

Optimal Battery Charging In a Solar Powered Robotic Vehicle with Solar Tracking Mechanism

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Abstract: This paper focuses on the design and construction of an optimization charging system for Li-Po batteries by means of tracked solar panels. Thus, the implementation of a complete energy management system applied to a robotic exploration vehicle is put forward. The proposed system was tested on the VANTER robotic platform—an autonomous unmanned exploration vehicle specialized in recognition. The interest of this robotic system lies in the design concept, based on a smart host microcontroller. On this basis, our proposal makes a twofold significant contribution. On the one hand, it presents the construction of a solar tracking mechanism aimed at increasing the rover's power regardless of its mobility. On the other hand, it proposes an alternative design of power system performance based on a pack of two batteries. The aim is completing the process of charging a battery independently while the other battery provides all the energy consumed by the robotic vehicle.

Keywords: Li-Po Battery, Mechatronic System, Photovoltaic (PV), Robotic Vehicle, Solar Tracker.

I. INTRODUCTION

The main object of this project to control the battery-charging system by means of tracked solar panels. Autonomous robotic vehicle have been often used for some years in solar power system Sojourner rover is the real example of this system. In which most of the supplied energy is generated by a reduce a size photovoltaic panel. In case of solar light, they should minimize consumption since its batteries in line could not be recharged when depleted. The mars Exploration rover was use of rechargeable batteries in space mission for the first time. The future Exo Mars mission solution of this work and and basis for the solar panel. This rover, thanks to high efficiency ultrathin film silicon cells constructed on carban-fiber rein forced plastic is capable of providing higher power. NASA design in spired different generation of exploration vehicles.K9 is example of this system, the autonomous operation and remote science exploration using rover. The field integrated design and operations, Jet propulsion Laboratory for long range mobile planetary science by advanced prototype technology, and Micro5, a series of robotic vehicle device for lunar exploration. The rover series has dual solar panel system coupled to an assisted suspension mechanism is main advantage. This prevents the manipulator arm mounted on the middle of the rover from having to minimize solar panel-generated power and allows it to dust solar panel surface.

II. MOTIVATION OF THE PROJECT

Other robotic exploration vehicles have also been developed in academic spheres. This is the case of SOLERO, developed by the 'Ecole Polytechnique F'ed'erale de

Lausanne, which reached optimal energy consumption by a combination of a smart power management and an efficient locomotion system. On the other hand, the Carnegie Mellon University developed Hyperion, a rover in which the major technological milestone was. The implementation of solar-synchronous techniques to increase the amount of energy generated by solar panels; and Zo'e, a rover capable of long-distance traverses under extreme environmental conditions devoted to science investigation at the Atacama desert .With an educational approach, Carnegie Mellon University also developed a personal exploration vehicle called PER. More recently, Lever and coworkers and have described the concepts of modeling, design, and fabrication of a robot-box prototype to be used in polar environments .The platform—known as Cool Robot—uses a control algorithm of maximum power point (MPP) aimed at maximizing system-supplied power for five PV modules designed as a cube. Finally, there are some noteworthy projects which main achievement is the optimal selection of solar energy and different power sources according to the operation conditions of a robot.

III. SYSTEM DESIGN

The implementation of a complete energy management system applied to a robotic exploration vehicle is put forward in this system the East sensors; west sensor and solar panel are fixed. East and west sensors are used to continuously sense solar energy either east side or west side according to that the solar panel will track the solar energy and battery will charge. Motor driver will charge through ARM Controller. The Zigbee communication net

work is used to transmit the information to monitor section as shown in Fig.1.

