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An Intelligent Power Management approach for Battery Operating Robotic Vehicle

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Abstract

This paper is about a robotic vehicle aims on the design of efficient charging system of batteries by means of tracked solar panels. The main attraction of this paper is the design concept of the charging and discharging cycles of the batteries based on the PIC micro-controller. The efficient charging system concept is designed on a PIC micro-controller. The energy system consists of two batteries and 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 control algorithm programmed in the PIC micro-controller. Since only one battery is charging at a time, the size of solar panel also can be minimized. The sensors attached to the battery system will monitor the battery's external parameters and thus the life time of battery can be increased based on the sensors readings. The readings from the vehicle will get in the remote PC.

Keywords: Photovoltaic(PV), robotic vehicle, solar tracker.

Introduction

Solar power is the most commonly using renewable energy in electronics field. The concept of battery charging using Solar panel has been used for some years. Many rovers are using Solar panel for their battery charging. An example for the rover using the solar power for charging is Sojourner which have reduced size photovoltaic (PV) panel [1] and the photovoltaic panel doesn't get the enough solar light 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 have come 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]. The concept of battery switching is used in VANTER a rover which have a pair of batteries [14]. The main problems faced in the existing systems were higher photovoltaic size, no battery protection from external environmental conditions and charging and discharging of the battery at a time reduces the life time of the battery.

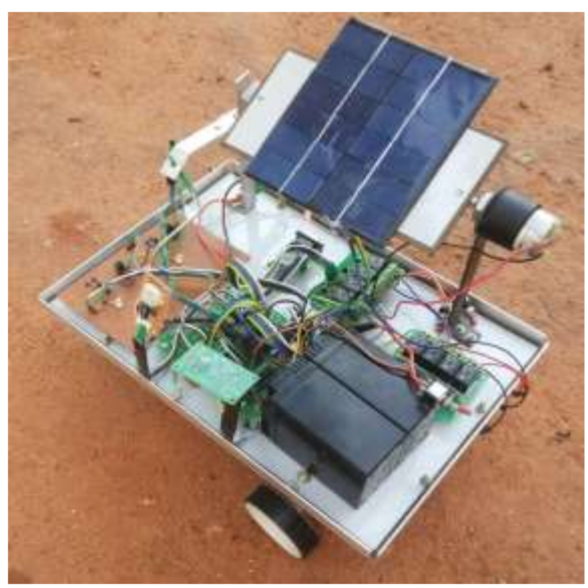

Fig. 1. Solar powered Robotic Vehicle

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This paper focuses to improve the operation of aforementioned robotic exploration rovers with intelligent purposes and also with the power system operations. Fig.1 represents the proposed system. The tool used in this proposed system is Visual Basic for indicating the external parameters like temperature, humidity for monitoring the battery external parameters. Visual Basic also gives the light sensors readings and provides Graphical User Interface (GUI). VB also includes the control switches for the vehicle movement control. The system reduces the size of the PV panels by charging one battery at a time and other will be connected to the load. This paper is presented as follows. The next section is the basic platform, which describes the hardware and software design. After that describes the solar tracking mechanism and the battery section. These sections control the battery charging, discharging and the switching between them based on the tracked solar panels readings. The final section includes the results and developments based on the work.

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. One motor will used to control the direction of the vehicle by changing its speed. The movement can be achieved by using dc motors (6V 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.2) consists of light sensors, solar panel and the power system components. These are designed with hierarchical control structure based on the PIC micro-controller

