Solar Powered Robotic Motor Vehicle

Rohit Kumar
School of ECE, Shri Mata Vaishno Devi University, India.

Sujeet Kumar Pathak
School of ECE, Shri Mata Vaishno Devi University, India.

Dr. Vipan Kakkar
School of ECE, Shri Mata Vaishno Devi University, India.

Abstract – This paper presents solar powered motor vehicle with the efficient charging system. This solar vehicle is used as one of the cardinal energy-saving vehicles where the application of renewable energy meets sustainable energy demand with reduction of fuel cost and purification of the atmosphere. The energy for the vehicle will be supplied by Solar panel (10W). For sufficient energy management, the charging system is used. The charging is independent of vehicle movements. When Solar panel will get sunlight, energy will be supplied to Charge controller. The battery which is connected to the charge controller will get charged via the energy received from the panel. The motor driver IC and the Bluetooth module will get power from the Arduino which gets power directly from the charge controller. Hence, the vehicle will move.

Index Terms – Solar panel, Light-Weight Vehicle, Renewable Energy, Lithium-Ion battery, Arduino, Solar Charge Controller.

1. INTRODUCTION

Energy is something which is inevitable for human survival on earth. We are either directly or indirectly dependent upon different forms of energy to meet our needs one form of such energy is the energy from the fossil fuels. The energy obtained from these sources can be used for generating electricity, running automobiles, etc. but, the fossil fuels are exhaustible as they are present in limited quantity and their regeneration takes millions of years. These are also the major source of pollution to the environment. So, we need to focus on the non-conventional sources of energy, to deal with these problems of fossil fuels. One of the possible solutions is to utilize renewable energy to meet our energy requirements. We have used solar energy as our source of energy and designed the solar-powered motor vehicle with the backup and charging system. The solar panel has been used increasingly in recent years to convert solar energy into electrical energy. Today, the reducing cost and increasing efficiency of solar energy technology have given rise to practical applications on earth from powering personal devices to provide utility power. Solar energy provides an advantage for satellites because the addition of fuel supply for satellites can be avoided while launching into orbit. But the advantages on earth are even greater. Solar-generated energy provides abundant and pollution-free energy which is not dependent on fuel delivery antecedent, foreign relations or the price machination of energy brokers. Moreover, solar power generation provides energy, where we need it and is highly scalable to match the electrical demand. Solar cells are reliable, have a long life and are very easy to maintain.

In this paper section 2 gives description about System and working methodology, section 3 describes about Hardware used, section 4 gives information about integrated system working, section 5 describes about the Results and section 6 includes Conclusion.

2. SYSTEM DESCRIPTION

Apart from the solar panel, to make a sufficient solar vehicle we have used energy efficient components like Arduino, Motor driver IC (L293D), Solar Charge Controller, Bluetooth module (HC-05), Lithium-Ion Battery. We have tried to make a lightweight mini vehicle having a chassis and other mechanical components bolted on it. We have used 200 rpm DC Geared motors for the faster movement and heavier loads. Two motors on the left and the two motors on the right are connected in series with each other so that they can be simultaneously moved forward or backwards. The Code is flashed into the Arduino before bolting it to the chassis. Whenever the vehicle is in presence of sunlight, the battery starts getting charged, else it provides power to the load from the stored energy. We have set a threshold in charge controller at 10.3 V so that whenever the voltage comes down under this value, the battery low led will glow and power to load gets terminated to prevent the battery from over-discharging. Through a DC connector, Arduino is connected to the load port of the charge module. Here, Arduino has the dynamic uses. We are getting 12V voltage from the load port of the charge controller into Arduino. The Motor driver gets the power from the Vin pin of the Arduino and it further distributes energy to the four motors connected to it, whereas Bluetooth module takes power anywhere between (3.3V-5V) from the 5V pin present on the Arduino. We have used L293D Motor driver. This is a controller. L293D is an IC which amplify the current. Actually, Motor driver is used to controlling the dc motor.

