Palestine Polytechnic University

College Of Engineering and Technology

Mechanical Engineering Department

Graduation Project

Solar Powered Service Vehicle

Project Team

Ahmad Suliman Manasra **Baker M. Abu-Hammad**

Project Supervisor

Dr. Zuhdi Salhab

Hebron-Palestine

January, 2014

Palestine Polytechnic University

(PPU)

Hebron –Palestine

Project Name

Solar Powered Service Vehicle

Project Team

Ahmad Suliman Manasra **Baker M. Abu –Hammad**

According to the project supervisor and according to the agreement of the Testing Committee Members, this project is submitted to the Department of Mechanical Engineering at College of Engineering and Technology in partial fulfillments of the requirements of (B.SC) degree.

Supervisor Signature

……………………………..

Examine Community Signature

………………………… ………………………….. ………………………

Department Head Signature

……………………………………

January, 2014

Abstract

Introduction (project summary):

The solar vehicle is a step in saving the nonrenewable sources of energy. The basic principle of solar car is to use energy that is stored in a battery during and after charging it from a solar panel. The charged batteries are used to drive the motor which serves here as an engine and moves the vehicle in reverse or forward direction. The electrical tapping rheostat is provided so as to control the motor speed. This avoid excess flow of current when the vehicle is supposed to be stopped suddenly as it is in normal cars with regards to fuel. This idea, in future, may help protect our fuels from getting extinguished.

Goals:

1. Using a free and clean energy.

2. Regardless of solar panels' high cost, but paying for one times comparing to the fuel energy.

3. Saving time and effort.

4. Eco-friendly vehicle.

Dedicated

To our parents who

spent nights and days doing their best

to give us the best…

To all students who

Wish for

better future…

To who love the knowledge

To who carry candle of science

To light his avenue

Of life…

To our beloved country Palestine…

To all of our friends…

Acknowledgement

First of all, we thank our supervisor **Dr. Zuhdi Salhab** who gave us a lot of their time and experience in order to complete the project. Also, he gave us the opportunity to start scientific life and methodology in real life by inspiring us the idea of this project. Also we thank **Dr. Mohammad Ghazie Al-Qawasmeh** and **DR. Momen Al-zughier** for their Guidelines and instructions and put us on the way of succeeding the project.

We would also give a lot of thanks to **Engineer Mohammad Al-Qawasmeh,** who's in charge of automotive work laboratory, who gave us a hand in succession the project. We also give a lot of thanks to the **Police Administration of Hebron and Bethlehem Cities**; we sincerely believe that this work wouldn't exist without their support. Also, we give a great thanks to our college for their psychological and financial support.

And we will not forget

Our great **Palestine Polytechnic University (PPU)**

Our **Mechanical Department (MD)**

Everyone who helped us

Contents

Table List

Figures List

Chapter One

Introduction to Solar Energy And Solar Vehicles.

1. **Solar energy and solar power.**
2. **Solar energy and the Environment.**
3. **Solar vehicle (advantages and disadvantages).**
4. **Solar vehicle components.**
5. **Previous studies and references.**
6. **Time completion schedule.**

Introduction

1.1 solar energy and solar power:

The renewable energy is vital for today's world as in near future the nonrenewable sources that we are using are going to get exhausted. The solar vehicle is a step in saving these nonrenewable sources of energy. The basic principle of solar car is to use energy that is stored in a battery during and after charging it from a solar panel. The charged batteries are used to drive the motor which serves here as an engine and moves the vehicle in reverse or forward direction. The electrical tapping rheostat is provided so as to control the motor speed. This avoids excess flow of current when the vehicle is supposed to be stopped suddenly as it is in normal cars with regards to fuel. This idea, in future, may help protect our fuels from getting extinguished.

1.2 Solar Energy and the Environment:

Using solar energy produces no air, water pollution and no greenhouse gases, but does have some indirect impacts on the environment. For example, there are some toxic materials and chemicals, various solvents and alcohols that are used in the manufacturing process of photovoltaic cell (PV), which convert sunlight into electricity. Small amounts of these materials are produced.

1.3 Solar vehicle:

A vehicle equipped with solar panels on the roof that receive sun energy and converted into electrical energy which pass through the electrical control circuits, batteries and regulation of power supply to suit the motor-generator that runs wheels' vehicle.

1.4 Advantages and Disadvantages of Solar vehicle:

1.4.1 Solar Vehicle Advantages:

1. Eco-friendly.
2. Free energy.
3. Providing service with less time, distance and more comfort.
4. Reduce Ozone depletion.
5. Less noise.
6. Easy to repair.

1.4.2 Solar Vehicle Disadvantages:

1. Less power comes from solar panel.
2. Because of low solar power efficiency, can't receive high speed.

3. Solar vehicle has limited application.

4. As a result of disadvantage number (2), so it cannot carry heavy load.

1.5 Solar Vehicle Components:

1. DC Electric motor-generator.
2. Mechanical Gear Reduction.
3. Photovoltaic (PV) array.
4. Charge Controller.
5. Electrical circuits for smooth progressively startup of the motor.
6. Two (12volt) Batteries.
7. Brake and Handbrake.
8. Three wheels.
9. Chassis and seating.
10. Suspension.
11. Bodywork, screen and etc.

II. BASIC FUNCTIONAL DIAGRAM

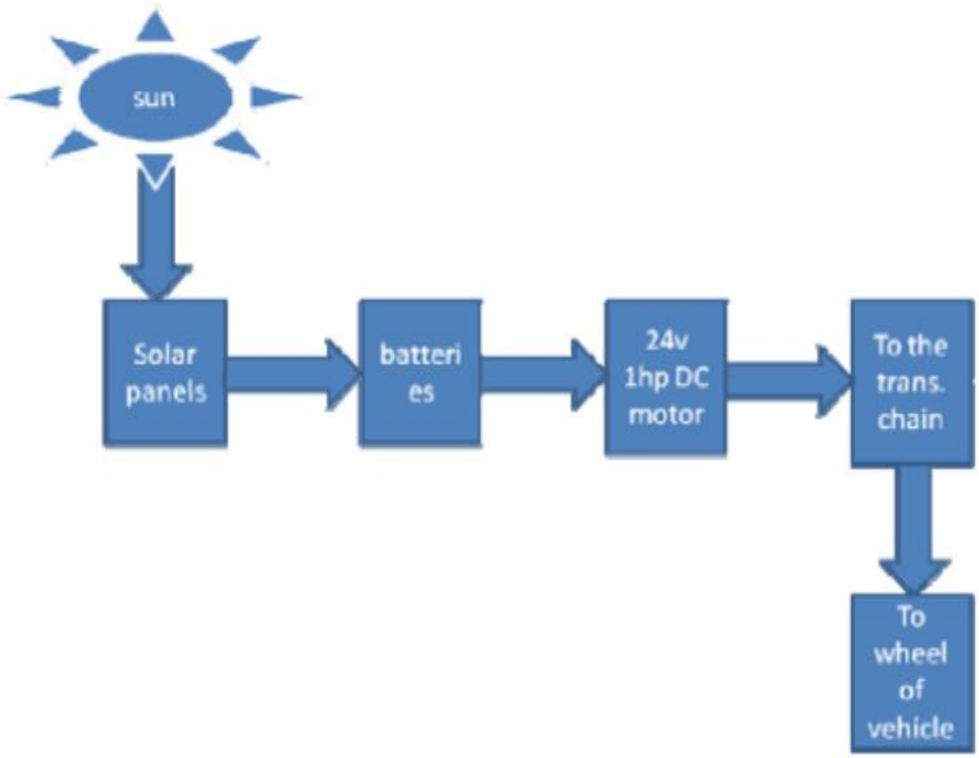


Fig. 1 Basic block Diagram Representation of Solar vehicle

Figure 1.1: Basic block diagram representation of Solar Vehicle.

1.6 Previous studies and References:

[1] M. W. Daniels and P. R. Kumar, "The optimal use of the solar power Automobile," Control Systems Magazine, IEEE, vol. 19, no. 3, 2005:

They described the relation between solar panels (Photovoltaic Panels) and automobiles, how to merge these concepts together to get a clear output that is free and less dangerous to the environment.

[2] "SOLAR VEHICLES AND BENEFITS OF THE

TECHNOLOGY", by John Connors, ICCEP paper 2007:

He found his future technology in this field by explaining the reasons of taking into account the solar energy "Free Energy" instead of fuel energy and the benefits of this technology in his scientific research paper.

[3] www.electricvehicle.com for the electrical design of the car and to know the technologies used in previous cars.

This website is concerning in the field of electrical vehicles with their clear energy. Also it mentioned his specific idea that inspired us as below:

"Electric Vehicle Inc. was formed to provide users access to Electric Vehicles, and other transportation alternatives to the conventional wasteful, polluting gasoline engine; to research and promote changes to the City Of New York transportation infrastructure facilitating the adoption of Electric Vehicles and Zero Emission Vehicles."

[4] Ford reveals solar-powered car with sun-tracking technology:

The concept car has a solar panel system on the roof that could power the car to run for up to 21 miles just on electricity.

From this concept, we decided to do the same in this project.

http://www.bbc.co.uk/news/technology-25575306.

[5] http://www.technologystudent.com/energy1/solcar1.htm for solar powered vehicles.

This website discussed the idea of using solar panels in simple productions.

1.7 Time completion schedule:

In order to finish the project in a specific time, it was decided to organize the time for the project by making a plan table which includes the number of weeks that needs to complete it, and tasks which should finish it in each week as shown below:

Task/week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Collecting information about project	■	■	■												
Reading			■	■	■										
Introduction						■	■	■							
Mechanical & Electrical Calculation							■	■	■	■					
Design by Catia									■	■	■	■			
Project documentation				■	■	■	■	■	■	■	■	■	■	■	
Collecting the project parts						■	■	■	■	■	■	■	■	■	■
Gathering the parts to produce the vehicle.						■	■	■	■	■	■	■	■	■	■

Table (1.1): Timing table.

This chapter was given a specific introduction about Solar Powered Service Vehicle Project, but lately, details of the mechanical and electrical parts will take place in the next chapters.

Chapter Two

Mechanical Parts in the Project

1. **Introduction.**
2. **Chassis.**
3. **Suspension.**
4. **Steering.**
5. **Brakes.**
6. **Tires.**
7. **Seat.**
8. **Gear Reduction.**
9. **Bodywork.**

2.1 Introduction

As it mentioned before, this project was designed for helping the messengers' job between university's buildings with a free energy. So it must be able to work under different operating conditions. This vehicle was designed in tricycle motor with one driver and could carry a load of 70kg, so it could reduce the time and human effort. This chapter aims to explain the mechanical parts with specific details of each element.

2.2 Chassis

It is the main component of the vehicle which has three main goals and that's' are:

1. Hold the weight of the components.
2. Provide stability state under operating and rigidity conditions.
3. Connect the other parts with it.

There are many types of chassis used in cars:

1. Unibody construction:

In which built as a one unit by casting method and the body sections serve as structural members (used on passenger cars), As shown in the figure 2.1a.

Figure 2.1a: Unibody type.

2. Body over frame construction (ladder frame):

Which uses a separate frame to which the body is bolted at various points (used on pickup trucks and large cars).So it was used because of its simplicity and to control general shape of the car as planned as shown in the figure 2.1b.

Figure 2.1b: ladder frame.

2.2.1 Ladder frame design:

A ladder frame is the simplest and oldest frame using in modern vehicular construction. It was originally adapted frame “horse and buggy” style carriages as it provided sucient strength for holding capacity was required then larger beam could be used. It was comprised of two beam that run the enter length of the vehicle. A motor pleased in the front (or rear sometimes) and supported at suspension points. Add the passenger compartment and a trunk with load it becomes a simple indeterminate beam.

2.2.1.1 Advantages and Disadvantages compered to Unibody chassis:

2.2.1.1.1 Advantages:

1. Easier to design.
2. Easier to repair after accidents.
3. Could allow a manufacturer to easily sub-contract portions of work.

2.2.1.1.2 Disadvantages:

1. Less resistant to torsional flexing (flexing of the whole car in corners).

The primary challenge in developing an effective solar car chassis is to maximize the strength and safety, but minimize the weight. Every extra pound requires more energy to move down the road. This means must be to minimize weight and a key area in the chassis. However safety is primary concern and the chassis must meet stringent strength and safety requirement.

A ladder frame can be considered structurally as grillages. It consists of two side members bridged and held a part by a series of cross members. The side members function as a resistance to the shear forces and bending loads while the cross members give torsional rigidity to the frame.

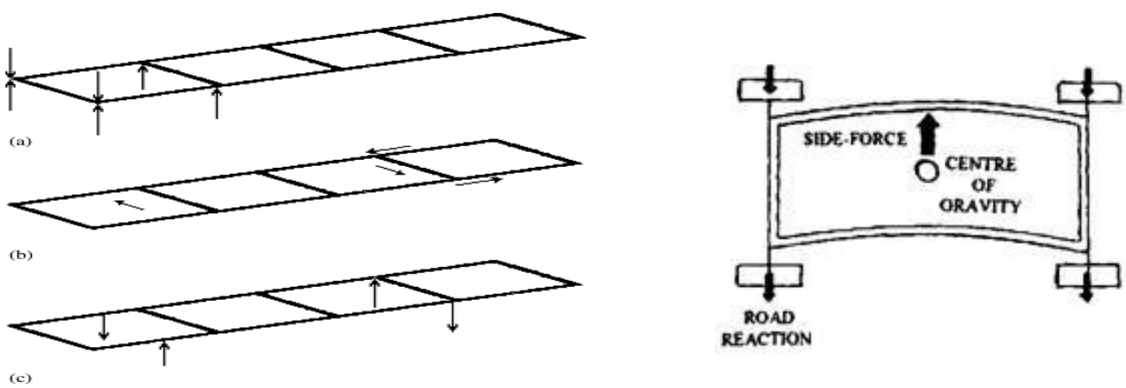
2.2.1.2 Ladder frame deflection modes

The ladder frame chassis is subjected to three load cases: bending, torsion and dynamic loads when the vehicle moving along the road. The bending and torsion loads are used by the weight of the component and in cases like the vehicle hit a bump. The dynamic load case comprises longitudinal and lateral loads during acceleration, braking and cornering.

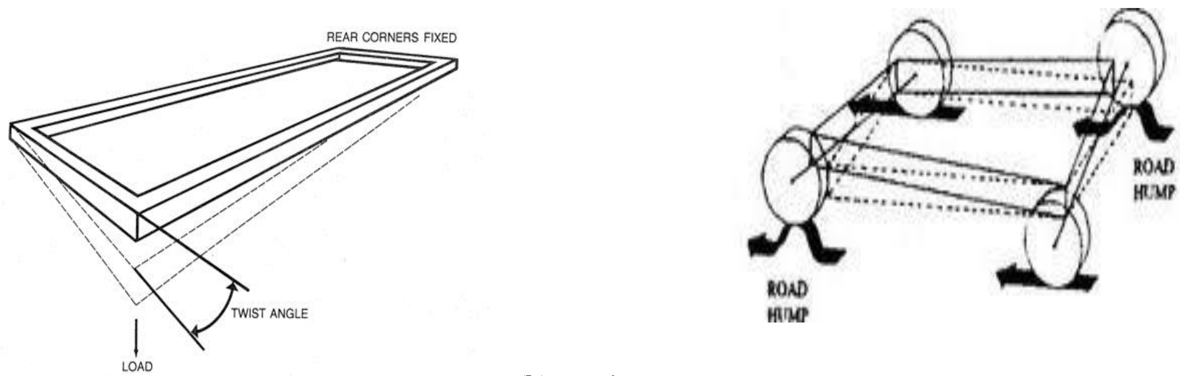
All these loading cases will cause the chassis to deflect. Strengthening of the ladder frame chassis is needed to reduce the effect of the deflection.

Types of deflections modes:

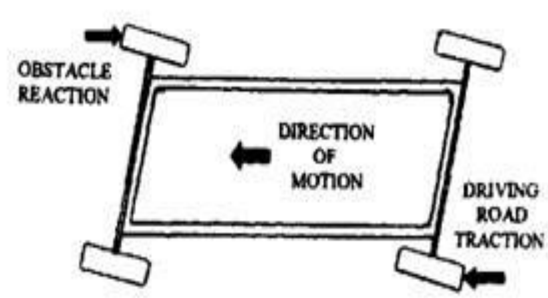
- Vertical bending.
- Torsion.
- Horizontal bending.
- Lozenging.



(a) Vertical &Horizontal bending.



(b) Torsion.

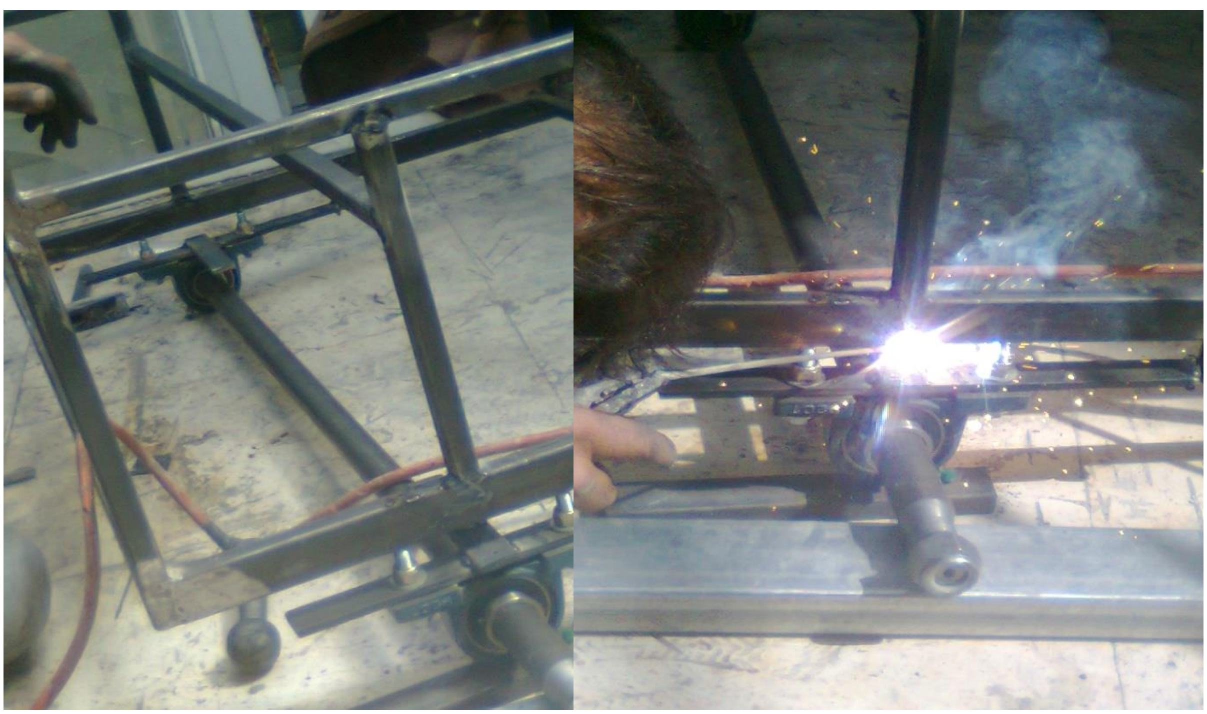


(c) Lozenging.

Figure 2.2.1.2 Ladder frame deflection modes.

For that specifications and advantages of the Ladder Chassis that described above, so it is used in this vehicle as the figures below explained:

(a) General shape of chassis.



(b) Installation of rear axle as a rear drive axle.

(c) General shape of chassis with steering system installed.

(d) Another view of chassis with complete installed rear axle and steering system.

Figure 2.3: Views of vehicle chassis.

2.2.2 Materials and stress analysis:

In this project, the frame was built by using steel material has specific properties to meet the safety.

Material	Steel
Young's modulus	2+e011N/m^2
Poisson's ratio	0.266
Density	7860 kg/m^3
Coefficient of thermal expansion	1.17e-005_K^o
Yield strength	2.5e+008N/m^2

Table (2.1): the properties of steel used in this project.

