Solar Powered Light Weight Vehicle for City Dwellers

Khairul Eahsun Fahim [1]
[1] Systems and Control Engineering,
IIT Bombay, Mumbai, India

Monzurul Karim Afgani [2]
[2] Electrical and Electronic Engineering,
BRAC University,
Dhaka, Bangladesh, Bangladesh

Abstract— **One of the front runners in the area of renewable energy resources today is solar power. Photovoltaic cells are used to convert solar energy in to useful electrical energy. The objective of this paper is to construct an efficient solar car, for the daily office commuters of city so that they can travel a fixed distance that they need to commute everyday on a reliable and economical car that essentially runs on free renewable solar energy. All calculations would be made bearing in mind the maximum distance travelled by office commuter since overcoming this distance would be the primary objective of the solar car to be built. The paper illustrates how the charge generated by an array of solar panels is received and its flow in and out of a battery pack is to be controlled using a microcontroller based charge controller to ensure efficient storing of charge in a battery pack. The stored energy would be divulged to a DC motor which would run the car. The design of a motor controller to control the car's speed and forward/reverse direction of motion is shown. The mechanical construction from scratch of the chassis along with all necessary mechanical systems is illustrated. Finally the wiring of the electrical system onto the mechanical body is demonstrated.**

Keywords— Solar; Photovoltaic; Microcontroller; Embedded Computing

I. INTRODUCTION

The quests for a constant, safe, clean, environmental-friendly fuel is never-ending. Carbon-based fuels, such as fossil fuels are unsustainable and hazardous to our environment. Some of the alternatives are renewable energy sources which include all fuel types and energy carriers, different from the fossil ones, such as the sun, wind, tides, hydropower and biomass. Amongst these elements, solar energy is preferred since it could provide the cleanest sustainable energy for the longest duration of time – the next few billion years. Photovoltaic production becomes double every two years, increasing by an average of 48 percent each year since 2002. Due to its innumerable benefits in environmental, economic and social aspects PV systems have becomes the world's fastest growing energy technology. It can arguably be said that the only limitation to solar power as an energy source is our understanding of developing efficient and cost effective technology which can implement it. Nothing on earth is free of cost, but what if we could find a way to implement free rides? Indeed it would be wonderful if our cars could continue to run without us having to spend billions on fossil fuels every year and to deal with natural hazards that their combustion leave behind.

If we could drive a solar-powered car, that auto dream would come true. Solar cars would harness energy from the sun via solar panels. A solar panel is a packaged, connected assembly of solar cells, also called photovoltaic cells which are solid state devices that can convert solar energy directly into electrical energy through quantum mechanical transitions. They are noiseless and pollution-free with no rotating parts and need minimum maintenance..

The electricity thus generated would then fuel the battery that would run the car's motors. Therefore we would obtain an electrically driven vehicle that would travel on "free" energy with no harmful emissions, that can utilize its full power at all speeds, and would have very little maintenance cost..

The main objective of this project is to construct a solar car to allow transport for people travelling a certain amount of distance every day, for instance, the office commuters of city with virtually no cost as it will run off free renewable solar energy. Since cars are the major mode of transport for office commuters in city, shifting to this eco-friendly car would be beneficial on an enormous scale the car would be able to commute safely a maximum round trip distance of 35km for which is considered to be one of the largest office travelling distances in a city. Calculations shown later prove that this is easily possible. The proto-type solar powered car to be designed and built specifically for the daily office goers of city would be light-weight, clean, environment friendly and completely independent of fossil fuels, explosive, foundry, clean room, and other environments that involve potential hazards for human workers. The scope of the project involves designing and constructing a proto-type solar powered clean car that would be economical, reliable and environmentally friendly. The specifications of the motor driving the car is calculated based on the intended desired speed and acceleration to be achieved. This will in turn help calculate the battery capacity and solar panel wattage required to travel the desired maximum round trip distance of around 35 kilometres on solar power alone .We are building a car according to the design outlined in a paper [1] which proposes a cheap, light-weight and environment friendly solar powered electric car for city dwellers to meet their daily needs.

