand. Solar energy is abundantly available that has made it possible to harvest it and utilize it properly. Solar energy can be a standalone generating unit. Thus it can be used to power rural areas where the availability of grids is very low. In order to tackle the present energy crisis one has to develop an efficient manner in which power has to be extracted from the incoming solar radiation. The power conversion mechanisms have been greatly reduced in size in the past few years. The development in power electronics and embedded systems has helped engineers to come up with very small but powerful systems to withstand the high power demand. The use of the newest power control mechanisms called the Maximum Power Point Tracking (MPPT) algorithms and interleaved buck topology has led to the increase in the efficiency of operation of the solar modules and thus is effective in the field of utilization of renewable sources of energy.

II. PV PANEL COMPONENTS

A. Photovoltaic cell

A photovoltaic cell or photoelectric cell is a semiconductor device that converts light energy into electrical energy by photovoltaic effect. A Photovoltaic cell is the building block of a solar panel. If the energy of photon of light is greater than the band gap then the electron is emitted and the flow of electrons creates current [1,2].

B. PV module

Usually a number of PV modules are arranged in series and parallel to meet the energy requirements. PV modules of different sizes are commercially available (generally sized from 60W to 170W). For example, a typical small scale desalination plant requires a few thousand watts of power [1,2].



C. PV modeling

A PV array consists of several photovoltaic cells in series and parallel connections. Series connections are responsible for increasing the voltage of the module whereas the parallel connection is responsible for increasing the current in the array. Typically a solar cell can be modeled by a current source and an inverted diode connected in parallel to it. It has its own series and parallel resistance. Series resistance is due to hindrance in the path of flow of electrons from n to p junction and parallel resistance is due to the leakage current. This model is known as a single diode model of PV cell [1,2]. In this model, current source (I) along with a diode and series resistance (R_s) is considered. The shunt resistance (R_{sh}) in

parallel is very high, has a negligible effect and can be neglected[1,2].

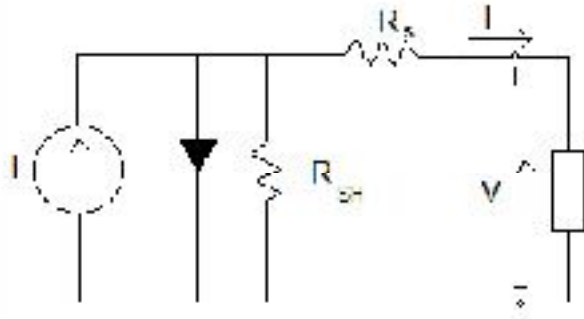


Fig.1: Single diode model of PV cell

The output current from the photovoltaic array is $I = I_{sc} - I_d(1)$

$$I_d = I_0 (e^{qV_d/kT} - 1) \quad (2)$$

Where,

I_{sc} is the source current, I_d is the diode current, I_0 is the

reverse saturation current of the diode, q is the electron charge, V_d is the voltage across the diode, k is Boltzman constant (1.38×10^{-19} J/K) and T is the junction temperature in Kelvin (K).

Using equation (2) in equation (1), we get

$$I = I_{sc} - I_0 (e^{qV_d/kT} - 1) \quad (3)$$

Using suitable approximations,

$$I = I_{sc} - I_0 (e^{q((V+IR_s)/nkT)} - 1)$$

Where,

I is the photovoltaic cell current, V is the PV cell voltage, T is the temperature (in Kelvin) and n is the diode ideality factor.

The I-V and P-V curves for a PV cell are shown in figure.2. It can be seen that the cell operates as a constant current source at low values of operating voltages and a constant voltage source at low values of operating current.

In the AB region of the curve the PV cell behaves as a current generator and in the CD region it behaves like a voltage source. In the intermediate zone BC, the characteristic of the PV cell is nonlinear, it is in this area that we find the MPP (Maximum Power Point) for which the PV cell provide its full power for certain atmospheric conditions.