We have made a simple android application which acts as a controller for our vehicle. In this application, there are six keys. All those six keys have different application. Four keys are for the movement in the four directions and one key is assigned for stopping the movement of the vehicle. There is one key on the top which is for connecting the application to the Bluetooth module. One of the major advantages of this application is that it does not require internet for its operation. It operates through Bluetooth facility which has the range up to 10m. In this paper, an endeavor has been made to make a vehicle which is simple in design, cost-effective, lightweight and solar energy is used to run this vehicle.

2.1. Working Methodology

The working methodology of solar powered car is illustrated via a flow chart. The major components of this system are Solar Panel, Solar Charge Controller, Lithium-Ion Battery, DC Geared motor, Bluetooth Module, an android device and Arduino.

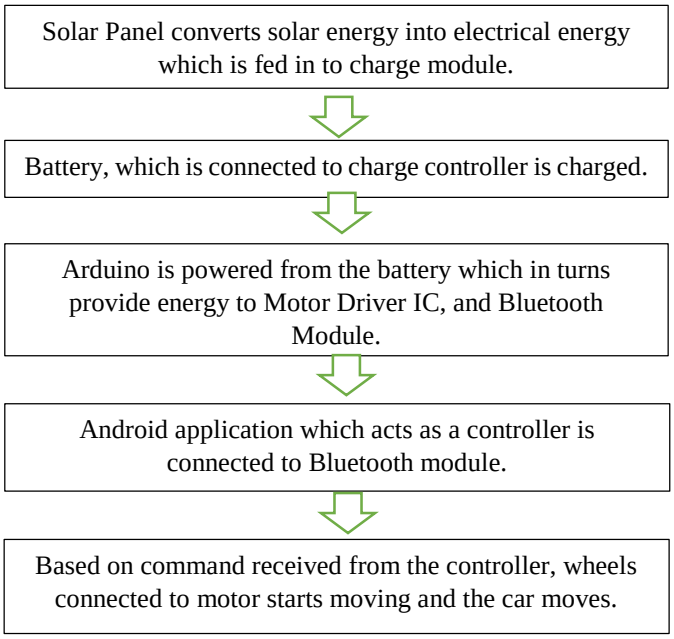

Figure 1 Flowchart of working methodology.

3. HARDWARE USED

The hardware used in the design of this system includes:

A. Solar Panel
B. Solar Charge Controller
C. Lithium-Ion Battery
D. Arduino Uno
E. Motor Driver IC (L293D)
F. Bluetooth Module (HC-05)
G. Android Application
H. Chassis
I. DC Geared Motor
J. Wheels

A. Solar Panel

Solar Panel is device which absorbs the sun's rays and convert them into electrical energy. These panels are generally made of photovoltaic cells which are arranged in a grid-like pattern on the surface of solar panel. These cells are made up of semiconductor material, usually silicon. To work, photovoltaic cells need to establish an electric field. Silicon is doped with other materials, namely Phosphorous into the top layer, which adds extra electrons, with a negative charge, and Boron into the bottom layer, which results in scarce of electrons, or a positive charge. This all adds up to an electric field at the junction between the silicon layers. Then, when a photon strikes the panel surfaces, the electrons are ejected. The silicon cell is covered with a grid of metals which directs these electrons in a path to create electricity. Amount of electrons released from the panel depends upon the intensity of sunlight incident on it. This produced electricity then can be guided through a wire to the load or to the battery for further application.

The performance of a solar panel is measured in terms of its capacity to convert the solar energy into electrical energy. The photons with sufficient amount of energy can only eject electrons which will produce electricity. The rest of the energy striking the panel is either reflected or is wasted as heat. So, the solar panels generally has low efficiency. In India, the panels available has an efficiency ranging from 12% to 20% [3].

The Solar panel used to design the system has the following specifications:

Parameters	Values
Peak power (Pmax)	10W
Max. power voltage (Vmp)	18.25V
Max. power current (Imp)	0.58A
Open circuit voltage (Voc)	20.12V
Short circuit current (Isc)	0.63A
Fuse Rating	15A
Dimension (L x B x H)	320x200x18mm
Weight	0.70kg

Table 1 Solar Panel Specifications.

Figure 2 Solar Panel.

B. Solar Charge Controller

Solar charge Controller is a device which regulates the voltage and current from the solar arrays to the battery in order to prevent overcharging and also over discharging. Charge controller basically influences the rate at which electric current is added to or drawn from the batteries.

