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Team # 9 - Senior Design Project Report

Fully Electric Car with Solar Cells as a Secondary Source of Power

In partial fulfillment of the requirements for the Degree of Bachelor of Science in Mechanical Engineering

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Abstract

Fossil fuels have taken off since the Industrial Revolution in the 18th century, and until today are still considered as an essential and ideal source of energy globally. Global consumption of fossil fuel has increased drastically in the past century and is nowhere close to slowing down; this is mainly due the rise of human population and growing industries for economic growth globally. Earth doesn't have unlimited reserves of fossil fuels, which will run dry soon if the dependency on them isn't reduced. Reducing the dependency on fossil fuels has presented itself as a huge challenge for humans.

In this project, a cheap & cleaner source of transportation, where the dependency on fossil fuels is minimized has been designed. An ICE vehicle (buggy) has been dismantled, modified and manufactured to a fully electric vehicle. The modification started by connecting a powerful brushless DC motor which is placed at the back and connected to the driveshaft using chain and sprocket system. This motor is powered by rechargeable batteries (4 lead-acid batteries, 12V each). These Lead-acid batteries are charged using an external power source by connecting it to the electricity grid (110V/220V). Furthermore efficient Solar Panels have been utilized as secondary source of power to charge the batteries; this reduces the dependency of the vehicle on external power sources. This Vehicle is capable of accommodating at least one passenger.

Acknowledgments

We would like to thank and appreciate Dr. Faramarz Djavanroodi for his time and his consistent effective input that vastly helped our project to rise among others. We would also like to genuinely thank Dr. Nader Sawalhi for the organized work and the motivation that he kept on providing all the mechanical engineering students in order to develop their professional and technical skills. Last but not least, we would like to thank our entire fellow group members for their contribution and dedication put in to this project.

List of Acronyms (Symbols)

Name	Unit	Symbol
Length	Meter (m)	L
Mass	Kilogram (Kg)	M
Time	Second (s)	t
Electric current	Ampere (A)	I
Stress	Pascal (Pa)	σ (Sigma)
Energy	Joule (J)	E
Force	Newton (N)	F
Power	Watt (W)	P
Voltage	Volt (V)	V
Electric Resistance	Ohm -- Ω	R
Area	meter squared (m^2)	A
Speed (Velocity)	kilometer per hour (km/h)	S
Angular Velocity	Radians per Second (rad/s)	ω(Omega)

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Chapter 1: Introduction

1.1 Project Definition

This project is aiming to design and build an automobile that runs primarily on electric batteries while runs partially on solar panels which will be the secondary source of power. This will require a clear understanding of electrical and solar components, design of an automobile, automobile mechanism. In terms of electric batteries, the car will use lead acid batteries which can be charged using the secondary source of power, which are solar arrays that use photovoltaic cells to convert sunlight into electricity. We are designing and creating a cleaner source of transport than an ICE dependent vehicle.

1.2Project Objectives

- To design and manufacture a vehicle with minimized dependency on fossil fuels (only for charging batteries of the car) and produces zero emission.
- To use solar panels as a secondary source of power, which can charge the batteries while parked under the sun, which eliminates the dependency on fossil fuels completely.
- Ensure the car can accommodate at least one passenger, while driving at various speeds up to 60 km/h.
- Identify, implement and explain the principles of force, motion and aerodynamics.
- Explain and demonstrate a fully functional prototype.
- Raise the awareness of renewable energy among fellow students.

1.3 Project Specifications

Our project has basically two systems, electric system and solar system. The components needed for both systems are solar panels, electric charge controller (Arduino), batteries, motor, motor controller and inverter, when converting the current from AC to DC is needed. In terms of the mathematical parameters and specifications of components, we have used 4 batteries of 12V connected in series, a motor controller for the DC series motor which delivers maximum power of 3kW to move the car with weight (including driver) 250-350 kg. What we were after in this project is to build a high efficient and emission free – clean mean of transport that is practical and logical. Firstly a used buggy was dismantled and the chassis was modified according to our design, ICE related components were also taken out of the buggy. Reinforced members were added to increase the stability and safety of the car. Then, we painted the chassis mainly to prevent corrosion and to cover all the dents and scratches and to make it look new and presentable. The initial conditions of the chassis can be seen in **Figure 1.1(a),(b),(c)** show how the chassis appearance after alteration of the chassis and after finishing the paint job. Here the project is still in the initial stage and further improvements and modifications have been applied in further parts.

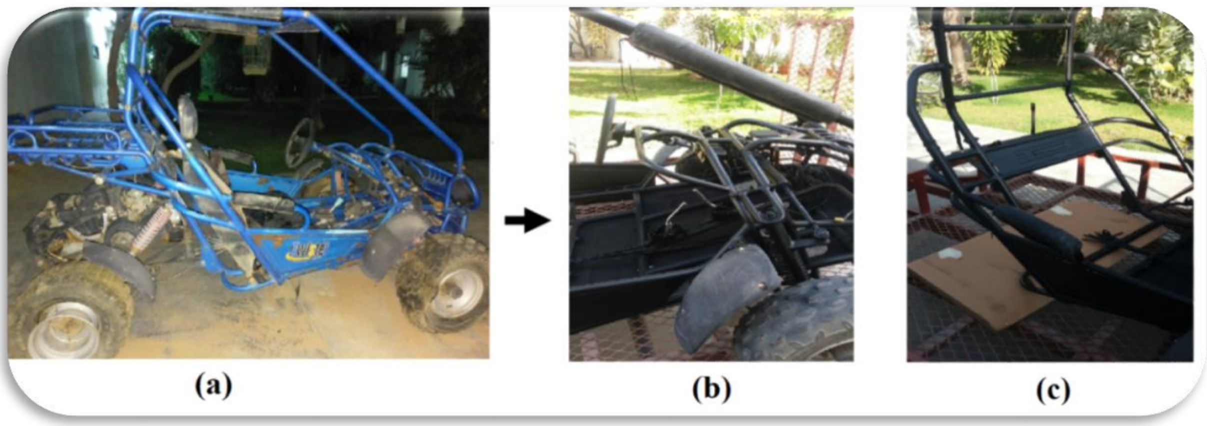


Figure 1.1: initial conditions of the chassis

1.4Applications

Some of the essential applications can be seen listed below:

1. Can be utilized for short distances drive.

2. Compactly designed with off road tires, which allows driving in narrow roads and on rough terrains.

3. Fully electric system to eliminate emission.

4. Solar power system independent of fossil fuels used to conserve energy.

Chapter 2: Literature Review

2.1 Project background

Fossil fuels have been an essential source of energy since the Industrial Revolution in the 18th century, and until today human kind depends on vastly as the main source of energy/power. Global consumption of fossil fuel has increased drastically in the past century and is nowhere close to slowing down; this is mainly due the rise of human population and growing industries for economic growth globally. According to British Petroleum's report [1] issued in 2013 based on the proven global oil reserves that Earth had approximately 1.69 Trillion Barrels of crude oil in reserves as of 2013. B.P has estimated these reserves will last around 53 years that is keeping in consideration that the annual global production won't increase further. Secondly according to USA Environmental Agency [2] the average temperature of Earth has risen by 1.8 Fahrenheit over the past century and is predicted to rise another 0.5 to 8.6 Fahrenheit.

We are close to running out of the natural resource known to us as fossil fuel, which means it high time that we have to start considering other options to turn to. Globally many institutes, research and development labs, and various universities are looking into renewable energy now as that seems to be the only logical and practical way. Furthermore Global Warming is turning out to be more real than expected by all, weather changes can be seen everywhere which is causing catastrophic effect not just to Earth but also to mankind. Solar vehicles and Electric vehicles are considered to be the future of automobiles. We as students want to play our role by contributing to solving these problems as much as possible. The project was decided on the basis to build a cleaner mean of transportation, which has a lesser dependency on fossil fuels and emits zero emission, while being economically affordable. This meant for us to go completely electrical and depend on natural source of energy as much as possible.

Renewable energy is vital for today's world. Solar energy is being used to produce electricity through sunlight. With the help of this technology we aim to make solar energy powered car in our project. The main component to build a solar car is the solar panel. The solar cells collect a portion of the sun's energy and store it into the batteries of the solar car. Before that happens, power trackers converts the energy collected from the solar array to the proper system voltage, so that the batteries and the motor can use it, thus, producing zero carbon emission. Electric cars on the other hand help reduce dependency on fossil fuels hugely; they cause zero carbon emission and thus help reduce Global Warming.

Geographically looking what the most obvious and essential place our project fits into is 'VISION 2030 Saudi Arabia', but that's not the only place our project fits into. The project fits in line with the projects going on at Major Universities globally related to renewable energy and reduction of carbon footprint.

2.2 Previous Work

The scope of this project is not relatively new. There are plenty of similar projects which tackled the same issue. It has always been hard to credit one single inventor for the invention of the first electric car. We look back at the first practical electric automobile in USA 'Morrison Electric' (**Figure 2.1**); it was built in the year 1890(built on a carriage). Morrison Electric was developed by a William Morrison who was a chemist interested in electricity. He used 24 of his self-improved storage batteries, giving an electric output of 112A and 58V to a 4HP motor, these batteries took 10 hours to recharge and weighed hefty 14.5kg (32lbs) each. [3]

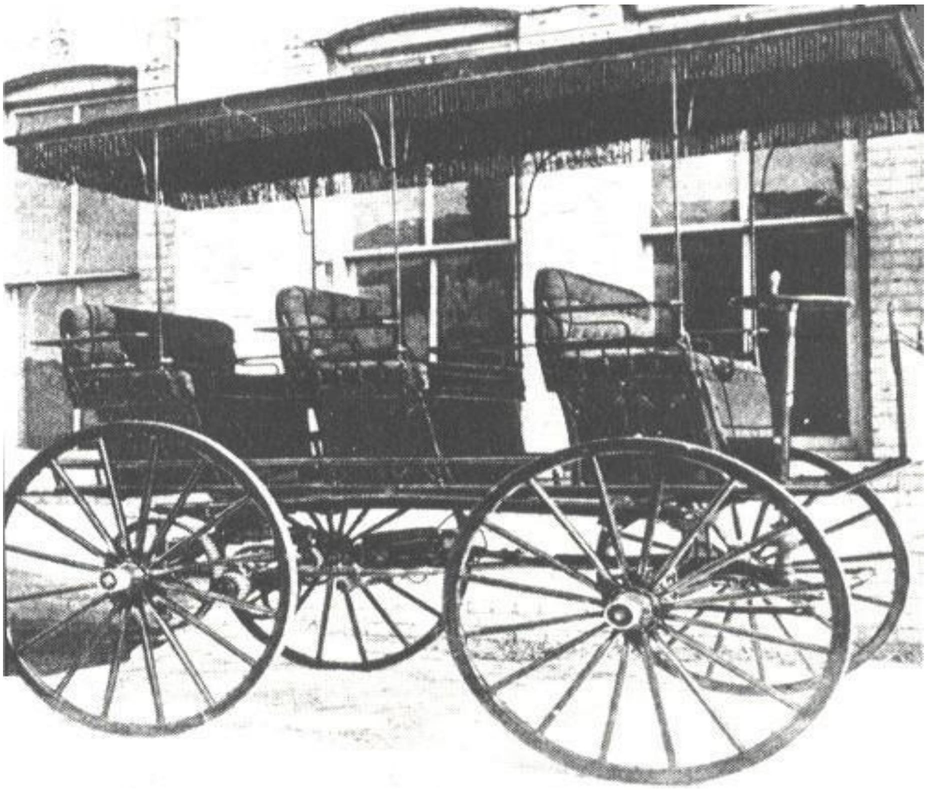


Figure 2.1: Morrison Electric, first practical electric automobile in USA

In addition, looking back at the first solar car **'Sunmobile' (Figure 2.2**), was invented by William G. Cobb in 1955 was a tiny 15-inch functional model, and first demonstrated to public on August 31st 1955. This Solar car used 12 photoelectric cells made out of a nonmetal substance Selenium. The first drivable solar car first shown in 1962 was a vintage 1912 Baker electric car converted by The International Rectifier Company (**Figure 2.3**). The car was mounted with over 10,640 individual solar cells on the rooftop to make it drivable. [4]

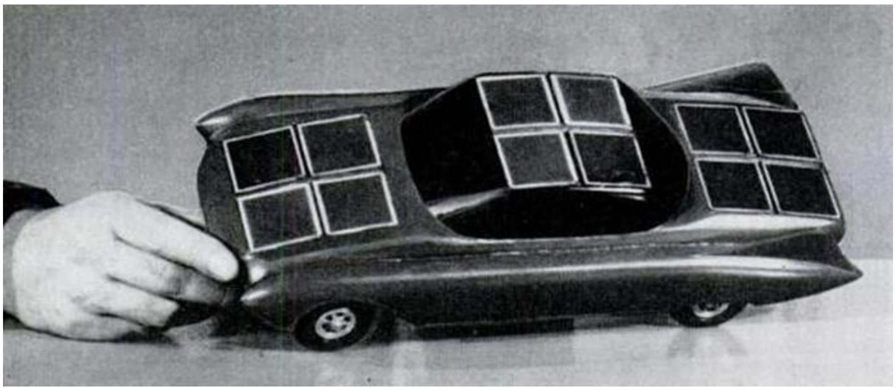


Figure 2.2: Sunmobile, the first solar car

Figure 2.3: The first drivable solar car (Vintage 1912 Baker)

Looking at the 21st century and recent development in electric cars and solar cars, the most obvious name in current market for electric car is Tesla. Tesla is one of the major Lithium-ion battery energy storage manufacturers in USA. They started by building efficient /rechargeable batteries, and now they are manufacturing completely electric cars which emit zero carbon emission. Tesla cars were a huge motivation for our project as they represent everything we are looking for in our car and more (antonymous driving was never a part of our project). Tesla Motors started working on its first electric car 'Tesla Roadster' in 2004, the model was later unveiled at the San Francisco Auto Show in 2006 as a prototype, this was not only a major step in history but it also made a lot of car manufacturers to jump for the electric car market. Roadster was the 1st electric car to use lithium-ion batteries [5]. Following are the Tesla Roadster Specifications show in **Figure 2.4**[6].