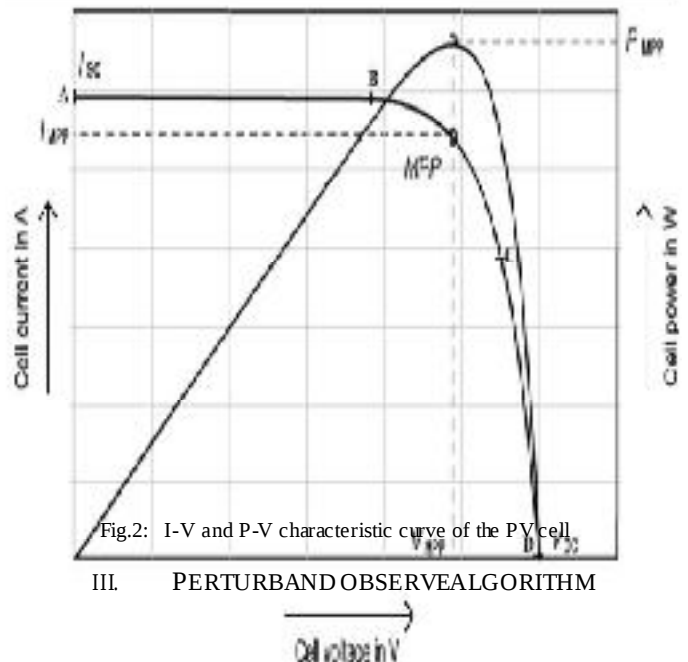


Fig.2: I-V and P-V characteristic curve of the PV cell

III. PERTURBAND OBSERVE ALGORITHM

The efficiency of a solar cell is very low. In order to increase the efficiency, methods are to be undertaken to match the source and battery or load properly. One such method is the Maximum Power Point Tracking (MPPT)[3,4,8]. This is a technique used to obtain the maximum possible power from a varying source (PV panel). In photovoltaic systems the I-V curve is non-linear, thereby making it difficult to be used to power a certain load or to store power in battery. This is done by utilizing a buck converter whose duty cycle is varied by using a MPPT algorithm.

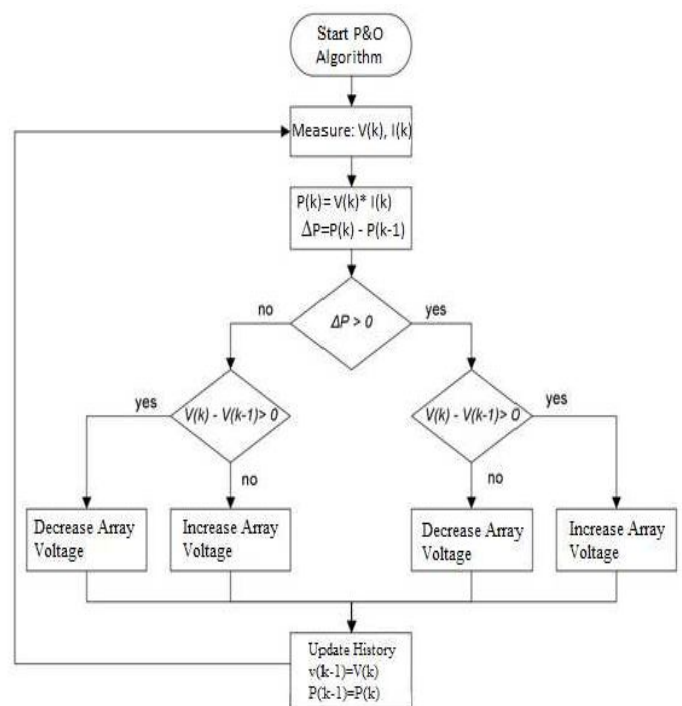
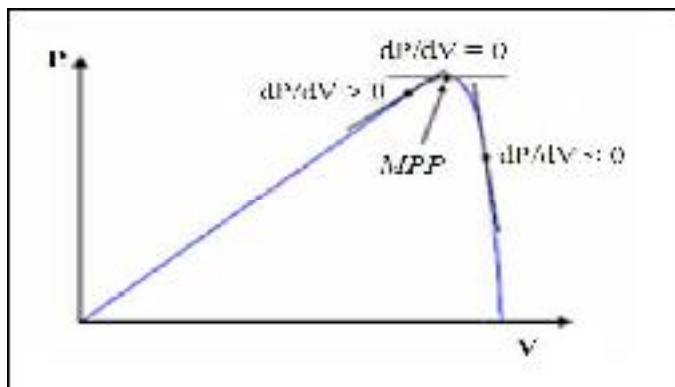


Fig.3: Flow chart of P&O algorithm

The P&O algorithm is one of the MPPT method generally the most used because of its simplicity and ease of implementation. As its name indicates, this method works by perturbing the system and observing the impact on output power of PV cell. The time complexity of this algorithm is very less [3,4,8]. The flow chart of working of P&O method is shown in Figure.3

From Fig.4 One sees that if the operating voltage is perturbed in a given direction and that the power increases ($dP/dV > 0$), then it is clear that the perturbation has moved the operating point toward the MPP. The P&O algorithm will continue to perturb the tension in the same direction. Suppose, if the power drops ($dP/dV < 0$) then the perturbation has moved the operating point away from the MPP. The algorithm will reverse the direction of the next perturbation. This algorithm is summarized in Table 1.



