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SIMULATION FOR OPTIMAL BATTERY CHARGING IN SOLAR POWERED-ROBOTIC VEHICLE

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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 was 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 recover'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. This aim is completing the process of charging a battery independently while the other battery provides all the energy consumed by the robotic vehicle**.**

I. INTRODUCTION

SOLAR power systems in autonomous robotic vehicles have been often used for some years. The VANTER robotic exploration vehicle aims to improve various aspects of the aforementioned rovers with scientific and academic purposes. The rover is developed to be plane chassis that can rotate independently. The four-wheel-drive(4WD) and the individual control of each wheel allow different types of movement, including Ackerman configuration, the crabbing manoeuvre or the rotation with inner inertial centre. The four wheels in VANTER are sustained by means of independent passive suspension of double aluminium fork to absorb terrain vibrations shown in figure.

II. EXISTING SYSTEM

SOLAR power systems in autonomous robotic vehicles have been often used for some Years. For real example sojourner rovers. In which most of the supplied energy is generated by a reduced size photovoltaic (PV) panel. However, in case of scarce to no solar light, the rover should minimize consumption, since it batteries in line could not be recharged when depleted. The use of rechargeable batteries in a space mission was used the first time in the mars exploration rovers. Nevertheless, the need for greater operation autonomy by spirit and opportunity was solved by means of larger deploy solar panels. This solution work as basis for design of solar panels for the future Exomars mission. This rover, thanks to its high–efficiency ultrathin film silicon cell constructed in reinforced plastic, is capable of providing high power.

III. PROPOSED SYSTEM

In this paper, to implement the maximum power tracking without robot, and also we can implement the maximum power tracking with robot and controbility from dot net and smart phone.

The concept of smart host microcontroller (SHM) for intelligent power management applied to an exploration vehicle. The following section presents the control of the battery-charging system by means of tracked solar panels, which is the main aim of the paper, design of its mechanical structure its electronic device and the graphical user interface (GUI) are presented. Aims to providing the necessary parameter for the battery sizing, charging, discharging algorithm, and the pv system sizing. Therefore developed methodology by testing the rover power system. Finally, the result and finding from the developed work presented.

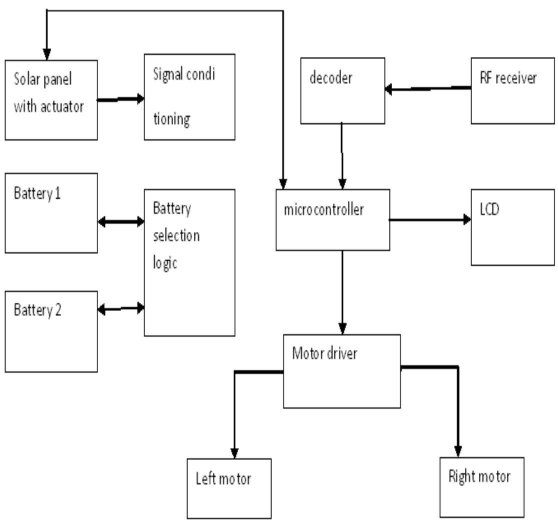

Fig.1. Block diagram of optimal battery charging in solar device

IV. WORKING METHODOLOGY

Each module is rated by its DC output power under standard test conditions, and typically range from 100 to 320 watts. The efficiency of a module determines the area of a module given the same rated output an 8% efficient 230 watt module will have twice the area of a 16% efficient 230 watt module. This robot is equipped with two batteries. The robot switches to the battery which has more charge. In this time the other battery starts charging via solar panel. This itelligence can be achieved by the use of microcontroller.

A. MECHATRONIC SYSTEM DESIGN

A typical power management design consists of smart batteries integrating both communication devices and electronics able 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.

The SHM is based on a PIC16F886 microcontroller, which monitors VANTOR consumption and decisions in a completely autonomous way. 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 instruments and VANTER software—is US$ 600.

B. PHOTOVOLTAIC SYSTEM WITH SOLAR TRACKING MECHANISM

When selecting the solar panels, VANTER physiognomy and consumption dictated its construction and electric requirements. The panel weight is a factor that limited its mechanical design; light-weight panels provide lower power consumption and require optimizing the robot's overall performance. The proposed PV system consists of three monocrystalline solar panels with laminated PET, whose dimensions are 200 mm × 3.2 mm and its weight is 0.7 kg per panel.