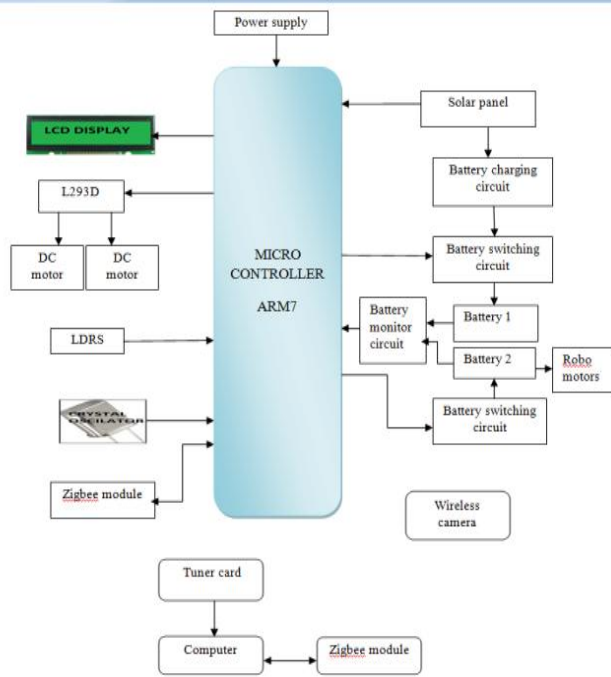


Fig.1. Block diagram of Robotic unit.

A. Description of Control Unit

The complete robotic section can be controlled through the control unit. The control unit consists of the Zigbee and PC. The PC used to monitor and control the robotic section through Zigbee communication as shown in Fig.2.



Fig.2. Control Unit.

IV. ARCHITECTURE OF VANTER

A. Description of Architecture Of Vanter

The robotic system programming is divided into three main code levels and its hardware was designed with a hierarchical control structure based on modular microcontrollers (see Fig. 3).The top level program, carried out in Lab VIEW language, is executed in a remote PC and offers a GUI to monitor and control the whole robotic vehicle [21]. The second code level, programmed in C language, runs autonomously on a master IC16F876A microcontroller aboard VANTER. Communication with the remote PC is performed by using a UHF modem for the centralized control of rover functions. The third code level consists of several slave microcontrollers distributed in an I2C network aimed at the distributed control of the VANTER driving functions (4×PIC16F88), remote manipulation, and power management.

B. Description of Power Management System of VANTER

A typical power management design consists of smart batteries integrating both communication devices and electronics able to control the charge. However, when an economical system is required, the concept of intelligence should be applied to software design for simple batteries.

One of the main objectives of this paper is the implementation of the SHM concept to develop a low-cost power management system aboard a robotic vehicle. The system consists of an electrical circuit interconnecting a PV system, a charger device, a selector system, a batteries monitor system, and a battery system (see Fig. 3).The SHM is based on a PIC16F886 microcontroller, which monitors VANTER consumption and decisions in a completely autonomous way [22]. The SHM has two main functions: 1) detecting environmental light level and controlling the solar tracking system to obtain the highest power; and 2) interpreting operation data from batteries and solar panels to control the working mode of the charger accordingly. The cost of this system regardless of the navigation instruments and VANTER software.

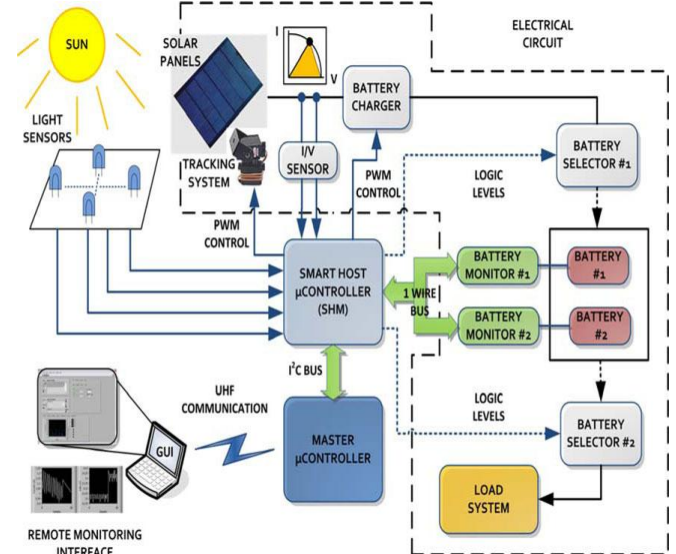


Fig.3. Overall scheme of the power management system of VANTER.

C. Batteries Switching System

The switching system consists of two MAX1538EVKIT 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 (see Fig. 3). 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 SHM-defined logical operation mode. This is based on the voltage thresholds programmed into the control algorithm.

