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Battery Charging Algorithm in a Solar Powered Robotic Vehicle based on Embedded System

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Abstract

This paper is about a robotic vehicle. The main objective of this robotic vehicle is to design an efficient charging system of batteries by means of tracked solar panels. The charging and discharging cycles of the batteries based on the PIC microcontroller is the design concept elaborated in this paper. On the PIC micro-controller the concept of efficient charging system is designed. The energy system consists of two batteries and these of two batteries are, one for charging independently from the solar panel and the other battery gives the energy for the Robotic vehicle. By implementing this method the efficient power management becomes possible. The switching time between the batteries can also be reduced by the control algorithm programmed in the PIC micro-controller.
Keyword- Robot, Photovoltaic (PV) System, PIC Controller

I. INTRODUCTION

Solar Power Systems in autonomous robotic vehicles have been often used for some years. For battery charging solar panels are used in many rovers. A real example is the Sojourner rover, in which most of the supplied energy is generated by a reduced-size Photovoltaic (PV) panel [1] and the photovoltaic panel does not get enough solar light and the batteries cannot be charged [2]. The concept of rechargeable batteries was first used in the Mars Exploration Rovers [3]. Later NASA designed rover for exploration and remote operation also [4]. The example for the remote science exploration and intelligent operation is the K9 rover [5]. Micro 5, a series of Robotic exploration vehicle also uses Solar panels for lunar exploration [6].

Some noteworthy projects were came whose main advantage is the efficient and optimal selection of solar energy and different sources of energy depends on the area of working [7]-[9]. Hyperion is an example for this type of rover which uses the concept of solar synchronous techniques for the better use of the energy generated by the solar panels [10]. Zoe is also a rover which uses two batteries. The main aim of this rover is to move long distance under tough conditions [11].

This paper focuses to improve the operation of aforementioned robotic exploration rovers with intelligent purposes and also with the power system operations. This paper is presented as follows. The next section explains the basic platform, which describes the hardware and software design. After that the PIC micro-controller based efficient battery charging. These two sections controls the battery charging, discharging and the switching between them based on the tracked solar panels readings. Then the next section focuses on the various parameters and charging and discharging cycles of the battery. The final section includes the results and developments based on the work.

II. BASIC PLATFORM

The rover consists of four wheels that can rotate independently. Since it can control independently the Ackerman configuration and different types of movement are also possible. Each wheel consists of two motors. When the motors rotate in the clockwise direction with constant speed, then the vehicle will move in the forward direction. So one motor can be used to control the direction of the vehicle by changing its speed. The movement can be achieved by using dc motors (12V and 60mA) that give 120 r/min. This robotic vehicle also consists of an Omni vision wireless camera. Due to its smaller size and weight the robotic vehicle can be used as a rover vehicle.

The basic platform that is the mobile robotic platform consists of hardware and software architectures. The hardware architecture (Fig.1) consists of light sensors, solar panel and the power system components. These are designed with hierarchical control structure based on the PIC micro-controller. The software architecture consists of three main program levels. The first level consists of LabVIEW language and is executed in a remote PC for the control and to display indications from the rover. This provides the user interface [12]. The communication between the remote PC and the rover is achieved by using a UHF modem. The second level consists of C language program which runs on a master PIC 16F876A micro-controller. The third level consists of program on several slave micro-controllers (4 × 16F88) distributed in I2C network for different rover operations.