Considering these properties and the vehicle weight distribution to meet the safety of not yielding or fatigue stress, so there are calculations which will be described below to meet the safety:

The vehicle weight will distributed into three parts 70 kg on rear axle each and 110 kg on front, but with respect to support reactions on front and rear suspensions, so the general stress analysis will be shown in the table below:

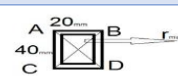
Stress analysis	
$\mathbf{F_{tot} on\ front = 1079\ N}$	$F_{front,right} = 539.6\ N$
$\mathbf{F_{tot} on\ rear = 1373.4\ N}$	$F_{front,left} = 539.6\ N$
$\mathbf{F_{rear,right} = 686.7\ N}$	$F_{rear,left} = 686.7\ N$
$\mathbf{R_{1,front,right} = 657.3\ N}$	$R_{1,front,left} = 657.3\ N$
$\mathbf{R_{2,rear,right} = 569\ N}$	$R_{2,rear,left} = 569\ N$
$\boldsymbol{\sigma_x}$: **Normal stress**	175.5 MPa
$\boldsymbol{\tau_{xz}}$: **Sheer stress**	1.2 MPa
$\boldsymbol{\sigma_1, \sigma_2}$: **principal stresses**	175.5 MPa
$\boldsymbol{\tau_1, \tau_2}$: **extreme value of sheer stress**	87.8 MPa
$\boldsymbol{\tau_{torsional}}$: torsional stress at rear axle from load torque (11.3 N.m)	80 kPa
Welding Analysis	
Pattern	
Electrode	E70xx
type	Fillet weld
Size	h= 6.1mm
Total length	120 mm

Table (2.2): the stress analysis of steel used in this project.

From the previous table and the calculations at the reference, we conclude that the principal stresses **(σ_1, σ_2)** are lower than yielding strength **(S_y),** so the vehicle is in safety mode if the vehicle weight will be same as **(250 kg).**

2.3 Suspension

The job of a car suspension is to maximize the friction between the tires and the road surface, to provide steering stability with good handling and to ensure the comfort of the driver.

The vehicle in this project has two type of suspension as shown in the figure below:

1. Rear suspension system:

It is a small size which appropriate for this design type and include two parts such as: spring and damper were taken from motorcycle.

(a) The top view of rear suspension system.

2. Front suspension system:

It is a small fork type which can put it in the front wheel fork just for the front tires and was taken from motorcycle, as shown in the figure below.

(b) Front suspension system before and after installation respectively.

Figure 2.4: Front and rear suspension system.

2.4 Brakes

Safety should be high priority for any designer for this reason; solar cars in this project meet stringent braking performance standards and are required to have two independent braking systems, the brakes use friction to convert kinetic energy into heat energy. Kinetic energy increases quadratically with velocity:

$$K = m\,{v^2}/{2}$$

Brake system in this project consists of front brake from motorcycle and an electrical assistant brake from the electric motor will be described later, as are shown in the figure below.

(a) Front brake with oil reservoir before and after installation.

(b) Front disc brake with piston.

(c) Electric assistant brake connected to the motor as a handbrake (before installation).

(d) Electric assistant brake after installation with the electric motor.

Figure 2.5: front brake and electric assistant brake (as a handbrake) system.

2.5 Steering system

One of the most important systems in the vehicle that which give the driver the ability to steer the vehicle under his requirements and under the road directions. In this project, was used the fork steering was taken from motorcycle steering because of its simplicity design and easy to install in the vehicle with simplicity controller as shown in the figure below.

(a) Installing of steering system.

(b) Steering system after installation.

(c) Another view of steering system.

Figure 2.6: Steering system.

2.6 Tires

The tires are crucial functional elements for the transmission of longitudinal, lateral and vertical forces between the vehicle and road. The tire properties should be as constant as possible and hence predictable by the driver. As well as their static and dynamic force transmission properties, the requirements described below depending on the intended use of the vehicle—are also to be satisfied. The requirements for tires on solar cars light and can be subdivided into the following five groups:

1. Driving safety.
2. Handling.
3. Comfort.
4. Service life.
5. Economy.

In this project, was used the wheels of motorcycle with the following specifications:

Model	**Front tire** **KENDA**	**Rear tires** **KENDA**
Tire	Radial	Radial
Size	120/90/R15	120/90/R15
Max Load	660 lbs.	430 lbs.
AT	36 psi	36 psi

Table (2.3): The specifications of tire.

From the table above, note that the size and maximum load of the front tire is larger than the rear tires because there is one tire front so that it can carry a double load as if it was two front tires.

(a) Side view of front tire before installation.

(b) Front view of front tire after installation.

(c) Side view of rear tire after installation.

(d) Top view of rear tire.

Figure 2.7: Front and rear tires.

2.7 Seating

Since the car for one passenger, so we need just one seat in the middle of the car. It was installed in an appropriate manner and it is suitable for brake and steering wheel.

2.8 Gear Reduction

For this, the drivetrain will consist of the electric motor and the means by which the motor's power is transmitted to the wheel causing the vehicle to move. A gearbox as such may also be unnecessary, since this car will be running at speed can be controlled in it by the electric circuit connected to the motor. Direct drive transmission where the motor is connected to the final drive through a chain with single gear reduction. This gives the motor more starting torque at a lower speed, but still allows the car to run efficiently at a higher speed.

Gear reduction reduces the motor revolutions from **(2300-766)** rpm at the wheel. Single reduction direct drive used by using two sprockets: the first one consists of **(17)** teeth on the output motor shaft and the other has **(52)** teeth put on direct with the rear axle and driving the rear wheels, so the total obtained reduction is **(3:1)** was selected because we need a higher torque than speed to overcome the vehicle load, so the calculations explain:

The output rotational speed at the second gear on the rear axle can be calculated by this equation:

$$\mathbf{N_{out}} = \frac{\mathbf{D_{in}}}{\mathbf{D_{out}}} * \mathbf{N_{in}} = \frac{\mathbf{0.07}}{\mathbf{0.21}} * \mathbf{2300} = \mathbf{766\ rpm} \qquad \textbf{(2.1)}$$

Where:

N_{out} : *the output speed at the output gear on the rear axle.*

D_{in}: *the input diameter of the input gear on the motor shaft.*

D_{out}: *the output diameter of the output gear on the rear axle.*

N_{in}: *the input speed at the input gear on the motor shaft.*

Then calculating the maximum velocity of the vehicle:

$$\boldsymbol{\omega_{out}} = \frac{\mathbf{2\pi N_{out}}}{\mathbf{60}} = \frac{\mathbf{2*\pi*766}}{\mathbf{60}} = \mathbf{80}\ {}^{\mathbf{rad}}\!/_{\mathbf{sec}} \qquad \textbf{(2.2)}$$

$$\mathbf{V_{max}} = \mathbf{r_{tire}} * \boldsymbol{\omega_{out}} = \mathbf{0.15} * \mathbf{80} = \mathbf{12}\ {}^{\mathbf{m}}\!/_{\mathbf{s}} = \mathbf{12} * \mathbf{3.6} \cong \mathbf{43}\ {}^{\mathbf{km}}\!/_{\mathbf{h}} \qquad \textbf{(2.3)}$$

Where:

ω_{out}: $the\ output\ rotational\ speed\ at\ the\ each\ wheel\ in\ \left({}^{rad}/_{sec}\right)$.

r_{tire}: $tire\ raduis$.

V_{max}: $maximum\ velocity\ of\ the\ vehicle$.

(a) Gear reduction direct drive.

(b) Input and output gears with chain after connected to the motor.

Figure 2.8: General views of gears.

2.9 Bodywork

Keeping the weight of a Solar Powered Car’s bodywork light weight, so many resistances should be neglect such as Aerodynamic drag and hitch forces. Also making the vehicle to reach the high limits of the motor’s speed. Furthermore, the mass of the vehicle determines the rolling resistance, and the rate of acceleration, the shape of the bodywork, determines the aerodynamic drag, which above 25 mph can rise significantly.

The way was this car designed to reduce the wind resistance, although it build to run at low speeds and used light materials made of plastic as a cover of the vehicle. The figures below of Catia bodywork are different from actual bodywork to provide a suitable job.

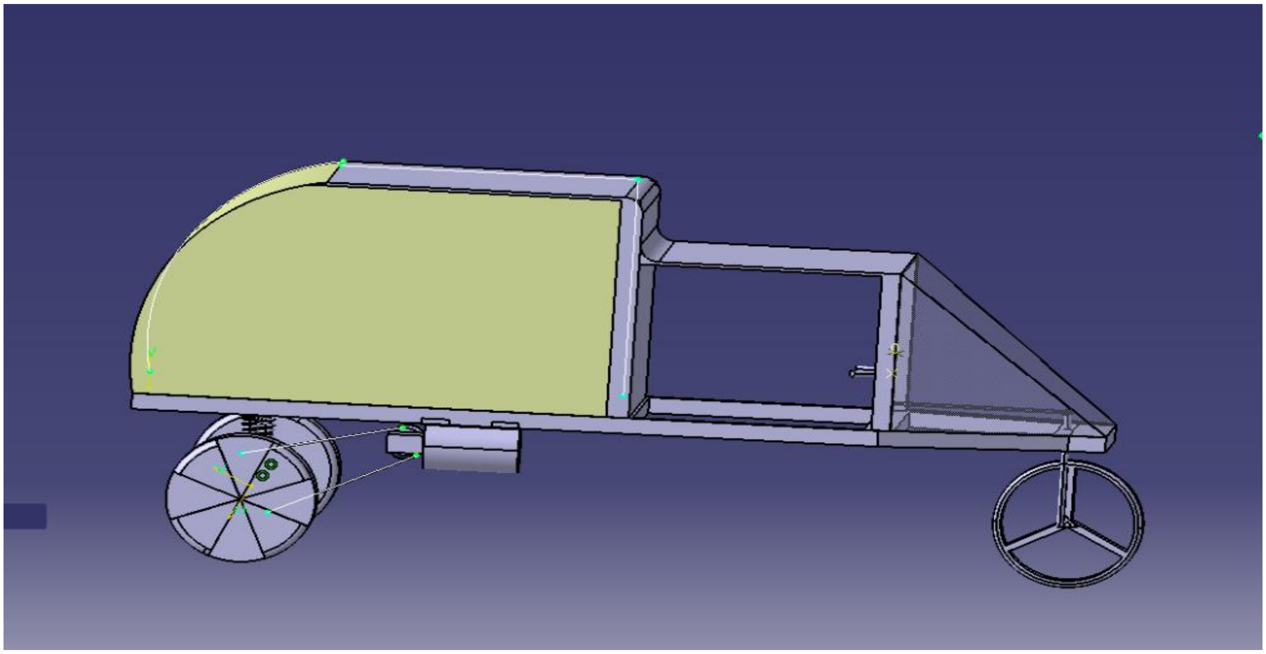


Figure 2.9 (a): Side view of the bodywork.

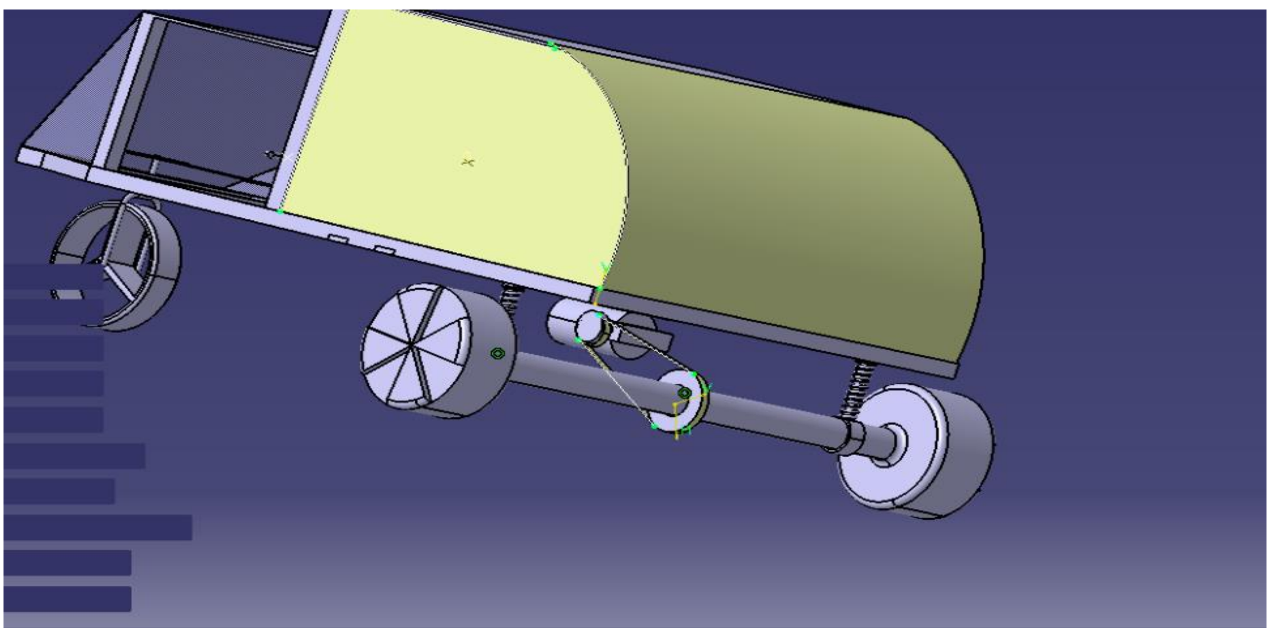


Figure 2.9 (b): Side view of the bodywork from different angle.

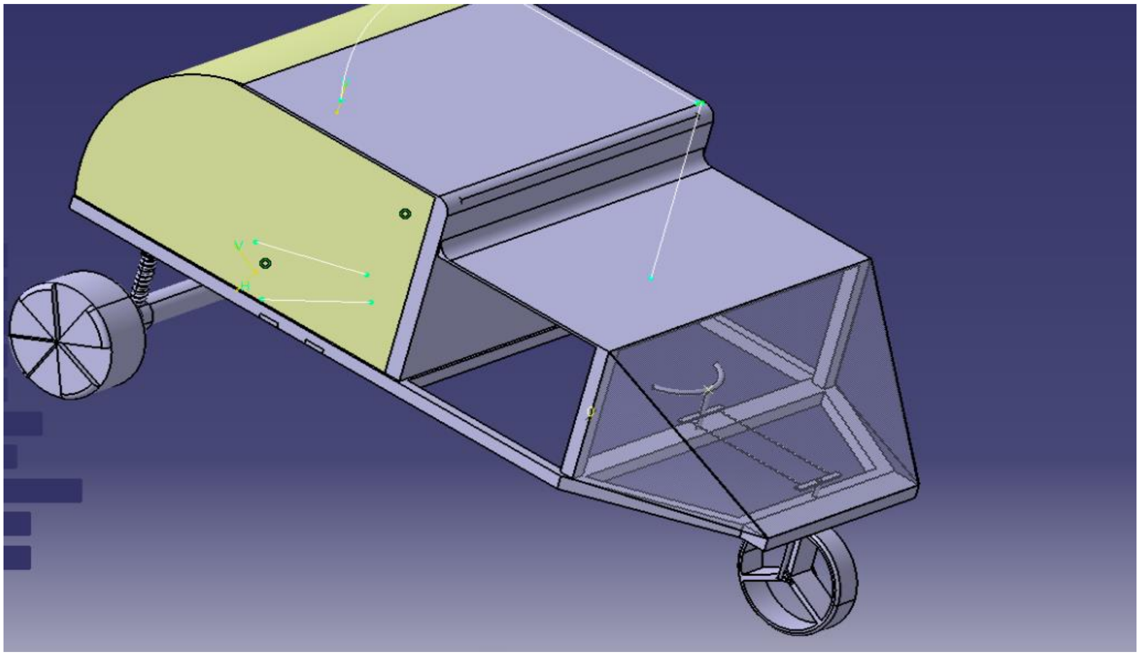


Figure 2.9 (c): Side view of the bodywork from different angle.

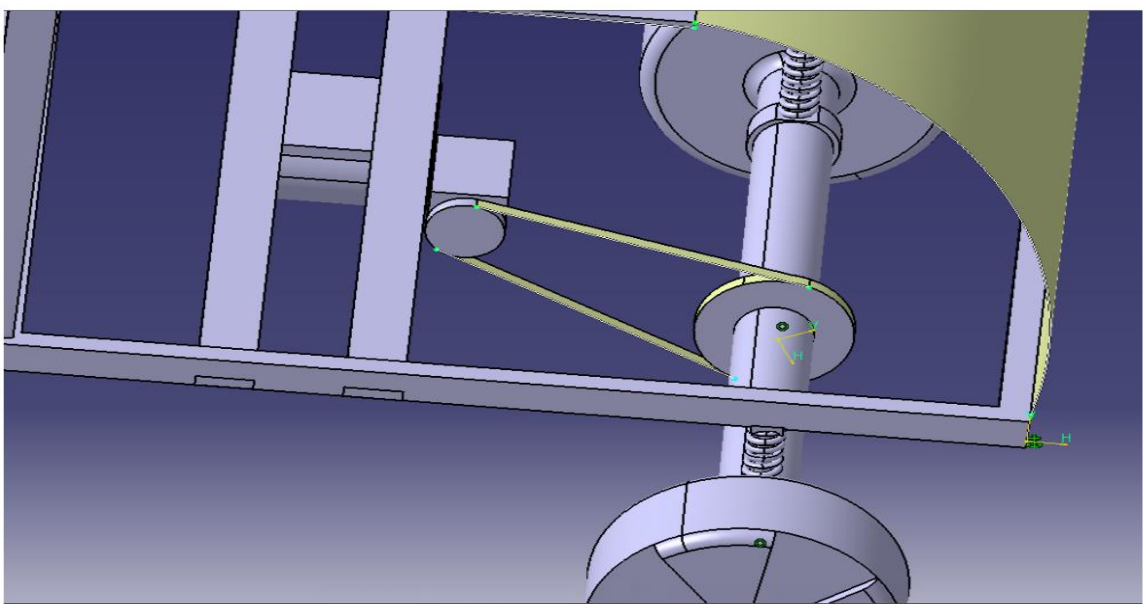


Figure 2.9 (d): special view shows the motor and gear reduction with in mesh state.

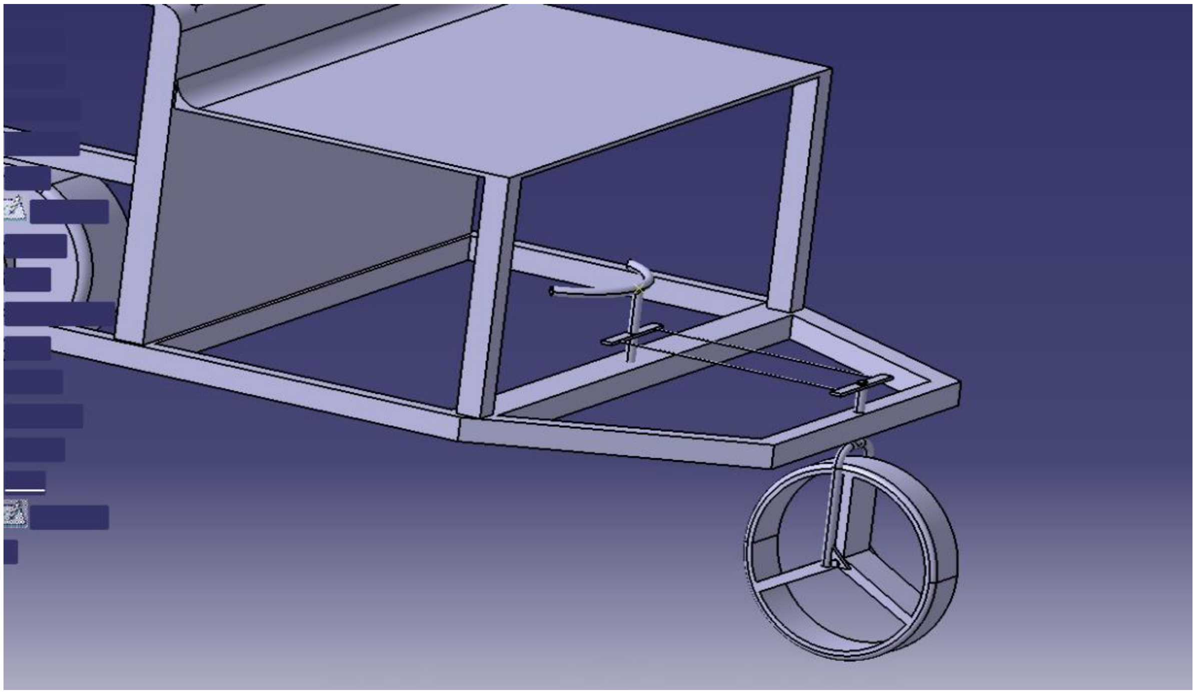


Figure 2.9 (e): Special view of front showing the steering mechanism.