The PV system provides power, keeping in mind that voltages and currents generated must adapt to the maximum and minimum values of the hardware. However, since the environmental natural features cannot be predicted at each instant, the quantitative energy from solar radiation cannot be predicted either. Thus, one of the main proposals of this paper is implementation of a solar tracking mechanism aimed at increasing power levels in the PV panels. Unlike other rovers that use in navigation techniques to guide their panels toward the sun, VANTER's mobility does not represent a disadvantage since the proposed tracker systems looks for the most powerful light source. Solar tracker prototypes built in mobile robots have proven that orientation of PV systems leads to increase energy efficiency relative to systems with fixed solar panels (20-50% per collector). This gain is depends on several construction strategies of the solar tracker such as the type of axis movement (either single or dual), types of sensors on which is based (photo resistors or photo conductive cells), and the accuracy rendered by the number of sensor pairs. On the contrary, parasitic load consumption associated to the proposed configuration (a mobile solar panel, two batteries, and electronics) compared to a simple system (a fixed panel, a battery, and electronics) compared to increased between 1.14% and 21.42%.Thus, standard dc motor was proposed to reduce the consumption up to 8.57%.

Figure shows the mechanical solar tracking system. This comprises a fixed solar panel mounted horizontally on VANTER and two panels with symmetrical movements. The mechanical structure is mounted on an aluminium chassis on which the electronics were mounted. On the top platform a methacrylate panel with two side supports has been assembled. The solar panels are mounted on pan and tilt units formed by two DYS0213MGs metal gear servos. Each pair of digital servomotors allows soft rotations with amplitude of 180 □ in azimuth and elevation, so that the solar panels can be oriented to toward any part of the space.

The tracking system design is based on solar-type CdS photoconductive cell. This consists of four Hamamatsu S9648-100 photo sensors mounted on a PCB attached to one solar panels of VANTER. The advantage of the selected devices is that they have a spectral sensitivity peak near 600 nm where light is considered to have more energy. To improve the performance of the tracking system, the photoconductive cells are arranged in a crosspiece and their field of vision is narrowed by means of opaque plastic tubes an outwardly directed gap. The advantage over other systems based on solar mathematical equations is that mechanism allows tracking as closely as possible to the solar position in any ambient light situation. To this end calibrating photo sensors' sensibility by means of variable resistors, which has the advantages of adapting to different brightness locations and lighting conditions?

Tracking the most powerful light source is possible because analog signals are obtained by the photo sensors since they already include both amplifier and signal conditioner integrated circuits. Proportional light values is compared in pairs and, from their different adjusting the control signal for azimuth and elevation required by the tracking system. Each servo is controlled by a pulse width modulation, whose duty cycle determines the required rotations. Instead of increasing or decreasing the duty cycle at fixed values until servos face the light source, rotations are achieved by means of PWM signals generated as follows:

$$Y=\exp(X+30/20). \quad (1)$$

This mathematical expression responds to an SHM programmed algorithm where y stands for servo displacement, x is the difference of illumination between each couple of photo sensors, and constants values experimentally obtained in ground testing. The advantage of this strategy relative to other types of equations is the servos performing large displacements when the lighting values between each pair of photo sensors evince high discrepancies on its axis. Similarly, shorter and accurate shifts are obtained when lighting values are approaching the most powerful light source. In this way, the pan and tilt` units try to place mobile solar panels perpendicularly to the most intense source available. Higher energy collection is therefore possible. On the other hand, the tracking algorithm also takes into account VANTER's kinematics configuration. Thus, it prevents servomotors from reaching limit positions during rotation so as to prevent solar panel from colliding with other robotic elements.

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. 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 movement. Selector 2 is used to connect the selected the battery to the load system. Therefore, the dynamic connections of the electric circuit are the carried out according to the SHM-defined logical operation mode. This is based on the voltage thresholds programmed into the control algorithm.

In the first row, selector 1 was programmed to charge battery 1 while selector 2 is preset to discharge battery 2. Charge current obtained from the PV panels is routed to the charger through selector 1 and, from the charger, to the selected battery. Likewise, the discharge current of battery 2 is routed to the load system through selector 2. The main advantage of the duel selector system is that it allows hot swapping of separated power supplies. In addition, in case both batteries were fully discharged, a working mode was programmed in selector 1 to supply the load system directly from the PV panels.

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.