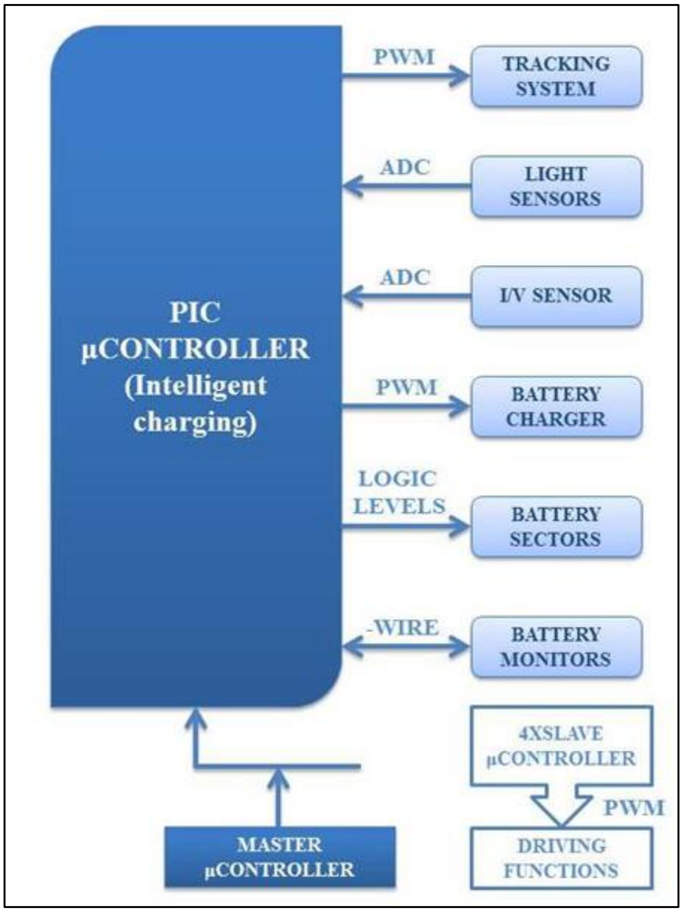

Fig. 1: Architecture of hardware

III. System Design

The efficient power management system consists of the batteries combined with the communicating devices and the other components able to control the charging and discharging of batteries. To make an economic system we designed an intelligent micro-controller. The idea of intelligence is applied in the software design.

The Intelligent micro-controller performs the low cost power management system for the rover. The power system includes the photovoltaic (PV) system, batteries section, charger device, selector system and monitor system. The intelligent micro-controller is the PIC 16F886 micro-controller which controls the power management of the system [13]. It has mainly two functions: 1) Controlling the solar panel by reading the surroundings light levels, 2) monitoring the readings from the batteries and the solar panels, then takes the appropriate decisions for charging and discharging.

A. Solar Tracking Mechanism

The selection of solar panels is very important for the efficient power management. The size and weight should be less for the easy control of solar panels. In this paper we are used the monocrystalline solar panels and whose dimensions are 200mm × 250mm × .2mm and the weight is 0.7 kg per panel. This paper focuses to track the solar panels according to the increasing power levels in the PV panels. The other systems using navigation techniques to control their panels towards the sun [12] but here, the rover controls its panels towards the maximum powerful light source. The gain of the system depends on the efficient axis movement of the solar panel and the sensor pairs mounted in it.

The mechanical solar tracking system consists of (a) a solar panel which is fixed and (b) two panels with symmetrical movements. The fixed solar panel is placed horizontally. The movable solar panels are connected with the metal gear servos. Fig. 2 is the schematic representation of the mechanical design of solar tracking system of the robotic vehicle: (a) upper solar panel, (b) mobile solar panels, (c) aluminium chassis, (d) methacrylate chassis, (e) methacrylate support, (f) pan and tilt unit, (g) pitch servomotor, and (h) yaw servomotor.

Solar –type CdS photoconductive cells are the basic of the tracking system. It consists of four sensors which are soldered on a PCB and is attached to one solar panel. The photoconductive cells are arranged in a crosspiece manner. The face of the sensors is narrowed by means of opaque plastic tubes to improve the performance of the tracking system. This method determines the brightness value at each cardinal point of the solar panel.