D. Charging and Discharging System

When describing the implemented system, two different parts can be distinguished: a first one exclusively devoted to the intelligent management of the charging/discharging process, including controlling and monitoring sensor signals, and a logical part devoted to power flow management through VANTER energy sources. MAX17005BEVKIT was the charger system used. This device consists of a dc–dc synchronous-rectified converter with step-down topology (efficiency over 90%) (see Fig. 5). The charger system is

Optimal Battery Charging In a Solar Powered Robotic Vehicle with Solar Tracking Mechanism

controlled by the SHM using a PWM signal applied to one of its terminals and supplies each battery according to a programmed algorithm. Between the PV system and the charger system there are a voltage conditioning capacitor and an I/V sensor from AttoPilot with 0–3.3 V output. The capacitor C_1 prevents voltage at the charger input pin V_{ch} from falling below the charge voltage of the battery cells V_{cv} when solar power is not capable of providing appropriate voltage level V_s . During that instant the capacitor is discharged with a current I_{ch} through the dc-dc converter. The role of the I/V sensor is detecting the current and voltage levels that solar panels provide to the charger device. The algorithm implemented in the SHM consists of a charge regulation by increasing the output current of the charger module according to the MPP. The MPP-tracking scheme is based on the dynamic power path management (DPPM) function described by Texas Instruments Incorporated [27]. This low-cost solution is a simplified MPP tracker able to harness 90–95% of maximum power. On this basis, a voltage variation in the PV panels is detected by the I/V sensor as a power variation.

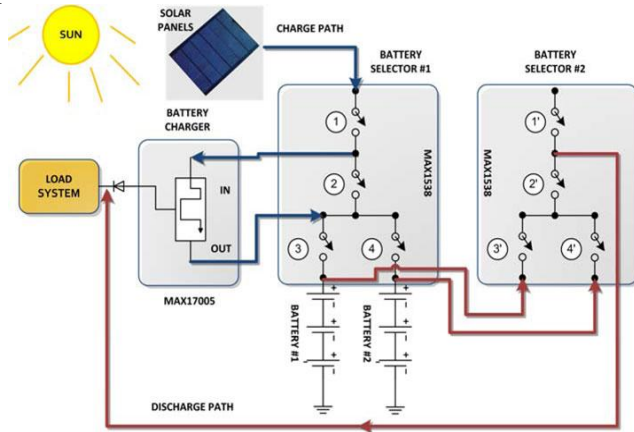


Fig.4. Overall connection diagram for batteries selectors. The logical operation for charging and discharging modes is shown in Table II.

Table I. Logical Operation Mode of the Battery Selectors

Battery Selector	1	2	3	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, O = Open, X = No Connected

E. Batteries Monitoring System

The aim of the monitoring system is maximizing the life and energy storage of Li–Po cells. Therefore, the main function of this system is monitoring the state of charge (SoC) of the batteries and accurate control of the charging–discharging cycles. The use of a dual battery monitor system was required for control and parameter measurement. This module consists of two DS2788EVKIT+ integrated circuits manufactured by Maxim- IC. Each of these is connected to the batteries in parallel so that the charge/discharge current passes through its measuring resistor and by means of a 1-Wire bus multi drop type, both to the load system and the charger through the SHM. The main advantage of the dual monitoring system is that it allows continuous measurement

of both the capacity of the battery in charge as well as of the one being discharged. Among other essential monitored parameters such as voltage, current, and temperature—which prevent batteries from working near their warming limits the monitor displays some other important parameters such as the batteries' SoC, relative capacity (%), absolute capacity (mAh), state of health (SoH), and internal resistor (R_{int}).

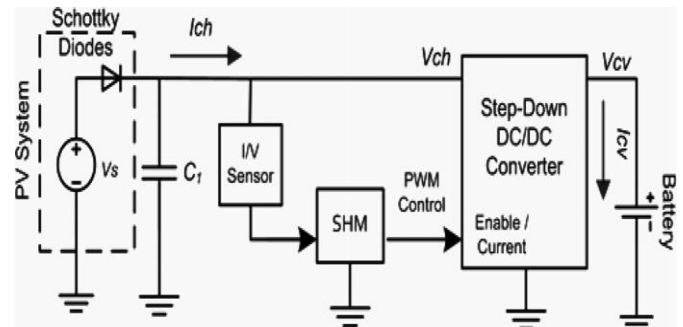


Fig.5. Connection diagram of the charger system.

F. Rechargeable Battery System

The design implemented in this paper proposes the use of two separate battery units working alternately. Thus, one of the batteries receives the charge current from the PV system while the other provides VANTER with all the energy it requires. Unlike other designs, in a conventional system the power source is used to recharge a single battery. As a disadvantage, the robot can only be used when the battery is fully charged and must remain idle during the recharging.