Tesla Roadster Specifications	
Style	2-seat, open-top, rear-drive roadster
Drivetrain	Electric motor with 2-speed electrically-actuated-manual-shift transmission with integral differential
Motor	3-phase, 4-pole electric motor, 248hp peak (185kW), redline 13,000 rpm, regenerative "engine braking"
Chassis	Bonded extruded aluminum with 4-wheel wishbone suspension
Brakes	4-wheel disc brakes with ABS
Acceleration	0 to 60 in under 4 seconds
Top Speed	125 mph
Range	245 miles (combined city/highway)
Battery Life	Useful battery, 100,000 miles
Energy Storage System	Custom microprocessor-controlled lithium-ion battery pack
Full Charge	As short as 3.5 hours

Figure 2.4: Tesla Roadster Specifications

Two other car makers (Renault & Nissan) have brought forward their respective electric cars to the market. Nissan's Leaf and Renault's Zoe are two very efficient compact electric cars. Nissan and Renault have formed a strategic alliance and decided to share electric car platform to pursue their goals/targets. Nissan Leaf was first manufactured in 2010 and hasn't changed much over the years except for an upgraded battery in 2016 to 30 kWh [7]. Its specifications can be seen below in **Figure 2.5**.

Manufacturer	Nissan Motor
Vehicle name	Leaf
	
Type	EV
Length × width × height (mm)	4445 × 1770 × 545
Curb weight (kg)	1520
Capacity (people)	5
Max. speed (km/h)	145
Drive method	Front-wheel drive
Per-charge range (km)	200 (JC08 mode)
Max. motor output （kW）	80
Max. motor torque （N・m）	280
Battery type	Li-ion rechargeable
Battery capacity (kWh)	24
Price	3,764,250 yen
Release date	Dec. 2010

Figure 2.5: Nissan Leaf Car Specification

Renault Zoe was first manufactured in 2012; the car wasn't noticed / shown interest in by customers till 2014. **Figure 2.6** shows that Renault Zoe has been the lead Electric Car sold in Europe for year 2017. Specifications of Zoe and its various models can be seen in **Figure 2.7.**

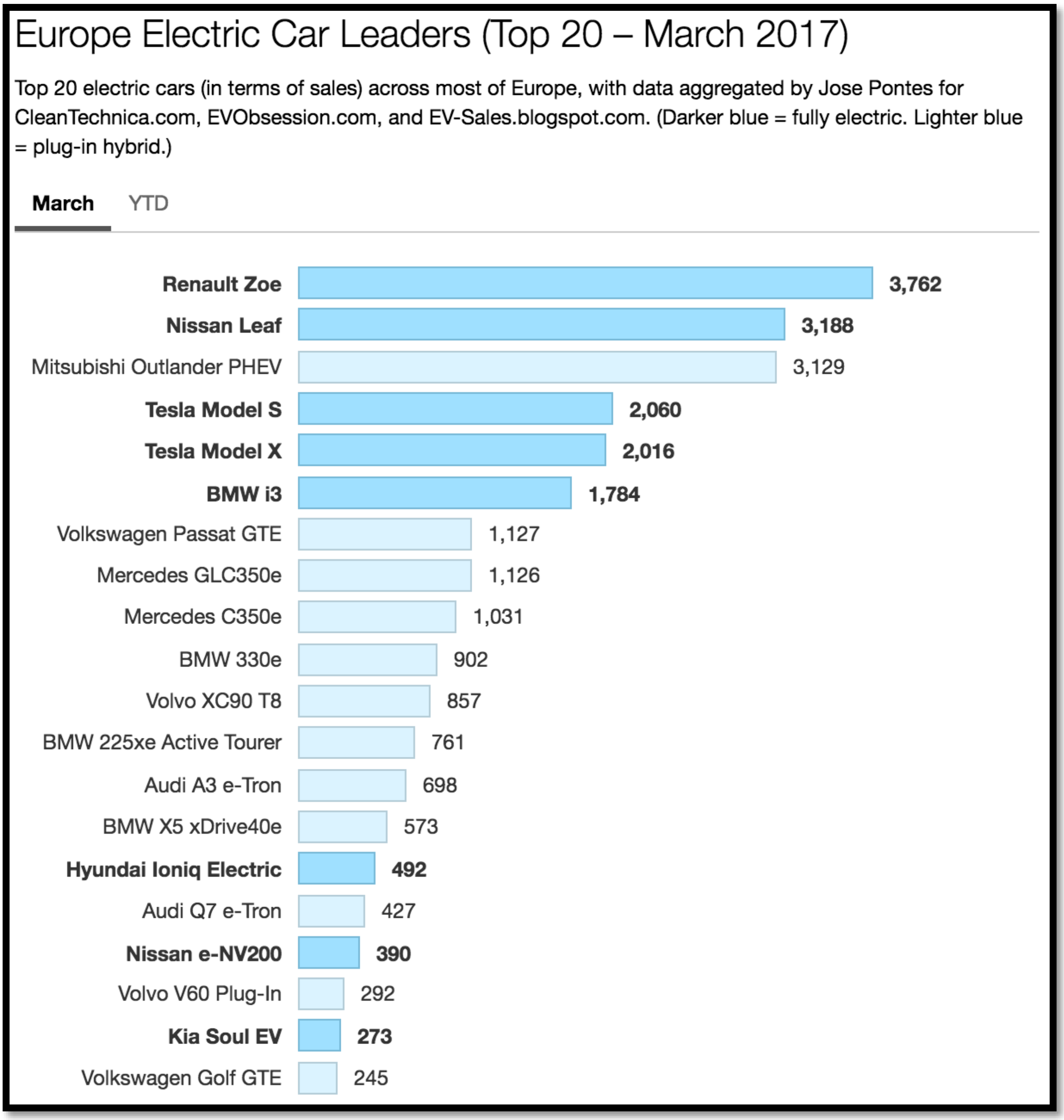


Figure 2.6: Renault Zoe, The Lead Electric car in 2017

ZOE version	Battery	Charge Time (0-80%, 43kW chargepoint)	Charge Time (0-100%, 7kW at home)	Range (miles) (Winter)	Range (miles) (Summer)	Range (miles) (NEDC)
Expression Nav R90 22kW	22kWh	1h00	4h00	71	106	149
Dynamique Nav R90 Z.E.40	41kWh	1h40	7h25	124	186	250
Dynamique Nav Q90 Z.E.40	41kWh	1h 05	8h25	112	174	230
Signature Nav R90 Z.E.40	41kWh	1h 40	7h25	124	186	250
Signature Nav Q90 Z.E.40	41kWh	1h 05	8h25	112	174	230

Figure 2.7: Specifications of Zoe and its various models

2.3 Comparative Study

The scope of this project is not relatively new. There are many of similar projects which tackled the same issue. For instance, at Ohio University [1], there was a competition regarding building a race car that uses the concept of utilizing clean energy. See **Figure 2.8**. Each student had the chance of building a small prototype consisting of a small battery, motor, and motor controller. The project might be small in size but the concept was sound.

Figure 2.8: Small Prototype of an Electric Vehicle

Also, in University Of Michigan, [2] a group of students built a hybrid car of a higher scale that uses solar energy. The project was huge and kind of complicated. The projects were sponsored by the board of Engineering. See **Figure 2.9**. The amount of electrical engineering knowledge was challenging in terms of constructing the proper circuit and the connection of the electrical components. The time spent to conduct this project lasted about a year.

Figure 2.9: University Of Michigan, Solar Car Project

Chapter 3: System Design

3.1 Design Constraints

We faced many Design Constraints while designing the system/subsystem of our project. The constraints are listed below:

- Specifications of the electrical components constrained us to a limited voltage output (These specifications are later mentioned in the report, under Section 3.3.2).
- Our car is limited to 48V (4 x 12V batteries). This limits the maximum power output, as a higher power output will require higher voltage.
- As the chassis was obtained and not manufactured from scratch, it only has steel used and not alloys which has increased the weight of the car significantly.
- Due to limited to power supply, we had to make a smaller and more compact car.
- Fitting electronic components into relatively compact space.
- Availability of parts in local market caused us to alter our design to match the parts bought off the internet.

3.2 Design Methodology

When building a powered prototype, there are a large number of formulas and calculations which must be met and considered to produce a sufficiently-powered, well-functioning and safe prototype. The main part of our project is the motor. The higher the power of the motor, the more work and performance our electric car can achieve and deliver. The first point that must be identified is the amount of watts that the motor can deliver. Below are basic approaches and some important formulas and calculation details to determine mechanical power requirements of a DC motor, torque, etc.

3.2.1 Speed and Gear Ratio

Gears normally act in pairs; the driving gear and driven gear. The driving gear is the gear that is rotated by the prime mover, and the driven gear is the gear that is pushed (or driven) into rotation by the driving gear. A gear ratio is the relationship between the speed of the driving and driven gear in a gear set.

$$\textbf{Gear Ratio} = \frac{[\boldsymbol{Driven\ Sprocket\ \#Teeth}]}{[\boldsymbol{Driving\ Sprocket\ \#Teeth}]} \qquad \textbf{Equation (3.1)}$$

Figure 3.1 shows a sprocket with 80 teeth and a driver sprocket of 10 teeth.

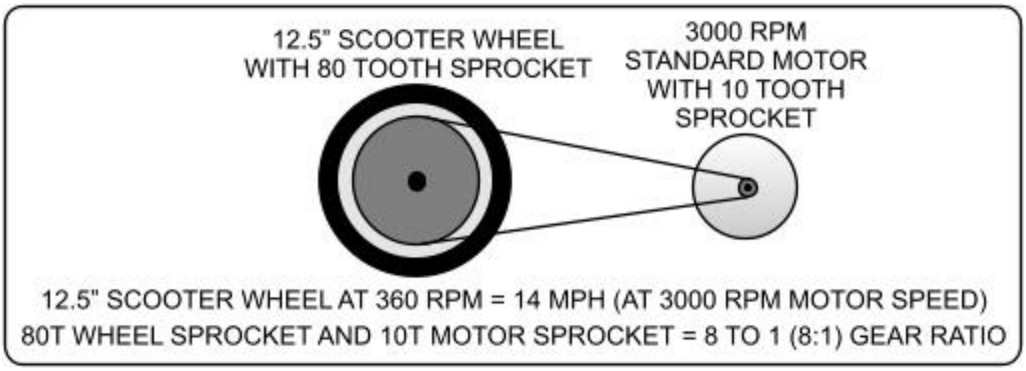


Figure 3.1: (8:1) Gear Ratio Chain-Sprocket Mechanism

In our Design Specification, we are using a driven gear (Sprocket) that has a number of 39 teeth, and a driver gear that is connected to the DC motor that has a number of 15 teeth. The gear ratio will give us a clear idea on how fast our electric\solar car can go. Our gear ratio is found to be (2.6:1). Then, we calculate the velocity by using the following equation:

$$\mathbf{V} = \left[(\boldsymbol{\pi})(\boldsymbol{D})\left(\frac{\boldsymbol{RPM}}{\mathbf{60}}\right)\right] / \left[\boldsymbol{Gear\ Ratio}\right] \qquad \textbf{Equation (3.2)}$$

3.2.2Mechanical Power Required

In dc motors, electrical power (P_{el}) is converted to mechanical power (P_{mech}). In addition to frictional losses, there are power losses in Joules/sec ($P_{j\ loss}$).