Figure 2.9 (f): General view of actual bodywork.

Figure 2.9 (g): General view of actual bodywork.

Figure 2.9 (h): General view of actual bodywork.

Figure 2.9 (i): General view of actual bodywork.

As the mechanical parts were detailed with specific information, the electrical parts will detail later in the next chapter.

Chapter Three

Electric Components of the Solar Car.

1. DC Motor.

2. Solar Photovoltaic Panels.

3. Solar Charger Controller.

4. Batteries

5. Microcontroller.

3.1 DC Motor:

The DC motor is the heart of the car. The batteries fed it with a supply voltage, so then the motor convert this voltage to output mechanical rotational to move the wheels by specific mechanism and with a different speeds. The DC motor is shown below.

Figure 3.1: DC motor installed in the vehicle.

Motor Type	Permanent magnet DC motor VIMEC S.R.L (MP71/424240654F20)
HP	1.22
Speed(RPM)	2300 RPM
Voltage	24V
Ampere	37.8A
Torque	2.7N.m
Output Form	Solid Shaft
Rotation	CW/CCW
IP	20
Pin	000028050
F.F	1
Date	11/98

Table (3.1): The properties or specification of DC motor used.

3.1.1 DC Motor Calculations:

The output rotational speed at the second gear on the rear axle can be calculated by this equation:

$$\mathbf{N_{out}} = \frac{\mathbf{D_{in}}}{\mathbf{D_{out}}} * \mathbf{N_{in}} = \frac{\mathbf{0.07}}{\mathbf{0.21}} * \mathbf{2300} = \mathbf{766\ rpm} \qquad \textbf{(3.1)}$$

Where:

N_{out} : $\textit{the output speed at the output gear on the rear axle.}$

D_{in}: $\textit{the input diameter of the input gear on the motor shaft.}$

D_{out}: $\textit{the output diameter of the output gear on the rear axle.}$

N_{in}: $\textit{the input speed at the input gear on the motor shaft.}$

Then calculating the maximum velocity of the vehicle:

$$\boldsymbol{\omega}_{\mathbf{out}} = \frac{\mathbf{2\pi N_{out}}}{\mathbf{60}} = \frac{\mathbf{2*\pi*766}}{\mathbf{60}} = \mathbf{80}\ \mathbf{rad}/\mathbf{sec} \qquad \textbf{(3.2)}$$

$$\mathbf{V_{max}} = \mathbf{r_{tire}} * \boldsymbol{\omega}_{\mathbf{out}} = \mathbf{0.15} * \mathbf{80} = \mathbf{12}\ \mathbf{m}/\mathbf{s} = \mathbf{12} * \mathbf{3.6} \cong \mathbf{43}\ \mathbf{km}/\mathbf{h} \qquad \textbf{(3.3)}$$

Where:

ω_{out}: $the\ output\ rotational\ speed\ at\ the\ each\ wheel\ in\ \left({}^{rad}/_{sec}\right)$.

r_{tire}: $tire\ raduis$.

V_{max}: $maximum\ velocity\ of\ the\ vehicle$.

Assuming that time to reach maximum velocity = 40 seconds. So by equations of motion and Newton's second law, the motor torque can be calculated to figure out if the motor is suitable for this kind of vehicle with variable load:

$$\mathbf{V_{2,max} = V_o + at} \tag{3.4}$$

$$\boldsymbol{So\ \ 12 = zero + 40a\ \ \ \rightarrow a = 0.3\ {}^{m}/_{s^2}}$$

Where:

$V_{2,max}$: $the\ maximum\ velocity\ of\ the\ vehicle$.

V_o: $the\ initial\ velocity\ of\ the\ vehicle$.

a: $the\ longitudinal\ acceleration\ of\ the\ vehicle$.

t: $time\ to\ reach\ maximum\ velocity$.

Now calculate the tractive force at the wheels by considering road loads are equal to zero to measure the torque of the vehicle load:

$$\sum \mathbf{F_x} = \mathbf{F_{x,f}} + \mathbf{F_{x,r}} = \mathbf{ma_x} = \mathbf{250 * 0.3 = 75\ N}. \qquad \textbf{(3.5)}$$

$$\mathbf{T_{load}} = \sum \mathbf{F_x} * \mathbf{r_{tire}} = \mathbf{150 * 0.15 = 11.3\ N.m} \qquad \textbf{(3.6)}$$

So finally,

$$\mathbf{T_{motor}} = \frac{\mathbf{D_{in}}}{\mathbf{D_{out}}} * \mathbf{T_{load}} = \frac{\mathbf{0.07}}{\mathbf{0.21}} * \mathbf{11.3 = 3.7\ N.m} \qquad \textbf{(3.7)}$$

Where:

$\sum F_x$: *the summation of tractive forces on both front and rear axles in x − axis direction.*

$F_{x,f}$: *the tractive force on front axle in x − axis direction.*

$F_{x.r}$: *the tractive force on rear axle in x − axis direction.*

T_{load}: *the load torque of the vehicle.*

T_{motor}: *the required torque from motor to overcome load torque.*

From these calculations, concluded that the electric motor was used in this vehicle is suitable to overcome variable load of the vehicle but take more time than (40 sec.) was assumed to reach the maximum speed.

$$\%\mathbf{Error\ of\ motor\ torque} = \left|\frac{\mathbf{T_{theo.}} - \mathbf{T_{act.}}}{\mathbf{T_{theo.}}}\right| = \left|\frac{\mathbf{3.7 - 2.7}}{\mathbf{3.7}}\right| * \mathbf{100} = \mathbf{27}\% \quad \textbf{(3.8)}$$

3.2 Solar Photovoltaic Panels:

Is a device that converts the energy of sunlight directly into electricity by the photo voltaic effects. Connecting cell in parallel will yield a higher current, Modules are then interconnected, in series or parallel, or both, to create an array with the desired peak DC voltage and current.

The power output of a solar array is measured in watts or kilowatts. In order to calculate the typical energy needs of the application, a measurement in watt-hours, kilowatt-hours or kilowatt-hours per day is often used. An array of solar cells converts solar energy into usable amount of direct current (DC) electricity.

3.2.1 Theory

Photos in sunlight hit the solar panel and are absorbed by semiconducting materials such as; Silicon. Electrons (negatively charged) are knocked loose from their atoms, allowing them to flow through the material to produce electricity. Due to the special composition of solar cells, the electrons are only allowed to move in a single direction. Complementary positive charges, called holes, are also created and flow in the opposite direction to the electrons.

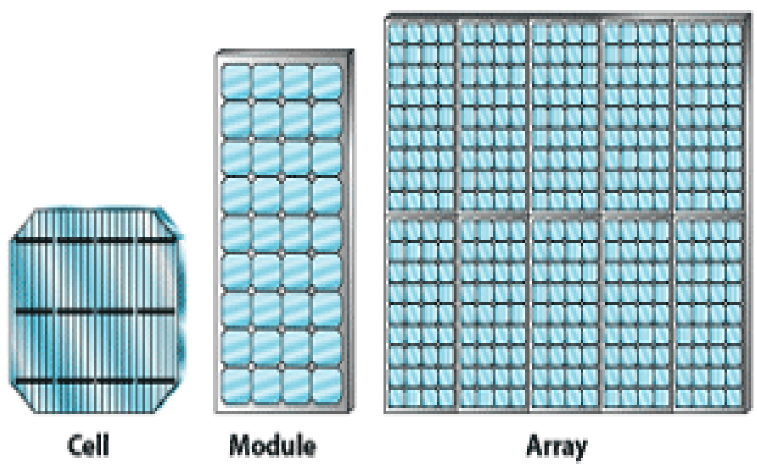


Figure 3.2: Cells, Modules, Arrays.

The solar array consists of hundreds of photovoltaic solar cells converting sunlight into electricity. In order to construct an array, PV cells are placed together to form modules which are placed together to form an array. In this project, Polly crystalline PV cells (two solar panels) were used with the following specifications:

Cell Type	**Polly Crystalline**
Module Peak Power	140 Watt
Product Code	M36
Module Efficiency (%)	13.7
Cell in series	36 cells (156mm x 156mm)in a 4 X9 matrix connected in series
Cell size (mm)	156 mm
Voltage at maximum power (V_{pm})	17.5 V
Open Circuit voltage (V_{oc})	22 V
Current at maximum power (I_{pm})	8 A
Short Circuit current (I_{sc})	8.6 A
Module size (mm) **(L x W x D)**	1500 x 670 x 45
Area (m^2)	1
Module weight (kg)	12

Table (3.2): Solar Panels Specifications.

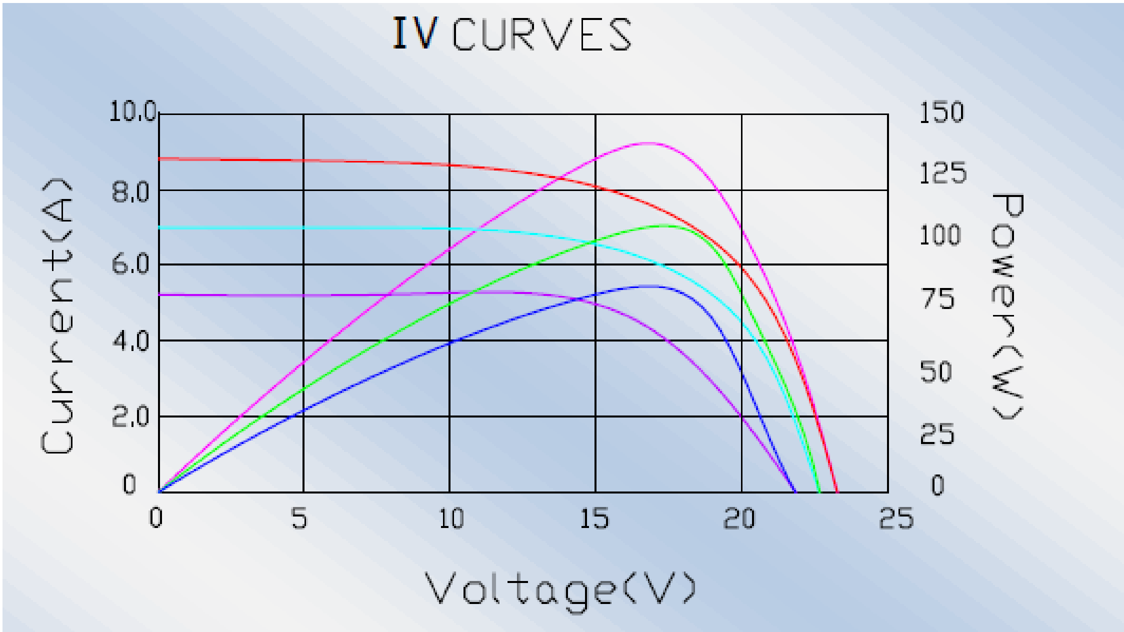


Figure 3.3: I V Curve for Polly Crystalline photovoltaic panel.

Figure 3.4: Polly Crystalline photovoltaic panel.

The solar array can be mounted in several ways:

1. Horizontal: This most common arrangement gives most overall power during most of the day in low latitudes or higher latitudes summers and offers little interaction with the wind.

2. Vertical: This arrangement is sometimes found in free standing or integrated sails to harness wind energy. Useful solar power is limited.

3. Adjustable: Free solar arrays can often be tilted around the axis of travel in order to increase power when the sun is low and will to the side.

4. Integrated: Some vehicles cover every available surface with solar cells. Some of the cells will be at an optimal angle whereas others will be shaded.

5. Remote: By mounting the solar array at a stationary location instead of the vehicle, power can be maximized and resistance minimized.

3.2.2 Solar Panel Calculations:

In order to figure out how much meter square of photovoltaic panels needed in this project, it must analyzing the total electric energy consumed by electric components and the electric power required to operate the vehicle under different operation conditions. First analyze and calculate the total electric energy consumed by electric components at daylight:

Electric components	Electric power(P in watt)	Operating time (t in hours)	Total energy consumed ($E_{tot}(Kwh) = P * t$)
Electric motor	907	Assuming one hour	0.907
Front LED Light	Zero at daylight	Zero	Zero

Table (3.3): Total electric energy consumed.

So the total area of photovoltaic needed:

$$A_{PV} = \frac{E_{tot}}{\eta_{PV}\eta_{cch}E_{SP}} = \frac{907}{0.14*0.85*5400\ ^{Kwh}/_{m^2}} = 1.41\ m^2 \qquad (3.8)$$

Where:

A_{PV}: *area of photovoltaic needed for the vehicle.*

η_{PV}: the standard efficiency of photovoltaic panels used in the vehicle.

η_{cch}: the standard efficiency of charge controller used in the vehicle.

E_{tot}: the total electric energy consumed by the electric components.

E_{SP}: the total sun light energy radiation of palestine.

From previous calculations, we used two solar panels with total area equal **($2m^2$)** and gives **(140 Watt for each panel so total power for two panels = 280 Watt)** to overcome losses and give more efficiency.

3.3 Solar Charge Controller:

Most batteries need around **(14 -14.5 volt)** to get fully charged so a charge controller, or charge regulator it regulates the voltage and current coming from the solar panels going to the battery. Most **"12 volt"** panels put out is about **16 to 20 volts**, so if there is no regulation the batteries will be damaged from overcharging and may prevent against overvoltage and it may also prevent completely draining ("deep discharging ") a battery, or perform controlled discharges and preventing reverse flow at night.

The reasons of panels given **17.5 V not 12 V** as want, is that if you do that, the panels will provide power only when cool, under perfect conditions, and full sun. This is not something you can count on in most places. The panels need to provide extra voltage so that when the sun is law in the sky, or you have heavy haze, cloud cover, or high temperatures, you still get some output from the panel. A fully charged battery is around **12.7** volt at rest **(around 13.6 under charge)**, so the panel has to put out at least that much under worst case conditions.

They range current begin from the small **4.5 amp** control, up to the **60 to 80 amp**, The most common controls used for all battery based systems are in the 4 to 60 amp range.

Figure 3.5 (a): 20I (20A, 12/24 V) charge Controller.

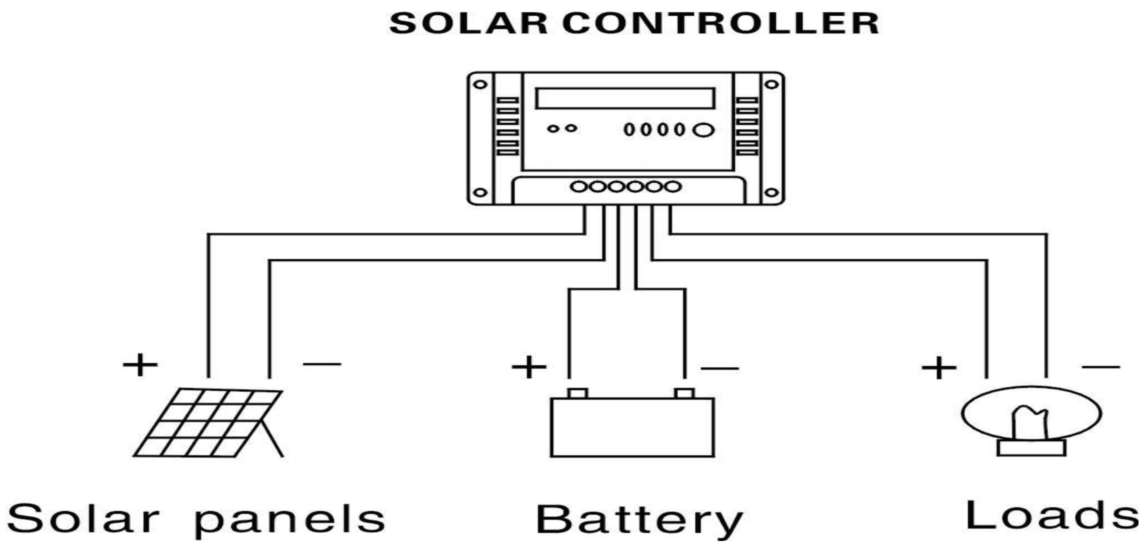


Figure 3.5 (b): 20I (20A, 12/24 V) charge Controller.

Installing the regulator near the battery on a suitable surface. This surface should be solid, even, dry and nonflammable. The battery cable should be as short as possible **(1-2 m)** and have a suitable cable diameter size to minimize loss. The solar charge controller properties should be compatible with the PV and Batteries specifications.

The properties of charge controller **(20I (20A, 12/24 V))** were used remember in following table (3.2):

Solar charge controller type	20I (20A, 12V)	20I (20A, 24V)
System voltage	12 V	24 V
Rated solar input	10 A/20 A	10 A/20 A
Rated load	10 A/20 A	10 A/20 A
25% current overload	1 min.	1 min.
Load disconnect	11.1 V	22.2 V
Load reconnect	12.6 V	25.20 V
Equalization voltage (30 min.)	14.6 V	29.2 V
Boost voltage (30min.)	14.4 V	28.8 V
Float voltage	13.6 V	27.2 V
Temp. Comp. (mV/C^o)	-30 mV	-60 mV
Terminals	For wire sizes to 6 mm^2	
Temperature	-35C^o to +55C^o	

Table (3.4): Specification of Charge Controller.

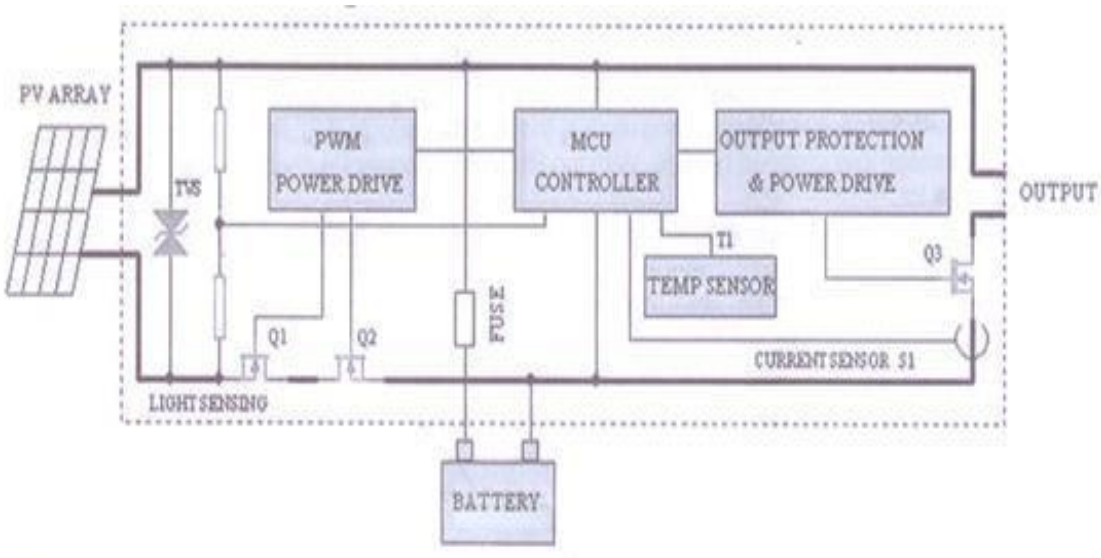


Figure 3.6: Solar Charge Controller Circuit Diagram.

From previous properties, we used two (12V) control charger to charge the batteries from panels with quit and fast method by avoiding the overcharge phenomena.