II. SYSTEM ARCHITECTURE

Solar cars are powered by the sun's energy ergo solar panels are the most important part of a solar car since they are solely responsible for collecting the sun's energy. The solar panels

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 7 Issue 02, February-2018

used in this project are mono crystalline and flexible. They can be mounted and fitted on top of the car or on the bonnet with ease owing to their thin semi-flexible nature.

The solar panels will collect energy from the sun and convert it into usable electrical energy, which in turn will be stored in the lead acid batteries to be supplied to the motor when necessary.

The batteries are connected to a charge controller which will ensure healthy life of the batteries by preventing it from over charging and over discharging. A microcontroller inside the charge controller is programmed to detect the voltages at the battery terminal and/or the solar panel terminals and accordingly determine what charging current the battery needs to be supplied.

A critical factor here is that the charge controller will be available with an additional input that can be used to charge the batteries from an AC power supply (simply by plugging in). Thus the solar car will have this plug-in charging system for use when there is not enough sunshine due to fog, cloud or rain. This provision for an external plug-in system to charge the batteries from the conventional AC power supply will allow the car to increase its overall utility.

The motor used is a DC-series excitation motor which is rated at 1 kW, 60V, 23 A. This DC-series motor is sufficient to get the car up and running as will be shown in details later. The motor controller is designed to control the speed of rotation of the motor as well as the direction of its rotation. In other words, it determines the cars speed and forward/reverse direction of motion of the wheels.

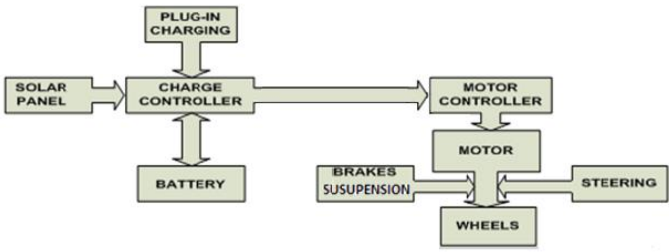

Fig. 2: Actual diagram of Differential mounted with 48V Brushless DC motor

These four components make up the mechanical part of the solar car. Front wheel steering is used as it tends to be more stable and safe. The suspension used is sophisticated enough to allow the user a stable ride and to protect the car and panels from sudden shocks and blows. A drum braking system as in conventional cars is used to provide the safety features of the car while travelling. The wheel selection is dependent upon the rolling resistance which would determine how far the solar car can travel with the available energy. Since thicker wheels tend to have higher rolling resistance, thinner but strong wheels are opted for.

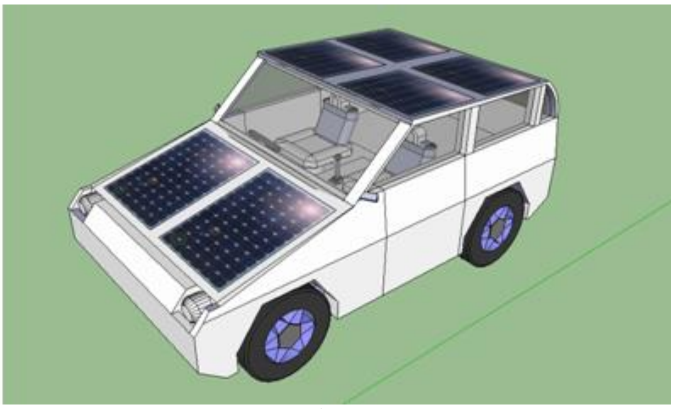

Fig. 1: 3D Model of the proposed solar car

III. ELCTRIC VEHICLE RATING CALCULATION

Solar cars compared to internal combustion engine vehicles are simpler in that they have few major components. However, being an electrical system makes precise calculations of the ratings of these major components of the car imperative at the design stage. The ratings of the 3 major components of the car that will be determined are [2]

1) The motor power rating required to achieve the necessary speed and acceleration.
2) The battery capacity which can support the distance required to be travelled.
3) The solar panel specifications needed to keep the battery sufficiently charged for the journey.