According to the rating of solar panels and the battery, the solar charge controller is selected. At peak temperature, the solar panel which we have used is giving current up to 1.2A. This current can damage the battery, if directly fed to the battery for charging. 12V/6A charge controller is an ideal choice for our system as it can easily protect the battery from high current. Our controller has two input and three output ports. One of the input port is for connecting the wires from solar cell, and other for connecting the terminals of the battery. Two of the output port is for connecting and the load and one of output port provides a 5V static output which can be used to charge mobiles phones while driving the car. Here the load, refers to the Arduino which further provides power to Motor Driver IC and Bluetooth Module.

Figure 3 Solar Charge Controller.

C. Lithium-Ion Battery

Lithium-ion batteries are a family of rechargeable batteries having high energy density and are commonly used in various types of electronics products today. Each cell has essentially three components: a positive electrode (connected to the battery's positive (+) terminal), a negative electrode (connected to the negative (−) terminal), and a chemical called an electrolyte in between them. The positive electrode is made from a chemical compound called lithium-cobalt oxide ($LiCoO_2$) and the negative electrode is generally made from carbon (graphite) and the electrolyte varies from one type to another.

When the battery is charging up, the positive terminal of battery releases some of its lithium ions, which move through the electrolyte to the negative, graphite electrode and remain there. The battery takes in and stores energy during this process. When the battery is discharging, the lithium ions move back across the electrolyte to the positive electrode, producing the energy that powers the battery. In both cases, electrons flow in the opposite direction to the ions around the outer circuit.

They are very popular as a variety of advantages are associated with them. They are much lighter in weight and smaller in size than any other batteries of same capacities, so where there is requirement of batteries having such specifications, these batteries are boon for that condition. They hold their charge. A lithium-ion battery pack loses only about 5 percent of its charge per month, compared to a 20 percent loss per month for NiMH batteries [4]. They can handle hundreds of charge/discharge cycles.

Since we are using simple DC geared motor, our main constraint was weight. Lighter the weight will be, less power will be required, efficiency will be increased and hence, power will be saved. Since, the Arduino is in need of Voltage in the range of 9V-12V, and current in the range of 400-500 mA (total current required by Arduino to run all four DC geared motors and Bluetooth Module). So, we have selected a battery which has rating of 12V/2000 mAh which can easily drive our circuit for four to four and half hours continuously.

Figure 4 Lithium-Ion Battery.

D. Arduino Uno

Arduino is an open-source electronics platform based on easy-to-use hardware and software. Arduino consists of both a physical programmable circuit board (often referred to as a microcontroller) and a piece of software, or IDE (Integrated Development Environment) that runs on our computer, used to write and upload computer code to the physical board. The. Unlike most previous programmable circuit boards, the Arduino does not need a separate piece of hardware in order to load new code onto the board. Through simple USB Cable, we can directly upload our code in to the Arduino. Additionally, the Arduino IDE uses a simplified version of C++, making it easier to learn to program. Finally, Arduino provides a standard form factor that breaks out the functions of the micro-controller into a more accessible package.

We have connected barrel jack pin of Arduino to the load port of the Charge Controller for receiving power. Further, Motor Driving IC is connected to the Vin pin of Arduino and HC-05 is connected to the 5V pin of the Arduino for powering up respective devices. Through USB Cable, we have uploaded the code to the Arduino for its operation.

Figure 5 Arduino Uno

E. Motor Driver IC (L293D)

The Motor Driver (L293D) is a dual H-bridge integrated circuit (IC). It act as a current amplifier which can drive small DC geared motors. In this driver, high current signal is used to drive the motors. It has two inbuilt H-bridge driver circuits which can drive two dc motor simultaneously, both in forward and reverse direction. The motor is controlled by input logic at pins 2 & 7 and 10 & 15, output pins are 3 & 6 and 11 & 14 whereas enable pins are 1 and 9 Input logic 00 or 11 will stop the corresponding motor. Clockwise and anticlockwise directions will be rotate in logic 01 and 10 respectively. Motor driver ICs are mainly used in autonomous robotics. A lot of microprocessors work at low voltages and need a small amount of current to work while motors require a relatively higher voltage and current. Since, Arduino cannot supply this amount of current directly to the motors. So, there is need of a device which can amplify the current and current requirement can be met. Therefore, we have used L293D Motor Driver IC to meet this need.