Note: Frictional losses in coreless dc motors are negligible).

$$\mathbf{P_{el} = P_{mech} + P_{j\ loss}} \qquad \textbf{Equation (3.3)}$$

Physically, power is defined as the rate of doing work. For linear motion, power is the product of force multiplied by the distance per unit time. In the case of rotational motion, the analogous calculation for power is the product of torque multiplied by the rotational distance per unit time.

$$\textbf{Mechanical Power} = (\mathbf{T})(\mathbf{W}) \qquad \textbf{Equation (3.4)}$$

Where: the mechanical power is basically another was of representing the rotational power. 'T' is the torque and 'W' is the angular velocity. The most commonly used unit for angular velocity is rev/min (RPM). In calculating rotational power, it is necessary to convert the velocity to units of radians/sec to give us the angular velocity. This can be accomplished by using the following equation:

$$W = (Speed\ \frac{Mi}{H})(\frac{1H}{3600\ s})\ (5280\ \frac{F}{Mi})(12\frac{in}{1F})(\frac{1\ Rotation}{2\pi(Radius)in})(\frac{2\pi\ radian}{1\ Rotation}) \qquad \textbf{Equation (3.5)}$$

We can find the amount of force needed to move the car by simply using Newton's second law:

$$\textbf{Motive Force} - \textbf{Frictional Force} - \textbf{Drag Force} = (\mathbf{M})(\mathbf{a}) \quad \textbf{Equation (3.5)}$$

Where 'Motive Force' is the force required to move the car at any given velocity, 'Frictional Force' is the force acting against the motion of the car between the surface and the ground, 'Drag force' is the force acting on the body to resist the motion of the car (Wind Resistance) and 'a' is the acceleration desired for the car to move with a specific speed with respect to a certain time range. The amount of torque that our car is put up to can simply be found using the following equation:

$$\textbf{Torque} = (\textbf{Force})(\textbf{Tire radius}) \qquad \textbf{Equation (3.6)}$$

Where 'Force' is obtained earlier and the 'Tire radius' is measured in inches.

3.2.3 Battery AH Rating

Our car is put up to 48V (4 x 12V batteries). Each battery varies in regards with the Ampere rating. We're using Lead-acid batteries of higher AH in order to maintain and sustain adequate flow of current to our DC motor. The power pack of a system is basically the amount of voltage (V) delivered to the system multiplied by the current flow (I).

$$\textbf{Power Pack} = (\mathbf{I})(\mathbf{V}) \qquad \textbf{Equation (3.7)}$$

Since we are building a fully electric car, we are aiming to increase the efficiency of our system. Speed, Pack KWh rating, driving conditions, aerodynamics, vehicle weight, hills, temperature, driving styles and several other factors play a huge role in our system efficiency. We need to benefit from our electrical input power as much as needed to convert to mechanical output power with minor losses. The efficiency (μ) can be found using the equation below:

$$\mu = [MechanicalOutputPower] \,/\, [ElectricalInputPower] \qquad \textbf{Equation (3.8)}$$

3.3 Product Subsystems and Components

Our system basically consists of two systems, electric and solar system. Solar cars carry photovoltaic cells in order to convert sunlight into energy. Photovoltaic cells are basically the components in solar panels that have a certain purpose which is to convert the sun's energy to electricity. They're made up of semiconductors; those can be usually made of silicon that absorbs the sunlight. The sun’s energy dissipates and frees electrons in the semiconductors, creating what’s called a flow of electrons. This flow of electrons generates electricity that charges the battery and the motor in solar cars. Solar cars have some key benefits. Their solar panels work silently and giving no noise, so they don’t add to the noise pollution already on the road. Solar panels don’t create greenhouse gases, as internal combustion engines do. Most importantly, solar energy is widely available, free, and grants the solar car driver complete independence from gasoline or diesel oil. Electric cars are powered by an electric motor (usually DC motors) instead of a gasoline or diesel engine. The electric car’s motor gets energy from a motor controller, which has a purpose of regulating the amount of power that should be delivered based on the driver’s use of an accelerator throttle. The electric car (also known as electric vehicle or EV) uses energy that is stored in its rechargeable batteries. Our project combines those two systems in one. **Figure 3.2** illustrates the two systems arranged together.

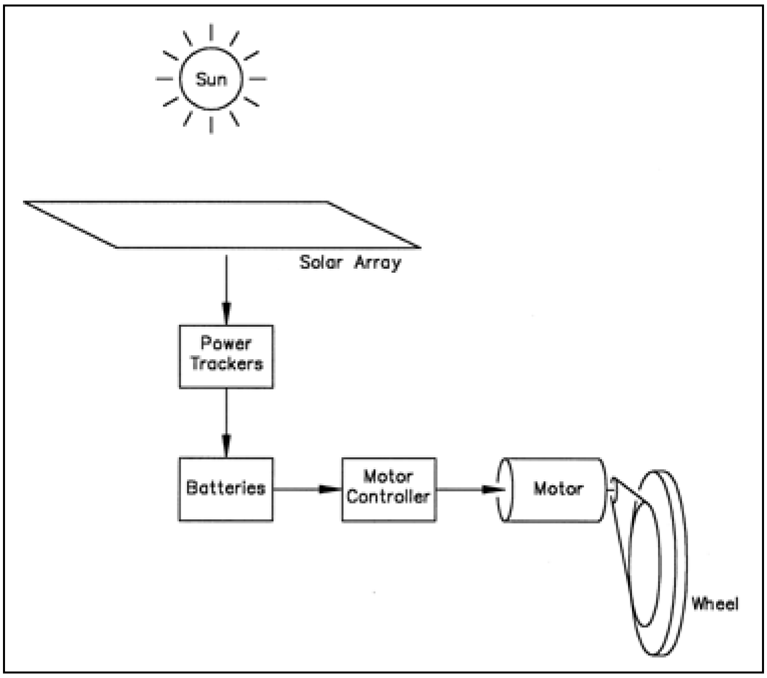


Figure 3.2: Arrangement of both Solar and Electric Systems

Each system in our car consists of a number of main parts. The solar system consists of the Solar panel, Solar Tracker (Solar Charger Controller) and a Battery. The electric system consists of the DC Motor, Motor Controller Assemblage, and Batteries. In order to convert the electrical power to mechanical power we need to implement a Chain-Sprocket mechanism in our car.

3.3.1 Solar System

- **Solar Panels**

We are using an OREX Model: AR-M100 W robust solar module with 40 solar cells. These modules can be used for off-grid solar applications. Those solar panels are ensured for a high-yield, long-term performance for every module produced. This solar panel has the following features:

- Increased system reliability and secured investment

- Robust frame to hold 5400 Pa load
- Salt Mist, ammonia and blowing sand resistance, apply to seaside, farm and desert environment

Specifications:

Table 3.1: Electrical Specifications for Solar Panel

Nominal maximum power	100W
Optimum operating Voltage	19.6V
Optimum Operating Current (Imp)	5.11A
Open Circuit Voltage (V)	24.8V
Short Circuit Current (A)	5.56A
Operating Temperature	-40oC~+85oC
Maximum System Voltage	1000V (IEC)/600V (UL)
Maximum Series Fuse Rating	10A
Power Tolerance	±5W

Table 3.2: Mechanical Specifications for Solar Panel

Cell Type	Mono crystalline
Cell Arrangement	40 (4×10)
Dimensions	120 x 54 cm
Weights	11 (kg)

Front Cover	Tempered glass
Frame material	Anodized aluminum alloy
Standard Packaging (Modules/Carton)	2pcs
90% Power Output	20 years Warranty
80% Power Output	30 years Warranty

- **Solar Charger Controller**

We will be using a 30A LCD solar charger controller. The controller has battery equalization which restores battery capacity, revives efficiency and extends battery life. The digital display shows charging stage, voltage, current and battery Amp Hours. A single 30A controller can manage up to 100 Watts of total solar power.

3.3.2 Electric System

- **DC Series Motor**

Our Motor is shown in **Figure 3.3**. It is a XQ-3-4 Series DC motor that has the following specifications:

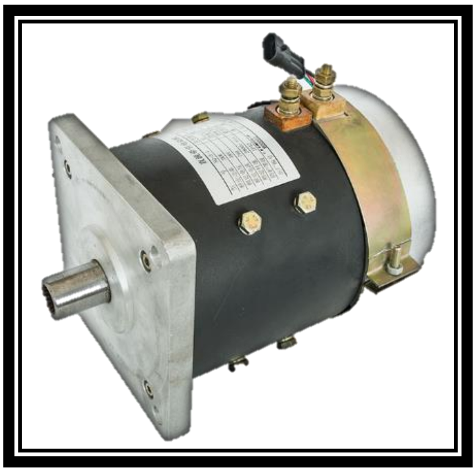


Figure 3.3: XQ-3-4 Series DC motor

- Nominal power rate: 3 kW
- Rated Speed: 2800 RPM
- Operating voltage: 48V
- Flange option: a square flange (as shown in the photos) can be provided for easy installation
- Speed sensor mating connector is included and the Insulation is classified: class H
- Dimensions (L×Ø): 272 (Max.) × 174 mm
- Weight: 21.4 kg
- Package environmental rating: IP2

- **<u>CURTIS DC Series Motor Controller Assemblage</u>**

CURTIS 1204M programmable series motor controllers are designed to provide smooth, silent, cost-effective control of motor speed and torque. This 1204M-5203 controller assemblage is a completed electric vehicle DC Series Motor control system. The assemblage includes:

- Controller
- Main contactor
- Forward / reverse contactor
- Fuses
- Wiring
- Heat-sink aluminum alloy installation plate
- Foot pedal accelerator (throttle)
- Plug-in connectors
- Installation (bolts, washes and nuts) kit Included

Figure 3.4 gives a closer look on the motor controller kit.

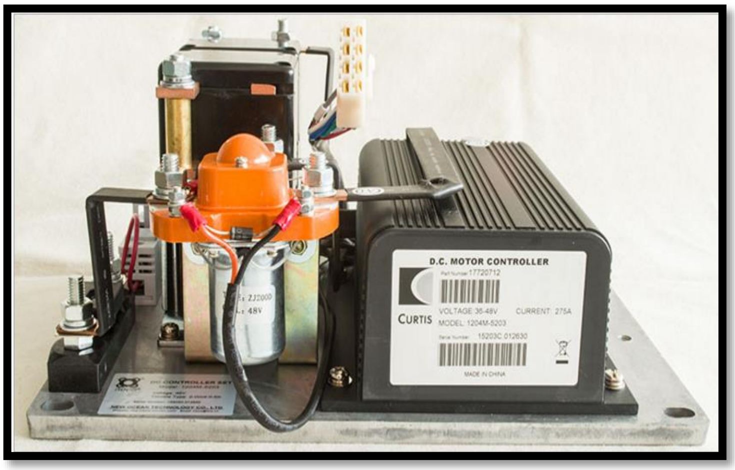


Figure 3.4: CURTIS DC Series Motor Controller Assemblage

CURTIS 1204M controllers are the ideal solution for a variety of electric vehicle applications, including industrial trucks, personnel carriers, material handing vehicles, golf cars, etc. The specifications of the DC Series Motor Controller Assemblage are listed below:

- full controlling set for 36V or 48V DC Series Motor
- proposed motor power rate: 2.3 – 3.6 kW
- simple motor connecting labels on assemblage
- easy installation with components mounted on a heat-sink aluminum alloy installation plate
- foot pedal accelerator (throttle), pre-wired for assemblage
- simple plug-in connectors
- Easy to install
- reinforced carton package, safe for international delivery

- **<u>Batteries</u>**

In our project, we decided to go with AC DELCO 12V 80AH Lead-Acid Batteries, see **Figure 3.5**. They are reliable and relatively come with a low cost. They are known for delivering higher flow of currents and lower internal impedance. Lead-Acid Batteries are not as highly reactive as Lithium Batteries, ad require an easier circuit connection to be charged by Solar Panels. Lead-Acid batteries use a chemical reaction to do work on charge and produce a voltage between their output terminals. We will be using four Lead-Acid batteries with a voltage of 12 V each and AH (Ampere Hour) of 80 AH. The batteries will be connected in series to deliver more voltage and thus more power. **Figure 3.6**shows the four batteries connected in series, giving us a power pack of 48 V. We use 4 batteries (12V each) in series to obtain 48V, which is the required voltage to run our DC Motor

Figure 3.5: AC DELCO 12V 80AH Lead-Acid Battery

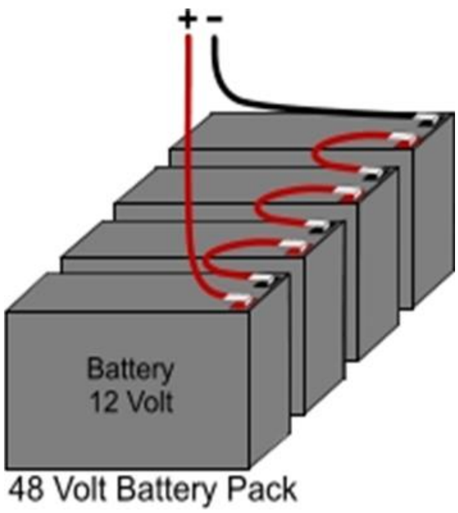


Figure 3.6: four batteries of 12 V connected in series

3.4 Design and Specification

We have used the mathematical equations discussed earlier to come up with the specifications of our project. This was implemented by using an online mathematical model to easily help us with the calculations. **Figure 3.7**shows the values obtained for the top Speed and Gear Ratio calculations using our specified input data.