The power rating of the motor will determine the battery capacity i.e. Ampere-hour charge and voltage needed to overcome the maximum distance that the solar car will travel on solar power alone. Consequently this in turn will determine the panel wattage required to sustain the battery charge.

The power needed to propel a vehicle can be determined by combining the forces that needs to be applied to the vehicle to move it with the vehicle speed at which this propelling force must be sustained. The drive torque generated by the motor for the wheels produces a drive force at the tire/road contact - it is this drive force that moves the vehicle. At the design stage it's easier to frame the calculation around this drive force rather than the drive torque. Thus the calculations in this section start by determining the size of this drive force, and given a set of speed at which the vehicle should move, the drive power is found.

The total drive force that has to act on the vehicle to make it move (or keep it moving) can be estimated by adding together individual force components that arise from different physical effects. These are force to overcome the rolling resistance of the wheels on the drive surface, force to overcome aerodynamic drag and force to accelerate the vehicle's mass. There may be other effects but these are usually the main ones. These opposing forces are accounted for as follows:

The rolling resistance force is the force resisting the rolling motion of the tires as they roll over the road surface. Factors that contribute to rolling resistance are the (amount of) deformation of the wheels, the deformation of the roadbed surface, and movement below the surface. Additional contributing factors include wheel diameter, speed, load on wheels etc. For example, a rubber tire will have higher rolling

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 7 Issue 02, February-2018

resistance on a paved road than a steel railroad wheel on a steel rail. Similarly, sand on the ground will give more rolling resistance than concrete. The rolling resistance force can be expressed as

$$F_{ROLLING} = \mu_R * W,$$

Where W is the weight of the car. μ_R is the coefficient of rolling resistance and is a constant that depends on the type of tires of the vehicle and the surface on which it will roll. Thicker tires with wider treads, although good for adhesion, however produce more rolling resistance. To conserve power solar cars need to use thinner tires. Also harder surfaces offer lower rolling resistance force than softer ones.
The aerodynamic drag force is simply the force exerted by the air to prevent the vehicle from moving through it. The aerodynamic drag force can be expressed as,

$$F_{DRAG} = [(1/2) * C_d * A_{cross} * \rho * (V)^2$$

Where C_d is the coefficient of drag of the vehicle, Across is its frontal area in square feet, ρ is a constant that accounts for the air mass density and Vis the vehicle's speed. To minimize drag for any given C_d, the coefficient of drag, and across, it's frontal area must be minimized.

Capacity is the measurement of how much energy the battery

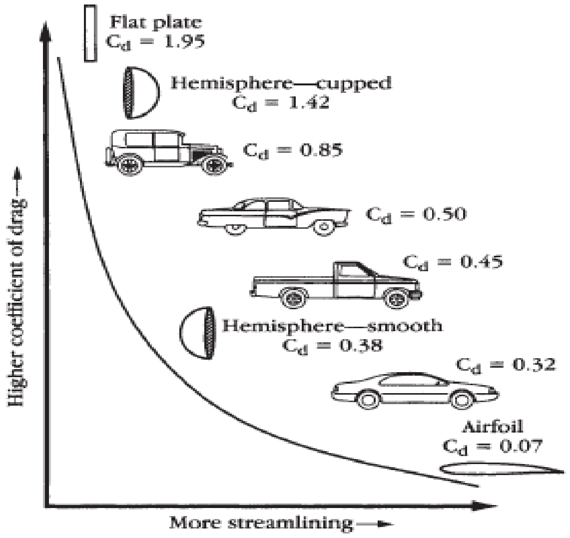

Fig. 3:
Drag coefficients of different vehicles. [3]

can contain (in Ampere-hours), analogous to the amount of water in a jug. The capacity required will be dependent on the cars acceleration and speed as well as the total distance the car will overcome before the battery charge is depleted.