3.4 Batteries:

The batteries are made of unit cells containing the chemical energy that is convertible to electrical energy, batteries connected in a series or parallel combination to deliver the desired voltage and energy to the power electronic drive system. This available chemical energy in a cell is converted into electrical energy only on demand, using the basic components of a unit cell, which are the positive and negative.

We can combine voltage by putting batteries in series, or combine Ah and current carrying capacity by putting them in parallel; you cannot affect the total power required of the batteries. Watts either way.

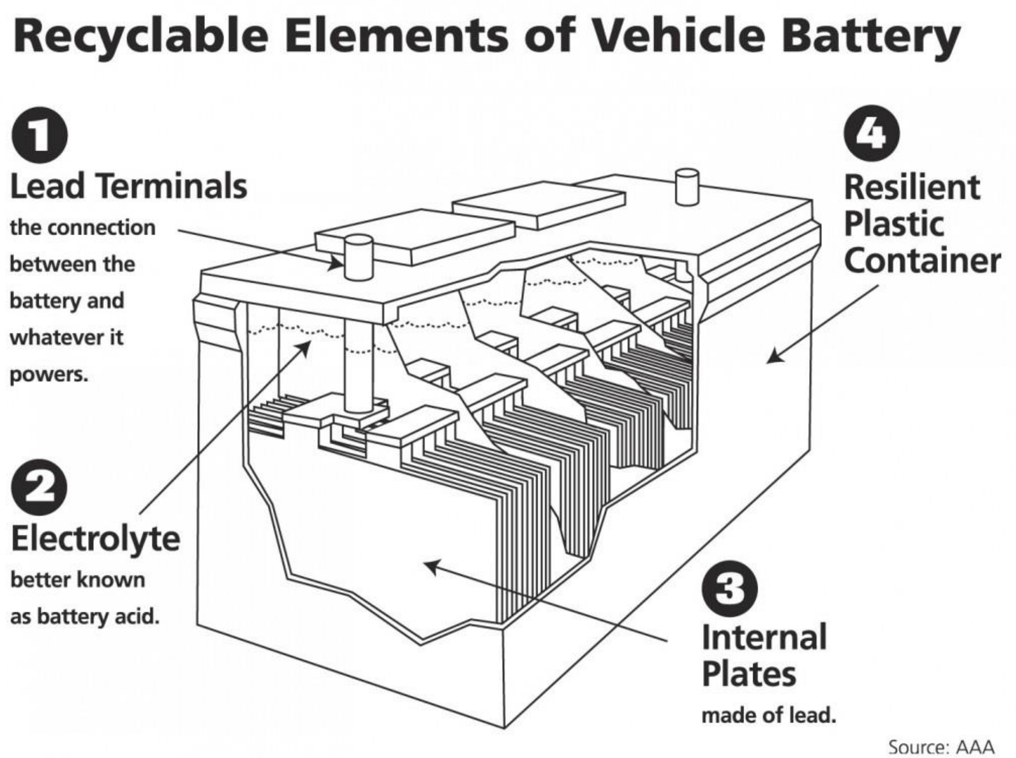


Figure 3.7: Battery components.

3.4.1 Components of the Battery Cells

1. Positive electrode.

2. Negative electrode.

3. Electrolyte.

4. Separator.

Multiple batteries connected together to create essentially one large battery of the required voltage and amp-hour capacity. The battery pack is equivalent to a petrol tank in a conventional car. A solar car uses the battery pack to store energy that will be used at some later time. Solar cars start usually with fully charged battery packs, but after the start, energy generated by the solar array can be used to recharge the batteries.

3.4.2 Battery types:

The type of battery can be describing referring to the material used as:

a. Carbon-zinc cell.

b. Alkaline cell.

c. Nickel-cadmium cell.

d. Edison cell.

e. Mercury cell.

f. Sealed batteries.

3.4.2.1 Power Safe (SBS) Battery (Sealed Battery)

A Power Safe battery is the designation for low maintenance lead-acid rechargeable batteries. Because of their construction, Power Safe batteries do not require regular addition of water to the cells.

These batteries have a pressure relief valve which will activate when the battery is recharged at high voltage, typically greater than 12 volts per battery. Valve activation allows some of the gas or electrolyte to escape, thus decreasing the overall capacity. The cell covers typically have gas diffusers built into them that allow safe dispersal of any excess hydrogen that may be formed during overcharge. They are not permanently sealed, but are maintenance free; and they can be oriented in any manner, unlike normal lead-acid batteries, which must be kept upright to avoid acid spills and to keep the plates orientation vertical. Cell may be operated with the plates horizontal (pancake style), which may improve cycle life.

At high overcharge currents, electrolysis of water occurs, expelling hydrogen and oxygen gas through the battery's valves. Care must be taken to prevent short circuits and rapid charging. Constant-voltage charging is the usual, most efficient and fastest charging method for Power Safe batteries, although other methods can be used.

Power Safe batteries are mainly used for many types of vehicles such as; passenger cars, heavy vehicle. But here they are used in solar power system.

They have several properties that differs from other types of batteries:

1. Maintenance free.
2. High power-to-weight ratio.
3. High energy density.
4. Low self-Discharge.
5. Long service life.
6. Requires very low ventilation.
7. Wide operating temperature range (-40°C to +50°C).
8. Available as 2V cells and 6V or 12V mono blocks with a capacity range of 7 to 360Ah.

Figure 3.8 (a): Types of Power Safe Batteries.

Figure 3.8 (b): side view of Power Safe Battery.

3.4.2.2 Duration under Load

Calculating how long a battery will last at a given rate of discharge is not as simple as “amp-hours” battery capacity decreases as the rate of discharge increases. For this reason, battery manufactures prefer to rate their batteries at very low rates of discharge, as they last longer and get higher ratings that way.

3.4.2.3 Calculating the battery Runtime

A battery can either be discharged at a low current over a long time or at a high current for only a short duration. The relationship between the discharge times (in amperes drawn) is reasonably linear on low loads. As the load increases, the discharge time suffers because some battery energy is lost due to internal losses. This results in the battery heating up.

3.4.2.4 Calculations

We used two batteries each one 12v and 51A, it's connected on series, so

Total volt= (12+12) = 24 volt

Total amperage = amperage of the two batteries= **102 A.**

Electrical power is measured in watts, and is equal to voltage times current:

$$P= E_{Bat.} \times I$$

The total DC batteries power:

Power= I × V= 51 × 24= 1.224 Kw

The total losses in **(907 Watts)** electric motor **10%,** hence:

1.224 × 0.1= 0.1224 Kw

The total benefit power = **1.1016 Kw.**

Considering that electric energy consumed by the motor is depending on vehicle's load and speed which they are variables so batteries run time will be more than 100 minutes, it may be reach many hours. Calculating batteries run time at full load by this equation:

$$\tau_{B.R.T} = \frac{\text{Battery (AH)}}{\text{Electric motor load (A)}} = \frac{51}{37.8} = 1.34 \text{ hours} \quad (3.9)$$

Where:

$\tau_{B.R.T}$: **Battery run time (hours).**

3.4.2.5 Batteries Charging Methodology

There are three different charging types for the batteries such as:

1. Constant-voltage charging as it mentioned before.

2. The solar energy that comes from the panels will recharge the batteries as it mentioned before.

3. Charging batteries by battery charging device.

3.5 Microcontroller

3.5.1 Microcontroller Preface

A microcontroller is a highly integrated chip, which includes on single chip, all or most of the parts needed for a controller. The microcontroller typically includes: CPU (Central Processing Unit), RAM (Random Access Memory), EPROM/PROM/ROM (Erasable Programmable Read Only Memory), I/O (input/output) – serial and parallel, timers, interrupt controller. For example, Intel 8051 is 8-bit microcontroller and Intel 8096 is 16-bit microcontroller.

Microcontrollers are designed for embedded applications, in contrast to the microprocessors used in personal computers or other general purpose applications.

3.5.2 Types of Microcontroller

Microcontrollers can be classified on the basis of internal bus width, architecture, memory and instruction set, such as;

1. The 8-Bit Microcontroller, examples of 8-bit microcontrollers are Intel 8051 family and Motorola MC68HC11 family.

2. The 16-Bit Microcontroller, examples of 16-bit microcontrollers are Intel 8096 family and Motorola MC68HC12 and MC68332 families.

3. The 32-Bit Microcontroller, examples of 32-bit microcontrollers are Intel 80960 family and Motorola M683xx and Intel/Atmel 251 family. The

performance and computing capability of 32 bit microcontrollers are enhanced with greater precision as compared to the 16-bit microcontrollers.

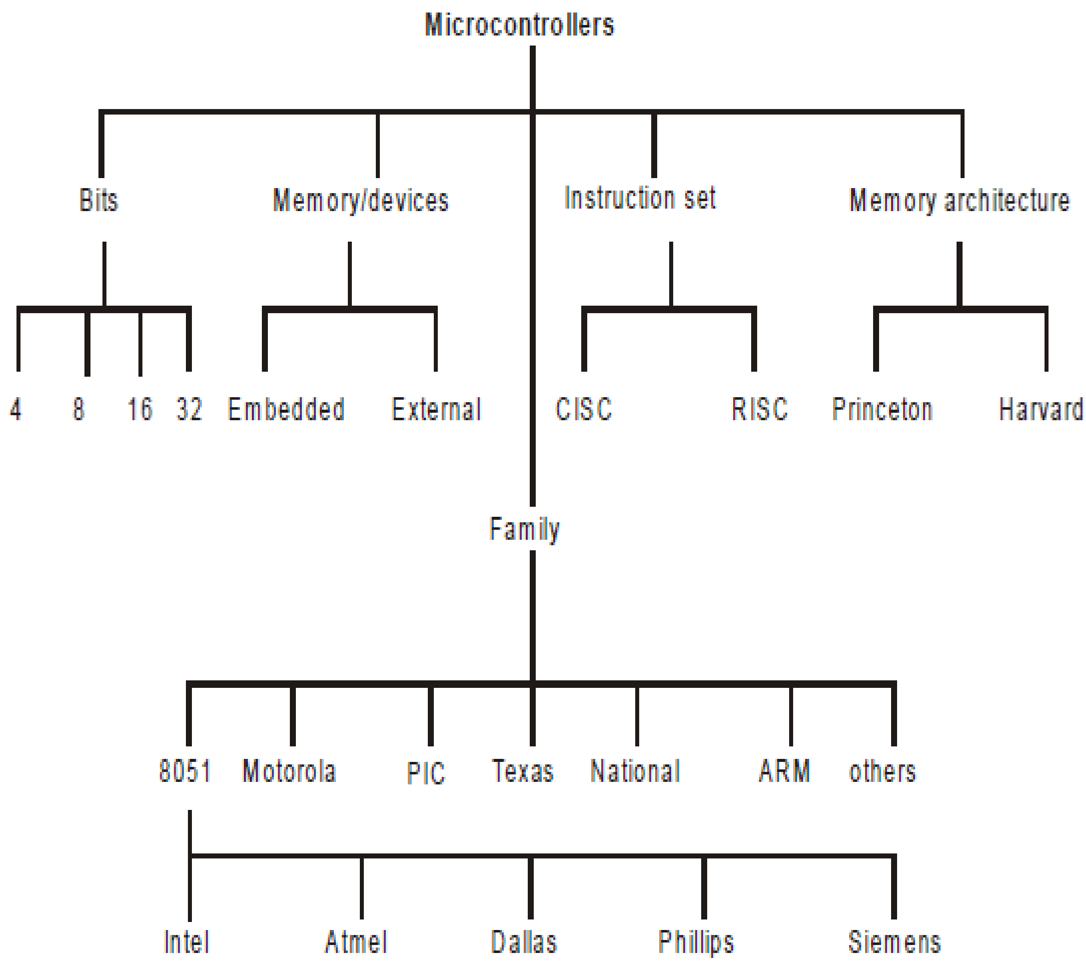


Figure 3.9: shows the various types of microcontrollers.

3.5.3 Microcontroller Methodology and Applications (In General)

Microcontrollers are used in automatically controlled products and devices, such as automobile engine control systems, implantable medical devices, remote controls, office machines, appliances, power tools, toys and other embedded systems. By reducing the size and cost compared to a design that uses a separate microprocessor, memory, and input/output devices, microcontrollers make it economical to digitally control even more devices and processes.

Mixed signal microcontrollers are common, integrating analog components needed to control non-digital electronic systems.

Some microcontrollers may use four-bit words and operate at clock rate frequencies as low as 4 kHz, for low power consumption (single-digit milliwatts or microwatts). They will generally have the ability to retain functionality while waiting for an event such as a button press or other interrupt; power consumption while sleeping (CPU clock and most peripherals off) may be just nanowatts, making many of them well suited for long lasting battery applications. Other microcontrollers may serve performance-critical roles, where they may need to act more like a digital signal processor (DSP), with higher clock speeds and power consumption.

3.5.4 Microcontroller and solar car project

In this project the use of (1Hp 24v DC) Motor with gears to rotate the rear axle and makes the vehicle moves, its necessary to use a microcontroller with six push buttons for three rise-up speed of the motor and other uses, so it can smoothly ranging the motor's speed from stand-still to maximum without any external damage from the motor' torque to the gears or to the rear axle (as a driving axle).

3.5.5 Solar car's microcontroller methodology

The design of this type of microcontroller, should receiving the 24v from the motor to give a smoothly rise-up different speeds with a digital circuits by formatting the microcontroller's software with special programs.

This is similar to the Automatic Transmission (AT), as the driver controlling the motor's speeds with push buttons without overshoot case. In addition, when the brake pedal is activated that's causing the microcontroller to stop the motor from rotating and return in action when the brake pedal is released. The six push buttons considered as:

1. Switch on/off button (switching on the motor to move the vehicle or off).

2. First speed button (smoothly rising –up the motor speed to prevent the start rough torque of the motor).

3. Second speed (moderate speed).

4. Third speed (it should be the maximum speed of the motor).

5. Disengaging the motor when the brake is activated, so that the motor would be generator to recharge the batteries.

6. Re-engaging the motor when the brake pedal is released to return in action and drive the vehicle.

The block diagram of the project's microcontroller is shown below.

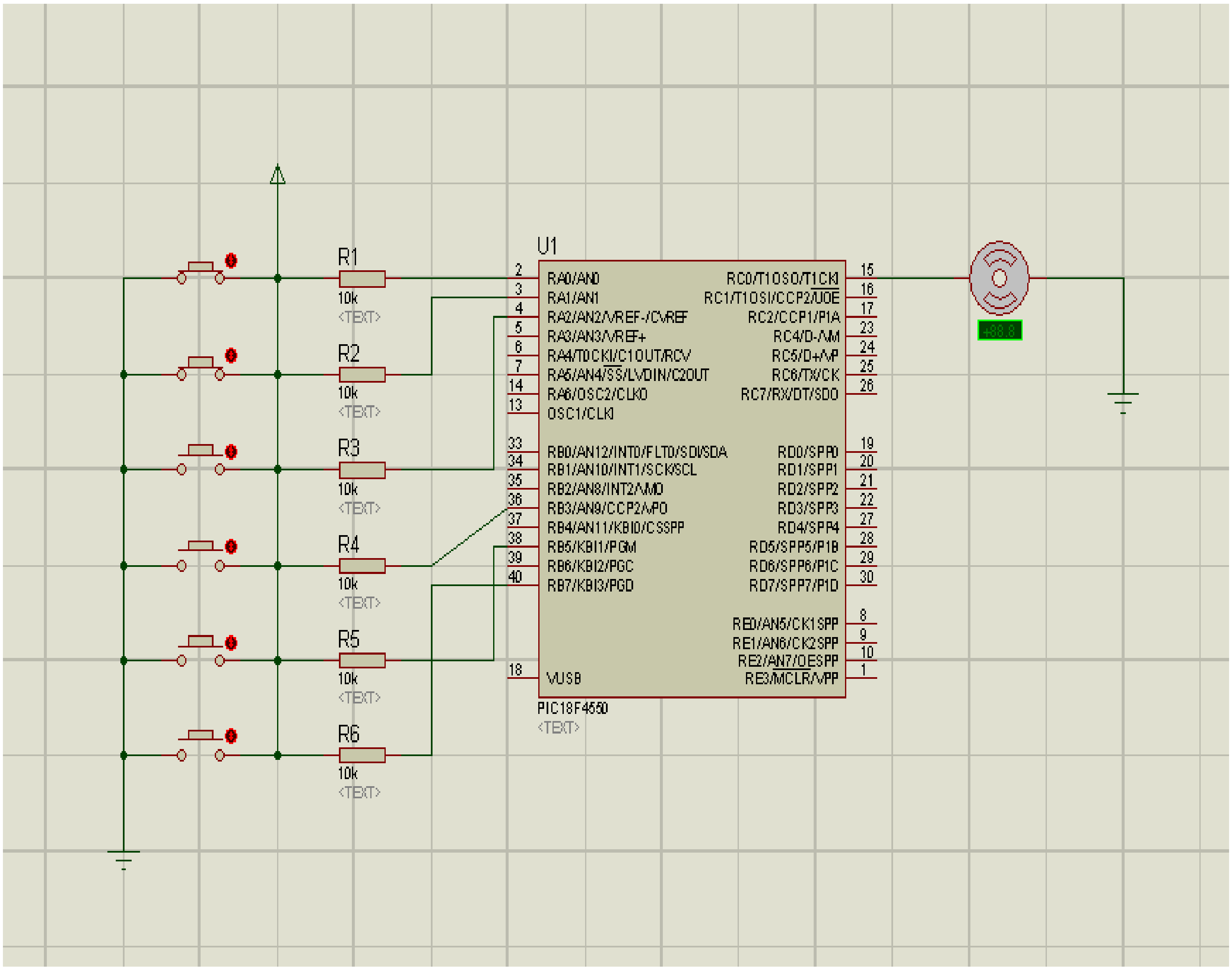


Figure 3.10: A block diagram of the project's microcontroller.

In this project, we could not use the microcontroller because of its' high cost and difficult installation due to difficult controlling the high amperage of the motor, so we used a simple electric circuit which divided the motor voltage into two section **(low speed at 12 Volt and high speed at 24 Volt) as shown in the figure below.**

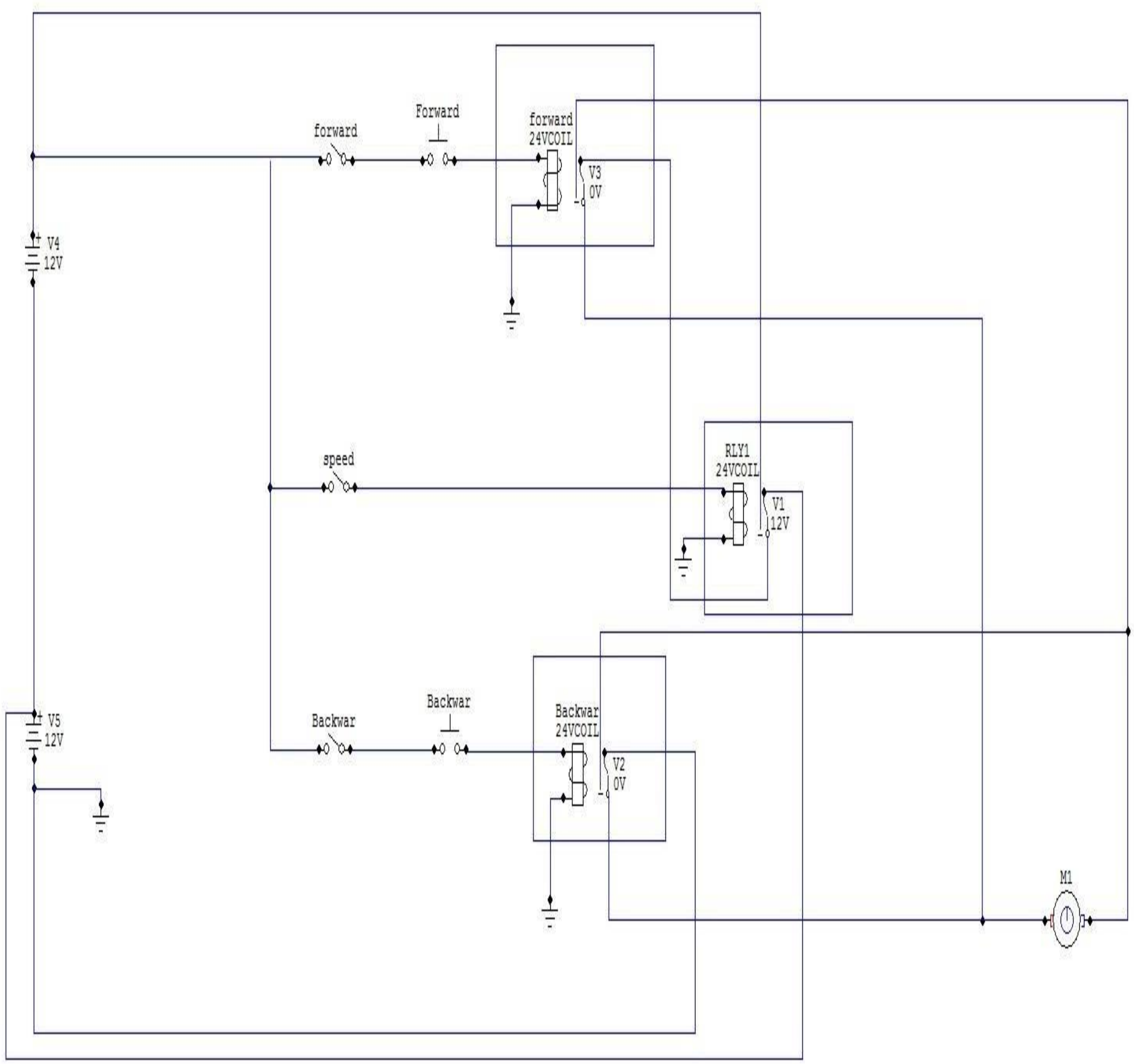


Figure 3.11a: Diagram of the electric circuit.