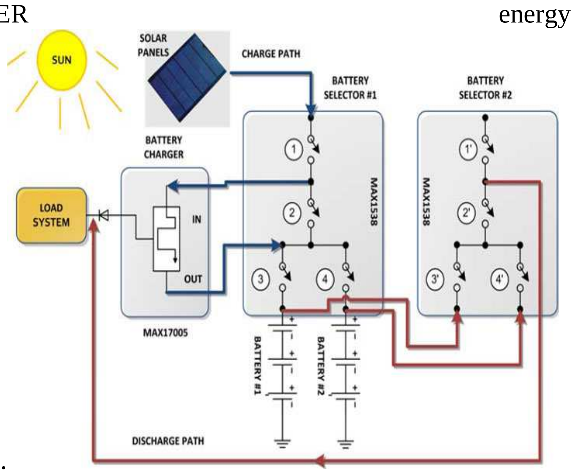

Fig.2. Overall connection diagram for batteries selectors.

MAX17005BEVKIT was the charger system used. The device consists of a dc-dc synchronous-rectified converter with step-down topology. The charger system is 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 an I/V sensor from the AttoPilot with 0-3.3 V output. The capacitor C_1 prevents voltage at the charger input pin V_{ch} from falling below the charger 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 panel provide to the charger device.

The algorithm implemented in the SHM consists of 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 function described by Texas Instruments Incorporated. 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. These signals are used by the SHM to enable, disable and control the charger current of the charger by means of a PWM signal. The solar panels were sized to obtain a voltage higher than the cut off level of the dc-dc convertor. This allowed us to implement a protection scheme against drop in solar power input to improve system performance and reliability
cannot dispense its supply unit.

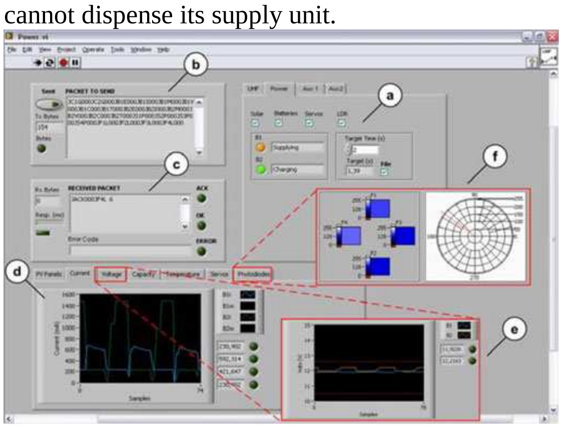

Fig .3. GUI of the power management system: (a) setup, (b) and (c) UHF system, (d) PV panels, (e) batteries monitor, and (f) solar tracker system.

The rechargeable system comprises two NanoPack V2 batteries of three Li-Po cells connected in a 3S2P configuration. The reasons for their choice were their high efficiency (98%), energy density, and long life in addition to their low size and weight without compromising a feasible cost. Thus, each battery provides the system is a capacity of 2400 mAh with a maximum voltage Vcc= 12.6 V and a size of 36 × 35 × 65 mm3.

E.REMOTE MONITOR INTERFACE

In addition to the GUIs of the navigation system and the 5-DOF manipulator arm aboard VANTER—as described in the power management system prevented in this paper may also be monitored from a remote PC. The virtual instrument is divided into several functional areas that facilitate the composition of the communication packets between the remote PC and VANTER by means of setup menus (a) and displays (b) and (c).the graphical representation of the values allows real time verification of solar panel generated voltage and current, batteries' current, voltage, and capacity as well as SoC and discharge, operation temperature, servo position and photodiodes light level. As an example of the monitoring interface operation, the switching states of the batteries current (d) and voltage (e) during the charging and discharging processes are shown in different tabs. Finally, tab (f) displays both photo sensor generated voltage levels and the magnitude and angle of the resulting vector.

V. POWER SYSTEM DESIGN

This section presents the sizes of the batteries system, the parameterization of the charging and discharging algorithm, and the sizing of the PV system in more detail.

A. BATTERIES SIZING

Each battery was sized taking into account both the maximum system consumption and VANTER continuous consumption under different operation conditions. It should be guaranteed that maximum system consumption always below the maximum battery deliverable discharge. Nevertheless, an Li-Po battery working at its maximum continuous discharge as the disadvantage of not providing the required performance and shortening its lifetime. VANTER consumption requirement is fully covered. Thus, setting the required backup time, the capacity of each battery can be estimated by means of the following formula:

$$\text{Capacity (mAh)} = t_{on}\text{ (min)} \times \text{Current demand (mA)} \,/\, 60\text{ min/h} \qquad (2)$$

Setting an operation time t_{on} = 1 h and a maximum consumption of 2000 mA—as expected in table—a capacity of 2000mAh is then required. Considering a difference of ~ 15% between the maximum and nominal capacity of a battery, a battery of 2400 mAh—as those chosen in this paper—covers this operation time.

