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Design and Implementation of MPPT Solar Charge Controller using Simulink

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***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.**

***Keywords:*-- 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].

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A. PV modeling

A PV array consists of several photovoltaic cells in series and parallel connections. Series connections are responsible for source and an inverted diode connected in parallel to it. It has increasing the voltage of the connection is responsible for array. Typically a solar cell module whereas the parallel increasing the current in the can be modeled by a current 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 (RS) isconsidered. Theshunt resistance (RSH)in parallel is very high, has a negligible effect and can be neglected[1,2].

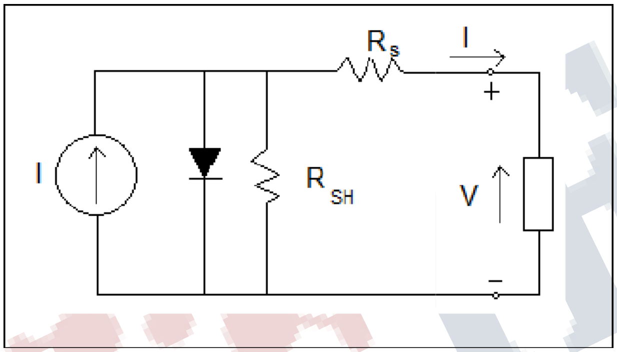


Fig.1: Single diode model of PV cell

The output current from the photovoltaic array is
I=Isc – Id(1)

Id= I0(eqVd/kT-1) (2)

Where,

Isc is the source current, Id is the diode current, I0 is the reverse saturation current of the diode, q is the electron charge, Vd is the voltageacross the diode, k is Boltzmann constant (1.38 * 10-19 J/K) and T is the junction temperature inKelvin (K). Using equation (2) in equation (1), we get

I = Isc– I0 (eqVd/kT - 1) (3)

Using suitable approximations, I = Isc – I0 (eq((V+IRs)/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.

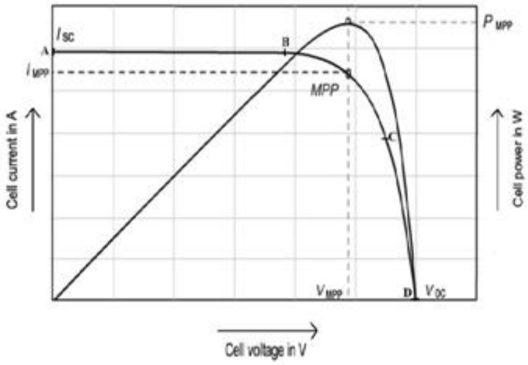


Fig.2: I-V and P-V characteristic curve of the PV cell

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-Ʊ 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.

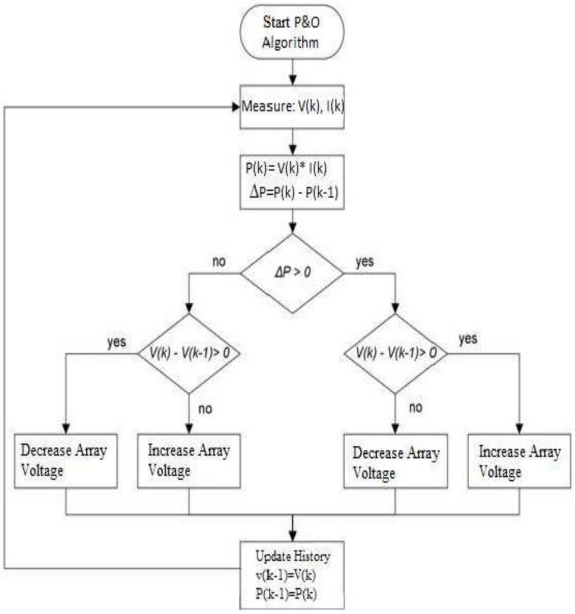
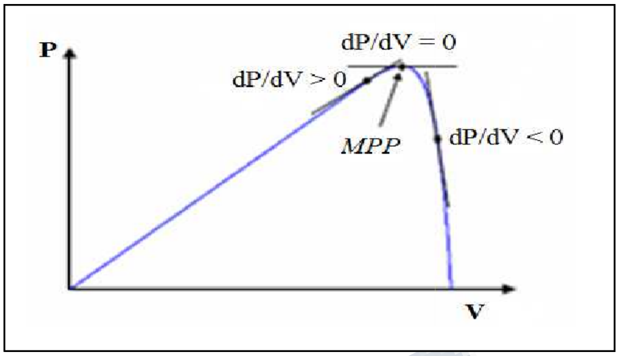