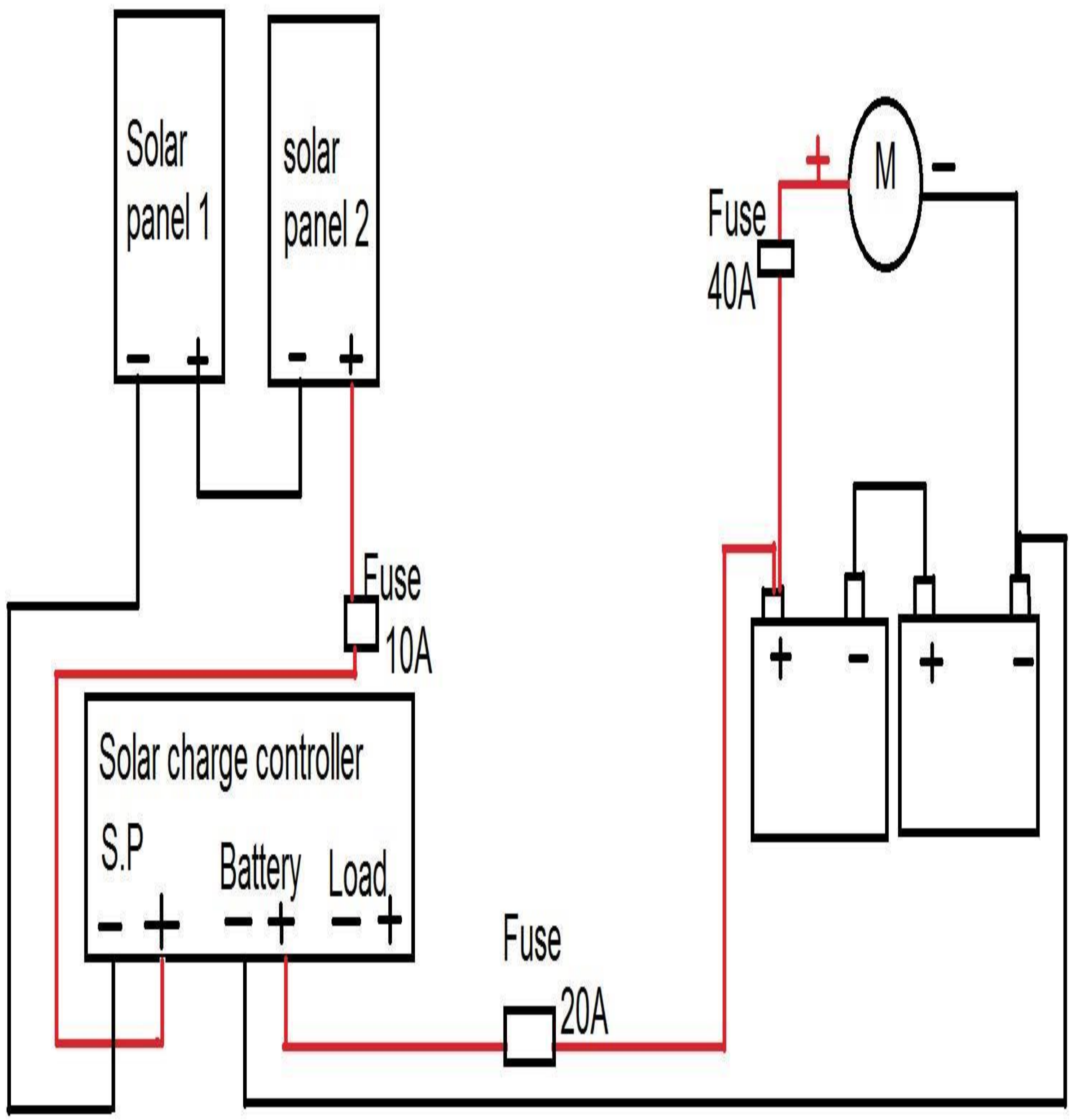


Figure 3.11b: Diagram of the electric circuit.

3.6 Block diagram of electric system

II. BASIC FUNCTIONAL DIAGRAM

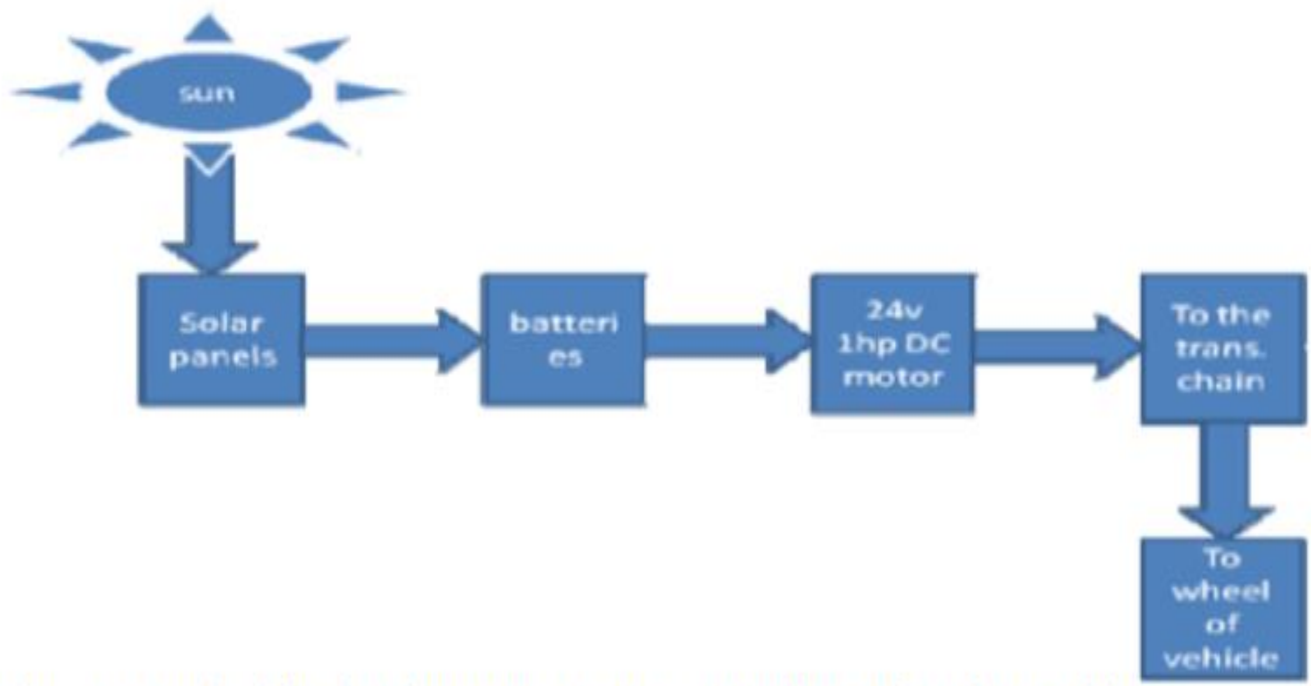


Fig. 1 Basic block Diagram Representation of Solar vehicle

Figure 3.12: Block diagram of electric system with further classification.

3.7 financial and economic study

In this section, the financial cost and expenses will detailed in general.

Table (3.5): Project pieces and their costs.

Piece name:	Piece cost:
Steel pieces	300 NIS
Metal works	450 NIS
Bearing & wheels	300 NIS
Lathing	300 NIS
Gears	300 NIS
Chain	100 NIS
Aluminum	100 NIS
Glass	100 NIS
Electric pieces(relay+ wiring+ solar panels+ charge controller+ switches+ light+ Batteries)	2000 NIS
Body cover	500 NIS
Total	4450 NIS

Chapter Four

1. Vehicle Resistances.

2. Performance.

4.1 Vehicle resistances

1. Rolling Resistance.

2. Aerodynamic Drag.

3. Grading Resistance.

4.2 General Description of Vehicle Movement

Figure 4.1 shows the forces acting on a vehicle moving up a grade. The tractive effort (F_t) in the contact area between tires of the driven wheels and the road surface propels the vehicle forward. It is produced by the power plant torque and is transferred through transmission and final drive to the drive wheels. While the vehicle is moving, there is resistance that tries to stop its movement. The resistance usually includes tire rolling resistance, aerodynamic drag, and uphill resistance. According to Newton's second law, vehicle acceleration can be written as:

$$\frac{dV}{dt} = \frac{\sum F_t - \sum F_{tr}}{\delta M_v} \tag{4.1}$$

Where:

V: Vehicle speed.

$\sum F_t$: The total tractive effort of the vehicle.

$\sum F_{tr}$: The total resistance.

M_v: The total mass of the vehicle.

δ: The mass factor, which is an effect of rotating components in the powertrain.

Equation (4.1) indicates that speed and acceleration depend on tractive effort, resistance and vehicle mass.

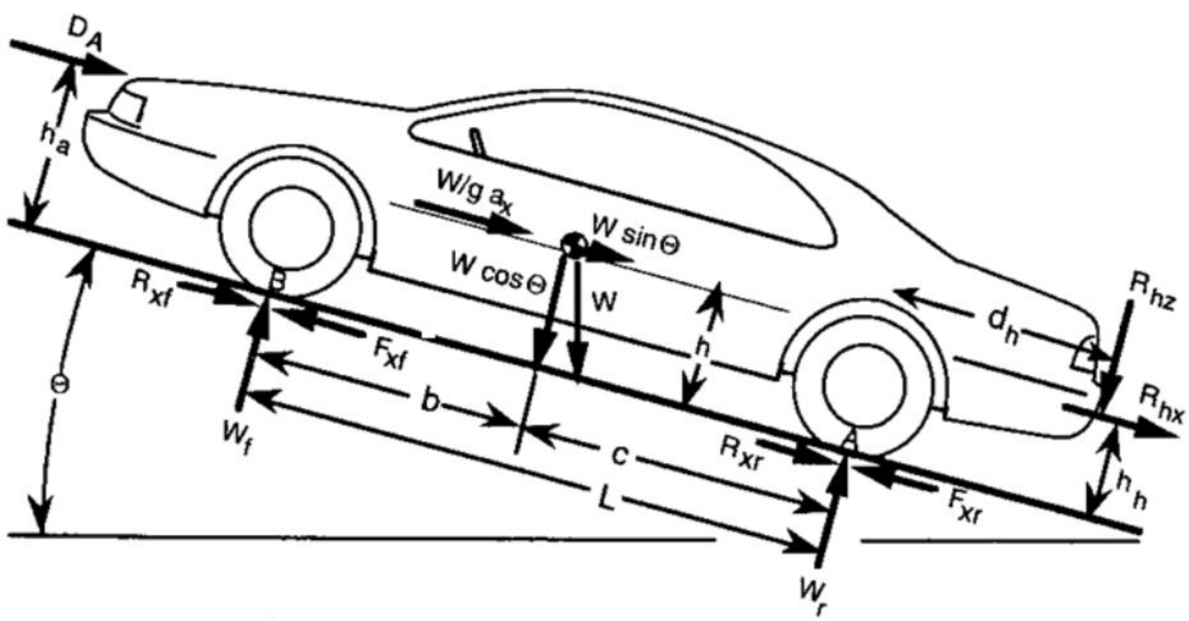


Figure 4.1 (a): Forces acting on a vehicle.

4.3 Vehicle resistance

As shown in figure (4.1.a), vehicle resistance opposing its movement includes rolling resistance of the tires, aerodynamic drag (F_w) and grading resistance (the term M_v g sinθ in Figure (4.1.a)). All of the resistances will be discussed in details in the following. But taken into consideration of solar vehicle's speeds as it's consider as low speeds, so that all the resistances will affect the motion of the vehicle except the aerodynamic resistance will account as zero resistance at low speeds.

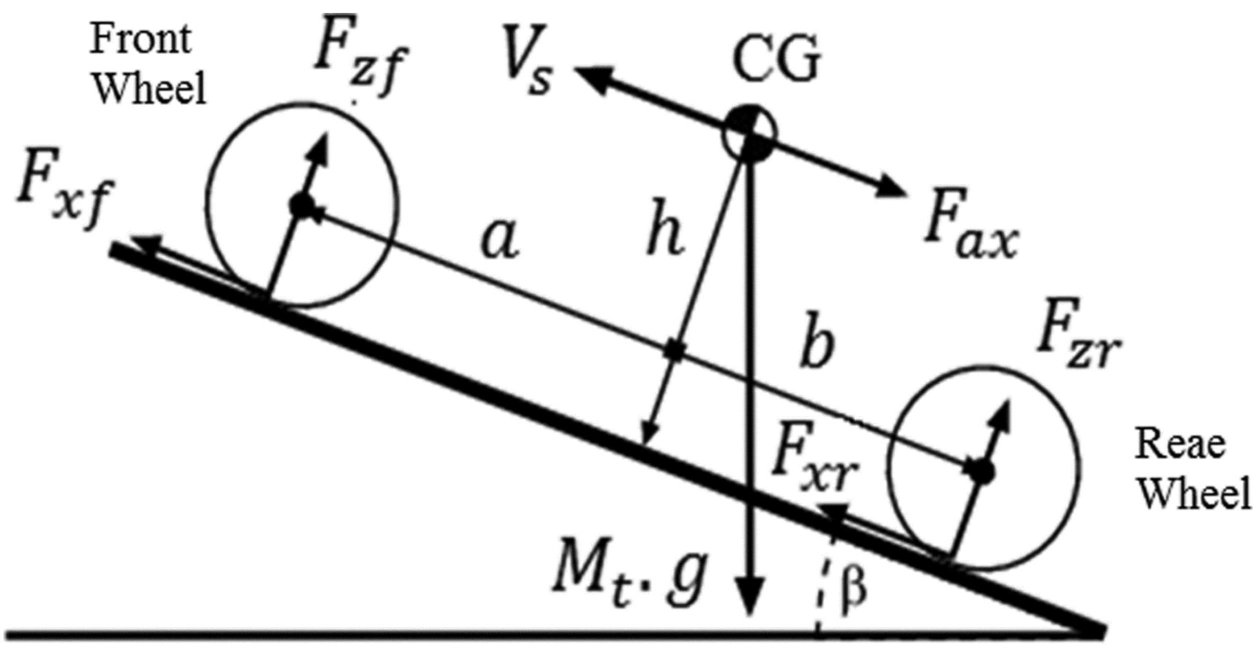


Figure 4.1 (b): forces acting on the three wheels solar vehicle.

4.3.1 Rolling Resistance

The rolling resistance of tires on hard surfaces is primarily caused by hysteresis in the tire materials. This is due to the deflection of the carcass while the tire is rolling. The hysteresis causes an asymmetric distribution of ground reaction forces.

$$\mathbf{F_r} = \mathbf{W} \times \mathbf{F_r} \tag{4.2}$$

Where:

W: The Weight of vehicle.

F_r : The coefficient of rolling resistance.

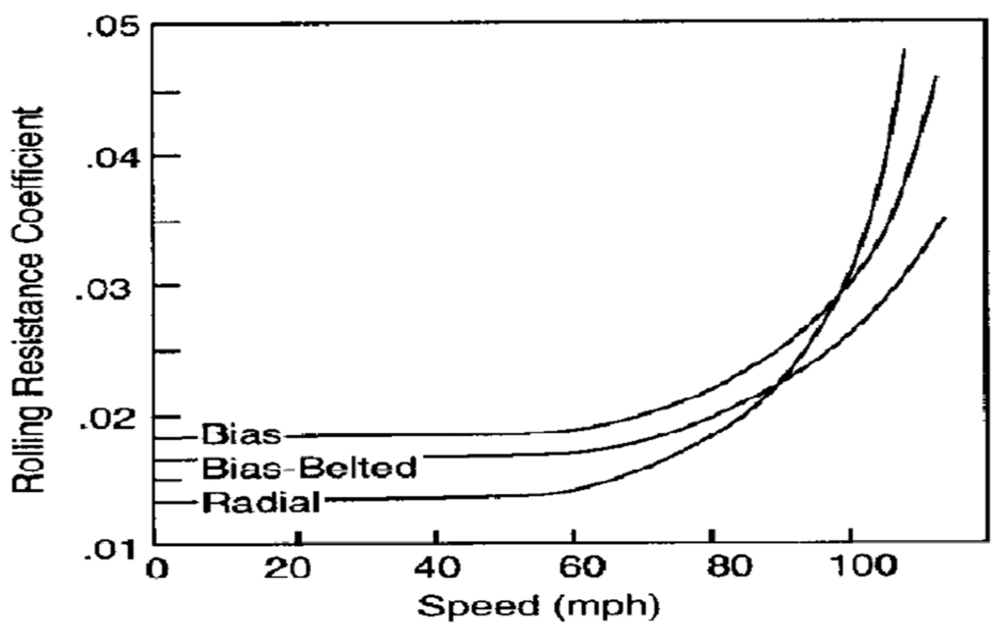


Figure 4.2: Speed vs. rolling resistance coefficient.

Component	Mass(kg)
Batteries	30
Electric motor + Gears	15
Charge controller	0.5
Chassis	20
Body	35
Solar Panels	24
Tire, axle and suspension system	20
Carry load	50
Driver	70
Total Mass	264.5 kg

Table 4.1: Masses OF Vehicle Components.

From equation (4.2), the rolling resistance must be calculated after determining total mass of the vehicle:

$$\mathbf{F_r = m * g * f_r = 264.5 * 9.81 * 0.013 = 33.7\ N}$$

Where:

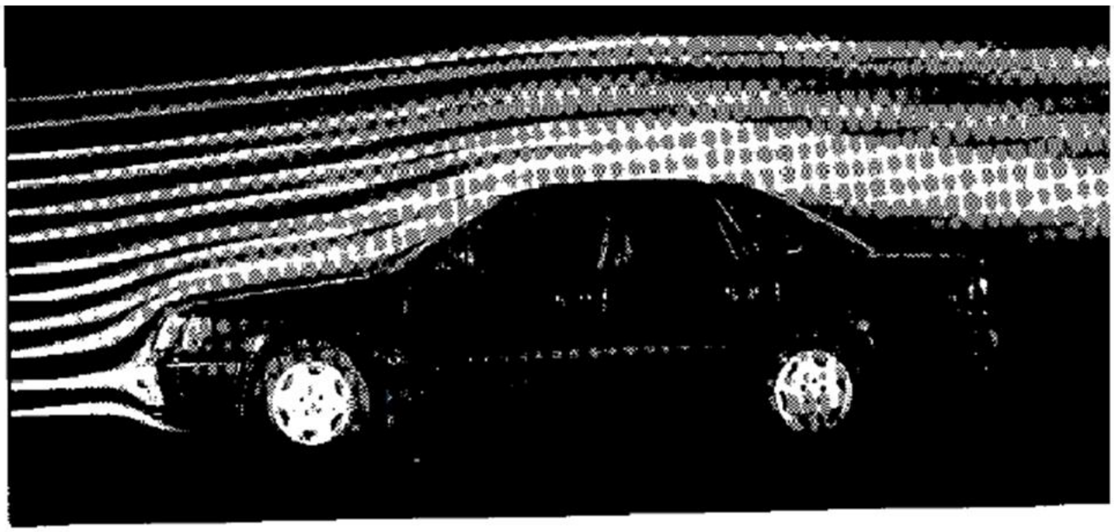
m: Total mass of the vehicle.

