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Design of Dual Battery Charging Scheme for Solar Powered Robotic Vehicle

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ABSTRACT

Shortage of non-renewable fuel in the future is an upcoming global issue; therefore renewable energy such as solar energy has gradually replaced non-renewable energy. The electricity generations of photo voltaic (PV) panels are strongly related with irradiation and temperature. The irradiation and temperature are not stable, therefore the electricity generations of the PV panel is not stable. In PV systems, irradiation and temperature continuously varies so, the maximum power point tracking (MPPT) techniques are used to give the highest power to the loads/batteries. The MPPT process with Purturb & Observe method is performed with a power electronic circuit and it overcomes the problem of voltage mismatch between the PV panels and the batteries/loads. In this study, an Arduino2560 (microcontroller) is employed to develop battery charge control system for PV panels. The system is composed of an Arduino2560, a PWM DC-DC converter, a battery selector and Li-Po battery. The programme of all circuitry is embedded within the microcontroller. In this paper results of optimal charging and discharging of dual batteries are discussed.

Keywords: ***Photovoltaic (PV) panel, Arduino, PWM DC-DC converter, Li–Po battery, robotic vehicle***

1. INTRODUCTION

Renewable energy sources are necessary to consider in accordance to environmental protection for future generation. Solar power is one of the important topics in renewable energy sources. Many researches have addressed the improvement of solar power system. Many types of PV power conversion systems have been developed including the grid-connected system for reducing the power dependence on the utility and the stand-alone system for providing power to the load. In case of Robotic vehicle batteries are required for energy storage. Electricity generation from solar panel is strongly related with solar radiation intensity. However as the intensity is not stable, charge efficiency is a very important topic in solar systems. Charge controllers are designed to improve charge efficiency and safety. The primary function of a charge controller is to protect the battery from overcharge and over discharge in a stand-alone PV system.

Fig 1: Solar powered Robotic Vehicle

Solar power systems in autonomous robotic vehicles have been often used for some years. A real example is the Sojourner rover, in which most of the supplied energy is generated by a reduced-size photovoltaic (PV) panel [1]. Output power provided via the photovoltaic conversion process depends on solar irradiation. The objective of this scheme is to design and develop an automatic Solar Tracker Robot (STR) which is capable to track maximum light intensity [2].The non-linearity of the Power-Voltage characteristics of a photovoltaic (PV) array that depends on the panel temperature and irradiance condition tends to inevitability of using Perturb and Observe Maximum Power Point Tracking (MPPT) technique for continuously tracking the maximum power at each ambient condition [3]. For use as an Li-ion battery charger. A mode-selectable synchronous buck DC–DC converter with high efficiency and low quiescent current is proposed [4]. Moacyr Aureliano Gomes de Brito et.al [5] presents evaluations among the most usual maximum power point tracking (MPPT) techniques, doing meaningful comparisons with respect to the amount of energy

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extracted from the photovoltaic (PV) panel [tracking factor (TF)] in relation to the available power, PV voltage ripple, dynamic response, and use of sensors. MPPT techniques are discussed in [6]-[8]. An improved perturb & observe (P&O), a sliding mode technique and a method based on power versus voltage variations are presented in [9].

2. PROPOSED METHODOLOGY

2.1 Hardware Design

Robotic unit is consist of four light sensors, tracking system, battery charger and battery selector circuits connected with solar panel which is movable around its axis in all directions. Arduino2560 processor is used for controlling complete circuitry. Arduino2560 programmed by master controller (PC). In this work Arduino2560 is used because of its user friendly nature.

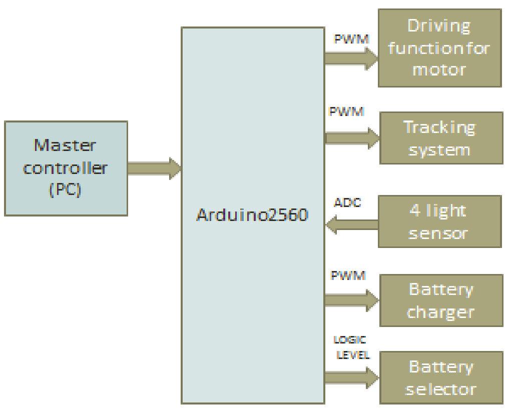

Fig 2. Functional block diagram for Robotic Vehicle

Stand-alone photovoltaic system is a combination of several elements such as PV array, DC/DC converter, load and most important a control algorithm to track the maximum power continuously as shown in fig 3.

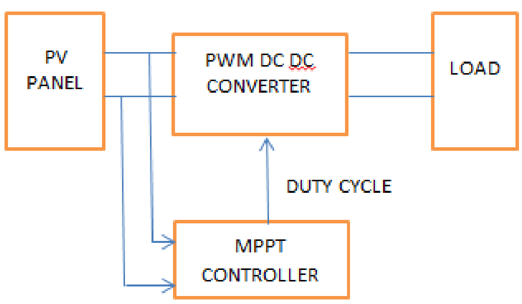

Fig 3. PV system

2.2 Solar (PV) Panel

A photovoltaic system is made up of several photovoltaic solar cells. An individual small PV cell is capable of generating about 1 or 2 W of power approximately depends of the type of material used. In the market the maximum power capacity of the module is 1 kW, even though higher capacity is possible to manufacture, it will become cumbersome to handle more than 1 kW module.