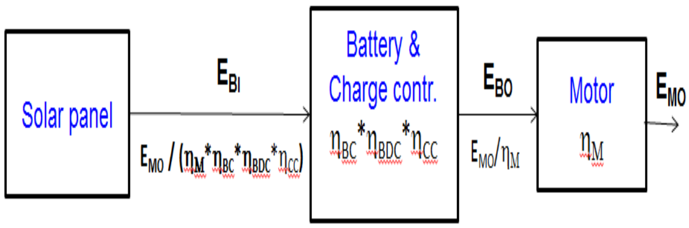

Fig 4: Total Energy Required From The Output Of Solar Panels

According to the system diagram in FIGURE 4 the total energy required from the output of solar panels,

$$E_{PO} = E_{BI} = 1.21 \text{ kW}$$

In , the solar insulation (solar radiation energy received) on average corresponds to 6 kWh/kW. Therefore the minimum required panel wattage is,

$$P_W = E_{PO}/ 6h = 201 \text{ W}$$

To account for the acceleration of the car the actual value chosen for the panel wattage was 5 panels of 50 W each i.e. 50*5 = 250 W

In conclusion, the round trip journey can be visualized in the following manner –
With battery fully charged start the journey and arrive to the destination. The battery is at the same time being discharged by the motor and charge by the solar exposure while driving. Battery should now be at max 40% depleted.

The car is now left subjected to solar exposure for about 6 hours while the user commits to his/her business. This will bring the batteries back to full charge.

The return trip is made with batteries still having sufficient charge to overcome the distance.

It is to be noted that the battery charge will only be depleted when the motor is driving the car. Thus during the time when the car is halted at traffic (unlike an internal combustion engine which will waste fuel) the batteries of the car will actually get charged by the solar exposure thus increasing the cars mileage.

IV. CHARGE CONTROLLER MECHANISM

The objective of the charge controller is to act as a battery management system (BMS) where it regulates the charging and discharging of the battery. The task is carried out using a PIC 16F876A microcontroller chip. Angled steel rectangular frame is supported by four additional steel bars whose are of same The microcontroller is expected to take decisions based on the terminal voltage of the battery and the solar panel/AC line. As a result it needs a mechanism to sense the voltage at the battery terminals precisely. After sensing the voltage the internal Analog to Digital converter (ADC) module of the PIC 16F876A then digitizes the analog terminal voltage at its input ports by dividing it into a proportion of 1024 quantized levels to increase the resolution of the voltage sensed. [4]
The battery and PV/AC module's out voltages may become too high for the microcontroller's voltage specifications and cannot be directly inputted to the microcontroller's ports. Thus the voltages from the battery/solar panel (V_{in}) must each go through a potential divider network in order to undergo voltage scaling before it can be inputted to the microcontroller input port (V_{out}).
Next, the ADC module of the microcontroller converts the input scaled voltage at its port to a quantized value. This value is a proportion of the 1024 quantized levels of the ADC.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 7 Issue 02, February-2018

For example:
If R_1 = 10kΩ, R_2 = 1kΩ and V_{in} = 11.4 V.
Then V_{out} = 11.4 V * (1kΩ / (10kΩ + 1kΩ)) = 1.036 V
And the digitized value of V_{out}= (1.036 V / 5 V) * 1024 = 212
[The 5 V is the microcontroller's power up pin voltage]
If R1 = 10kΩ, R2 = 1kΩ and Vin = 11.4 V.
Then Vout = 11 V * (1kΩ / (10kΩ + 1kΩ)) = 1.0 V
And the digitized value of Vout= (1.0 V / 5 V) * 1024 = 204
[The 5 V is the microcontroller's power up pin voltage]
It is observed that using the ADC module allows us to break down even a small difference of (11.4 – 11) = 0.4 V into a larger difference of (212-204) = 8 quantized levels. Thus an increase in operating resolution is obtained.