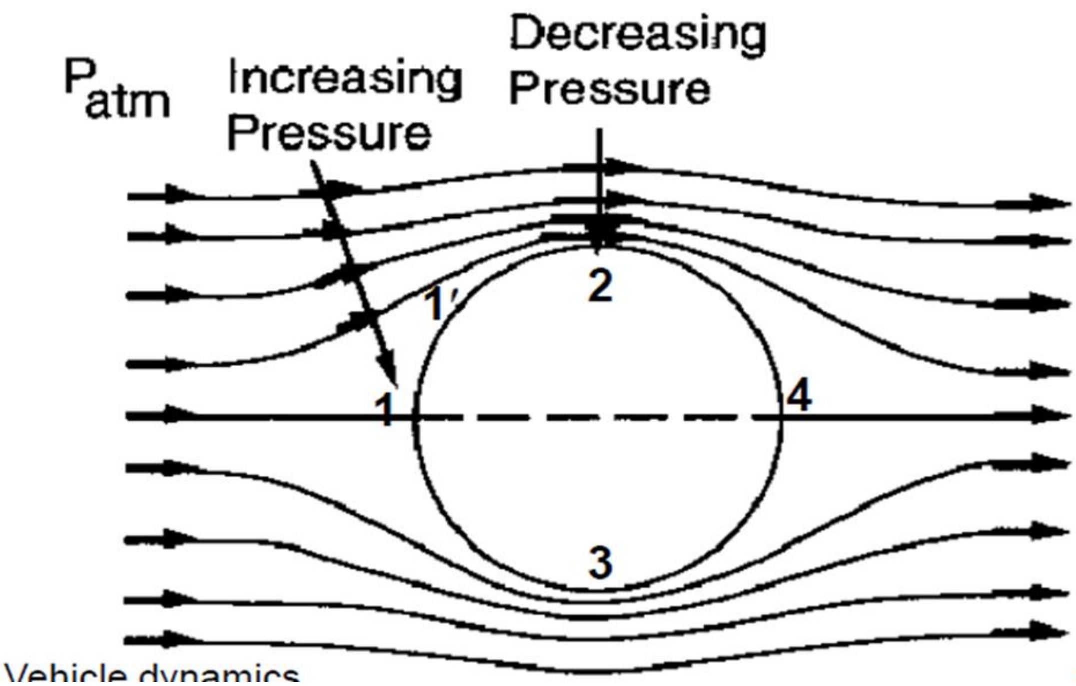
g: gravity acceleration.

4.3.2 Aerodynamic Drag

A vehicle traveling at a particular speed in air encounters a force resisting its motion. This force is referring to “Aerodynamic Drag”. It mainly results from two components: Shape Drag and skin friction.

Shape Drag: The forward motion of the vehicle pushes the air in front of it. However, the air cannot instantaneously move out of the way and its pressure is thus increased, resulting in high air pressure. In addition, the air behind the vehicle cannot instantaneously fill the space lift by the forward motion of the vehicle. This creates a zone of low air pressure. The motion has therefore created two zones of pressure oppose the motion of the vehicle by pushing it forward (high pressure in front) and pulling it backward (low pressure in the back) as shown in figure (4.3). The resulting force on the vehicle is the shape drag.





Decreasing
Pressure
P_{atm}
Increasing
Pressure
1'
2
1
4
3
Vehicle dynamics

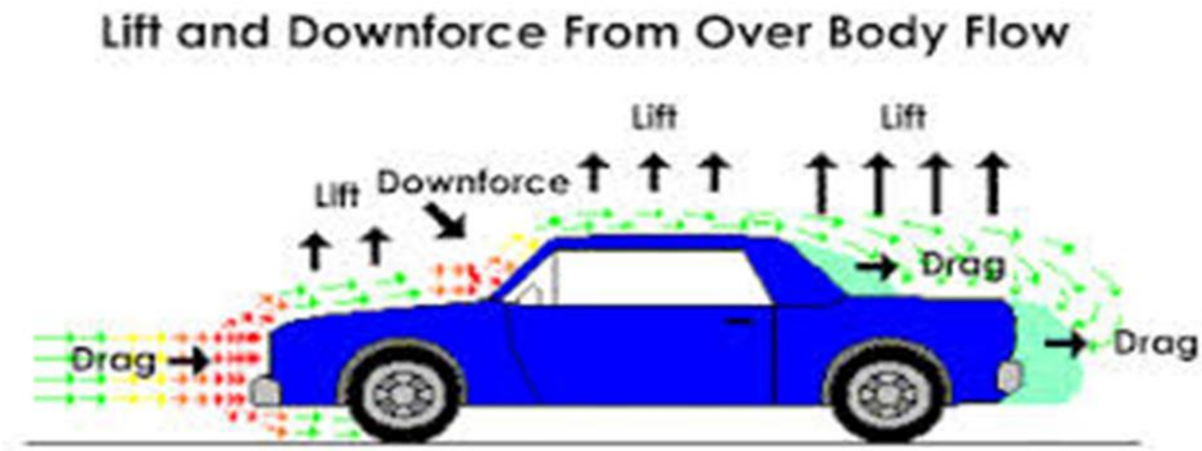


Figure 4.3: shapes of drag.

Skin Drag: Air close to the skin of the vehicle moves almost at the speed of the vehicle while air far from the vehicle remains still. In between, air molecules move at a wide range of speeds. The difference between two molecules produces a friction that results in the second components of aerodynamic drag.

Aerodynamic Drag is a function of vehicle speed (**V**), vehicle front area (A_f), shape of the vehicle and air density (ρ). Aerodynamic drag is expressed as:

$$\mathbf{D_A = \frac{1}{2}\,\rho\, V^2 C_D A} \tag{4.4}$$

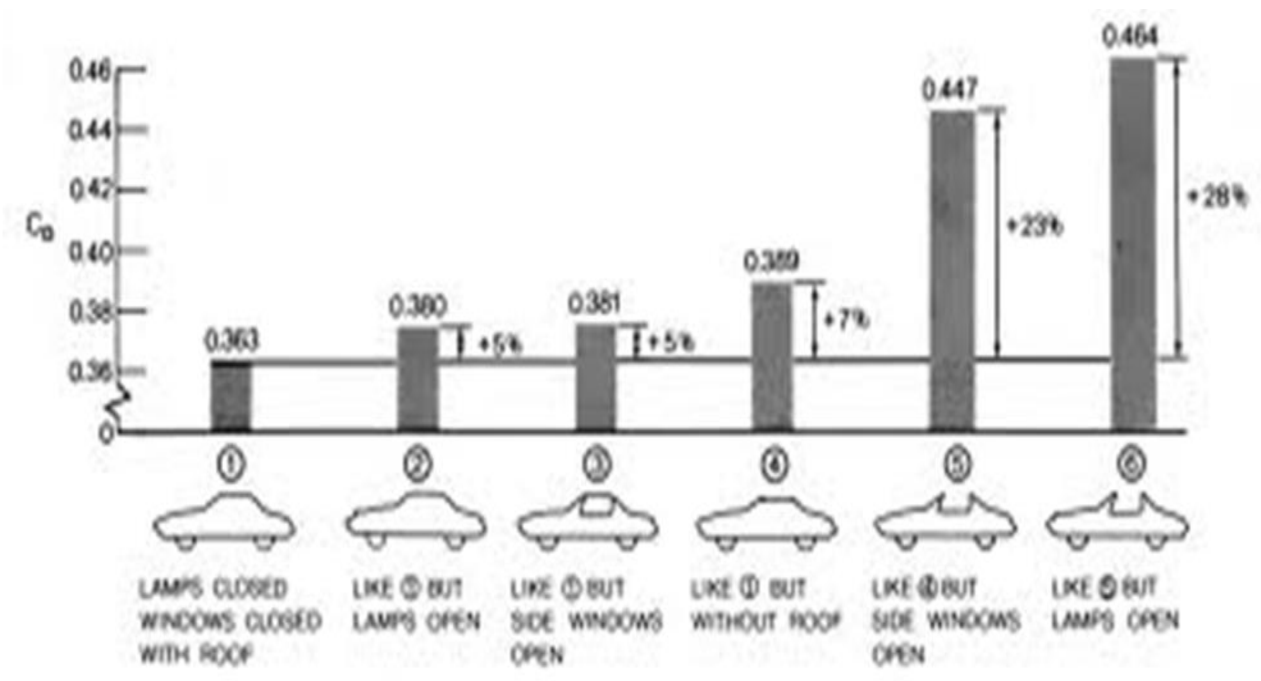
Where:

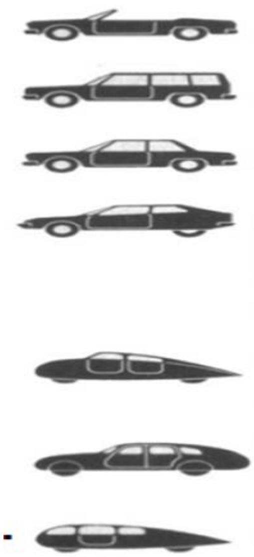
C_D : is the aerodynamic drag coefficient that characterized the shape of the vehicle as shown in the figure (4.3).

ρ : The air density.

V: Vehicle speed.

A: Frontal area.





	Drag coefficient c_d	Drag power in kW, average values for $A = 2\ m^2$ at various speeds[1]) 40 km/h	80 km/h	120 km/h	160 km
Open convertible	0.5...0.7	1	7.9	27	63
Station wagon (2-box)	0.5...0.6	0.91	7.2	24	58
Conventional form (3-box)	0.4...0.55	0.78	6.3	21	50
Wedge shape, headlamps and bumpers integrated into body, wheels covered, underbody covered, optimized flow of cooling air.	0.3...0.4	0.58	4.6	16	37
Headlamps and all wheels enclosed within body, underbody covered	0.2...0.25	0.37	3.0	10	24
Reversed wedge shape (minimal cross-section at tail)	0.23	0.38	3.0	10	24
Optimum streamlining	0.15...0.20	0.29	2.3	7.8	18
Trucks, truck-trailer combinations	0.8...1.5	–	–	–	–
Motorcycles	0.6...0.7	–	–	–	–
Buses	0.6...0.7	–	–	–	–
Streamlined buses	0.3...0.4	–	–	–	–

Figure 4.4: Indicative drag coefficients for different body shapes.

So the aerodynamic drag parameters takes the following values and the values of (D_A) for different vehicle speed are shown in table (4.2):

$C_D = 0.65$

$\rho = 1.25\ kg/m^3$

V= 0-40 km/h

A= $1m^2$

V (km/h)	V (m/s)	C_D	A (m^2)	ρ (kg/m^3)	D_A: Drag Force (N)
0	0	0.65	1	1.25	0
5	1.389	0.65	1	1.25	1.54
10	2.778	0.65	1	1.25	3.14
15	4.167	0.65	1	1.25	7.1
20	5.556	0.65	1	1.25	12.54
25	6.945	0.65	1	1.25	19.6
30	8.333	0.65	1	1.25	28.21
35	9.722	0.65	1	1.25	38.4
40	11.111	0.65	1	1.25	50.15

Table (4.2): Drag Force.

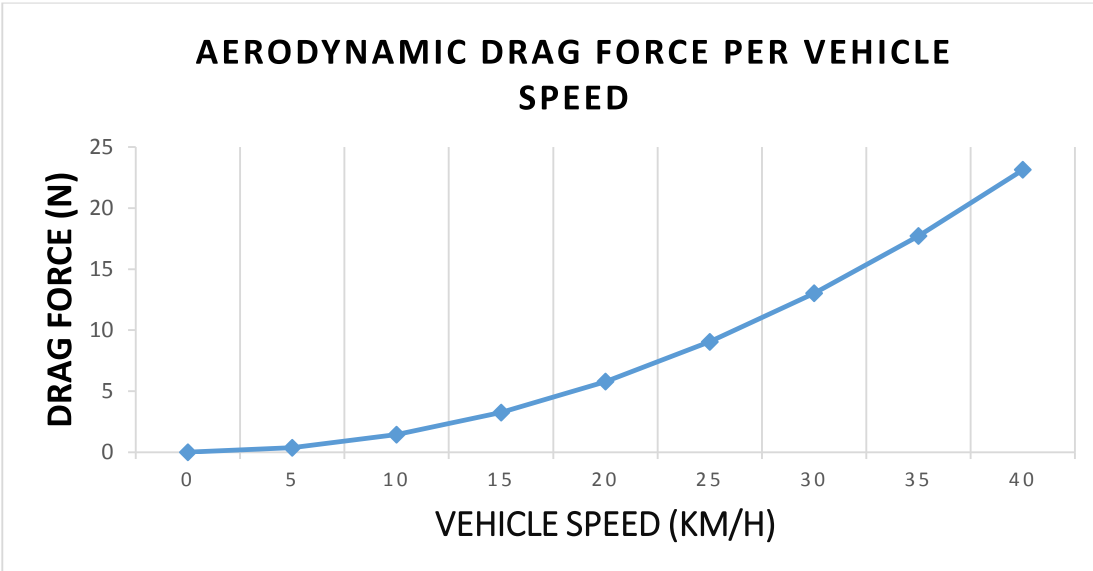


Figure 4.5: Hill Climbing Force.

From figure (4.6), indicate that aerodynamic drag has an efficient effects at high speeds which means in this vehicle with low speed range, the aerodynamic drag become negligible or very low effects.

4.3.3 Grading Resistance

When a vehicle goes up or down a slope, its weight produces a component which is always directed to the downward direction. This component either opposes the forward motion (Grade Climbing) or helps the forward motion (Grade descending). In vehicle performance analysis, only uphill operation is considered. The grading force is usually called grading resistance. The grading resistance can be expressed as:

$$F_g = M_v g \sin\theta \tag{4.5}$$

Where:

M_v : Mass of the vehicle.

θ : Road angle.

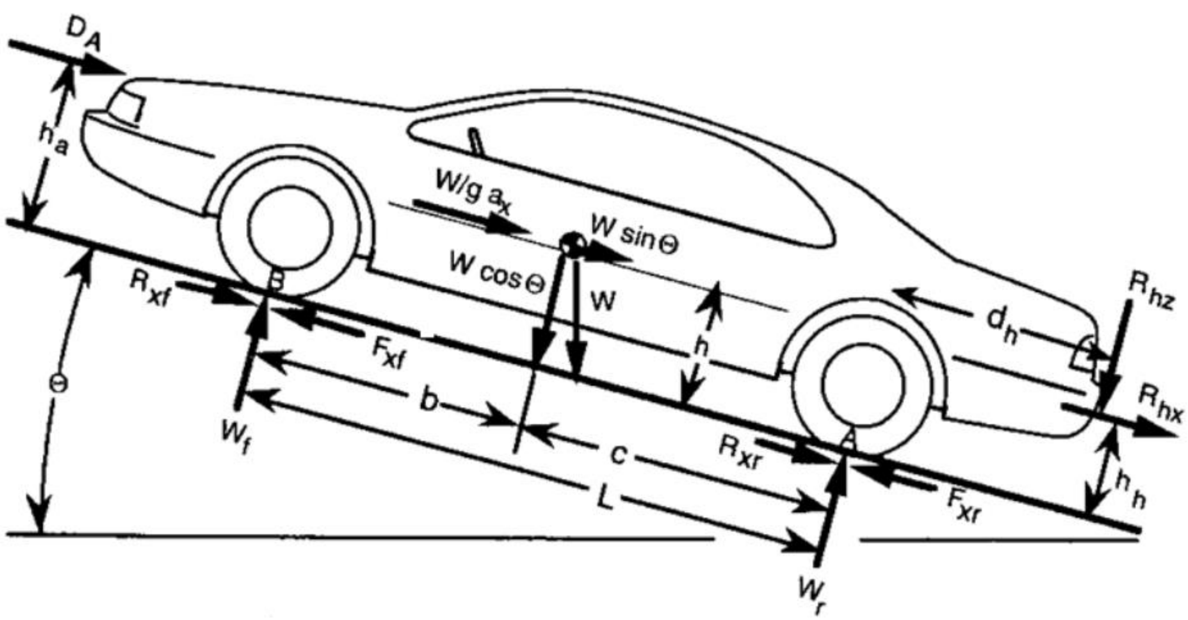


Figure 4.6: Automobile climbing a grade.

So the grading resistance parameters takes the following values and the values of (F_g) for different road angle are shown in table (4.3):

$M_v = 264.5 \text{ kg}$

M_v (kg)	g (m/s^2)	θ(deg)	F_g(N)
264.5	9.81	3	135.8
264.5	9.81	6	271.2
264.5	9.81	9	405.9
264.5	9.81	12	539.5

Table (4.3): Grading resistance at vary road angle.

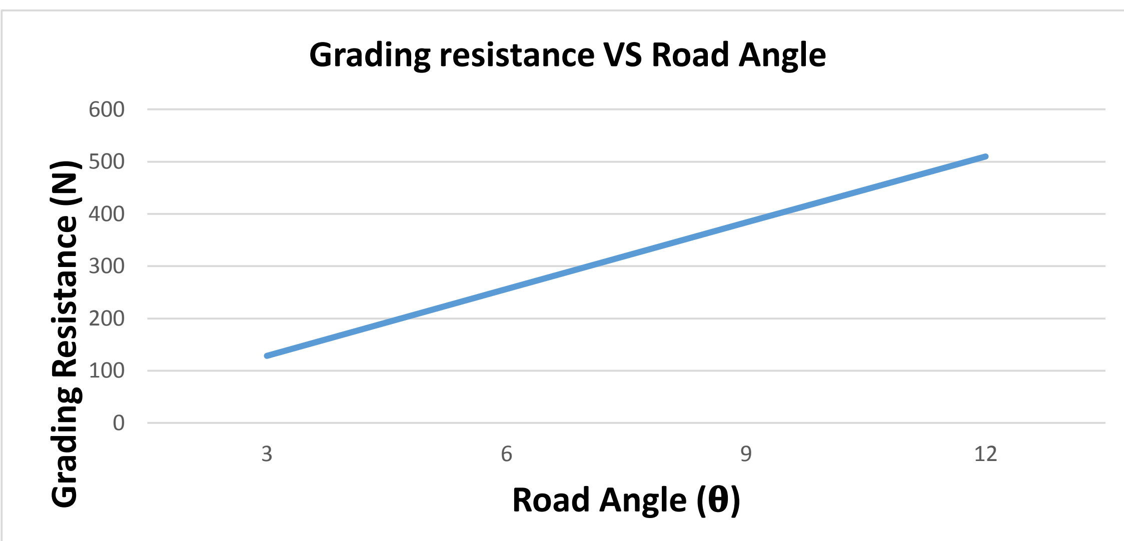


Figure 4.7: Vehicle grading resistance vs. road angle.

4.4 Vehicle Performance

4.4.1 Vehicle Performance:

Basic vehicle performance includes maximum cruising speed, grade ability, and acceleration. The maximum speed of a vehicle can be easily found by the intersection point of the resistance curve (aerodynamic drag plus rolling resistance).