The process is periodically repeated until the MPP is reached. The system oscillates around the MPP. The oscillation can be minimized by decreasing the size of the perturbation. However, a too small perturbation slows considerably tracking the MPP. Then there is a compromise between accuracy and speed [3,4].

Table.1

Perturbation	Change in Power	Next perturbation
Positive	Positive	Positive
Positive	Negative	Negative
Negative	Positive	Negative
Negative	Negative	Positive

IV. BLOCKDIAGRAM

The overall system block diagram consists of PV panel, charge controller, battery and load. The charge controller contains an interleaved DC-to-DC buck converter, MSP430 microcontroller, photovoltaic full bridge driver. Interleaved buck converter matches the PV module voltage to battery voltage. Voltage and current at different nodes are present to sense the voltage and current at different nodes and give them to Microcontroller. The microcontroller is preprogrammed to operate the buck converter at maximum power point by using perturb and observe algorithm. The overall block diagram is shown in Fig.5

A. Sensors

The implementation of current sensors in the charge controller is essential to achieve desired functionality of the system. The sensors are the devices that are going to be in charge of monitoring and communicating everything that was happening in the system to the microcontroller.

B. Microcontroller

The microcontroller is responsible for all input and output processing of the entire photovoltaic system. The tasks included reading sensor values, controlling battery-charging circuitry, monitoring system performance and anomalies, along with transmitting data. It is programmed such that the system always operates at the maximum power point [5]. MSP430F132 is the microcontroller used in this design. The microcontroller automatically generates the pulse width modulation signals as per P&O algorithm which is given to vary the duty cycle of the interleaved buck converter.

C. Interleaved Buck converter

The DC voltage from the panel varies depending on the light intensity, which varies based on the time of the day and solar panel temperature. A Buck converter or DC-to-DC regulator is needed to increase or decrease the input panel voltage to the required battery level.

The interleaved buck converter consists of 4 discrete N type MOSFET's [7] in a full bridge configuration as shown in Fig.6. The gate signal for the MOSFET's is provided by microcontroller through photovoltaic full bridge driver.

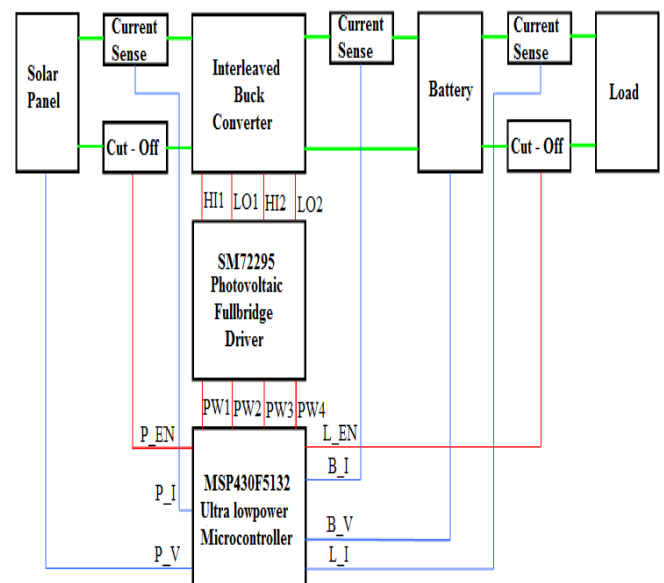


Fig.5: Block diagram

D. Photovoltaic full bridge driver-SM72295

The SM72295 is an IC especially designed to drive 4 discrete N type MOSFET's in a full bridge configuration. The drivers provide fast efficient switching of MOSFET's

The connection of photovoltaic full bridge driver between microcontroller and interleaved buck converter is shown in Fig.6. The microcontroller provides a PWM signals as per the P&O algorithm which is given to the SM72295 driver. The driver internally drives the 4 MOSFET's of the interleaved buck

The diagram shows a dual-output DC-DC converter. The input is a PV source connected to the VIN pin of the SM72295 through a 15mΩ resistor (R16). The converter is configured to provide two outputs: 5V and 10V. The 5V output is regulated by a feedback network consisting of resistors R9 and R10, and a capacitor C1. The 10V output is regulated by a feedback network consisting of resistors R11, R12, R13, and R14, and a capacitor C2. The converter also includes a 5V/10V pin for output selection. Various other pins are connected to ground or specific biasing points, including SIA, SOA, HOA, VCCA, LOA, LON, VCCB, LBB, HOB, HSB, BOUT, ICUT, SOB, and SIB. The output voltage is labeled Vout.