For higher power output, PV cells can be connected together to form higher power modules. Solar PV systems are usually consists of numerous solar arrays, although the modules are from the same manufactures or from the same materials, the module performance characteristics varies and on the whole the entire system performance is based on the efficiency or the performance of the individual components.

Solar panels are heavily dependent on the intensity and the nature of light falling on them to produce any kind of voltage. The output varies right from 0.2V to 21.2V. Table 1. shows the solar panels behavior at different intensities of light.

Table 1.Solar panels behavior at different intensities of light

Conditions	Open circuit voltage across the panel
Covered with cardboard	0.263V
Covered with Paper	2.5V
At the window(11am)	14.72V
In the lab	7.62V
Using a torchlight at distance 15cm	11.22V
At the terrace(2pm)	21.2V(maximum Voc=21.4V)

2.2.1 *PV array model*

The basic block of PV module is the solar cell which is simply described as a p-n semi-conductor junction that directly converts solar radiation into DC current using the photovoltaic effect. The electrical equivalent circuit of solar cell is shown in figure 4.

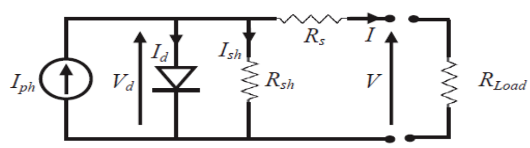

Fig 4. Single Diode Equivalent Circuit of PV Module

$$I = I_{ph} - I_{sat} \cdot \left[\exp\left(\frac{q.(V + R_s.I)}{nkT} \right) - 1 \right] - \frac{V + R_s.I}{R_{sh}} \quad (1)$$

where I and V denotes the output current (A)and voltage (V) of a solar array, *Iph* is the generated light current (A) at certain insulation, *Isat* denotes a diode reverse saturation current (A), *q* is the electronic charge =1,6x10-19C, *n* refers to a dimensionless deviation factor from the ideal p–n junction diode, *k* is Boltzmann's constant =1.3807x10^-23 JK-1, *T* denotes a solar cell temperature (K), *Rs* is the series resistance (Ω) that represents the internal losses, while *Rsh* is a shunt resistance (Ω) corresponds to the leakage current to ground.

2.3 PWM DC DC Converter

The buck converter is known to be a step-down converter where the ratio between its input voltage (vi) and the output voltage (vo) is controlled by the duty cycle (d) of the switch. The schematic of PWM DC/DC converter is shown in figure 4

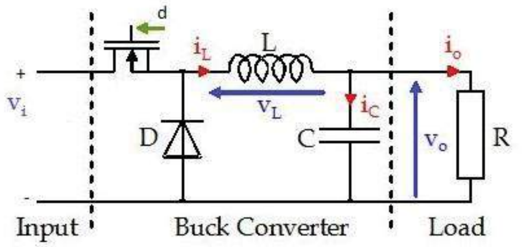

Fig 5. PWM DC/DC converter.

Under the assumption that the buck converter is working in continuous current mode, the converter input–output voltage relationship can be represented by the following (averaged) relation in equation 2.

$$d = \frac{v_o}{v_i} \qquad (2)$$

The selection of capacitor and inductor size is a major part in designing a buck converter that is mainly affected by the selection of the switching frequency (*fs*).At higher switching frequency, the value of inductor will be lower in order to produce continuous current and smaller capacitor size to limit output ripple. The minimum inductor value (*Lmin*) is determined as quoted in equation 3.

$$L_{min} = \frac{v_o\,(v_i - v_o)}{\Delta i_L \times f_s \times v_i} \qquad (3)$$

Where Δi_L the inductor ripple current calculated as in equation 4 while Io is the maximum output current.

$$\Delta i_L = 0.2 \times i_o \qquad (4)$$

For the buck converter to operate at CCM, the inductance value has to be 25% greater than Lmin [23] as in equation 5.

$$L = 1.25 \times L_{min} \qquad (5)$$

The pulsating current produced by the switching action is smoothed by the capacitive filter at the input/output where the capacitance value is determined by equation 6, as Vr is the ripple voltage.

$$C = \frac{\Delta i_L}{8 \times f_s \times v_r} \qquad (6)$$

2.4 Battery Charging

The switching system consists of two selectors with break-before-make operation logic. Their function is connecting electrically the charge and discharge paths between the batteries, the charger module, and the load system. That is, selector 1 is inserted between the charger and the dual-battery pack. Its function is routing the current from the PV panels to the input of the charger and, from there, to the battery selected in each moment. Selector 2 is used to connect the selected battery to the load system. Therefore, the dynamic connections of the electric circuit are carried out according to the Arduino-defined logical operation mode.