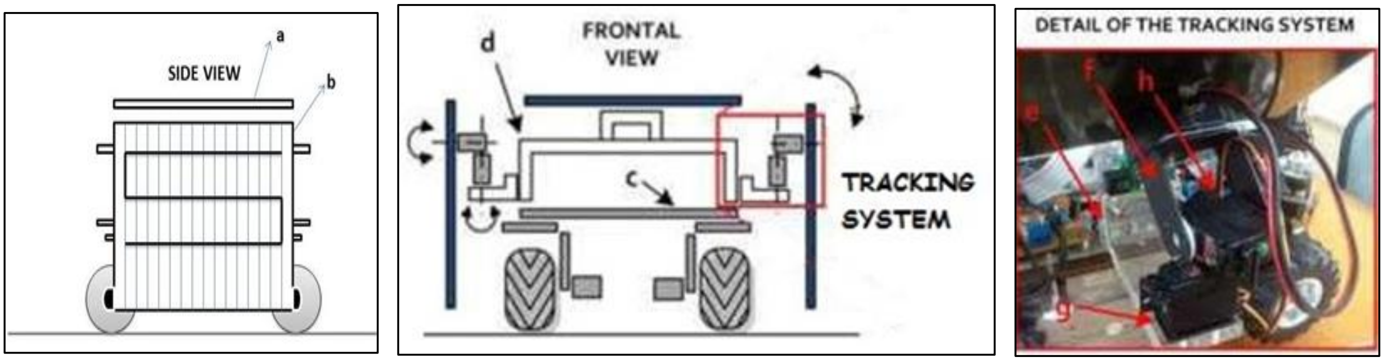

Fig. 2: Mechanical design of the solar tracking system of Robotic vehicle: (a) fixed solar panel, (b) movable solar panels, (c) aluminum chassis, (d) methacrylate chassis, (e) methacrylate support, (f) pan and tilt unit, (g) pitch servomotor, and (h) yaw servomotor.

The values from each pair of the sensors are compared and from their difference the panels adjusting to the most powerful light source with the help of servo motors. The photosensors include both amplifier and signal conditioner integrated circuit. The servomotors used for controlling the solar panel directions by pulse with modulation (PWM) and whose duty cycle determines the required motion. The rotations are achieved by means of PWM signals generated as follows:

$$y = \exp((x + 30) / 20)$$

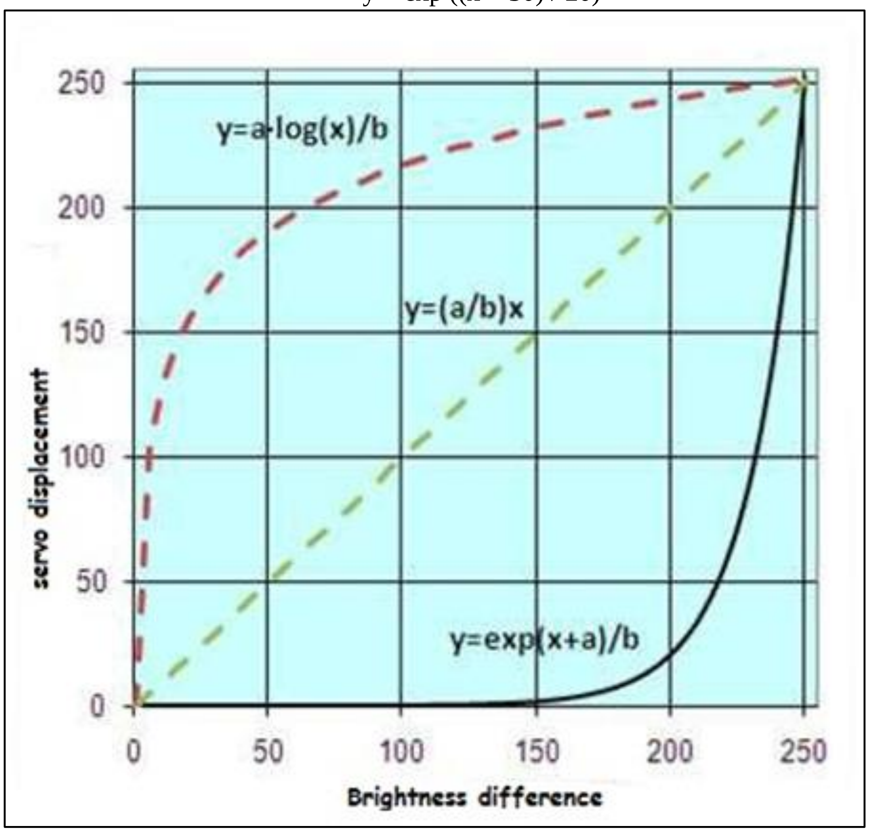

Fig. 3: Graphical representation of different servo control signals: equation implemented (continuous line) and other equations studied (dashed line)

This expression responds to an intelligent micro-controller programmed algorithm, where y is the servo displacement and x is the difference between the illuminations of each couple of photosensor, constants are the experimentally obtained values (Fig. 3). The mobile solar panels come perpendicular to the most powerful light based on this expression. Thus maximum energy collection is possible.