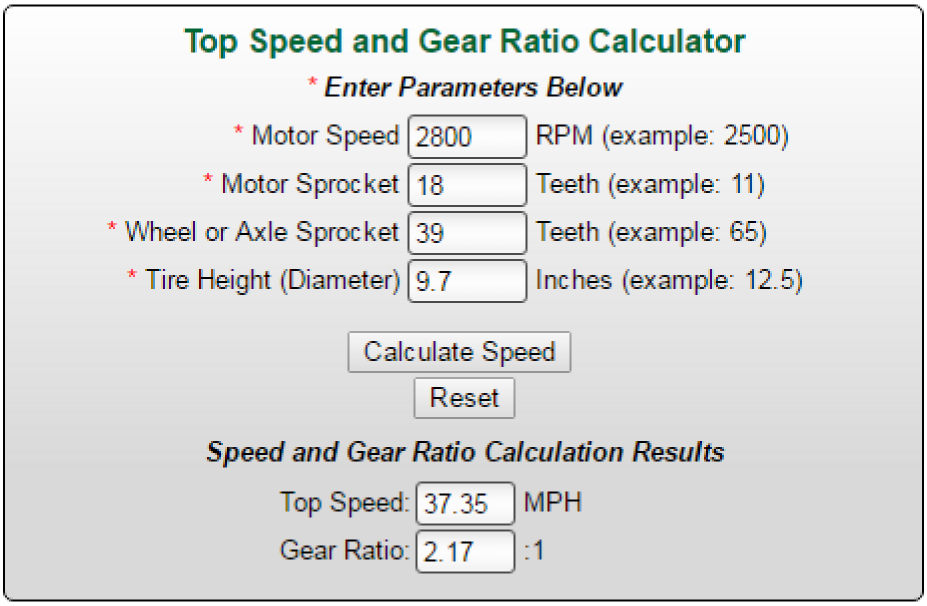


Figure 3.7: Values Obtained for the Top Speed and Gear Ratio

This calculator determines the top speed of the vehicle with average margin for mechanical, rolling, and wind resistance. The more are these resistance factors the slower is the top speed compared to the calculation. The amount that the top speed will be reduced by resistance depends on many factors such as the power of the motor, weight of the vehicle and rider, size and air pressure of the tires, incline degree that the vehicle is going up, and headwind. The top speed could also be increased above the top speed calculation by riding downhill, or riding with a strong wind against your back.

Figure 3.8 shows the values obtained for the Battery Pack needed according to our specified input data; wattage of 3792 V and a ride time of 60 minutes for our electric car to be driven.

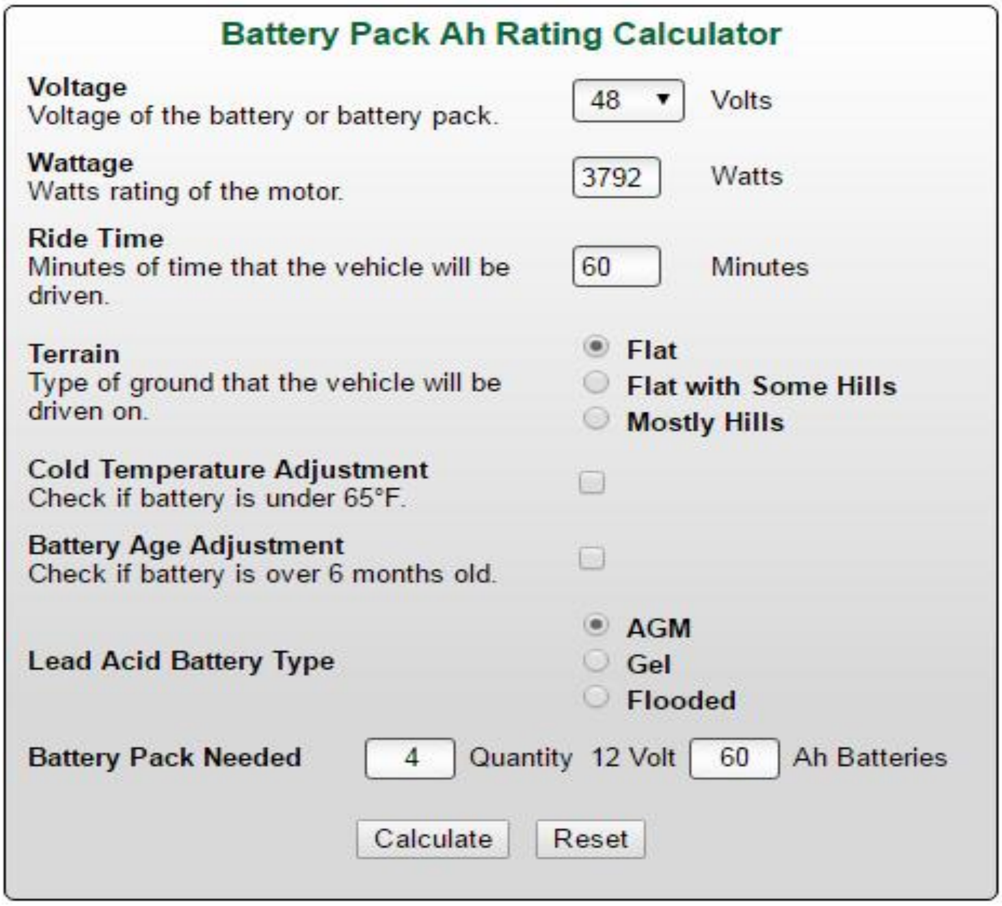


Figure 3.8: Values Obtained for the Battery Pack

This calculator provides an estimate of the battery size needed for a single or double occupant electric car. It accounts for an average factor in all parameters such as headwinds, tailwinds, excessive rolling resistance and various terrains. Other design criteria have been calculated using the mathematical equations discussed earlier and we obtained the following overall design specifications:

- Velocity = 60 km/h
- Angular Velocity = 113.06 rad/s
- Acceleration = 0.84 m/s^2

- Mass = 350 Kg
- Force = 294.93 N
- Torque = 33.03 Nm
- Motor Sprocket = 18 Teeth
- Wheel or Axle Sprocket = 39 Teeth
- Gear Ratio = 2.17 : 1
- Tire Diameter = 0.235 m
- Battery Voltage = 12V
- Battery Pack Voltage = 48V
- Battery AH Rating = 60 A
- Mechanical Power Output = 3078 Watts
- Electrical Power input = 3800 Watts
- Power Losses = 722 W
- Efficiency = 0.81 = 81 %

3.5 Implementation

We now have a clear understanding on how to start the project. Despite the fact that we have a compact space in our car, we managed to decide on where to place the parts. The solar panel will be placed on top in order to perpendicularly attract more sun rays. The batteries will be placed in the back. The motor controller assemblage will be placed next to the batteries and the DC motor for an ease of connections. We have the motor connected in the rear side of the car in order to attach the motor sprocket with the rear axle sprocket.

Figure 3.9 clearly shows the position of each component that we have.

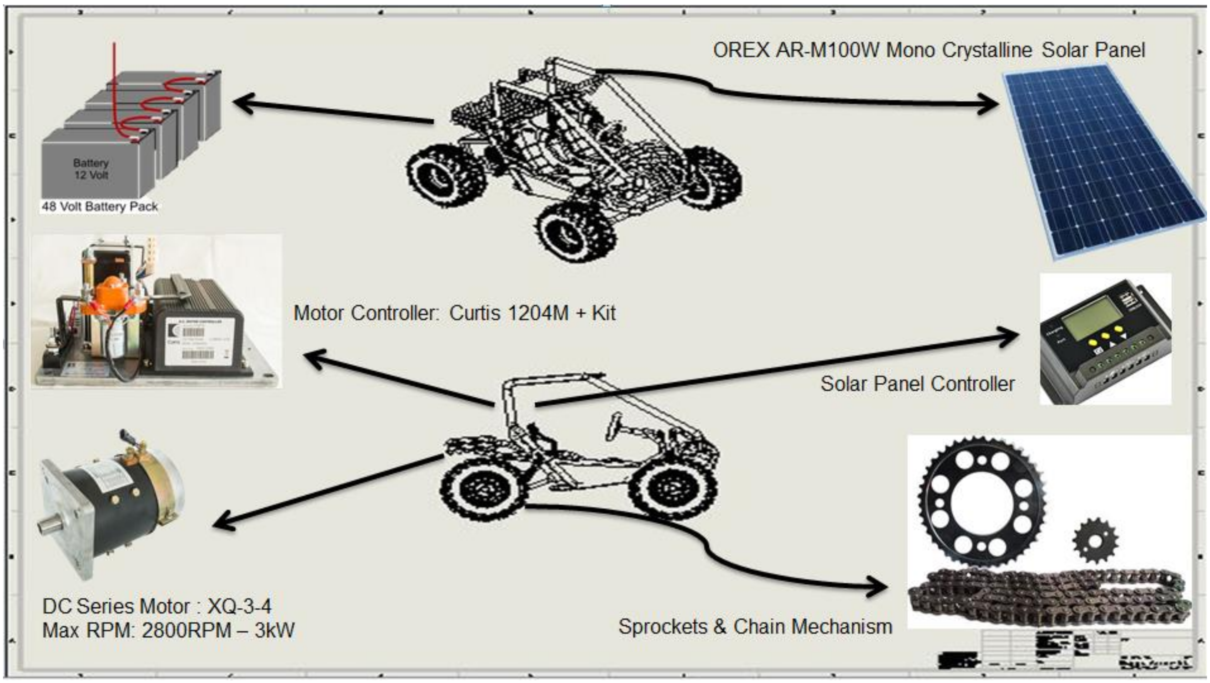


Figure 3.9: Arrangement of components

Chapter 4:   System Testing and Analysis

4.1   Subsystem 1 → Electric System

Objectives

- To verify the voltage being delivered to the motor.
- To analyze the code that is programmed in the motor controller.
- To check the sensitivity for the throttle in correspondence with max and min pedal movement.

Setup

We have taken the car to a workshop for an electrician to test our system. We had the electric subsystem prepared (DC motor, motor controller, batteries) for testing. We have implemented the mating connections between the DC motor and the motor controller based upon the guidelines in the manual (See Appendix E). **Figure 4.1** shows the mating connections between the motor controller and the batteries. We connected the batteries in series to gain a maximum voltage of 48 volts (12V x 4).**Figure 4.2** shows the four 12 batteries connected in series. Then we connected the motor controller to the output + and – terminals of the battery.

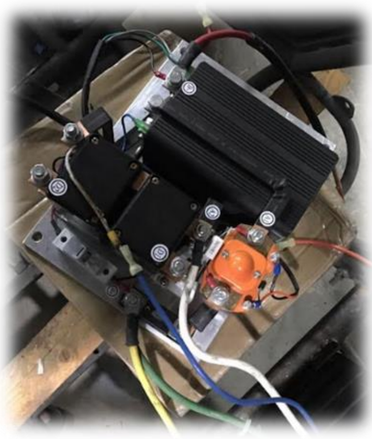


Figure 4.1: Mating connections between the motor controller and the batteries

Figure 4.2: Series Connection for Batteries

Results

- Electric system was working decently in general.
- Batteries were charging properly from an external generator port.
- Rotation of motor by using the throttle pedal proved that both the DC motor and motor controller were connected properly as the guidelines illustrated in the manual
- Batteries were drained when driving at max speed for one hour.
- Batteries charging time from an external generator source took approximately 10 hours.

4.2 Subsystem 2 → Solar System

Objectives

- Checking the solar panel charging status.
- Checking the charge level of the batteries.
- Ensure the functioning of the solar charger controller.
- Having the system to run in harmony with the electric system.

Setup

We have placed the solar panel containing 40 photovoltaic cells on top of our car. This is mainly to get an orthogonal angle from the sun to the solar panel to maximize the capturing of sun rays. We got the solar panel connected to the solar controller that was connected to the battery. **Figure 4.3** shows the mounting of solar controller on the car, and, **Figure 4.4** shows the mounting of solar panel.