NB: The resistor network's job is to scale the voltage of the solar panels and battery down to levels acceptable by the microcontroller. Therefore the values R1 & R2 are not in fact arbitrarily chosen. They have to be calculated according to the max value outputted by the solar panel and the battery as well as the max value acceptable by the microcontroller.
If Vimax = max voltage that can be outputted by the solar panel or battery.
&Vomax = max voltage that can be input to the microcontroller port.
Then, Vomax = (R2 / (R1 + R2)) * Vimax
Therefore conversely, R2 = R1 * (Vomax / (Vimax –Vomax))
So if R1 is chosen arbitrarily (within acceptable limits of course) then R2 must be chosen according to the above equation.
For the circuit it was assumed that R1 = 1500k, which produced R2 = 100k according to the above calculations for the solar panel where maximum voltage is expected to be 80 V. For the battery, the maximum voltage being expected to be 75V, R1 = 1400k, which produced R2 = 100k
The battery requires output of 90% PWM 10% PWM and 0% PWM as have been said before. Between the solar panel/AC line and the battery is connected a IRZ44N MOSFET , which is low power consuming, high input impedance NPN MOSFET ideal for very fast switching. The PWM is generated by the MOSFET remaining "OFF" for a specified amount of time, for every time period, according to the specified PWM percentage to be applied. In this way, the MOSFET applies an average D.C voltage from the solar panel to the battery according to the PWM specified. The PWM at CCP2 port pin of the microcontroller controls the switching operation of the BJT BC547 which in turn controls the switching operation of the MOSFET. The MOSFET and BJT are used together to form a configuration with higher current gain and lower output impedance than would be the case if they were used singly.
An LED is switched ON or OFF to indicate whether the load is being charged by the PV array or not respectively through the programming code.

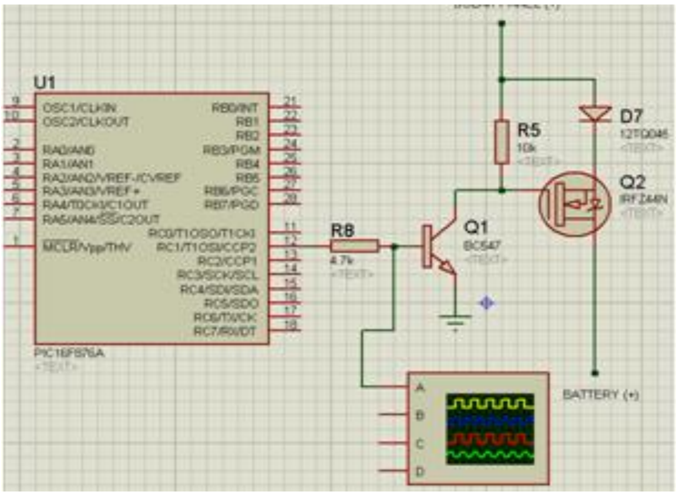

Figure 5: Controlling charging voltage by PWM

V. POWER SUPPLY AND WIRING SYSTEM

At the intermediate stage of development, there was a need to test the DC motor's performance. As a result a means of providing controllable high DC voltage and current supply was necessary. Therefore a combination of a variac and a AC to DC power supply was constructed for motor testing purposes. An AC-DC power supply was designed to charge the battery and drive the motor. Two Full bridge rectifier is connected to transformer and one 10000uF capacitor is connected in parallel with the rectifier. KBPC3510 full bridge rectifier is used to rectify the AC voltage The current rating of the rectifier is 30 A.

To charge the battery and test the motor the desired output of power supply had to be at least 75V, while the input voltage would be 220V. Hence the design of the transformer would depend on the ratio of the primary to secondary winding. If the primary voltage from utility source is V_p and secondary voltage of transformer is V_s.