B. Battery Switching Operation

The switching system consists of two MAX1538EVKIT selectors with break-before-make operation logic. The function of software section is to connect the batteries, charger system and load for charging and discharging purposes (Fig. 4). The battery selector routes the current from the PV panels to the input of the charger and also to the battery selected. Selector 1 is placed in between of the charger and the dual-battery pack. Selector 2 connects the battery to the load system. The electrical connections are made by the intelligent micro-controller based on the threshold voltage values that are programmed in it. The logical operation mode of the battery selectors are shown in the Table II. When the battery selector mode is 1 then the battery 1 will be in the charging state. While battery selector mode is 2 then battery 2 will be in the discharging state. In Fig. 4 the charge current that obtained from the PV panel is routed to the charger module and the discharging current of the battery is routed to the load system. There is also another feature to operate load by directly using the power from the PV panel. This condition is used when two batteries are fully discharged.

C. Charging and Discharging

The charging and discharging operation is managed by the intelligent micro-controller which consists of the control algorithm. This is based on MPP (Maximum Power Point) by increasing the output current of the charger module.

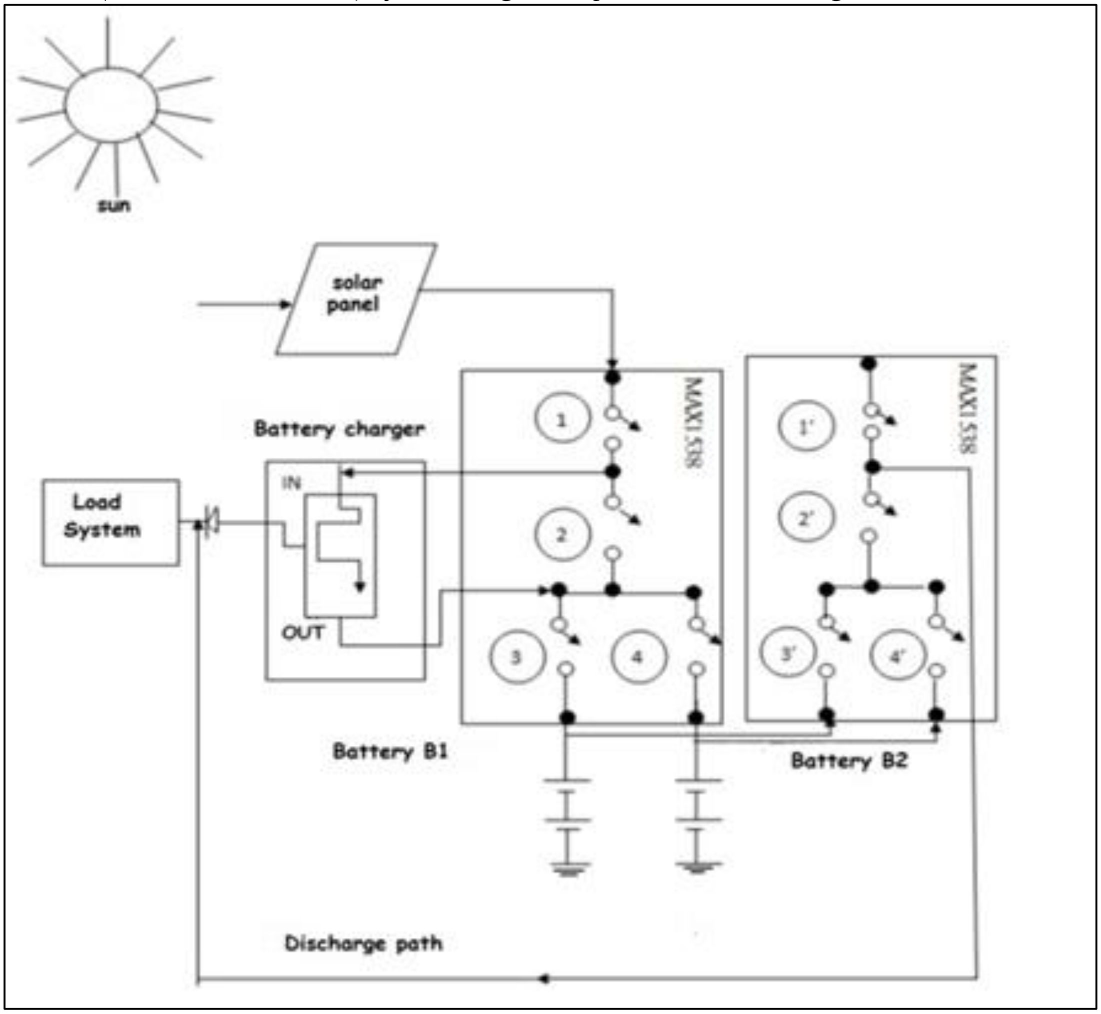

Fig. 5: Overall connection diagram for batteries selectors

Battery Selector		*2*		*4*	*1'*	*2'*	*3'*	*4'*
#1 charging & #2 discharging	*C*	*O*	*C*	*O*	*X*	*C*	*O*	*C*
#1 discharging & #2 charging	*C*	*O*	*O*	*C*	*X*	*C*	*C*	*O*

'C'- Closed & 'Open'

Table 1: Logical operation mode of the battery selectors

The MPP tracking scheme is based on the dynamic power path management (DPPM) [14]. By this method the voltage variation in the PV panel is detected by the I/V sensor as a power variation and these signals are used by the intelligent micro-controller. The intelligent micro-controller enable, disable and control the charger module by means of a pulse width modulated (PWM) signal. The algorithm in the intelligent micro-controller first checks the power from the PV panel (Fig. 5). If it has appropriate power then the intelligent micro-controller increases the output current of the charger up to the maximum regulation current. If the power from the PV panel is low then the intelligent micro-controller immediately reduces the current drawn to the battery until power stabilizes at the power panel.