Figure 4.3: Shows the mounting of solar controller on the car

Figure 4.4: Mounting of Solar Panel on the Car

Results

- The solar panel and the solar controller were functional.
- The solar panels were charging all 4 Batteries.
- The time it takes the solar panel to fully charge all batteries (4) is 36.8 hours.

4.3 Subsystem 3 → Mechanical System

Objectives

- Ensure the proper implantation of the mechanical system in general
- Testing the functionality of the disc-brake
- The brake range for the car to come to a full stop.
- The connection of the sprocket-chain mechanism.
- The status of the chain connected to the rear sprocket when driving at max speed

Setup

We have moved our car to a workshop to ensure the proper implantation and functionality of our mechanical system. We have manufactured and built steel bars for the DC motor to be mounted in the rear of the car. Those can be as testing the disc brake, the sprocket-chain mechanism. Those two applications have been mounted on the car and tested. **Figure 4.5** shows the mounting of the DC motor in the rear compartment.

Figure 4.5: Mounting of DC motor in the car

Results

- The testing showed that the car has an acceleration of 0.84m/s2
- The braking Distance from top speed (60Km/h) to a fully stop is 25 Meters
- Testing showed that the Chain/Sprocket Mechanism had no slack
- The brake master cylinder was leaking oil and it had to be changed

4.4 Overall Results, Analysis and Discussion

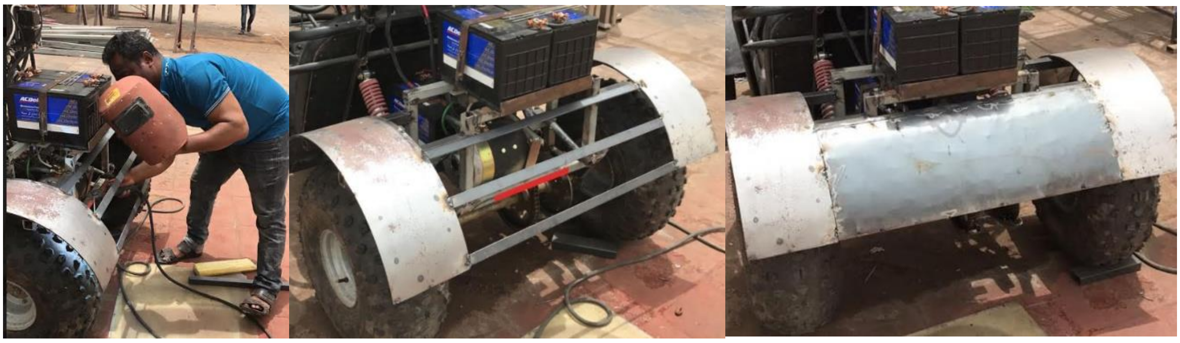
The testing for the three systems was an essential approach to get a clear idea of how each system is functioning as it is supposed to be. We have worked upon our testing results and went through decision making process to modify, and replace malfunction component, i.e. brake master cylinder. **Figure 4.6** shows the malfunction component, i.e. brake master cylinder.

. **Figure 4.6:** Malfunctioned Brake Master Cylinder

We have replaced the brake master cylinder with a new one as **Figure 4.7** shows.

. **Figure 4.7:** New Brake Master Cylinder

Then we went for braking testing and the results were appealing. We calculated the braking distance from the maximum speed (60Km/h) to a full stop. We reached to an outcome that the car stops after a braking distance of 25 meters. Then we applied an acceleration test from 0Km/h to testify our desired input of 0.84m/s2 according to the calculated max speed. The result satisfied our specification criteria. We have also tested our chain-sprocket mechanism for any looseness in the chain at various speeds, and this resulted in no slack in the system. After ensuring that the mechanical system worked properly, we have implemented rear fenders and bumpers for our car. This is mainly to secure the DC motor and the lower two batteries in the rear of the car. **Figure 4.8: a, b, c** show the installation of both the fenders and bumper.



a b c

Figure 4.8: Installation of both the fenders and bumper

Finally, in order to reduce aerodynamic drag, we have installed a windshield using Polycarbonate glass. We have used the same material to install glass doors on the car as well. **Figure 4.9: a, b** show the mounting of Polycarbonate glass**.**

a b

Figure 4.9: Mounting of Polycarbonate glass

Our final prototype can be seen below in **Figure 4.10.**

Figure 4.10: Final Prototype.

Chapter 5: Project Management

We as a team had utmost confidence in methodology and workmanship while performing each task; this sets us in a place where we work under the umbrella of project management. Project management is not just for project managers, there is more to project management than is usually assumed. A project can be defined as a transitory strive intended to create a remarkable item, administration or result which is governed by fixed time duration and capital. This attempt is intended to meet specific goals.

Project management is a discipline that requires planning, controlling and execution of work as a team to achieve certain set goals and targets. It is the procedure and movement of arranging, sorting out, inspiring, and controlling assets, methodology and conventions to accomplish our objectives.

Like any other task or project, this senior year project of ours required high level of project management as we had many tasks to do in a short period of time. Accomplishing our primary tasks turned out to be a challenge, as we had many limitations in regards to the time, extent and capital for the project. Besides that, accomplishing the best quality was just impractical without legitimate tools and it further required research centers.

Despite what might be expected, to the previously mentioned significance of applying project management, it is additionally apparent that the project had a limited resources and previous researches. Along these lines, a basic and customary methodology, which is the Gantt chart, was implemented to ensure the senior year project is effectively finished inside the predetermined time and spending outlines.

5.1 Project Plan

The project planning decided once we formed our group, this consisted of coming up with suitable and realistic project ideas. Once the topic was decided we started working on a detailed plan and made a list of the to-do tasks, each task had its own start and end date. A project plan table can be seen below in **Table 5.1.**

Table 5.1: To-Do tasks, Project Plan

Task Name	Start Date	End Date	Duration	% Complete	Status
Brainstorming	02-05-17	02-15-17	9d	100%	Completed
Study of Mechanism	02-10-17	02-15-17	4d	100%	Completed
Instructor Meeting #1	02-16-17	02-16-17	1d	100%	Completed
Literature Review	02-22-17	03-03-17	8d	100%	Completed
Sketching Design	02-24-17	02-27-17	2d	100%	Completed
Calculations	03-05-17	03-10-17	6d	100%	Completed
Instructor Meeting #2	03-09-17	03-09-17	1d	100%	Completed
Ordering/Looking For Components	03-11-17	03-24-17	11d	100%	Completed
Submission of Literature Review	03-05-17	03-05-17	1d	100%	Completed
Submission of 1st Progress Report & Oral Presentation	04-16-17	04-19-17	4d	100%	Completed
Acquiring Components and Starting Assembly#1	03-25-17	04-10-17	12d	100%	Completed
Acquiring Components and Starting Assembly#2	04-10-17	04-11-17	2d	100%	Completed
Acquiring Components and Starting Assembly#3	04-11-17	04-13-17	3d	100%	Completed
Testing & Inspection	04-14-17	04-21-17	6d	100%	Completed
2nd Progress Report	04-23-17	04-25-17	3d	100%	Completed
Finalizing Thesis Writing, Poster, Project Powerpoint Presentation and a Summary Document for Conference Publication	05-01-17	05-14-17	1d	100%	Completed
Final Report Submission Deadline	05-20-17	05-22-17	2d	100%	Completed
Presentation Day and Submission of Video, Poster and Brochures	05-29-17	05-25-17	1d	100%	Completed
Final Bound Thesis (Leather Bound)	05-29-17	05-31-17	5d	100%	Completed

Most of the tasks were worked upon by all the team members, may it be in form of completing it or revising it.

5.2 Contribution of Team Members

Table 5.2: Contribution of Team Members

#	Task	Team Member Assigned	Progress (0%-100%)	Duration to Completion
1	**Project Background**	Ammar & Abdulhadi	50% each	1 Week
2	**Previous Work**	Abdulaziz Al-Momen & Abdulaziz Abu Aishah	50% each	1 Week
3	**Comparative Study**	Ali	100%	2-3 Weeks
4	**Researching Body Specifications**	Ammar & Ali	50% each	3 Weeks
5	**DC Motor Research**	Abdulhadi & Ammar	50% each	1-2 Weeks
6	**Solar Panel Research**	Abdulaziz Al-Momen	100 %	1 Week

7	**Motor Controller Research**	Abdulaziz Abu Aishah	100%	1 Week
8	**Researching a Suitable Battery**	Abdulhadi	100%	1 Week
9	**Design Requirements, Constraints and Specifications**	Abdulaziz Al-Momen & Ali Raza	50% each	3 Weeks
10	**Locating Ergonomic Parts**	Ammar	100%	1 Week
11	**Contacting providers and comparing quotations**	Abdulaziz Abu Aishah & Abdulhadi	50% each	1 Week
12	**Design Methodology and Considerations**	Abdulaziz Al-Momen	100%	3 Weeks
13	**Product Subsystems and Components Purchase**	Abdulaziz Abu Aishah	100%	2-3Weeks
14	**Implementations**	Ali Raza & Abdulaziz Abu Aishah	50% each	1-2 Weeks

15	**System Testing and Analysis**	All Group Members	20% Each	1 Week
16	**Subsystem 1**	Ammar & Abdulhadi	50% each	1 Week
17	**Subsystem 2**	Abdulaziz Al-Momen	100%	1-2 Weeks
18	**Over All Results, Analysis and Discussion**	All Group Members	20% each	1 Week

5.3 Project Execution Monitoring

- Weekly meetings were conducted with Project Advisor (Dr. Faramarz Djavanroodi) and project Co advisor (Dr. Nader Sawalhi).
- Weekly meetings were conducted only with team members.
- Constant communication with team members on 'whatsapp' for constant update on progress.
- Research & Report Making
- Making weekly drafts of progress.
- Acquiring a Chassis
- Research on required subsystems components.
- Purchase of subsystem components
- Testing of Mechanical Subsystems
- Testing of Solar Panels
- Testing efficiency of the car

5.4 Challenges and Decision Making

Due to the uniqueness of our project in this region of the world, we faced many challenges and obstacles that other groups may not have experienced. These challenges and obstacles are listed below and further explained after.

- Budget
- Availability of Chassis
- Availability of Parts
- Shipment of Parts
- Cooperative Workshops / Skilled Worker
- Time Duration
- Extra load by other courses.

5.4.1 Budget

As we all are students and not working, so maintaining the budget to a level where everyone feels comfortable and keep it fair with other fellow students was quiet difficult due to the cost of parts / subsystem components.

5.4.2 Availability of chassis

As we were sticking to a minimum and reasonable budget with very specific dimensions, we aimed at acquiring used chassis. This was a hard task as most used chassis were either rusted or deformed to a level that restoring it would require more capital and a lot of time or didn't match our required dimensions at all.

5.4.3 Availability of parts

Acquiring a DC Motor with the right Motor Controller with our specifications was the most difficult one among all the challenges we faced, as no company manufactures a DC Motor in Saudi Arabia or neighboring countries and neither are they available in the local market. This forced us to go online and purchase the DC Motor and Motor Controller online from a secure and trust worthy manufacturer.

5.4.4 Shipment of Parts

Shipment of parts took a very long time as the provider's office was located in USA, but the parts had to be shipped from China as their manufacturing plant was located in China.

5.4.5 Cooperative Workshops / Availability of Skilled Worker

The chassis we purchased had some rust and extra link members that weren't required and they only added more weight; adding more load to the motor, therefore reducing our cars efficiency. To get rid of these members, coat the chassis to prevent rust, weld new link members to the chassis and to connect the electronic equipment we needed help as we didn't have the right tools or enough experience with welding or working with complex electronic equipment like the motor controller. Unfortunately most places denied our request to assist us, which was either because they didn't have the right understanding or enough place to accommodate us.

5.4.6 Time Duration

Due to delay in acquiring the necessary parts, and the order from the Ministry of Education to end the semester 2 weeks earlier than scheduled, we were very short on time and this reduced the margin of error & for anything to go wrong during testing.

5.4.7 Extra load by other Courses

The announcement from the ministry didn't just affect out final year project, but also affected other courses and project which again presented itself as a huge challenge which we tackled professionally.

To tackle all of the above mentioned challenges and difficulties we faced, we performed as a team under the supervision of our Advisors. By following the guidance given to us from our Advisors and using our Project Management skills we were able to overcome each and every challenge that we came across and finished everything on time to present a fully functional prototype, which was fully tested accompanied by a detailed technical report.

5.5 Project Bill of Materials and Budget

5.5.1 Bill of materials (BOM)

A bill of material (BOM) shown as **Table 5.3** is basically a list of all the raw material, sub components and all the parts with exact quantity used to manufacture or build a specific project / product. This list is very helpful to tack where each component is installed / used as per the initial design; this list is also used for cost estimate of the project and inventory control.