4.4.2 Acceleration Performance:

The acceleration performance of a vehicle is usually describe by its' acceleration time and distance covered from zero speed to certain high speed on level ground. Using Newton Second law, the acceleration of the vehicle can be written as:

$$\mathbf{a} = \frac{dV}{dt} = \frac{F_t - F_f - F_w}{M_v \delta} = \frac{\left(\frac{T_p i_o i_g \eta_t}{r_d}\right) - M_v f_r g - (1/2)\rho_a C_D A_f V^2}{M_v \delta} \quad \mathbf{(4.7)}$$

Where:

δ: the mass factor, considering the equivalent mass increase due to the angular moments of the rotating components. The mass factor can be written as:

$$\textbf{Mass factor} = 1+0.04+0.0025\eta_{tf} \quad \text{or} \quad \frac{M_v+M_r}{M_v}$$

Where:

M_r: The effective mass of rotating components.

From previous equation the acceleration time, (t_a) from low speed (V_1) to high speed (V_2) can be written as:

$$t_a = \int_{V_1}^{V_2} \frac{M_v \delta V}{\left(\frac{T_p i_o i_g \eta_t}{r_d}\right) - M_v f_r g - (1/2)\rho_a C_D A_f V^2} dV \qquad (4.8)$$

Acceleration performance of a vehicle is evaluated by the time used to accelerate the vehicle from a low speed (**V_1: usually zero**) to high speed (**V_2**). For passenger car, acceleration performance is more important than maximum cruising speed and grade ability, since it is the acceleration requirement, rather than the maximum cruising speed or the grade ability, which dictates the power rating of the motor driving the acceleration time for an EV and SV can be expressed as:

$$\mathbf{t_a} = \int_0^{V_2} \frac{M_v \delta V}{\left(\frac{P_t}{V_b}\right) - M_v f_r g - \left(1/2\right)\rho_a C_D A_f V^2} \mathbf{dV} + \int_{V_b}^{V_f} \frac{M_v \delta V}{\left(\frac{P_t}{V}\right) - M_v f_r g - \left(1/2\right)\rho_a C_D A_f V^2} \mathbf{dV} \tag{4.9}$$

Where:

(V_b) and (V_f) are the vehicle base speed, and the final acceleration speed, respectively, and (P_t) is the tractive power on the driven wheels transmitted from the traction motor corresponding to the vehicle base speed. The first term on the right-hand side of previous equation is in corresponding with the speed region lower than the vehicle base speed, the second term is in corresponding with the speed region beyond the vehicle base speed.

For initial evaluation of the acceleration time VS the tractive power, one can ignore the rolling resistance and the aerodynamic drag and obtain:

$$\mathbf{P_t} = \frac{\delta M_v}{2t_a}\left(V_f^2 + V_b^2\right) \tag{4.10}$$

To determine the tractive power rating accurately, the power consumed in overcoming the rolling resistance and dynamic drag should be considered, the average drag power during acceleration can be expressed as:

$$\overline{\mathbf{P_{drag}}} = \frac{\mathbf{1}}{\mathbf{t_a}}\int_{\mathbf{0}}^{\mathbf{t_a}}(\mathbf{M_v g V f_r} - \frac{\mathbf{1}}{\mathbf{2}}\boldsymbol{\rho}_{\mathbf{a}}\mathbf{C_D A_f V^3})\mathbf{dt} \qquad \mathbf{(4.11)}$$

The total tractive power for accelerating the vehicle from zero to speed **(V_f)** in **(t_a)** seconds can be finally obtained as:

$$\mathbf{P_t} = \frac{\boldsymbol{\delta}\mathbf{M_v}}{\mathbf{2t_a}}\left(\mathbf{V_f^2} + \mathbf{V_b^2}\right) + \frac{\mathbf{2}}{\mathbf{3}}\mathbf{M_v g V_f f_r} + \frac{\mathbf{1}}{\mathbf{5}}\boldsymbol{\rho}_{\mathbf{a}}\mathbf{C_D A_f V_f^3} \qquad \mathbf{(4.12)}$$

Symbol	Shortcut to	Value
M_v	Vehicle mass	264.5 kg
δ	Mass factor	1.2
t_a	Acceleration time	40 seconds
V_b	Initial speed	0 m/s = 0 km/h
V_f	Final speed	11.111 m/s = 40 km/h
f_r	Coefficient of rolling resistance	0.013
ρ	Air density	1.25 kg/m^3
C_D	Drag coefficient	0.65
A_f	Frontal area of the car	1 m^2

Table (4.4): Parameters for vehicle.

$$P_t = \left(\frac{1.2*264.5}{2*40} * (11.111)^2 - (0)^2\right) + \left(\frac{2}{3} * 264.5 * 9.81 * 0.013 * 11.11\right) + \left(\frac{1}{5} * 1.25 * 0.65 * 1 * (11.11)^3\right)$$

$$= 490 + 250 + 222.9 = 843\ W = 0.963\ kW$$

Power require to accelerate the mass = 0.490 kW

Power require to overcome the rolling resistance = 0.250 kW

Power require to overcome the drag resistance = 0.223 kW

Total needed power = 0.963 kW

Rated power from electric motor = 0.907 kW

From previous calculations, it is obvious that the motor was selected for the vehicle is appropriate to overcome road loads and accelerate the vehicle, but with a small difference.

References

[1] M. W. Daniels and P. R. Kumar, “The optimal use of the solar power Automobile,” Control Systems Magazine, IEEE, vol. 19, no. 3, 2005:

They described the relation between solar panels (Photovoltaic Panels) and automobiles, how to merge these concepts together to get an clear output that is free and less dangerous to the environment.

[2] “SOLAR VEHICLES AND BENEFITS OF THE

TECHNOLOGY”, by John Connors, ICCEP paper 2007:

He found his future technology in this field by explaining the reasons of taking into account the solar energy “Free Energy” instead of fuel energy and the benefits of this technology in his scientific research paper.

[3] www.electricvehicle.com for the electrical design of the car and to know the technologies used in previous cars.

This website is concerning in the field of electrical vehicles with their clear energy. Also it mentioned his specific idea that inspired us as below:

“Electric Vehicle Inc. was formed to provide users access to Electric Vehicles, and other transportation alternatives to the conventional wasteful, polluting gasoline engine; to research and promote changes to the City Of New York transportation infrastructure facilitating the adoption of Electric Vehicles and Zero Emission Vehicles.”

[4] Mehrdad Ehsani, Texas A&M University, Yimin Gao, Texas A&M Uneversity, Ali Emadi, Illinois Institute of Technology. "Modern Electric, Hybrid Electric, and Fuel Cell Vehicles, Fundamentals, Theory and Design", 2005.

[5] Ron Hodkinson and John Fenton, Light weight Electric/Hybrid Vehicle Design.

[6] K.NEWTONMC, BSc, ACGI, AMInstCE, MIMechE Late Assistant Professor, Mechanical and Electrical Engineering Department. The Royal Military College of science The motor vehicle, Thirteenth Edition 2001.

[7] Battery Technology Life Verification Test Manual, Harold Haskins (USABC), Vince Battaglia (LBNL), john Christophersen (INEEL), February 2005.

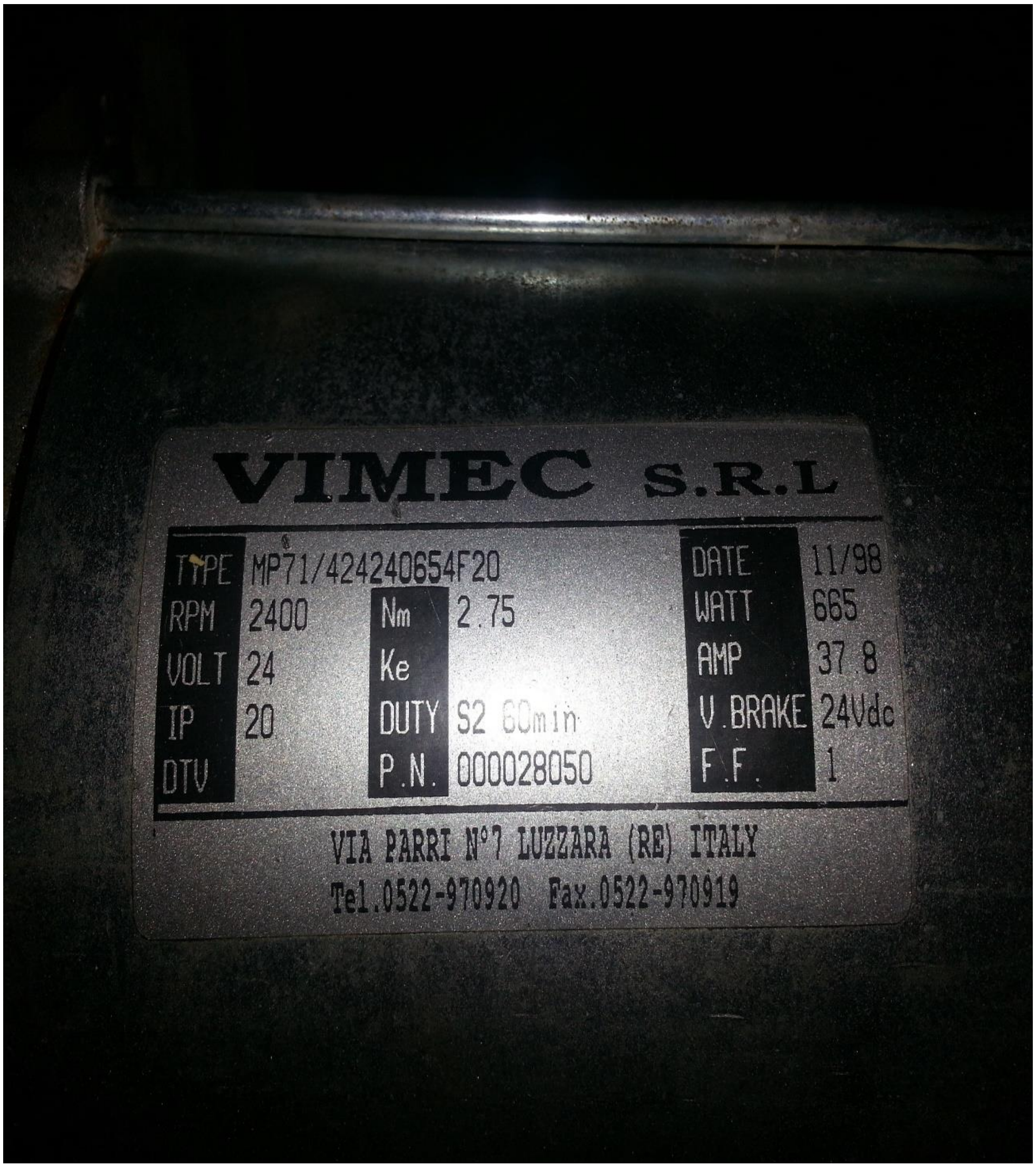
[8] Gopal K. Dubey, Fundamentals of Electrical drives, Narosa Publishing House, 1995.

[9] http://www.windsun.com/ChargeControls/ChargeCont.htm

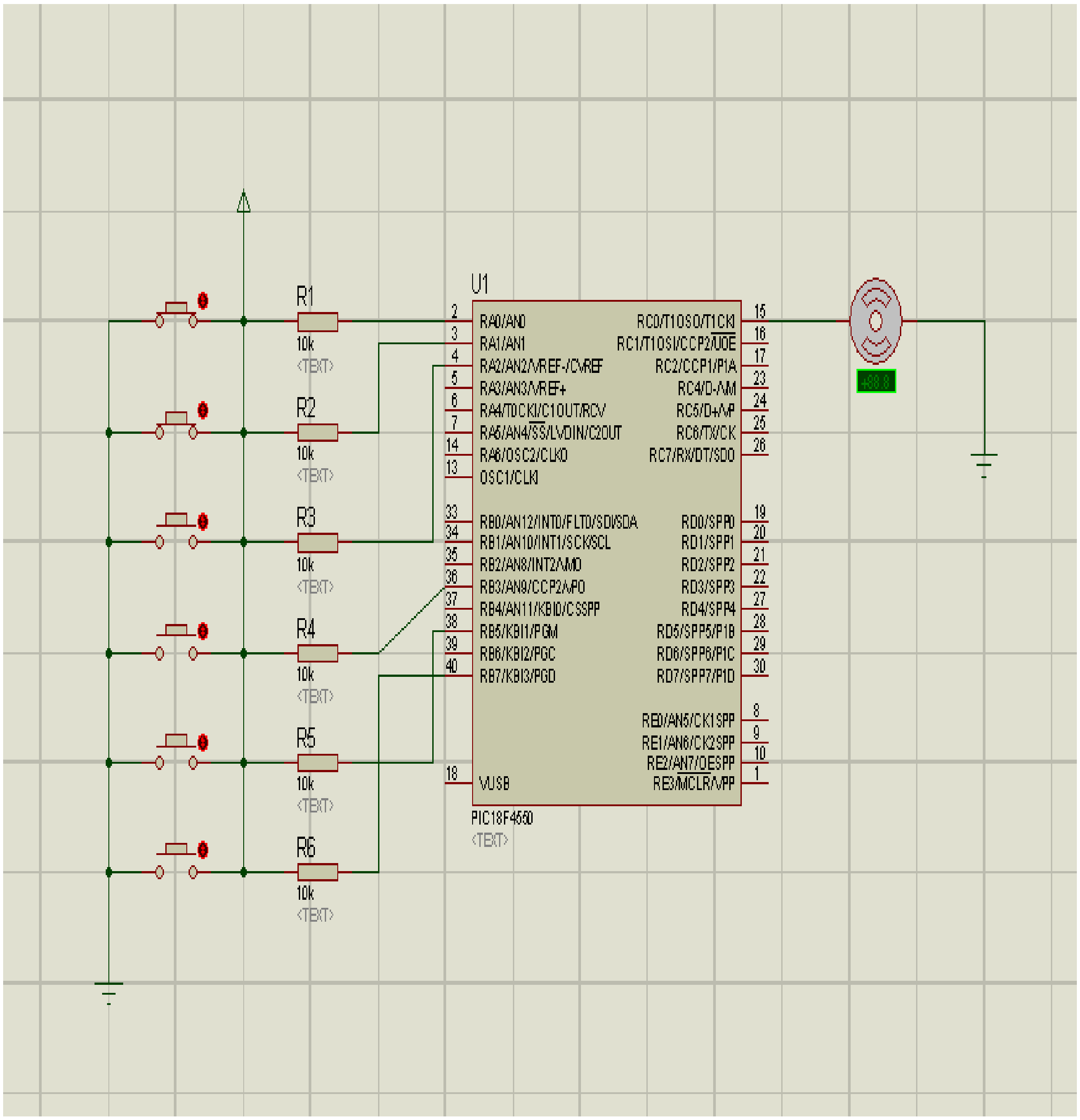
[10] http://www.makeitsolar.com/solar-energy-information/08-solar-future.htm

Appendix

Appendix A: Motor Data sheet.

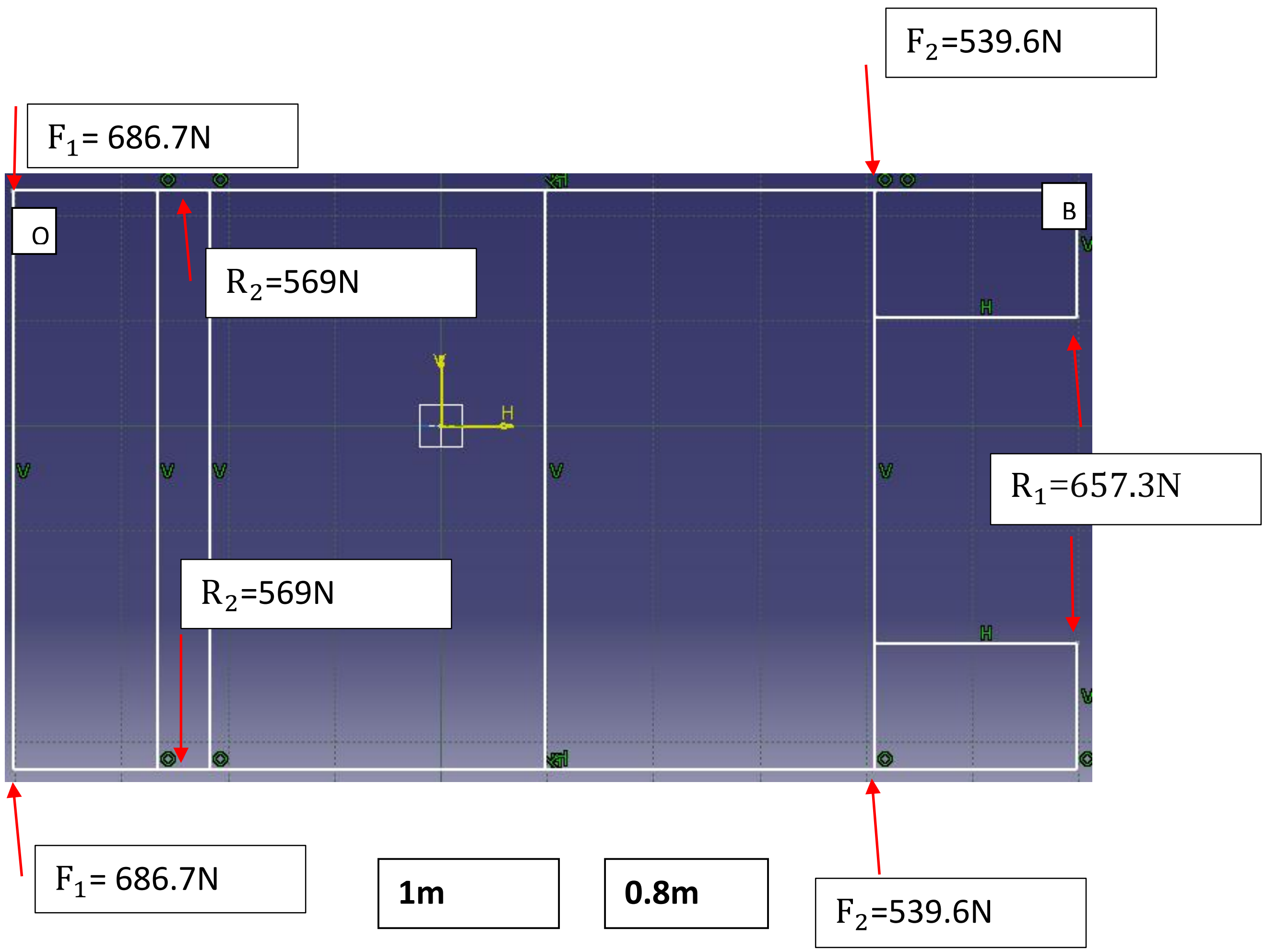


Appendix E: Microcontroller diagram



Appendix F:

Chassis design (Analysis & Calculations):