We have connected the motor output to the input pins present on the IC. The output of left motor from the IC is connected to the Pin 3, 4 and the output of right motor is connected to Pin 5, 6 on the Arduino.

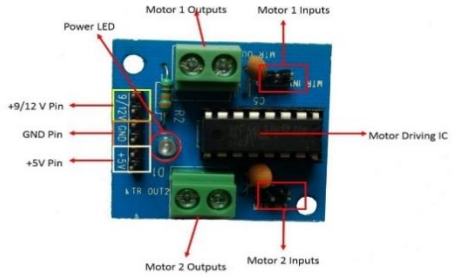

Figure 6 Motor Driver IC (L293D)

F. Bluetooth Module (HC-05)

The Bluetooth module HC-05 is power efficient, compact and easy to use module. This is Bluetooth SPP (serial port protocol) module. It is designed for wireless serial connection. This is an ideal solution for a short range of communication. It has a range of 10m. It requires 3.3V-5V of voltage and contains six pins. These six pins are STATE, RDX, TDX, GND, VCC and EN. STATE pin is used for the act as a status indicator. It also tells us that signal is coming or not, signal strength, paired or unpaired etc. RDX pin is used for receiving the signal. TDX pin is used for transmitting the signal. GND is for Ground. VCC is for the supply voltage (3.3v -5v). EN pin is used for a start the functionality of Bluetooth device. If EN is low then Bluetooth module will not work. It should be always high for working.

We are powering up this device from the Arduino and transmitting the instruction received from the android application to the Arduino for control of vehicle movement.

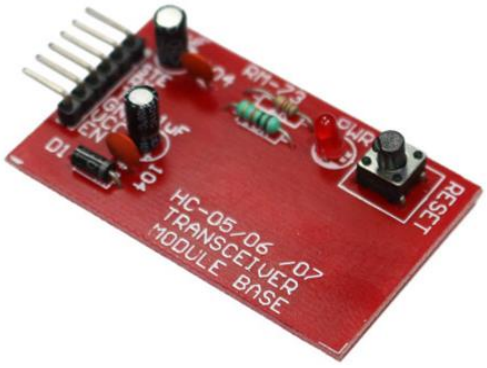

Figure 7 Bluetooth Module (HC-05)

G. Android Application

An android application is developed for controlling the movement of our vehicle [6]. It has six icons which perform different set of operations. The five keys placed in the center of the application is for the movement in the four directions namely up, down, left and right and the fifth icon is for stopping the vehicle. This application does not requires any other connectivity except Bluetooth for its smooth functioning. At first, we pair up our application to the module. Then we click on the Bluetooth icon, where we can see the list of paired devices. We select our module named HC-05. After successful connection, a green color "Connected" will be shown on the application. After this, we can click on the direction icon and can move our vehicle in whichever direction, we want our vehicle to move.

Figure 8 Android Application Layout

H. Chassis

Chassis is a skeletal frame on which various mechanical parts like motors, tires, axles etc. are bolted. The chassis is considered to be the most significant component of an automobile. It is the most crucial element that gives strength and stability to the vehicle under different conditions.

Figure 9 Chassis.

We have used a heavy metal chassis which has specifications of Length of 195mm, Width of 105mm and Height of 47mm. It has four holes for connecting DC geared motors and a hole for connecting caster wheel in the front. It has various small holes on its back for bolting various Integrated Circuits. Solar panel is also integrated to this chassis via additional wooden support, as they are lighter in weight.

I. DC Geared Motor

DC Motor converts the electrical energy into the mechanical energy. It is widely used. Working principle of DC motor is when current carrying conductor is placed in magnetic field, it gets torque and wants to move. This is called motoring action. When current flows in reverse direction in conductor than the direction of rotation of conductor is also reverse. When electric field and magnetic field meets then it produces a magnetic force. Fleming left-hand rule is followed for rotation of the motor. We have used four 200 rpm DC Motor with Metal Gearbox. We are supplying 12V to each motor. It has 6mm of diameter, 122gm weight and no load current =70mA (max). Among four motors we have connected two motors in series. One group of the motors is connected to the left side of chassis and other two motors are connected to the right side of two wheels. The four wheels are further connected to this motors.