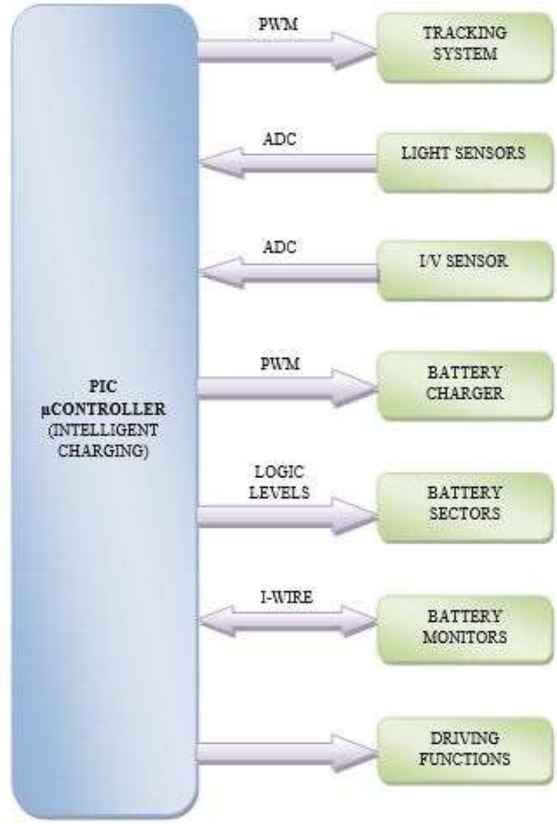

Fig. 2. Hardware Architecture

The software architecture consists of two main program code levels. The first level consists of Visual Basic 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 Zigbee. The second level consists of C language program which runs on a PIC 16F877A micro-controller.

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 have used the monocrystalline solar panels and whose dimensions are 200mm × 250mm × 3.2mm 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 [20].

In this paper, three Light Dependent Resistors (LDR) are used to detect the intensity of

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light. LDR the sensor that varies its resistance depends on the intensity of light falling on it. When the intensity of the light decreases, the resistance of the sensors increases and the intensity of light increases the resistance of the sensors decreases. So it is easy to find the high intensity light source. The arrangement of the sensors is shown in the Fig. 3. The face of the sensors can be narrowed by means of opaque plastic tubes to improve the performance of the tracking system

Fig. 3. Light Sensors. (a), (b) Side light sensors, (c) Middle Light Sensor

The motors are used for controlling the solar panel directions by pulse width modulation (PWM) and whose duty cycle determines the required motion. The pulse width modulation duty cycle is determined from the sensors value. The VB software in the remote PC acts as Graphical User Interface which gives the sensors readings and also provides the control switches for the vehicle movement. Fig. 4 shows three sensor readings, LDR1 is the middle sensor, LDR2 and LDR3 are the side sensors. From the simulation result it is clear that the middle sensor is getting the higher intensity of light so the PV panel will automatically adjust to the horizontal position to get the maximum energy.

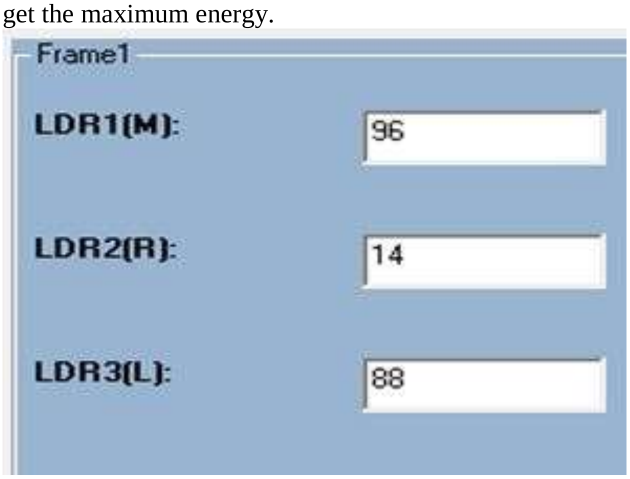

Fig. 4. Light Sensor Readings.

Battery Section

Battery Section consists of a pair of Lead- acid batteries, charging section and a sensor section. The availability, performance and the cost considering lead acid batteries are well suited for many applications. Fig. 5 shows the pair of lead acid battery and the sensor. Since lead acid battery contains corrosive acid and some chemicals the chances of leakage of gases and some chemicals are there. Hence the installations of sensors like humidity sensor and gas sensor monitors the battery's physical parameters. The readings from the sensors are also available in the GUI (Fig. 6)