Fig.3: Flow chart of P&O algorithm

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 if the power drops (dP/dV<0) then the perturbation has 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, movedtheoperating point away from the MPP. The algorithm will reverse the direction of the next algorithm is summarized in Table 1. perturbation.



The process is periodically repeated until the MPP is reached. The system oscillates around the MPP.The oscillation can be microcontroller through photovoltaic full bridge driver. 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 PVpanel, charge controller, battery and load. The charge controller contains aninterleaved DC-to-DC buck converter, MSP430 microcontroller, photovoltaic full bridge driver. Interleaved buck converter matches thePV module voltage to battery voltage. Voltage and currentsensors are present to sense the voltage and current at different nodes and givethem to microcontroller. The micro controller is preprogrammed to operate the buck converter at maximum power point by usingperturb 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 thelight intensity, which varies based on the time of the day andsolar panel temperature. A Buck converter or DC-to-DC regulator is needed toincrease or decrease the input panel voltage to the requiredbattery 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.

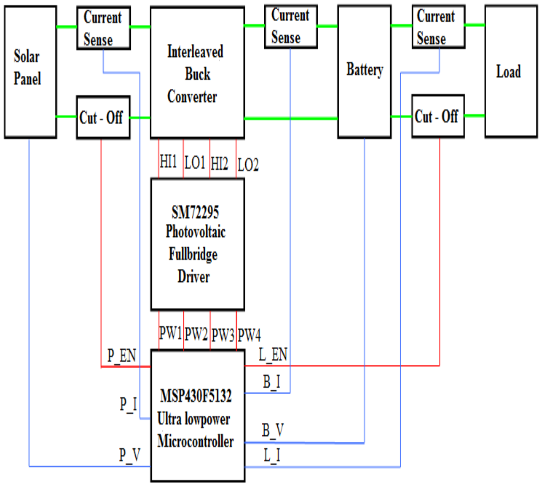


Fig.5: Block diagram

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 intern drives the 4 MOSFET's of the interleaved buck converter to vary the duty cycle of the buck converter and to increase the efficiency of operation of the solar modules and to extract maximum amount of power from the solar panel[6]

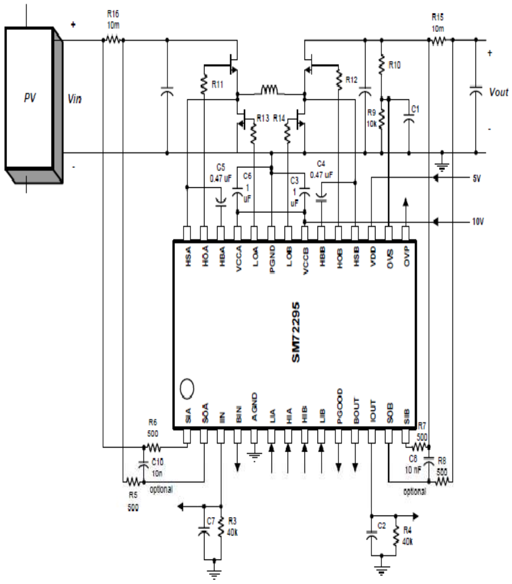


Fig.6: Four discrete N type MOSFET's in a full bridge configuration(Buck converter) driven by SM72295 driver.

E. Battery

The batteries used in photovoltaic MPPT charge controller served as a way to store energy so that devices can be powered in the event that the sun is not shining and when more power is needed than can be provided by the solar arrays at a given time. The battery bank also provides a large energy capacity, run at 12V, and provides a large output current to handle high power loads. The series connection of batteries is used if voltage required is high. Parallel connection of batteries is used if the current required is high.