Figure 10 DC Geared Motor.

J. Wheels

Wheels are the circular object which revolves on an axle and are fixed below a vehicle or other object facilitating movement or transportation while supporting a load. We have used plastic wheels for designing of our system as these types of wheels are light in weight. The diameter and width of wheel and the diameter of the Shaft Hole that have been used here are of respectively 70 mm, 20mm and 6mm. Dc geared motor that have been used, has the same diameter of its rotor as that of Shaft Hole of the wheels. A caster wheel is a wheel equipped which allows the vehicle to rotate itself in the direction it is being propelled. We have used a caster wheel which has an Outer Diameter of 32 mm, Inner Diameter of 19 mm and Height of 22 mm.

Figure 11 Wheels.

4. INTEGRATION OF ALL PARTS

All the hardware components are integrated and finally the robotic vehicle is developed. Power is supplied to the Arduino which further supplies power to other components. The solar panel is mounted just above the chassis with light-weight metal sheet gripped firmly. Different view of our robotic vehicle is shown in figure 12 and figure 13.

Figure 12 Top View of Robotic Vehicle

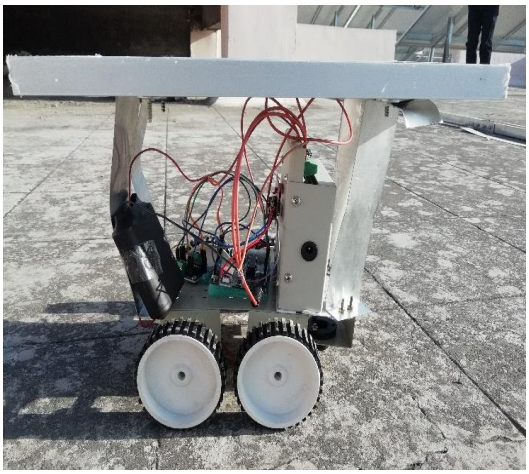

Figure 13 Side View of Robotic Vehicle

5. RESULTS & DISCUSSION

The "Connected" status on the application screen shows that our application is connected to the Bluetooth module successfully. Now, we can move our vehicle in any direction according to our requirement. The four direction icon helps in the smooth movement of the vehicle. The stop icon in the middle is for emergency brake.

The approximate calculation of charging time and running time is mentioned below:

On connecting two terminals of solar panel, battery and load to the charge controller, the charge controller provides constant 12V supply to the load, which is same as that of battery. So, for charging and discharging time, the parameters of voltage can be ignored.

For charging time:

Battery Capacity: 2000 mAh

Solar Panel Current Supply: 560 mA (At 30° C)

To full charge this battery using the solar charge controller, an approximate charging time four to five hours is required.

Discharging time:

On Full charge, Battery Capacity: 2000 mAh

Total current required by circuit: 450-500 mAh

So, on full charge of battery, the vehicle can run up to four hours continuously.

An analysis is carried out to understand the impact of load, mounted on chassis on the velocity of our vehicle. The analysis result is summarized in Table 2.

Load (Kg)	Velocity (Km/hr)
No load	1.46
0.5	1.42
1.0	1.37
1.5	1.29
2.0	1.22
2.5	1.17
3.0	1.05

Table 2 Load and Velocity Relation

The designing of the whole system depends on the application of the vehicle and accordingly the components has been chosen right from the motor to the solar modules. The motor of the required rating is chosen first. From the rating of the motor, the battery which can satisfy its starting current and full load current is selected, and then according to the rating of the

battery, the solar charge controllers and the solar panels are selected.

6. CONCLUSION

This robotic vehicle runs efficiently utilizing the solar energy. In a developing country like India, solar energy can become boon to meet its energy requirement. The dependency on the fossil fuels and compressed natural gas can be drastically reduced if this type of energy seeking mechanism is taken in to operation. Also, unlike fossil fuels, this renewable energy is abundant in quantity and does not emit any kind of harmful emission. So, the proposed methodology is very much efficient and effective and can be developed further for its usage in the domain of public transportation.

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