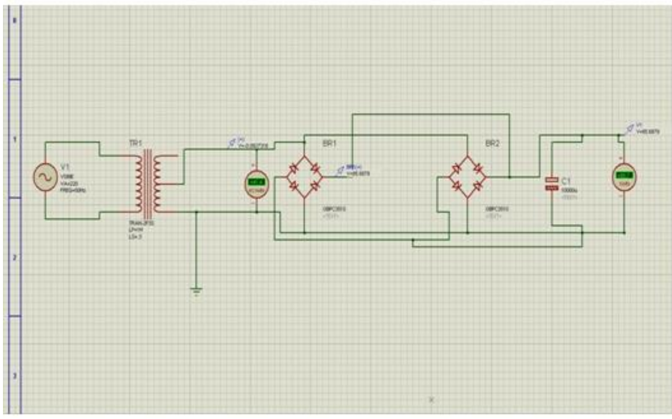

Figure 6: AC – DC Rectification Circuit

The motor controller allows the motor to rotate at different speed; it takes the input from the battery and gives output for motor. The controller used in the solar car has an input and output rating of 48 to 60 volt and has a current rating of max 30 ampere. There are two outputs from the motor controller, one for the acceleration pedal and other for the motor. The internal circuitry for acceleration control further converts the input voltage into low current system.

A DC or main contactor works just like relay. Its heavy duty contacts (typically rated at 30 to 60 ampere) allow us to control heavy currents with a low-voltage. A single-pole, normally open main contractor is placed in the high-current circuit between the battery and motor controller. When it is energized typically by turning the ignition switch on- high current power is made available to the motor controller which then follows to the motor. It is also put for an emergency shutdown option, for example when the battery reaches its minimum depth of discharge the motor has to be disconnected; in this case the contactor is disconnected to make sure no more current is drawn

A DC circuit breaker is like a switch and resetting fuse. The purpose of this heavy-duty circuit breaker (typically rated at 50 to 150 A) is to instantly interrupt main battery power in the event of a drive system malfunction and to routinely interrupt battery power when servicing and recharging. For convenience, this circuit breaker is normally located near the battery pack. The purpose of the safety fuse is to interrupt current flow in the event of an inadvertent short-circuit across the battery pack.

It is a mechanical based system with three gear position to change the motor direction. The two end of motor armature windings and one end of the field winding is connected to gear the box, the other end of the field winding takes output from the motor controller, for certain orientation of gear box connection the gear shaft changes the polarity of the motor by positioning a metal contact in between the armature and field windings connections.

Shunts are precisely calibrated resistors that enable current flow in a circuit to be determined by measuring the voltage drop across them. A voltmeter is placed over the shunt. The voltage drop in the shunt is divided by the shunt value to obtain the current drawn by motor.

The instrumentation system includes a key switch, throttle control, monitoring wiring and 60 to 12 volt converter. The low voltage power source will simply be provided from the car's battery pack by using 60 to 12 converter. This will help us to avoid an extra charge controller installation for using an auxiliary battery. Using a converter will thus require only one charge controller for the entire system

VI. MECHANICAL PROGRESS

The start of the mechanical aspect of the car was made by obtaining two rear wheels along with an axle connecting them. This was the only mechanical piece of the car that was bought whole. Every other little part was obtained one by one or made right in our workshop and then assembled together. In other words 90% of the car is a new design made to serve our purpose of comfortably carrying 2 passengers at favourably high speeds across the roads and highways of city.

An initial framework of two solid pipes was constructed to support the rear wheels and motor. This structure was made to allow us to observe how the entire front part of the car should be designed and adjusted with the rear wheels and axle.

Figure 7: Rear Wheel and Axle.

The suspension mechanism needed to be such that the front wheels are free to jerk up and down when hitting the road bumps while causing the chassis to remain still. After fitting the suspensions and wheels, a strong steel framework was built that would adequately hold it all together. The framework would also cause most of the pressure of the weight of the passengers and on-board materials to be concentrated and spread amongst the suspensions. Also, the front of the car was strengthened with additional steel framework to absorb crash impact from causing injury to passengers.

The purpose of using suspension is to maximize the friction between tires and it makes the steering more stable and gives the passengers a feeling of smooth ride.