B.CHARGE AND DISCHARGE POWER SYSTEM

On the other hand, threshold values for the dynamic charging/discharging regulation were defined in the SHM-programmed algorithm to prevent Li-Po batteries from damaging and to extend their life cycle. The charging and discharging process parameterization has been set considering the battery electrical model, where the battery stands for a voltage source with an internal resistor in series R_{int} specified by the manufacture. Considering the voltage drop across the battery and a cutoff voltage V_{cutoff} for the recharging and discharging algorithm, a maximum and minimum voltage at the V_{up} and V_{end} were defined for the charging and discharging protection conditions accordingly.

C.SIZING OF THE PHOTOVOLTAIC SYSTEM

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 corresponds to the voltage of the fully charged battery during voltage regulation, which in this case corresponds to V_{oc} = 12.6 V. In a dc-dc converter with step down topology a voltage higher than 12.6 V is required at the input, so the PV panel voltage at the MPP must exceed this value. Beside each battery employs a capacity of 2400 mAh, its charge being advisable at the rate between 0.2 and 0.7 C. This corresponds to a charge current between 480 and1680mA, with an intermediate value of 0.5 C (1200mA) a relatively good choice. These considerations, the power required by

D.RESULT AND DISCUSSION

Each module is rated by its DC output power under standard test conditions, and typically range from 100 to 320 watts. The efficiency of a module determines the area of a module given the same rated output an 8% efficient 230 watt module will have twice the area of a 16% efficient 230 watt module. This robot is equipped with two batteries. The robot switches to the battery which has more charge. In this time the other battery starts charging via solar panel. This itelligence can be achived by the use of microcontroller

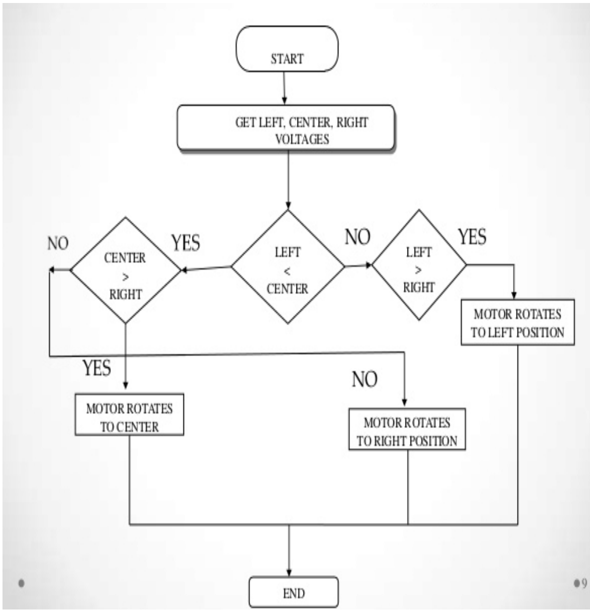

Fig.4. Flowchart for solar panel tilting

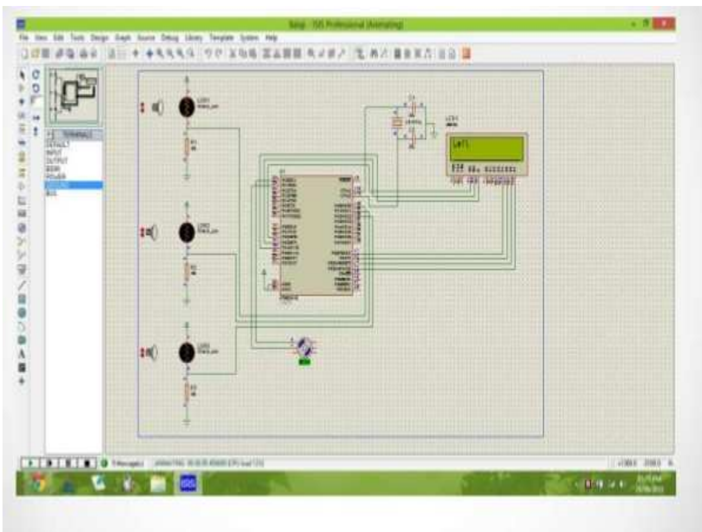

Fig.5. Simulation block interfacing stepper motor

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 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 solution does not attempt to achieve high charging times or great operating times but 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.

Experimentation shows that the charging and discharging processes that require careful Li-Po cells became possible due to a fine SHM-implemented control algorithm. To this end, practical implementations of the switching battery system according to the operating limit values.

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