V. FEATURES OF CHARGE CONTROLLER

Solar charge controller is the heart of every solar system, and is required to monitor and control the power going into and coming out of the battery. It also managesthe power generated by the solar panel to ensure it does not overcharge the battery. The charge controller also ensures that the connected loads don't over-discharge the battery,thereby damaging it. This charge controller has the built in current sensors at both PV panel end and battery end.

VI. RESULTS

In this project the MPPT charge controller is designed to get a voltage 12V and maximum current of 20A. The results are tabulated in the Table 2.

Table 2

Vi(v)	Ii(A)	Vo(v)	Io(A)	Pi(W)	Po(W	Effi
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

From the Table 2 we observe the variation of buck converter output with respect to varies PV input. When the PV panel input is 17.19V and 15.06A, the output of buck converter is 12.44V and 20A current and efficiency is 96.1%. The maximum efficiency is obtained is 97.3% when PV input is 17.42V.

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

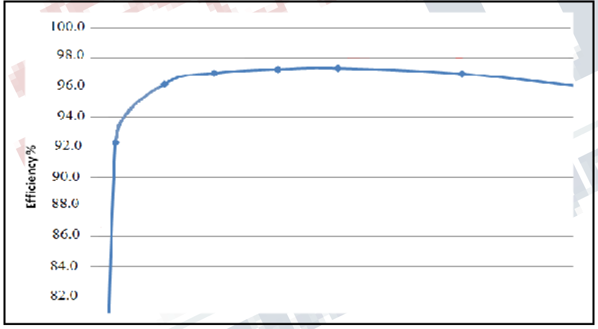


Fig.7: Plot of efficiency

VII. WAVEFORMS

A. Switching Node Waveforms

Fig.8 is for12V System, 20A Load. Individual channel switch nodes in waveforms show interleaved operation

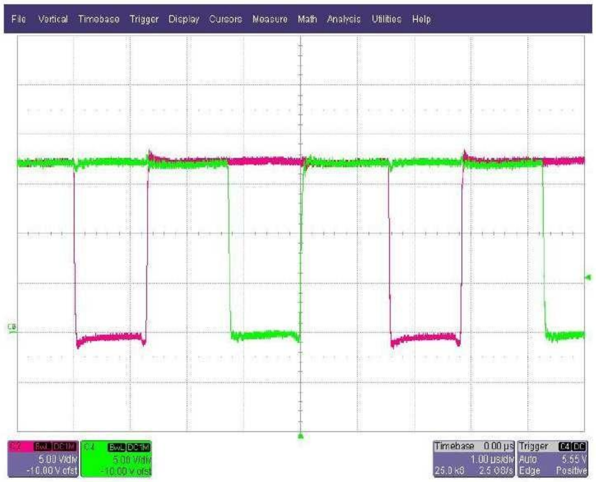


Fig.8Buck Converter output

Fig.9 is for12V System, 10A Load. Individual channel switch nodes in waveforms show interleaved operation.

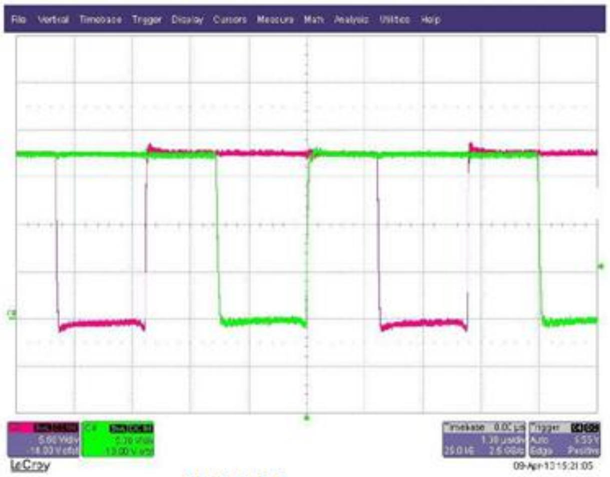


Fig.9 Buck Converter output

B. MPP Acquisition

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

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