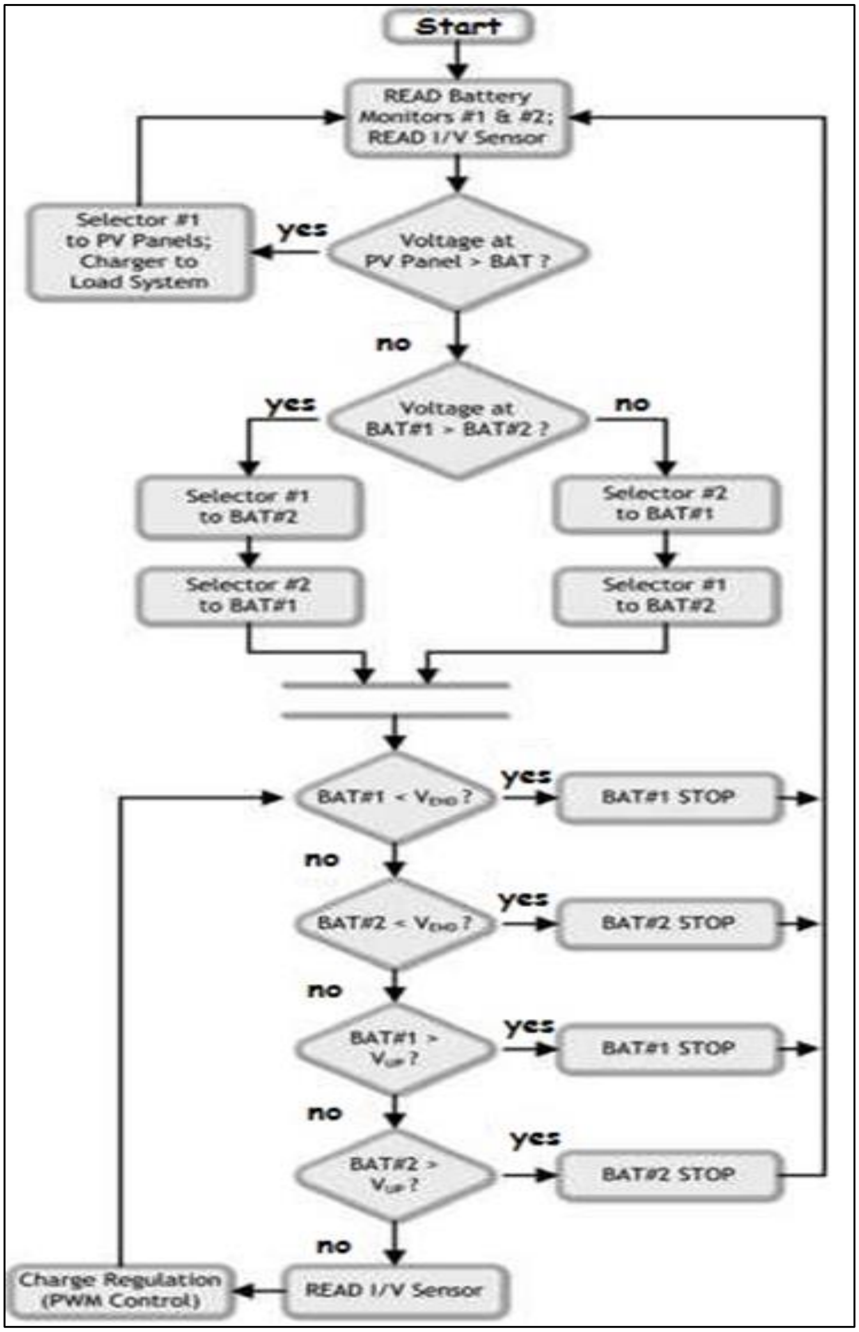

Fig. 5: Charging and discharging cycle algorithm

D. Rechargeable Battery System

This paper proposes two batteries units and is working alternatively. At a time one battery one battery will be charging by using the PV panels' current and at the same time another battery will deliver the energy needed for the robotic vehicle. Fig. 6 shows the different strategies of solar powered robots with battery system. In fig. 6 (a) shows dual battery system, (b) shows conventional system, and (c) shows the load sharing system. In this paper the design of independent charging and discharging cycles are implemented. This helps to reduce the size of solar panel since it charging only one battery at a time. The rechargeable system consists two NanoPack V2 Batteries of three Li-Po cells connected in a 3S2P configuration. This provides high efficiency, energy density and long life in addition to their low size and weight.

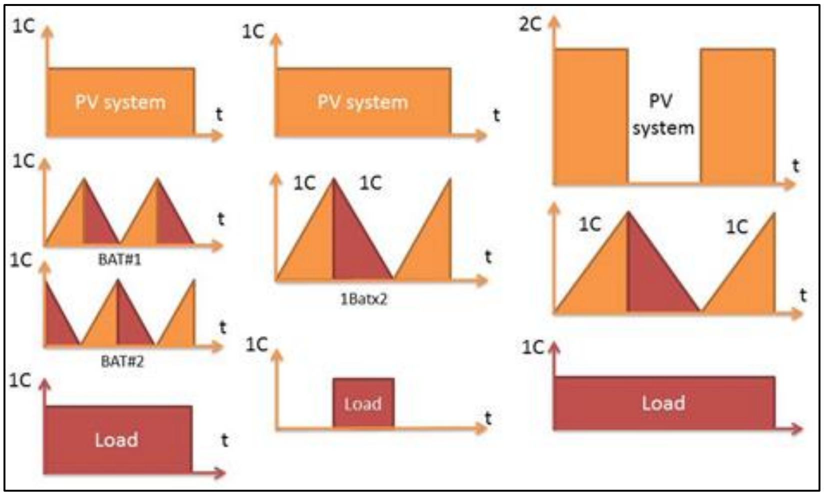

Fig. 6: Different strategies of solar-powered robots with battery system

IV. MEASURING PARAMETERS

The threshold values for the dynamic charging and discharging regulations are defined in the intelligent micro-controller programmed algorithm to prevent Li-Po batteries from damaging and to extend their life cycle (Fig. 5). The power requirement of the PV system results from the estimation of the voltage and current values that the charger supplies to the battery. The maximum voltage at the charger output is approximately equal to the voltage of the fully charged battery during voltage regulation, which corresponds to VOC = 12.6 V. Figure 7 is the graph that shows the charge curve of three Li-Po cells and the measures were taken in each battery cell at periods of 100ms. This graph shows different states from the initial voltage to the protection voltage Vup, after that a portion of unused voltage is defined V_{cutoff} to avoid damages in the Li-Po batteries. Figure 8 is the discharge graph of the cells and that varies from the initial voltage to the protection voltage Vend, below which there is a portion of unused voltage and is called as cutoff voltage, V_{cutoff}.