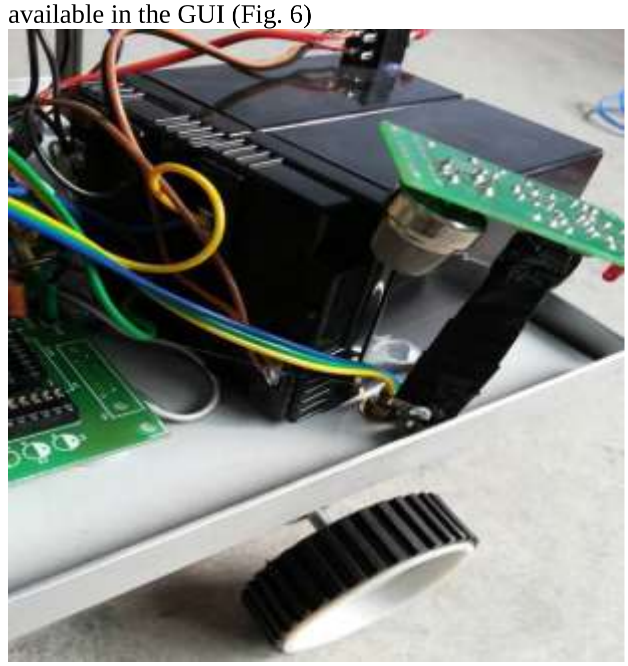

Fig. 5. Pair of Lead acid battery and gas sensor

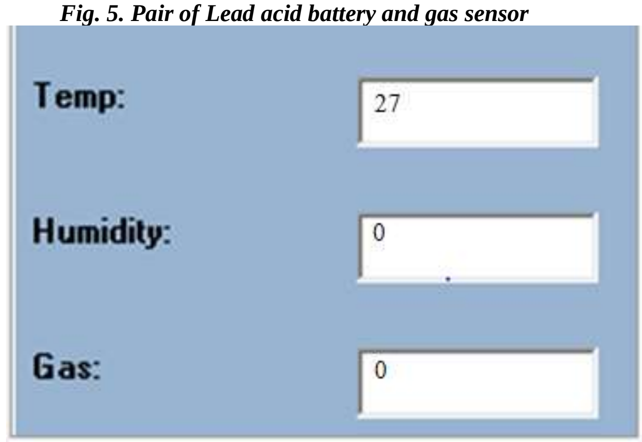

Fig. 6 Sensor Readings window in the Remote Laptop.

A. Battery Switching Operation

The switching system consists of two MAX1538EVKIT selectors with break-before-make operation logic. The function of software section is to

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connect the batteries, charger system and load for charging and discharging purposes (Fig. 7). The battery selector 1 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 I. 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. 7 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.

B. Charging and Discharging

The intelligent micro-controller consists of the control algorithm which manages the charging and discharging operation. This is based on MPP(Maximum Power Point) by increasing the output current of the charger module [15]. The MPP tracking scheme is based on the dynamic power path management (DPPM). By this method the voltage variation in the PV panel is detected by the I/V sensor in the charger section 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. 7) 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

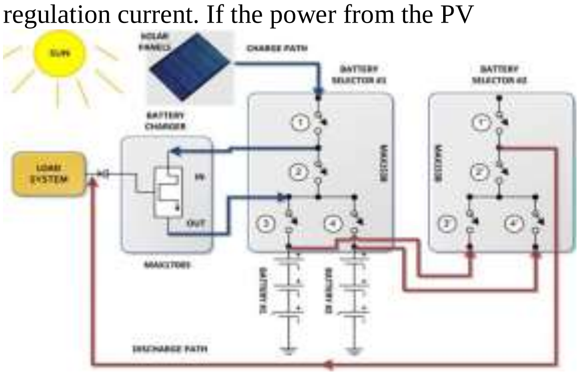

Fig. 7. Overall connection diagram of battery selectors

Table i

Logical operation mode of the battery selectors

Battery Selector	1	2	3	4	5	6	7	8
#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, O = Open, X = No Connected

panel is low then the intelligent micro-controller immediately reduces the current drawn to the battery until power stabilizes at the power panel.

C. Rechargeable Battery System

This paper proposes two batteries units and is working alternatively. At a time 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. 8 (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 of two Lead Acid batteries. This provides high efficiency, energy density and long life in addition to their low size and weight.

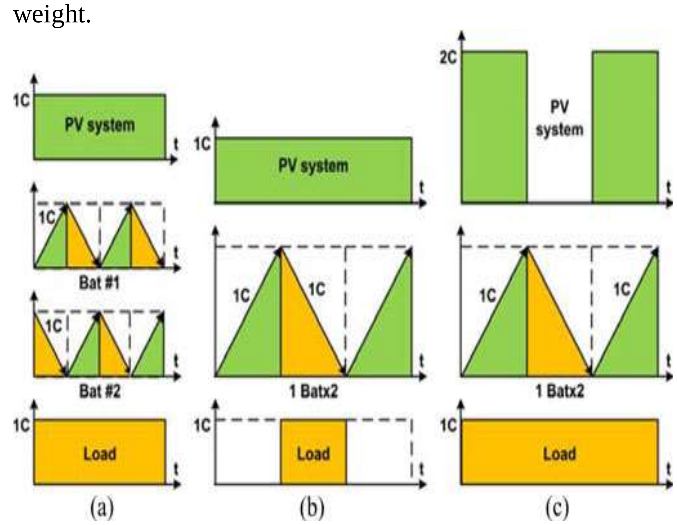

Fig. 8. Different strategies of solar-powered robots with battery system

D. Measuring Parameters

The threshold values for the dynamic charging and discharging regulations are defined in the intelligent micro- controller programmed algorithm to prevent lead acid batteries from damaging and to extend their life cycle (Fig. 9). The power