E. Battery

V. FEATURES OF CHARGE CONTROLLER

VI. RESULTS

Vi(v)	Ii(A)	Vo(v)	Io(A)	Pi(W)	Po(W)	Efficiency
17.70	0.01	0.0	0.00	0.14	0.00	0.0
17.01	0.76	12.01	0.99	12.93	11.93	92.3
17.16	2.19	12.05	3.00	37.58	36.17	96.2
17.27	3.61	12.09	5.00	72.34	60.46	97.0
17.52	5.40	12.15	7.57	94.61	91.98	97.2
17.42	7.20	12.20	10.00	125.42	122.03	97.3
17.33	11.0	12.32	15.00	190.63	184.79	96.9
17.19	15.06	12.44	20.00	258.88	248.70	96.1

The plot of output current versus efficiency for 12V solar charge controller is shown in Fig.7

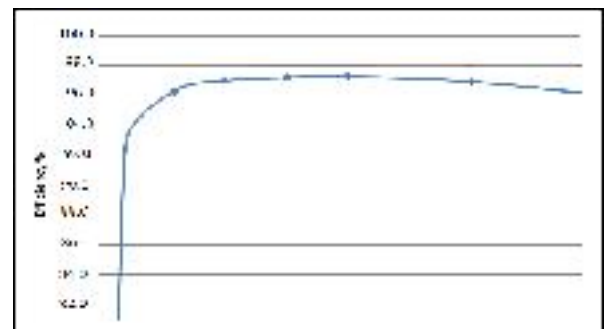


Fig.7: Plot of efficiency

VII. WAVEFORMS

A. Switching NodeWaveforms

Fig.8 is for 12V System, 20A Load. Individual channel switch nodes in waveforms show interleaved operation



Fig.8 Buck Converter output

Fig.9 is for 12V System, 10A Load. Individual channel switch nodes in waveforms show interleaved operation



Fig.9 Buck Converter output

B. MPPAcquisition

Fig.10 is for 12V System, 20A Load. Here the red line indicates PV input voltage, and yellow line indicates output current.

From the waveforms in Fig.10 we observe that for PV input of 17.5V the output current is nearly 20A.



Fig.10: MPP Acquisition

CONCLUSION

The use proposed MPPT solar charge controllers for 12V systems gives efficiency above 96%. This efficiency figure includes the losses in battery reverse protection MOSFET and panel reverse flow protection MOSFET, which are part of the design. The high efficiency is the result of the low gate charge MOSFETs used in the design, and the interleaved buck topology used. The interleaved buck topology reduces the component stresses by a great extent. Thus this solar MPPT

charge controllers can be used to utilize maximum power out of solar panel.

REFERENCE

- [1]. A. Luque and S. Hegedus. "Handbook of Photovoltaic Science and Engineering", John Wiley & Sons Ltd, 2003.
- [2]. A.D. Halmsen et al, "Models for a Stand-Alone PV System", University of Denmark, 2000.
- [3]. W.Xiao, "A Modified Adaptive Hill Climbing Maximum Power Point Tracking (MPPT) Control Method For Photovoltaic Power Systems", The University of British Columbia, 2003.
- [4]. V. Salas, E. Olías, A. Barrado, A. Lázaro, "Review of the maximum power point tracking algorithms for stand-alone photovoltaic systems", Solar Energy Materials & Solar Cells 90 (2006) 1555—1578.
- [5]. <http://www.ti.com/lit/ds/symlink/msp430f5132.pdf>
- [6]. <http://www.ti.com/lit/ds/symlink/sm72295.pdf>
- [7]. <http://www.ti.com/lit/ds/symlink/csd18532q5b.pdf>
- [8]. Jacob James Nedumgatt, Jayakrishnan K. B, Umashankar S, Vijayakumar D., Kothari D. P, "Perturb and Observe MPPT Algorithm for Solar PV Systems-Modeling and Simulation," School of Electrical Engineering VIT University.
- [9]. M.A.Elghendy, B.Zahawi and D.J. Atkinson, "Comparison of Directly Connected and Constant Voltage Controlled Photovoltaic Pumping Systems," IEEE Transactions on Sustainable Energy, Vol. 1, No. 3, pp. 184-192, Oct. 2010.
- [10]. M.A.Elghendy, B.Zahawi and D.J. Atkinson, "Assessment of Perturb and Observe MPPT Algorithm Implementation Techniques for PV Pumping Applications," IEEE Transactions on Sustainable Energy, Vol. 3, No. 1, pp. 21-33, Jan. 2012.