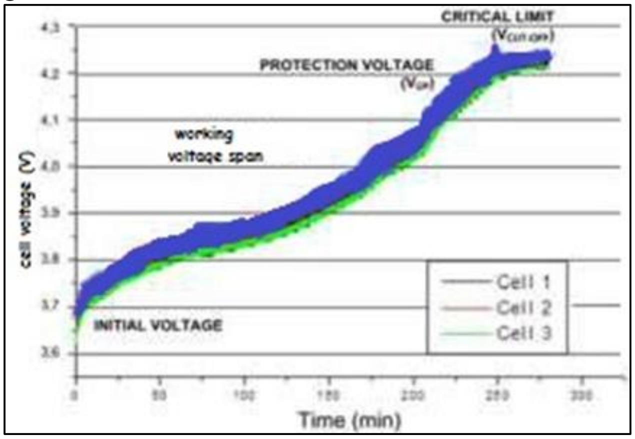

Fig. 7: Charge voltage characteristics

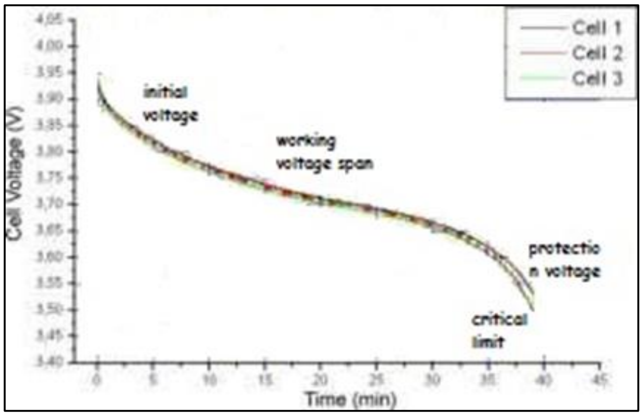

Fig. 8: Characteristics of discharge voltage

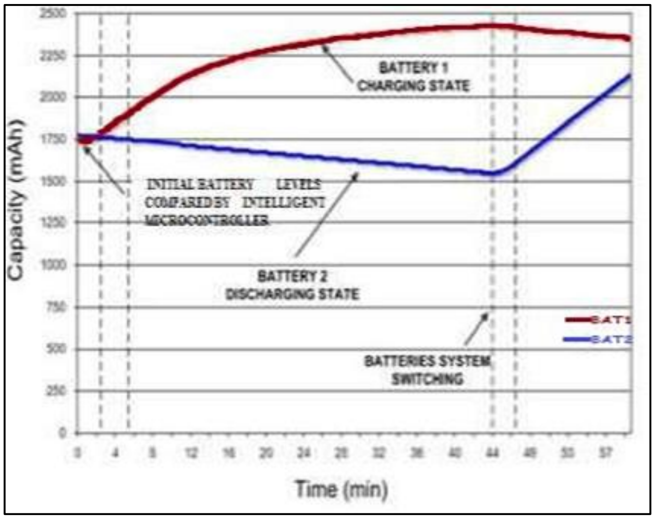

Fig. 9: Capacity curves in the batteries

Figure 9 is the capacity curves in the batteries for charging and discharging cycles. First the algorithm of the intelligent micro-controller finds the battery with lower capacity and doing its charging while the battery with higher capacity supplies the load system.

V. Conclusion

This paper has presented an intelligent energy management system in a robotic vehicle. The proposal includes the construction of a solar tracker mechanism that capable of tracking maximum intensity of light. Only one battery is charging at a time and hence the solar panels are smaller in size. An intelligent micro-controller is designed for the efficient charging and discharging by means of an MPP tracking scheme based on the DPPM.

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