From the previous figure of vehicle chassis, take beam (OB) and by sheer section, will give the following parameters:

$$\mathbf{M_{max} = 583\ N.m}$$

$$\mathbf{V_{max} = 657.3N}$$

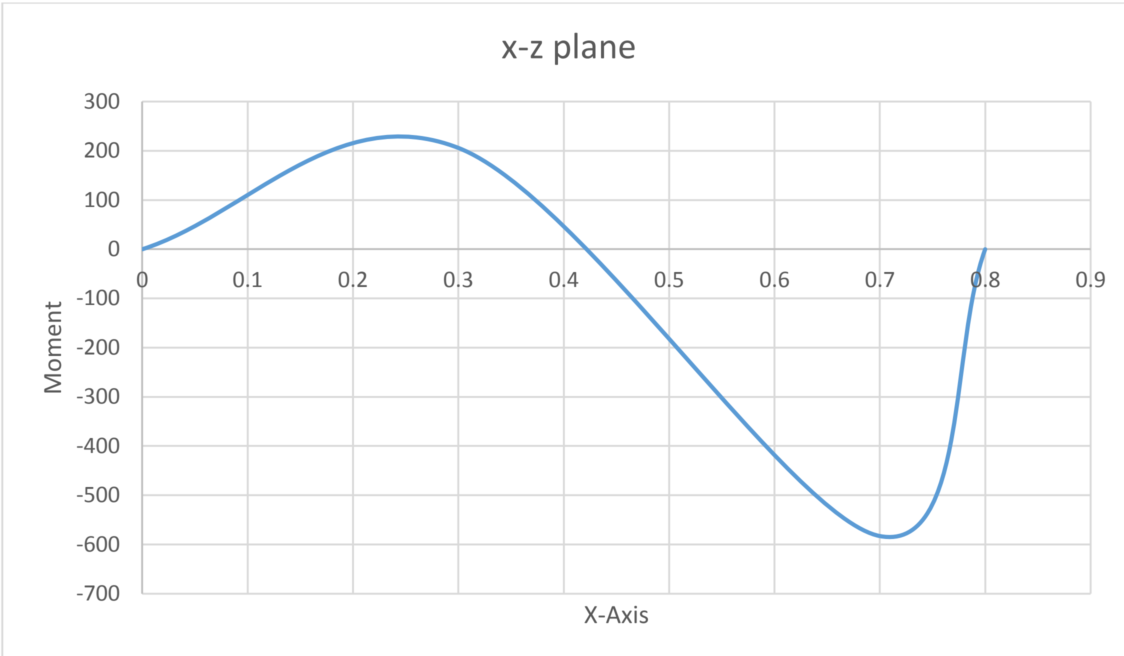
So $\boldsymbol{\sigma}_{\mathbf{x,max}} = \frac{\mathbf{Mc}}{\mathbf{I}} = \frac{\mathbf{583*0.02}}{\mathbf{0.6667}} = \mathbf{175.5MPa}$

$$\boldsymbol{\tau}_{\mathbf{zx,max}} = \frac{\mathbf{3V}}{\mathbf{2A}} = \frac{\mathbf{3*657.3}}{\mathbf{2*0.02*0.04}} = \mathbf{1.2MPa}$$

But ($\boldsymbol{\sigma_{x,max} = \sigma_1 < S_y}$)**,** so the vehicle is in safety mode if the vehicle weight will be same as **(250 kg).**

The torsion stress at the rear axle:

$$\boldsymbol{\tau}_{\mathbf{torsion}} = \frac{\mathbf{T_{load}*c}}{\mathbf{J}} = \frac{\mathbf{11.3*16}}{\boldsymbol{\pi}\mathbf{*(0.035)^3}} = \mathbf{80\ kPa}$$



Chassis design (Analysis & Calculations):

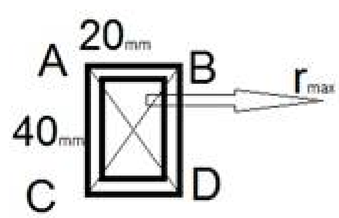
Welding analysis:

Assume E70xx

b=0.02m d= 0.04m

h=??

$$\tau_{all} = 0.3S_{ut} = 0.3 * 482 = 144.6 \text{ MPa}$$



A= 1.414 *h*(b+d) =1.414*h*(20+40) =0.0848h m^2

$$\mathbf{J_u = \frac{(20+40)^3}{6} = 36\ m^3}$$

J=0.707h*J_u= 0.707*h*36000= 25.452h $\mathbf{m^4}$

Primary sheer:

$$\boldsymbol{\tau}' = {}^{\mathbf{F_1}}\!/_{\mathbf{A}} = \frac{\mathbf{0.686}}{\mathbf{0.0848h}} = \mathbf{8.089/h}$$

Secondary sheer:

$$\boldsymbol{\tau}'' = {}^{\mathbf{Mr_{max}}}\!/_{\mathbf{J}}\ @\ \mathbf{r_{max}} = \sqrt{(\mathbf{0.01})^2 + (\mathbf{0.02})^2} = \mathbf{0.022m}$$

And M= 1800F_1

So $\boldsymbol{\tau}'' = {}^{\mathbf{Mr_{max}}}\!/_{\mathbf{J}} = \frac{\mathbf{1800*0.686*0.022}}{\mathbf{25.452h}} = \mathbf{1.06/h}$

$$\tau_B = \frac{1}{h}\sqrt{(8.089)^2 + (1.06)^2 + 2 * 8.089 * 1.06 * \cos 45} = 8.86/h$$

$$\tau_{all} = \tau_B = 144.6\ \text{MPa} = \frac{8.86}{h}$$

So h= 0.0061 m=6.1mm

LandStar series
Solar Controller

LandStar series solar charge controller that adopts the most advanced digital technique and operates fully automatically. The Pulse Width Modulation (PWM) battery charging can greatly increase the lifetime of battery.

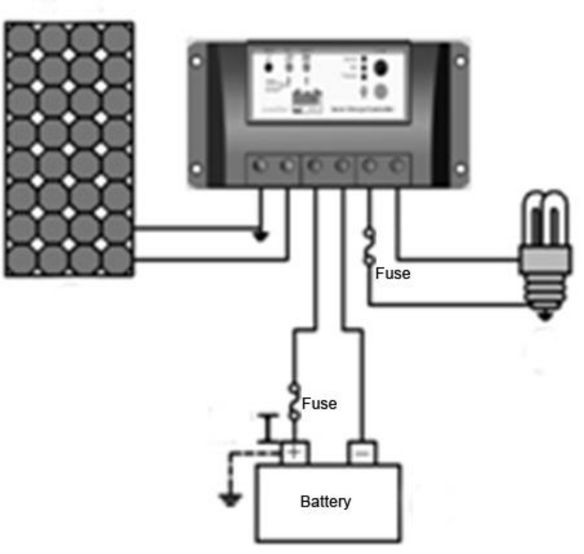
Application:

Ideal for off-grid solar system that loads are normally on or controlled by manual.

★ Solar traffic system
★ Solar home system
★ Unattended CCTV Equipment
★ Wild automatic detection equipment

Features:

◆12/24V auto work
◆High efficient Series PWM charging
◆Use MOSFET as electronic switch
◆ Gel, Sealed and Flooded battery type option
◆ Temperature compensation
◆Electronic protection: over charging, over discharging, overload, short circuit , and overheating
◆ Reverse protection: any combination of solar module and battery



LandStar Series Solar Controller

Electrical parameters	LS1024	LS1524	LS2024
Nominal System Voltage	12 / 24VDC auto work		
Rated Battery Current	10A	15A	20A
Max. Battery Voltage	32V		
Charge Circuit Voltage Drop	≤0.26V		
Discharge Circuit Voltage Drop	≤0.15V		
Self-consumption	≤6mA		

Battery Voltage Parameters (temperature at 25℃)			
Battery charging setting	Gel	Sealed	Flooded
Equalize Charging Voltage	——	14.6V;x2/24V	14.8V;x2/24V
Boost Charging Voltage	14.2V;x2/24V	14.4V;x2/24V	14.6V;x2/24V
Float Charging Voltage	13.8V;x2/24V	13.8V;x2/24V	13.8V;x2/24V
Low Voltage Reconnect Voltage	12.6V;x2/24V	12.6V;x2/24V	12.6V;x2/24V
Low Voltage Disconnect Voltage	11.1V;x2/24V	11.1V;x2/24V	11.1V;x2/24V
Equalize Duration	——	2 hours	2 hours
Boost Duration	2 hours	2 hours	2 hours

Environmental parameters		Mechanical Parameters	LS1024	LS1524/LS2024
Working temperature	-35℃ to +55℃	Overall dimension	140x65x34mm	144x75x45mm
Storage temperature	-35℃ to +80℃	Mounting dimension	130x45mm	135x55mm
Humidity	10%-90% NC	Terminal	$4mm^2$	$10mm^2$
Enclosure	IP30	Net weight	0.15kg	0.25kg

BEIJING EPSOLAR TECHNOLOGY CO., LTD.
Tel:010-82894112/962
www.epsolarpv.com
Fax:010-82894882

PowerSafe® SBS

RANGE SUMMARY

The EnerSys® range of PowerSafe® SBS batteries continues to offer unrivalled choice and performance in compact and energy dense configurations. PowerSafe SBS batteries are manufactured to the highest international standards and are ideal for reliable use in all wireless and fixed-line communication applications. PowerSafe SBS batteries are also widely used in cable TV, emergency lighting, power generation and offshore applications.

The PowerSafe SBS battery range is available in several configurations including the front terminal series, which has become extremely popular in leading edge telecom applications. Smaller than the competition, the design of the front terminal series offers improved flexibility where space is limited and makes installation and maintenance easier and faster.

PowerSafe SBS batteries are designed to cope with raised temperatures and harsh environments. The advanced pure lead plate technology and unique manufacturing methods used by EnerSys, make PowerSafe SBS batteries the first choice for long and trouble-free service. The maximum operating temperature of the PowerSafe SBS J battery series can be extended to 80°C via an optional metal jacket.

Features & Benefits

- **Capacity range: 7Ah - 360Ah**
- **2V, 6V, and 12V configurations**
- **High energy density**
- **Long design life**
- **Up to two year shelf life**
- **Wide operating temperature range: -40°C to +50°C**

EnerSys®
Power/Full Solutions

RESERVE POWER

Construction

- Positive plates - pure lead grids manufactured using a unique process
- Negative plates - provide perfect balance with the positive plates to ensure optimum recombination efficiency
- Separators - superior quality microporous glass mat separator with high absorption and stability
- Containers and lids - UL94 V-0 rated flame retardant material, highly resistant to shock and vibration (J types are PPE+PS resin, all others are ABS)
- Electrolyte - high grade dilute sulphuric acid absorbed into separator material
- Terminal design - leak resistant patented dual seal terminal design
- Self-regulating pressure relief valves - prevent ingress of atmospheric oxygen
- Flame arrestors - built into each bloc for increased operational safety

Installation and Operation

- PowerSafe® SBS batteries are designed for use in cabinets or on stands, close to the point of use. A separate battery room is not required
- Cells and monoblocs can be mounted in any orientation except inverted
- Recommended float charge voltage: 2.29Vpc @ 20°C (68°F) or 2.27Vpc @ 25°C (77°F)
- Up to two year shelf life
- Low maintenance: no water addition required
- Several PowerSafe SBS battery types are also available for underwater applications

Standards

- Designed to be compliant with international standard IEC 60896/21 & 22
- Classified as "Long Life" according to Eurobat guide 1999
- Conforms to Telcordia® SR-4228
- Recognised by UL (UL Standard 1989)
- Approved as non-spillable cargo for ground, sea and air transportation in accordance with US DOT Regulation 49 and ICAO & IATA Packing Instruction 872
- The management systems governing the manufacture of PowerSafe SBS products are ISO 9001:2008 and ISO 14001:2004 certified

General Specifications

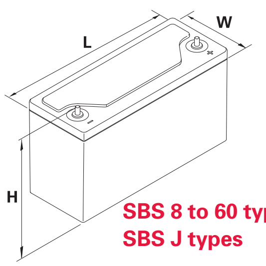
Battery Type	Number of Cells	Nominal Voltage (V)	Nominal Capacity (Ah) 10 hr rate to 1.80Vpc @ 20°C	Nominal Capacity (Ah) 8 hr rate to 1.75Vpc @ 77°F	Nominal Dimensions (mm) Length	Nominal Dimensions (mm) Width	Nominal Dimensions (mm) Height	Typical Weight (kg)	Short Circuit Current (A)[2]	Internal Resistance (mΩ)[2]	Terminals
SBS 8	6	12	7	7	138	86	99	2.7	455	27.1	2 x M4 F
SBS 15	6	12	14	14	200	77	140	5.7	891	13.5	2 x M6 M
SBS 30	6	12	26	26	250	97	156	9.5	1556	7.9	2 x M6 M
SBS HB30[1]	6	12	26	26	250	97	156	9.6	1556	7.9	harness
SBS 40	6	12	38	38	250	97	206	12.7	2184	5.6	2 x M6 M
SBS 60	6	12	51	51	220	121	261	18.5	2618	4.4	2 x M6 M
SBS 110	3	6	115	116	200	208	239	21.2	3804	1.7	2 x M8 M
SBS 130	3	6	132	133	200	208	239	22.7	4111	1.4	2 x M8 M
SBS 300	1	2	310	307	200	208	239	21.7	8700	0.23	2 x M8 M
SBS 390	1	2	360	361	200	208	239	23.2	11101	0.18	4 x M8 M
SBS J13[3]	6	12	12	12	175	83	129	5.2	957	13.0	2 x M6 F
SBS J16[3]	6	12	15	15	181	76	167	6.7	1111	11.0	2 x M6 F
SBS J30[3]	6	12	26	26	166	175	125	11.8	1766	7.0	2 x M6 F
SBS J40[3]	6	12	39	39	197	165	170	17.4	2400	5.2	2 x M6 F
SBS J70	6	12	64	64	329	166	174	27.6	3500	3.5	2 x M6 F
SBS B8	6	12	31	31	280	97	159	10.3	1270	10.0	2 x M8 F
SBS B8F	6	12	31	31	303	97	159	10.3	1270	10.0	2 x M6 M
SBS B10	6	12	38	38	280	97	184	12.8	1390	9.0	2 x M8 F
SBS B10F	6	12	38	38	303	97	184	12.8	1390	9.0	2 x M6 M

Notes:

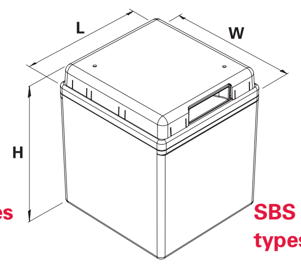
[1] SBS HB30 battery is fitted with a 533mm/21 inch harness that terminates in a 2-pin polarised plug-in connector, which is compatible with embedded power SLC systems.

[2] Figures obtained via IEC method.

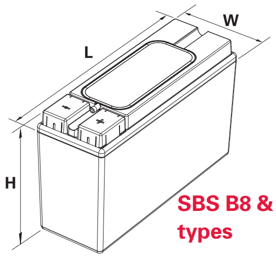
[3] Optional metal jackets are available for SBS J types. To order an SBS J type with a metal jacket add "X" to the part number (eg: "SBS J13X").



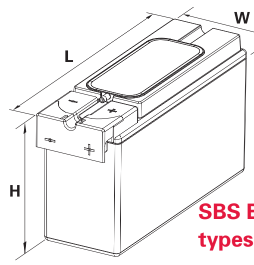
SBS 8 to 60 types
SBS J types



SBS 110-390 types



SBS B8 & B10 types



SBS B8F & B10F types

EnerSys
Power/Full Solutions

www.enersys-emea.com

EnerSys World Headquarters
2366 Bernville Road
Reading, PA 19605
USA
Tel: +1 610 208 1991
+1 800 538 3627
Fax: +1 610 372 8613

EnerSys EMEA
EH Europe GmbH
Löwenstrasse 32
8001 Zürich
Switzerland

EnerSys Asia
152 Beach Road
Gateway East Building
Level 11
189721 Singapore
Tel: +65 6508 1780

Contact:

Publication No. EN-SBS-RS-008 - May 2013 - Subject to revisions without prior notice. E.&O.E.

SOLARTECH POWER, INC.

SPS Solar Panel Store
Everything you need to go Solar!
www.solarpanelstore.com

J-Series
140W PV Module
SPM140P-BP

Solartech J-Series Modules

Solartech photovoltaic J-Series Modules are constructed with high efficient polycrystalline solar cells and produce higher output per module than others in it class. This industrial grade module is an industry standard among various industry professionals.

Features

- Accessible junction box with 4-1/2 knockout for ease of installation.
- (EVA) with TPT cushions the solar cells within the laminate an ensures the operating characteristics of the solar cells under virtually any climatic condition
- Rigid anodized aluminum frame and low iron tempered glass
- Easily accessible grounding points on all four corners for fast installation
- Proven junction box technology

Reliability

- Proven superior field performance
- Tight power tolerance

Qualifications and Certifications

TÜV IEC ETL LISTED UL LISTED

UL No.: E330673 TUV No.:0000022551 IEC No.:C1-ASN07001 ETL No.:4001057

Applications

- Traffic & Safety
- Federal Government
- Oil & Gas
- Security
- Telecommunications
- Water and Wastewater
- Weather & Environmental Monitoring
- RV Camper
- Emergency Power
- Telemetry
- SCADA, RTU, GPS
- Marine
- Area Lighting & Sign

Model Number
SPM140P-BP

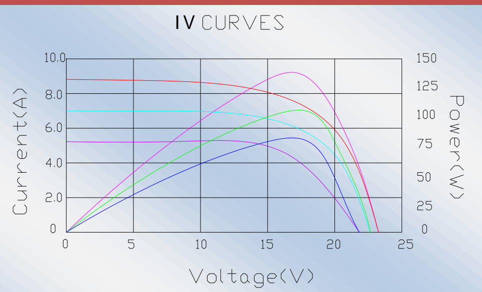
Electrical Characteristics

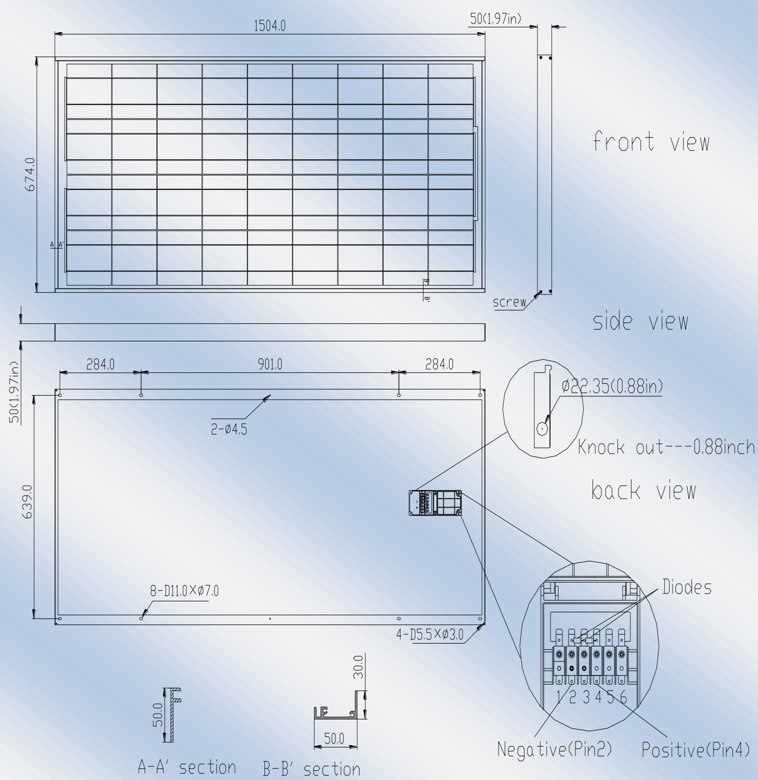
Max power(Pm)	140W
Maximum power voltage(Vpm)	17.5V
Maximum power current (Ipm)	8.0A
Short circuit current (Isc)	8.6A
Open circuit voltage (Voc)	22.0V
Module efficiency	13.7%
Tolerance	±5%
Nominal Voltage	12V
Temperature coefficient of Voc	-0.36%/K
Temperature coefficient of Pm	-0.46%/K
Temperature coefficient of Isc	0.05%/K
NOCT	48℃±2℃
Maximum series fuse rating	12A
Maximum system voltage	1000V

Mechanical Characteristics

Construction	Tempered glass, silicon cell, EVA, Polyester with Tedlar
Solar Cells	36 cells (156mm x 156mm) in a 4x9 matrix connected in series
Front Cover	High transmission 3.2mm(1/8'') glass
Encapsulant	EVA(Double layers)
Back Cover	White polyester
Frame	Anodized aluminum
Junction Box	IP65, UL94-5VA material
Diodes	Schottky by-pass diodes
Terminal	Accept 8-14 AWG wire
Dimensions	59.2in(1504mm)x26.5in(674mm)x1.97in(50mm)
Weight	26.51lb (12.0kg)
Operating Temperature	-40℃～90℃
Storage Humidity	<90%

IV Curves





Warranty

25-year limited warranty of 80% power output;
12-year limited warranty of 90% power output;
5-year limited warranty of materials and worksmanship

Certifications

IEC61215, TUV certification

UL 1703 certification

ETL Class I ,Division 2,Groups C and D certification