Table 5.3: Bill of material (BOM)

#	Name of the Part	Specifications	QTY	Unit Price (SR)	Total Price (SR)
1	Chassis	Steel & Aluminum	1	(Sponsored)	(Sponsored)
2	DC Motor	DC Series Motor Model: XQ-3-4	1	500 USD	500 USD
3	DC Motor Controller	Programmable DC Series Motor Controller Assemblage Model: 1204M-5203	1	450 USD	450 USD
4	Battery	12 V	4	(Sponsored)	(Sponsored)
5	Battery Charger	48 V	1	(Sponsored)	(Sponsored)

6	Tires	8”	4	160 USD	160 USD
7	Solar Panel	OREX AR-M100W	1	120 USD	120 USD
8	Solar Panel Controller	OREX AR-M100W Controller	1	54 USD	54 USD
9	Chain & Sprocket	18-39 Gear Ratio	1	40 USD	40 USD
10	Fiber Glass Body	Bumper (Front & Rear)	1	499 USD	499 USD
11	Windshield	Plastic	1	40 USD	40 USD
12	White LED Bulbs	Head Lights	2	8 USD	16 USD
13	Red LED Bulbs	Tail Lights	2	8 USD	16 USD
14	Nuts / Bolts / Washers	Various	100	-	54 USD
Total Price					**1949 USD (7309.63 SR)**

5.5.2Final Budget

This sections contains the complete cost of the project, **Table 5.4** shows the complete broken down in to Subsections.

Table 5.4: Final Budget Table

#	Item	Cost (SR)
1	Material	2,436.5 SR
2	Manufacturing	4,873 SR
3	Final Report (3 Spiral Copies)	400 SR
4	Final Report (3 Leather Copies)	600 SR
5	Poster	300 SR
6	Brochures	200 SR
7	USB Sticks (3)	150 SR
Total Project Cost		**9,127 SR**

Chapter 6: Project Analysis

6.1 Life-long Learning

While going the process of making our senior project, from deciding the right project till the day we demonstrated it we learned a lot of things by facing several challenges. We learned a lot from the guidance and instructions we got from our Project Advisors and from our seniors who have already graduated, as they had already just experienced this process. We as a team learned a lot from each other has each one of us different expertise and different past experiences with mechanical engineering related projects. Furthermore we went over to the internet to study previously done similar projects globally. We utilized the skills we learned in Circuit 1, Design II Lab and Solid works, as we designed our chassis before acquiring one and altering it. Working on the Solar Panels taught us a lot which is the kind of knowledge which will help us in future where renewable energy shall be the primary source of energy.

We learned a lot of lessons that are lessons we will benefit from all our professional lives. Managing the time and planning everything was the advice given to us by our Advisors and by the end it proved to be one of the best advice we've gotten, as if we wouldn't have had managed time our project would've never completed. We learned how to work as a team, communicate with each other and perform a task when assigned to by the team.

Be improved and polished the skills we learned in our previous courses like the skills of using Solidworks, material selection etc. We used this skill to design our chassis, design our mechanical systems and also to evaluate and calculate the exact required parts for the completion of our project. We learned how to work on a motor controller and solar panel controller which are very similar to Arduino. We used LabVIEW to sketch our electrical system with the help of fellow students from Electrical Engineering to better understand how our electric circuit works.

6.2 Impact of Engineering Solutions

6.2.1 Renewable Energy

As mentioned earlier in our introduction, renewable energy is the way to go to as Earth has limited reserves of fossil fuel remaining. Our car reduces the dependency on fossil fuel drastically. It primarily depends on electricity power grid to charge the batteries which can be achieved from renewable energy like solar energy, wind energy, nuclear energy or geo energy. The car secondarily relies on the solar panels connected on the roof top of the car to charge batteries. This is the 1st project of its kind in this region which attracts attention and increases awareness to the global issue of fossil fuels while introducing people to alternative efficient source of power and driving the cars. Furthermore reducing dependency on fossil fuels reduces Carbon Emission which is a major global issue like running out of fossil fuels. Reducing Carbon Emission can help reduce global warming, global warming has turned out to be a real threat to all of us, as the average global temperature is rising dramatically causing droughts, natural disasters like flooding and uncontrollable climate changes globally caused by melting of Arctic caps.

6.2.2 Economy

It's well know how Saudi Arabia's economy heavily depends on exporting Petroleum Products and Fossil Fuels, but at the same time most of the fossil fuel drilled out of the Earth and processed is consumed by vehicles locally. If this dependency on fossil fuels can be reduced, it can help boost the economy by exporting the remaining fuel. This dependency can only be reduced by moving to alternatives which is renewable energy for vehicles such as Solar Energy. By moving from fossil fuels to renewable energy can help gain capital return and help support VISION 2030. Moving to renewable energy means moving to solar energy, solar energy requires efficient solar panels. Silica based components are vastly used inside the solar panels, silica is made of sand grain and where better to manufacture them but locally at Saudi Arabia where there is abundance of Silica everywhere.

6.3 Contemporary Issues Addressed

The main issue addressed here as stated before is to reduce the dependency on fossil fuel and to increase the export therefore increasing the total revenue. Electric cars have a huge effect in the society economically and environmentally. Electric cars like Tesla Cars and Toyota Prius are gaining a lot of attention and increasing awareness as they are economical and are a cleaner source of transportation. Several car manufacturers are designing and manufacturing Hybrid or Electric cars, such as BMW i8 which uses recycled material for the chassis of the car and several other German car makers like Audi and Mercedes have started manufacturing Hybrid Electric Cars. This trend is moving across the world as car manufacturer have started realizing that fossil fuel cars would be history in the next decade or two. Green Vehicles / Eco-Friendly Vehicles such as electric cars are being promoted internationally. Germany has a passed a resolution in 2016 to ban all petrol fueled cars by the year 2030, while only allowing citizens to purchase cars that are driven by electric battery or hydrogen fuel. Electric cars should be taken more seriously and should not be considered as a joke like how it was a few decades ago.

Our project primarily addressed issues like dependency on fossil fuels and global warming, which have started to become not only a regional issue but also a global issue. Global warming is not only changing the weather globally but also causing a lot of health problems in densely populated cities of the world and in developing countries due to lack of awareness on this situation. Reduced dependency on fossil fuel saves a lot of fuel to be used at local power generation plants and can be exported to countries which don’t have natural reserves of fossil fuels. Creating such awareness is not only limited to cars, it opens a door to various other projects like using renewable energy at power generation plants and water distillation plants in Saudi Arabia.

Chapter 7: Conclusions and Future Recommendations

7.1 Conclusions

Fossil Fuels are still considered as an essential and ideal source of energy. Reducing the dependency on fossil fuels is considered to be a huge challenge. We are utilizing a cleaner source of energy; this was achieved by utilizing electric batteries, Dc Motor and a Solar Panel to charge the batteries. Our testing shows that our car can reach the top velocity 60km/h and that it is stable and safe Summary of main results. Previous word done by other groups in different fields was slightly based on a single source system. It was either electric or solar. What we did is combining the two systems to be incorporated in a car. The individual experience that each one of us has been through is priceless and very informative and knowledgeable. We learned more about power generation and utilizing renewable energy. We eventually had a chance to put what we have learned through the years in PMU to a real life project. This was basically achieved due to dedication, passion and hard work. There are a couple of pointers that were concluded at the end of our project. Those are:

- Implementation of Electric Cars is possible in Saudi Arabia.
- Solar Panels can be used in Electric cars in Saudi Arabia to have cleaner energy, due to abundance of sunlight throughout the year.

7.2 Future Recommendations

The recommendations that we have come up regarding our project can be listed as follow:

- Implementation of Electric Cars is possible in Saudi Arabia.
- Solar Panels can be used in Electric cars in Saudi Arabia to have cleaner energy, due to abundance of sunlight throughout the year

Chapter 8: References

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Appendix A: Monthly Progress Reports

SDP – WEEKLY MEETING REPORT
Department of Mechanical Engineering **Prince Mohammad bin Fahd University**

SEMESTER:	SPRING	ACADEMIC YEAR:	2017
PROJECT TITLE	Fully Electric Car with Solar Cells as a Secondary Source of Power		
SUPERVISORS	Advisor Name: Dr. Roodi Co-Advisor Name: Dr. Nader Sawalhi		

1st Month: February

ID Number	Member Name
201302233	Ali Raza Nawaz
201302533	Amar Al-Brahim
201300043	Abdulaziz Al Momen
201200290	Abdulhadi Al Qahtani
201300128	Abdulaziz Abu Aishah

List the tasks conducted this month and the team member assigned to conduct these tasks

#	Task description	Team member assigned	Progress 0%-100%	Delivery proof
1	Project Background	Ammar & Abdulhadi	50% each	✓
2	Previous Work	Abdulaziz Al-Momen & Abdulaziz Abu Aishah	50% each	✓
3	Comparative Study	Ali	100%	✓
4	Researching Body Specifications	Ammar & Ali	50% each	✓

List the tasks planned for the month of March and the team member/s assigned to conduct these tasks

#	Task description	Team member/s assigned
1	**DC Motor Research**	**Abdulhadi & Ammar**
2	**Solar Panel Research**	**Abdulaziz Al-Momen**
3	**Motor Controller Research**	**Abdulaziz Abu Aishah**
4	**Researching a Suitable Battery**	**Abdulhadi**

- **To be Filled by Project Supervisor and team leader:**
- **Please have your supervisor fill according to the criteria shown below**

Outcome f: An understanding of professional and ethical responsibility.				
Criteria	**None (1)**	**Low (2)**	**Moderate (3)**	**High (4)**
f1. Demonstrate an understanding of engineering professional and ethical standards in dealing with public safety and interest	Fails to Demonstrate an understanding of engineering professional and ethical standards in dealing with public safety and interest	Shows limited and less than adequate understanding of engineering professional and ethical standards in dealing with public safety and interest	Demonstrates satisfactory an understanding of engineering professional and ethical standards in dealing with public safety and interest	Understands appropriately and accurately the engineering professional and ethical standards in dealing with public safety and interest

Outcome d: An ability to function on multidisciplinary teams.				
Criteria	**None (1)**	**Low (2)**	**Moderate (3)**	**High (4)**
d1. Ability to develop team work plans and allocate resources and tasks	Fails to develop team work plans and allocate resources and tasks	Shows limited and less than adequate ability to develop team work plans and allocate resources and tasks	Demonstrates satisfactory ability to develop team work plans and allocate resources and tasks	Understands and applies proper and accurate team work plans and allocate resources and tasks
d2. Ability to participate and function effectively in team work projects	Fails to participate and function effectively in team work projects	Shows limited and less than adequate ability to participate and function effectively in team work projects	Demonstrates satisfactory ability to participate and function effectively in team work projects	Understands and participates properly and function effectively in team work projects

d3. Ability to communicate effectively with team members	Fails to communicate effectively with team members	Shows limited and less than adequate ability to communicate effectively with team members	Demonstrates satisfactory ability to communicate effectively with team members	3. Understands and communicates properly and effectively with team members

Indicate the extent to which you agree with the above statement, using a scale of 1-4 (1=none; 2=Low; 3=Moderate; 4=High)

#	Name	Criteria (d1)	Criteria (d2)	Criteria (d3)	Criteria (f1)
1	**Ali Raza**	4	4	4	4
2	**Amar Al-Brahim**	4	3	3	3
3	**Abdulaziz Al Momen**	3	3	4	3
4	**Abdulhadi Al Qahtani**	3	3	3	4
5	**Abdulaziz Abu Aishah**	3	4	3	3

Comments on individual members

Name	Comments
Ali Raza	None
Amar Al-Brahim	None
Abdulaziz Al Momen	None
Abdulhadi Al Qahtani	None
Abdulaziz Abu Aishah	None

	SDP – WEEKLY MEETING REPORT
	Department of Mechanical Engineering **Prince Mohammad bin Fahd University**

SEMESTER:	**SPRING**	**ACADEMIC YEAR:**	**2017**
PROJECT TITLE	**Fully Electric Car with Solar Cells as a Secondary Source of Power**		
SUPERVISORS	**Advisor Name: Dr. Roodi** **Co-Advisor Name: Dr. Nader Sawalhi**		

2nd Month: March

ID Number	Member Name
201302233	**Ali Raza Nawaz**
201302533	**Amar Al-Brahim**
201300043	**Abdulaziz Al Momen**
201200290	**Abdulhadi Al Qahtani**
201300128	**Abdulaziz Abu Aishah**

List the tasks conducted this month and the team member assigned to conduct these tasks

#	Task description	Team member assigned	Progress 0%-100%	Delivery proof
1	**DC Motor Research**	**Abdulhadi & Ammar**	**50% each**	✓
2	**Solar Panel Research**	**Abdulaziz Al-Momen**	**100 %**	✓
3	**Motor Controller Research**	**Abdulaziz Abu Aishah**	**100%**	✓
4	**Researching a Suitable Battery**	**Abdulhadi**	**100%**	✓

List the tasks planned for the month of March and the team member/s assigned to conduct these tasks

#	Task description	Team member/s assigned
1	**Design Requirements, Constraints and Specifications**	**Abdulaziz Al-Momen & Ali Raza**
2	**Locating Ergonomic Parts**	**Ammar**
3	**Contacting providers and comparing quotations**	**Abdulaziz Abu Aishah & Abdulhadi**
4	**Design Methodology and Considerations**	**Abdulaziz Al-Momen**

- **To be Filled by Project Supervisor and team leader:**
- **Please have your supervisor fill according to the criteria shown below**

Outcome f:
An understanding of professional and ethical responsibility.