If the roads were flat and if there was no irregularity, there was no need of suspension. But we are to go highways that have subtle imperfections and so there is interaction between the wheels of the car and the road. So there is a force applied to the wheels due to these imperfections. These forces have both magnitude and direction. When there is a bump underneath the tires, the wheel jumps upward and downward perpendicular to the road surface. When there is an imperfection, the wheel experiences a vertical acceleration

Without an intervening structure, all of wheel's vertical energy is transferred to the frame, which moves in the same direction. In such a situation, the wheels can lose contact with the road completely and due to gravity the car can slam back into the road. So to neutralize the force of this vertically accelerated wheel suspension is needed.

Carbon suspension used in this car serves three special purposes namely road isolation, road holding, cornering.

Road isolation is the vehicle's ability to absorb or disseminate road shock from the passenger compartment. The goal of road isolation is to allow the car body to ride without any disturbance while travelling over Rough Street. This problem was solved using the suspension. The suspension basically absorbs energy from road bumps and dissipates it without causing undue oscillation in the vehicle.

The second principle that can be stated is the road holding. Road holding is basically the degree to which a car maintains contact with the road surface in various types of directional changes and in a straight line (Example: The weight of a car will shift from the back tires to the front tires we press the brake. Because the nose of the car dips toward the road, people often call this type of motion as "dive." The opposite effect is known as "squat". Squat occurs during acceleration. It shifts the weight of the car from the front wheels to the rear wheels. So it's our concern to keep the wheels in contact with the street, because it is the friction between the wheels and the street that affects a cars ability to move, accelerate and brake. Here again the suspension transfers vehicle weight from one

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 7 Issue 02, February-2018

side to another and front wheel to back wheel, as this weight transfer reduces the grip of the wheel on the street.
Another important feature of the suspension is the cornering. The goal of this cornering is to minimize the roll of the car body, which occurs as centrifugal force pushes outward on a vehicle's centre of gravity while cornering. It raises one side of the car and lowers the opposite side during this time.

Figure 8: Suspension System

VII. DISCUSSION

Demand of fuel is increasing day by day. To cope up with the demand of this increasing fuel demand it's time to look for alternate sources. Solar energy is by far the best choice because it is cheap, environment friendly and most importantly it is supplied by an endless source of energy. So finally we hope that the day is not so far when a large percentage of world population will use this technology and convert their car into a solar powered light weight one.
In order to cope with the increasing demands for fuel and the disastrous environment pollution due to driving carbon-based vehicles, it is quite necessary to switch to a new source of energy, i.e. the solar power which would be a cheap, efficient, limitless and of course an eco-friendly alternative.
Solar-powered electric vehicles are safe with no volatile fuel or hot exhaust systems. They are zero emission vehicles, odourless, smokeless and noiseless. They require minimal maintenance, are more reliable with little or no moving parts and can be efficiently charged nearly anywhere. Needless to say it is very much cost efficient.

Experimental results which have been obtained shows efficient performance of the industrial robot in terms of the capability of the robot to unload heavy loads in a short time. This industrial robot promises to be beneficial to industries where the importance of such type of robot as explained in this paper is immense. This robot that is used as a trolley to carry heavy loads from one place to another is very helpful to the society in terms of reducing risk of accidents that usually happen to labors while working in industries and carrying heavy goods on foot. In this paper the mechanical design is explained for the industrial robot which has proved to be feasible based on the movement on the desired track. Differential and a single Brushless DC motor usage has been the best choice instead of using two DC motors connected with two rear wheels because this robot has been able to make both right and left turn smoothly while carrying heavy loads

REFERENCES

[1] Sanjana Ahmed, Ahmed Hosne Zenan, and M. M. Rahman, "A Two-Seater Light-Weight Solar Powered Clean Car: Preliminary Design and Economic Analysis",3rd International Conference on the Developments in Renewable Energy Technology, ICDRET 2014, May 29-31, 2014 Dhaka, Bangladesh.
[2] "Build your own Electric Vehicle", Seth Lehman and Bob Brant, 2nd Edition.
[3] https://en.wikipedia.org/wiki/Drag_coefficient
[4] http://www.facstaff.bucknell.edu/mastascu/eLessonsHTML/Interfaces/ConvAD.html