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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 V_{OC} =6.6 V

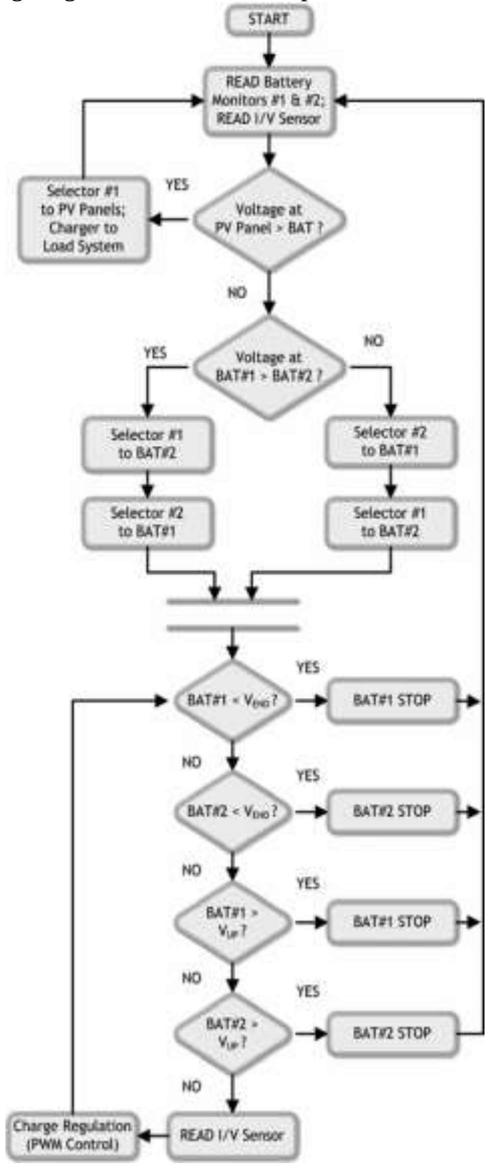

Fig. 9 Algorithm of the charging and discharging cycle

Lead- acid battery emits small amount of hydrogen gas while proper charging. Over charging of lead acid battery can produce hydrogen-sulphide gas. The gas is colorless, very poisonous and flammable. Thus by implementing the gas sensor the batteries life can be monitored. A lead acid battery produces some hydrogen gases also but the amount is minimal when charged correctly. Hydrogen gas is explosive and one would need a concentration of 4% to create an explosion. This level will only be achieved if large lead acid batteries were charged in a seal room. MQ-8 is the sensor used here because it is the suitable sensor to sense hydrogen concentrations in air.

Lead acid battery mainly consists of Lead, Sulfuric acid and corrosive chemicals. Lead is a toxic metal. If leaked on to the ground, the acid and lead particulars contaminate the soil and become airborne when dry. The sulfuric acid in a lead acid battery is highly corrosive and is potentially more harmful than acids used in other battery systems. Lead acid batteries that are damaged or missing a cap can leak acid. The leakage of these corrosive chemicals results the entire damage of the components in the robotic platform. Humidity is the presence of water in air. The presence of water vapor in air may result the formation of fungi in the battery leads. This will produce loose connection. So humidity sensor is attached near the battery. This will measure the humidity of the environment and also sense the leakages in the battery. SY-HS-220 is the humidity sensor module used in the system. This module converts the relative humidity in to output voltage. The rated voltage of the sensor module is dc 5V and the operating temperature is 0-60^{o}C.

Conclusion

Solar energy is one of the most powerful renewable energy sources. This paper has presented an intelligent energy management system in a robotic vehicle using solar energy for charging batteries. The proposal includes the construction of a solar tracker mechanism that capable of tracking maximum intensity of light and the efficient switching between the two batteries has done there by increasing the life time of the batteries by the proper switching of batteries at desired voltage levels.

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.

Solar energy is the most clean and strong energy resources. Earth receives 174 petta watts of incoming solar radiation at the upper atmosphere at any given time, and is our best source of hope for the future.

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