Criteria	None (1)	Low (2)	Moderate (3)	High (4)
f1. Demonstrate an understanding of engineering professional and ethical standards in dealing with public safety and interest	Fails to Demonstrate an understanding of engineering professional and ethical standards in dealing with public safety and interest	Shows limited and less than adequate understanding of engineering professional and ethical standards in dealing with public safety and interest	Demonstrates satisfactory an understanding of engineering professional and ethical standards in dealing with public safety and interest	Understands appropriately and accurately the engineering professional and ethical standards in dealing with public safety and interest

Outcome d:
An ability to function on multidisciplinary teams.

Criteria	None (1)	Low (2)	Moderate (3)	High (4)
d1. Ability to develop team work plans and allocate resources and tasks	Fails to develop team work plans and allocate resources and tasks	Shows limited and less than adequate ability to develop team work plans and allocate resources and tasks	Demonstrates satisfactory ability to develop team work plans and allocate resources and tasks	Understands and applies proper and accurate team work plans and allocate resources and tasks
d2. Ability to participate and function effectively in team work projects	Fails to participate and function effectively in team work projects	Shows limited and less than adequate ability to participate and function effectively in team work projects	Demonstrates satisfactory ability to participate and function effectively in team work	Understands and participates properly and function effectively in team work projects

			projects	
d3. Ability to communicate effectively with team members	Fails to communicate effectively with team members	Shows limited and less than adequate ability to communicate effectively with team members	Demonstrates satisfactory ability to communicate effectively with team members	3. Understands and communicates properly and effectively with team members

Indicate the extent to which you agree with the above statement, using a scale of 1-4 (1=none; 2=Low; 3=Moderate; 4=High)

#	Name	Criteria (d1)	Criteria (d2)	Criteria (d3)	Criteria (f1)
1	**Ali Raza**	4	4	4	4
2	**Amar Al-Brahim**	3	3	3	4
3	**Abdulaziz Al Momen**	3	4	3	3
4	**Abdulhadi Al Qahtani**	3	3	4	3
5	**Abdulaziz Abu Aishah**	4	3	3	3

Comments on individual members

Name	Comments
Ali Raza	None
Amar Al-Brahim	None
Abdulaziz Al Momen	None
Abdulhadi Al Qahtani	None
Abdulaziz Abu Aishah	None

	SDP – WEEKLY MEETING REPORT
	Department of Mechanical Engineering Prince Mohammad bin Fahd University

SEMESTER:	SPRING	ACADEMIC YEAR:	2017
PROJECT TITLE	Fully Electric Car with Solar Cells as a Secondary Source of Power		
SUPERVISORS	Advisor Name: Dr. Roodi Co-Advisor Name: Dr. Nader Sawalhi		

3rd Month: April

ID Number	Member Name
201302233	Ali Raza Nawaz
201302533	Amar Al-Brahim
201300043	Abdulaziz Al Momen
201200290	Abdulhadi Al Qahtani
201300128	Abdulaziz Abu Aishah

List the tasks conducted this month and the team member assigned to conduct these tasks

#	Task description	Team member assigned	Progress 0%-100%	Delivery proof
1	Design Requirements, Constraints and Specifications	Abdulaziz Al-Momen & Ali Raza	50% each	✓
2	Locating Ergonomic Parts	Ammar	100%	✓
3	Contacting providers and comparing quotations	Abdulaziz Abu Aishah & Abdulhadi	50% each	✓
4	Design Methodology and Considerations	Abdulaziz Al-Momen	100%	✓

List the tasks planned for the month of March and the team member/s assigned to conduct these tasks

#	Task description	Team member/s assigned
1	**Product Subsystems and Components Purchase**	**Abdulaziz Abu Aishah**
2	**Implementations**	**Ali Raza & Abdulaziz Abu Aishah**
3	**System Testing and Analysis**	**All Group Members**

- **To be Filled by Project Supervisor and team leader:**
- **Please have your supervisor fill according to the criteria shown below**

Outcome f: An understanding of professional and ethical responsibility.				
Criteria	**None (1)**	**Low (2)**	**Moderate (3)**	**High (4)**
f1. Demonstrate an understanding of engineering professional and ethical standards in dealing with public safety and interest	Fails to Demonstrate an understanding of engineering professional and ethical standards in dealing with public safety and interest	Shows limited and less than adequate understanding of engineering professional and ethical standards in dealing with public safety and interest	Demonstrates satisfactory an understanding of engineering professional and ethical standards in dealing with public safety and interest	Understands appropriately and accurately the engineering professional and ethical standards in dealing with public safety and interest

Outcome d: An ability to function on multidisciplinary teams.				
Criteria	**None (1)**	**Low (2)**	**Moderate (3)**	**High (4)**
d1. Ability to develop team work plans and allocate resources and tasks	Fails to develop team work plans and allocate resources and tasks	Shows limited and less than adequate ability to develop team work plans and allocate resources and tasks	Demonstrates satisfactory ability to develop team work plans and allocate resources and tasks	Understands and applies proper and accurate team work plans and allocate resources and tasks
d2. Ability to participate and function effectively in team work projects	Fails to participate and function effectively in team work projects	Shows limited and less than adequate ability to participate and function effectively in team work projects	Demonstrates satisfactory ability to participate and function effectively in team work projects	Understands and participates properly and function effectively in team work projects

d3. Ability to communicate effectively with team members	Fails to communicate effectively with team members	Shows limited and less than adequate ability to communicate effectively with team members	Demonstrates satisfactory ability to communicate effectively with team members	3. Understands and communicates properly and effectively with team members

Indicate the extent to which you agree with the above statement, using a scale of 1-4 (1=none; 2=Low; 3=Moderate; 4=High)

#	Name	Criteria (d1)	Criteria (d2)	Criteria (d3)	Criteria (f1)
1	**Ali Raza**	4	4	4	4
2	**Amar Al-Brahim**	3	3	3	3
3	**Abdulaziz Al Momen**	4	3	3	3
4	**Abdulhadi Al Qahtani**	3	3	4	3
5	**Abdulaziz Abu Aishah**	3	4	3	4

Comments on individual members

Name	Comments
Ali Raza	None
Amar Al-Brahim	None
Abdulaziz Al Momen	None
Abdulhadi Al Qahtani	None
Abdulaziz Abu Aishah	None

	SDP – WEEKLY MEETING REPORT
	Department of Mechanical Engineering Prince Mohammad bin Fahd University

SEMESTER:	SPRING	ACADEMIC YEAR:	2017
PROJECT TITLE	Fully Electric Car with Solar Cells as a Secondary Source of Power		
SUPERVISORS	Advisor Name: Dr. Roodi Co-Advisor Name: Dr. Nader Sawalhi		

4th Month: May

ID Number	Member Name
201302233	Ali Raza Nawaz
201302533	Amar Al-Brahim
201300043	Abdulaziz Al Momen
201200290	Abdulhadi Al Qahtani
201300128	Abdulaziz Abu Aishah

List the tasks conducted this month and the team member assigned to conduct these tasks

#	Task description	Team member assigned	Progress 0%-100%	Delivery proof
1	Product Subsystems and Components Purchase	Abdulaziz Abu Aishah	100%	✓
2	Implementations	Ali Raza & Abdulaziz Abu Aishah	50% each	✓
3	System Testing and Analysis	All Group Members	20% Each	✓

List the tasks planned for the month of March and the team member/s assigned to conduct these tasks

#	Task description	Team member/s assigned
1	**Subsystem 1**	**Ammar & Abdulhadi**
2	**Subsystem 2**	**Abdulaziz Al-Momen**
3	**Over All Results, Analysis and Discussion**	**All Group Members**

- **To be Filled by Project Supervisor and team leader:**
- **Please have your supervisor fill according to the criteria shown below**

Outcome f: An understanding of professional and ethical responsibility.				
Criteria	**None (1)**	**Low (2)**	**Moderate (3)**	**High (4)**
f1. Demonstrate an understanding of engineering professional and ethical standards in dealing with public safety and interest	Fails to Demonstrate an understanding of engineering professional and ethical standards in dealing with public safety and interest	Shows limited and less than adequate understanding of engineering professional and ethical standards in dealing with public safety and interest	Demonstrates satisfactory an understanding of engineering professional and ethical standards in dealing with public safety and interest	Understands appropriately and accurately the engineering professional and ethical standards in dealing with public safety and interest

Outcome d: An ability to function on multidisciplinary teams.				
Criteria	**None (1)**	**Low (2)**	**Moderate (3)**	**High (4)**
d1. Ability to develop team work plans and allocate resources and tasks	Fails to develop team work plans and allocate resources and tasks	Shows limited and less than adequate ability to develop team work plans and allocate resources and tasks	Demonstrates satisfactory ability to develop team work plans and allocate resources and tasks	Understands and applies proper and accurate team work plans and allocate resources and tasks
d2. Ability to participate and function effectively in team work projects	Fails to participate and function effectively in team work projects	Shows limited and less than adequate ability to participate and function effectively in team work projects	Demonstrates satisfactory ability to participate and function effectively in team work projects	Understands and participates properly and function effectively in team work projects

d3. Ability to communicate effectively with team members	Fails to communicate effectively with team members	Shows limited and less than adequate ability to communicate effectively with team members	Demonstrates satisfactory ability to communicate effectively with team members	3. Understands and communicates properly and effectively with team members

**Indicate the extent to which you agree with the above statement, using a scale of 1-4 (1=none; 2=Low;
3=Moderate; 4=High)**

#	Name	Criteria (d1)	Criteria (d2)	Criteria (d3)	Criteria (f1)
1	**Ali Raza**	4	4	4	4
2	**Amar Al-Brahim**	4	4	3	3
3	**Abdulaziz Al Momen**	3	4	3	4
4	**Abdulhadi Al Qahtani**	4	3	4	3
5	**Abdulaziz Abu Aishah**	3	3	4	4

Comments on individual members

Name	Comments
Ali Raza	None
Amar Al-Brahim	None
Abdulaziz Al Momen	None
Abdulhadi Al Qahtani	None
Abdulaziz Abu Aishah	None