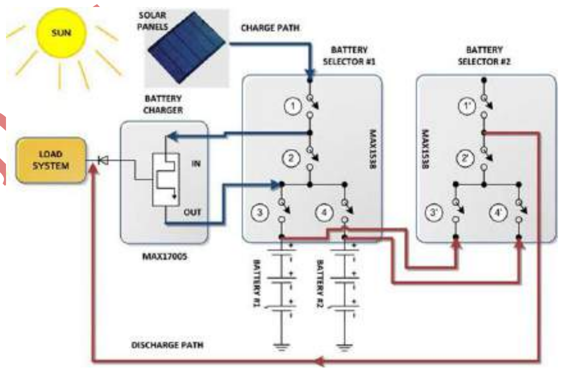

Fig 6.Overall connection diagram for batteries selectors.

2.5 Maximum Power Point Tracking Perturb & Observe Method

A MPPT tracking algorithm will be used to control the duty cycle of a DC DC converter. In this way, the algorithm will force the solar panel to operate at, or very close to, its maximum power point.

The P&O is probably the most commonly used approach out of all the MPPT methods used today, as it is lacking in complexity and can be relatively easy to implement. It works by periodically incrementing or decrementing the voltage of the PV array. The change in power is then observed. If the perturbation has resulted in an increase in the output power then the algorithm continues to perturb in the same direction. If there is a decrease in power then the algorithm will perturb in the opposite direction. When the P&O algorithm has found the MPP it never actually settles on it, rather it oscillates around it.

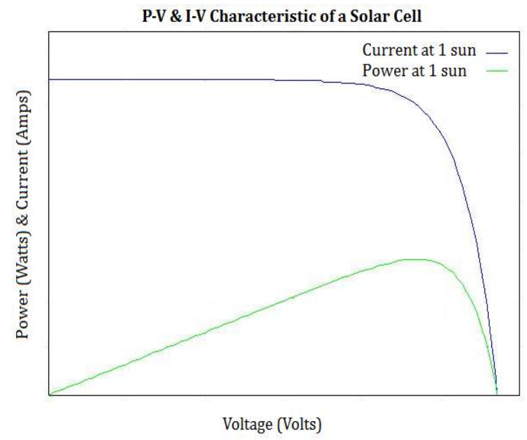

Fig.7 PV characteristic of a Solar Cell using MPPT

3. RESULT

As an example of the battery system working in an alternate way, Figs.8 & 9 shows the charging and discharging operation. The capacity stored and delivered to the load system in terms of power during the charging and discharging. Initially, the battery selector of the vehicle detects the battery with lower capacity and carries out its charging while the battery with higher capacity supplies the load system.

Thus, in the Fig. 8 battery 1 receives the charge current until reaching a set rate of~1500mA,while battery 2 is only supplying Robotic Vehicle active electronics (IL ~250 mA).The graph illustrates how battery 1 passes from the constant current charging phase to the constant-voltage charging phase when Vup reaches 12.15 V for this test. Then, the charge current of battery 1 begins to drop while stabilizing the voltage and battery 2 continues in discharge until the end voltage is reached (Vend = 11.2 V for this test). In this point, at t=44 min the switching of the batteries system is observed.

The turn-OFF and turn-ON times of the batteries take place in a time ttrans = 6 μs in which no supplies are connected to each other during the transition. In summary, the constant-current charging phase—in which the Li–Po battery is considered charged to a 75–80%—takes up relatively short time, while the following phase (80% to 95–100%) takes much longer as shown.

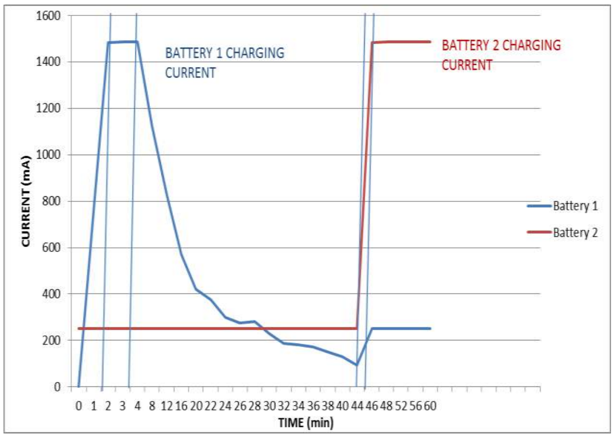

Fig. 8. Current curves in the batteries for a charging and discharging cycle.

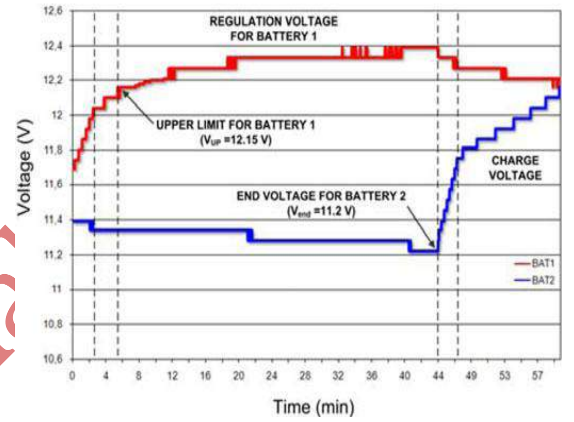

Fig 9. Voltage curves in the batteries for charging and discharging cycle.

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