V. RESULTS

The implementation of a complete energy management system applied to a robotic exploration vehicle is put forward in this system the East sensors; west sensor and solar panel are fixed. East and west sensors are used to continuously sense solar energy either east side or west side according to that the solar panel will track the solar energy and battery will charge. When Robotic vehicle is used in the industrial applications then the temperature sensor and Gas sensor will measure the temperature and Gas in the field environment and send it to the monitoring section as shown in Figs.6 to 14.

A. The Robotic Vehicle



Fig.6. best battery charging using solar energy for robotic vehicle based on relay host microcontroller without power supply.



Fig.7. Best battery charging using solar energy for robotic vehicle based on relay host microcontroller.



Fig.11. Robot moving to the Right displayed on the LCD.



Fig.8. Charging the first battery with the solar power displayed on the LCD.

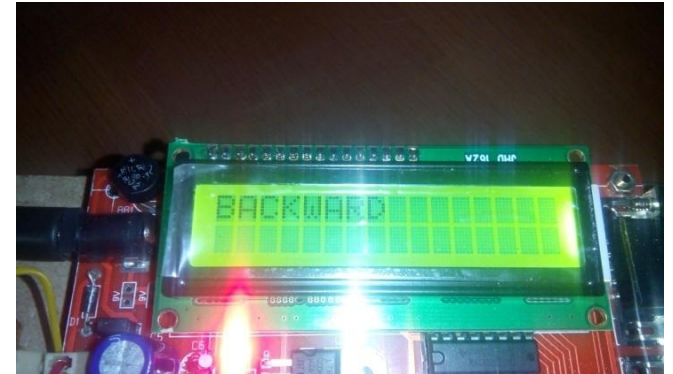


Fig.12. Robot moving to the Backward displayed on the LCD.



Fig.9. Charging the Second battery with the solar power displayed on the LCD.



Fig.13. Robot moving to the Forward displayed on the LCD.



Fig.10. Robot moving to the left displayed on the LCD.



Fig.14. Robot moving to the Stop displayed on the LCD.

B. PC Results

The complete robotic section can be controlled through the control unit as shown in Fig.15. The control unit consists of the Zigbee and PC. The PC used to monitor and control the robotic section through Zigbee communication.

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X-CTU [COM1]
About
PC Settings | Range Test | Terminal | Modem Configuration
Line Status | Assert | Close Com Port | Assemble Packet | Clear Screen | Show Hex
DTR  | RTS  | Break 
. F
. FORWARD S
. STOP B
. BACKWARD S
. STOP R
. RIGHT L
. LEFT S
. STOP F
. FORWARD B
. BACKWARD R
. RIGHT L
. LEFT S
. STOP S
. STOP

OPTIMAL BATTERY CHARGING IN A SOLAR POWER
ROBOTIC VEHICLE
=====
. F. FORWARD ON B. BACKWORD OFF R. RIGHT L. LEFT
S. STOP

. SOLAR WEST SIDE
. SOLAR WEST SIDE
. SOLAR WEST SIDE
. SOLAR WEST SIDE
. SOLAR WEST SIDE
. SOLAR EAST SIDE
. SOLAR EAST SIDE
. SOLAR EAST SIDE.....

CDM1 | 9600 8-N-1 FLOW:NONE | Rx: 13048 bytes
    
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Fig.15. Results displayed on PC through the ZIGBE.

VI. CONCLUSION

This paper has presented a smart energy management system applied to a robotic platform called VANTER, an autonomous unmanned vehicle devoted to exploration tasks. The proposal includes the construction of a solar tracker mechanism based on mobile PV panels aimed at increasing system energy. Its main advantage is that the amount of generated power is independent from the rover's mobility, since the proposed mechanism is capable of tracking maximum light intensity. Delivering the systems' energy requirements while recharging the backup battery was made possible by implementing a dual system of selectors, monitors, and batteries. This strategy implies small solar panels to power a single battery at a time. A relatively good compromise between total weight, capacity available, and source-required power is reached. This solution does not attempt to achieve high charging times or great operating times but to prove a sustainable and commercially feasible solution applied to a robotic vehicle. In this sense, an SHM was designed for optimal charge regulation by means of an MPP tracking scheme based on the DPPM.

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