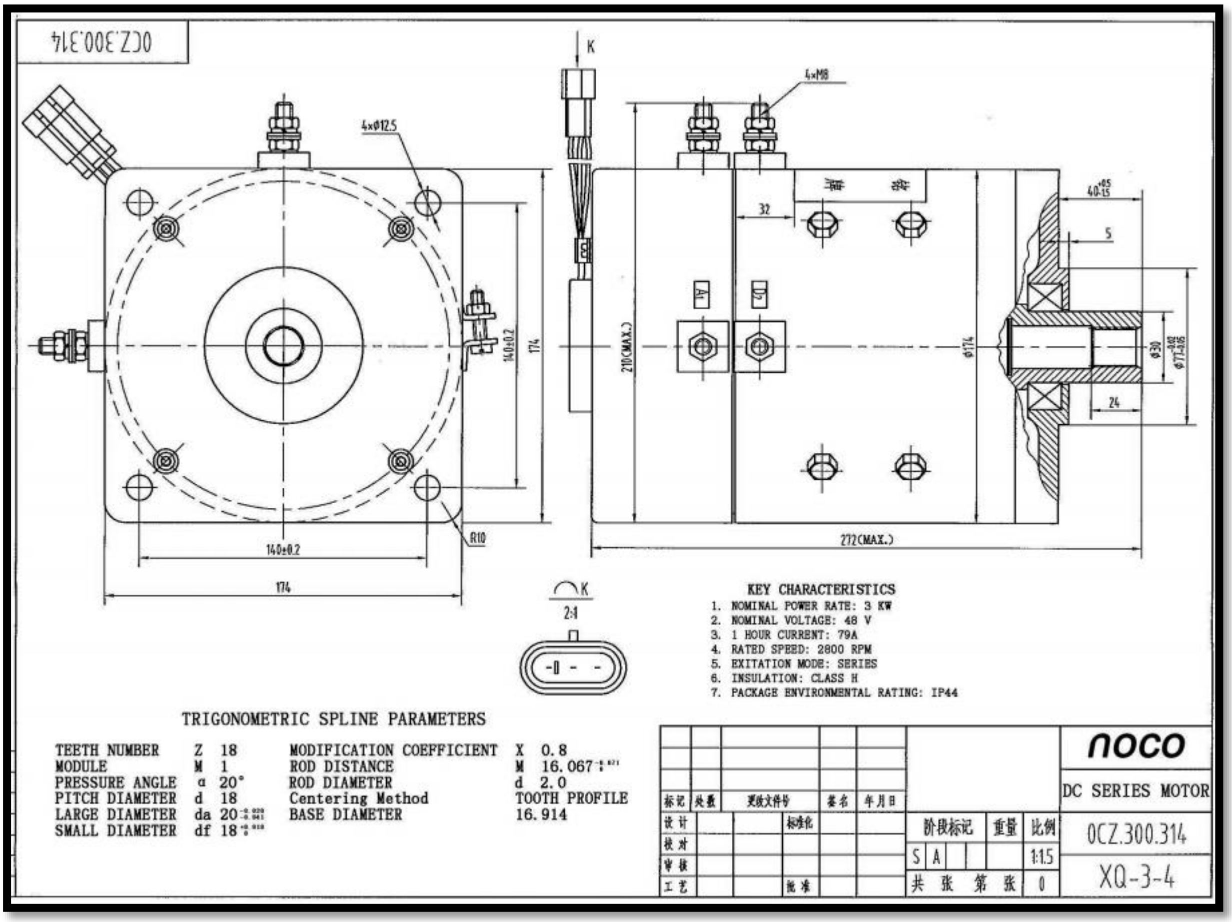
Appendix B: Bill of Materials

#	Name of the Part	Specifications	QTY	Unit Price (SR)	Total Price (SR)
1	Chassis	Steel & Aluminum	1	(Sponsored)	(Sponsored)
2	DC Motor	DC Series Motor Model: XQ-3-4	1	500 USD	500 USD
3	DC Motor Controller	Programmable DC Series Motor Controller Assemblage Model: 1204M-5203	1	450 USD	450 USD
4	Battery	12 V	4	(Sponsored)	(Sponsored)
5	Battery Charger	(Sponsored)	1	(Sponsored)	(Sponsored)
6	Tires	8”	4	160 USD	160 USD
7	Solar Panel	OREX AR-M100W	1	120 USD	120 USD
8	Solar Panel Controller	OREX AR-M100W Controller	1	54 USD	54 USD
9	Chain & Sprocket	18-39 Gear Ratio	1	40 USD	40 USD
10	Steel Body	Bumper (Rear)	1	499 USD	499 USD

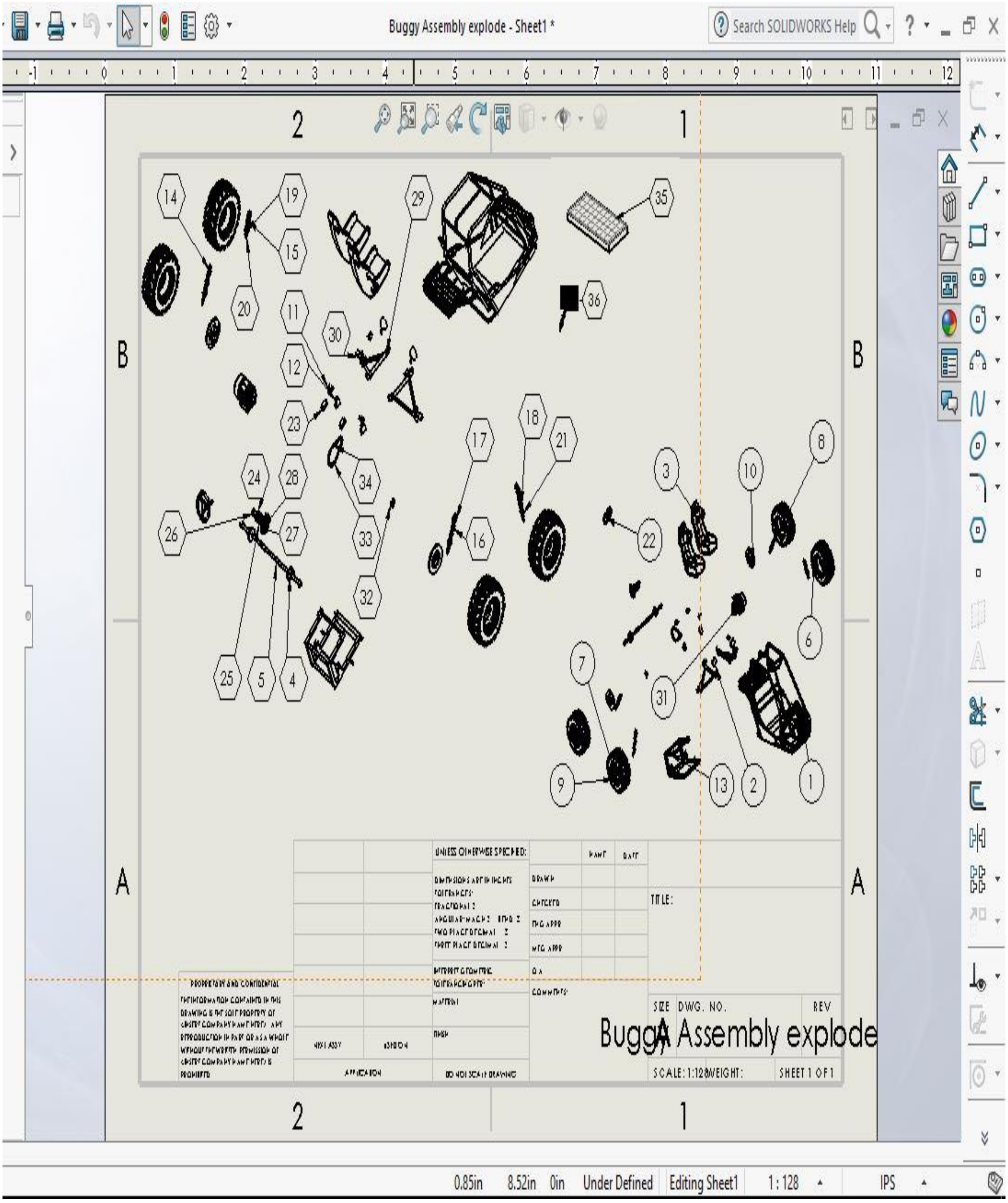
11	Windshield	Plastic	1	40 USD	40 USD
12	White LED Bulbs	Head Lights	2	8 USD	16 USD
13	Red LED Bulbs	Tail Lights	2	8 USD	16 USD
14	Nuts / Bolts / Washers	Various	100	-	54 USD
Total Price					**1949 USD** **(7309.63 SR)**

(Bill of Material used with Specified Quantities and Assigned Prices)

Appendix C: Datasheets



(DC Series Motor Solidworks Datasheet)

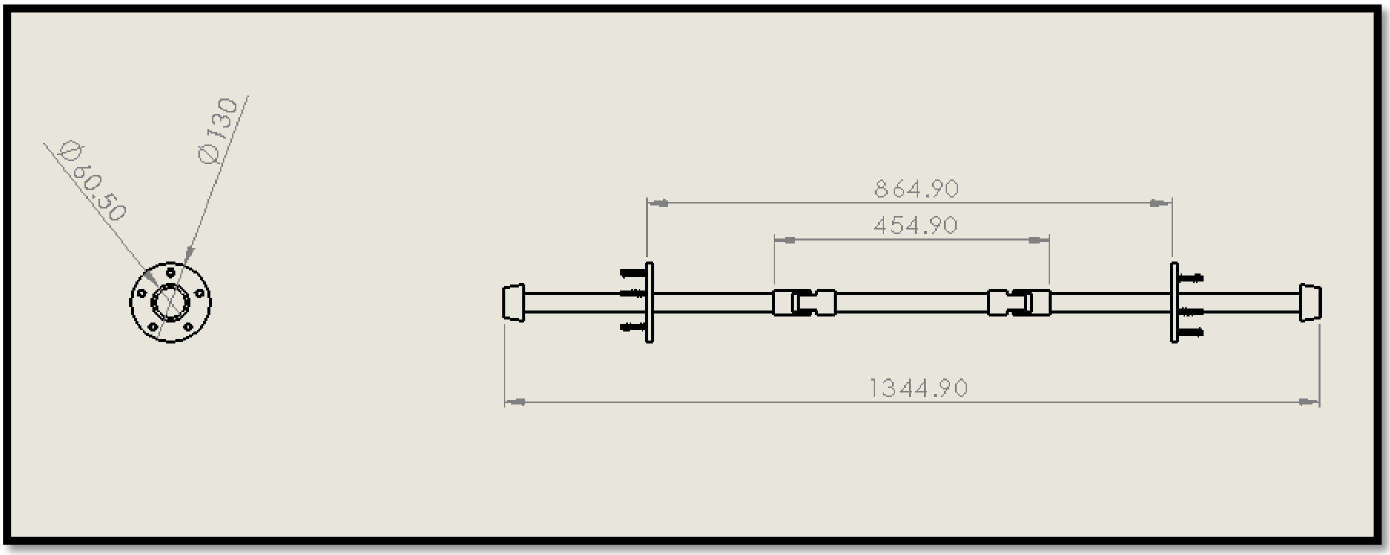


(Exploded View of Car Components)

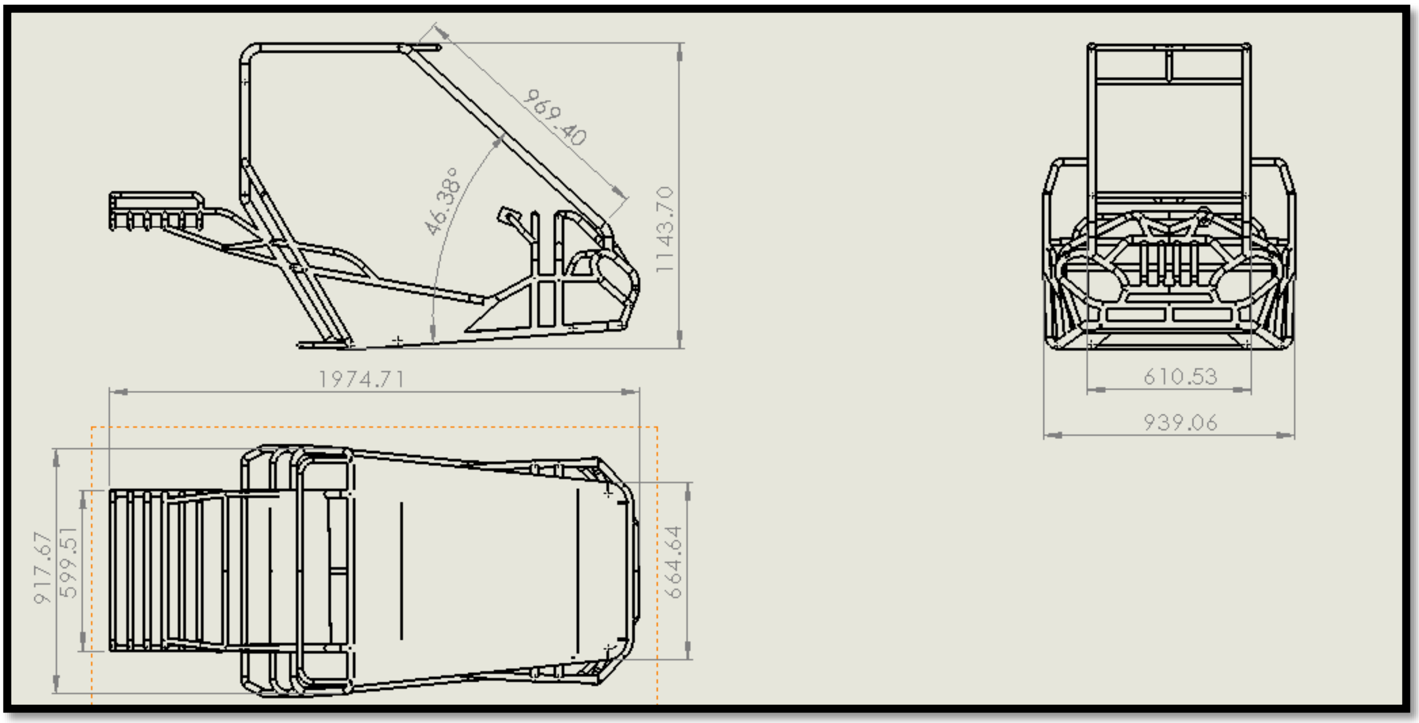
ITEM NO.	PART NAME	QUANTITY
1	CHASSIS	1
2	HEADLIGHT	2
3	SEAT	2
4	HUB + CARDON SHAFT	2
5	CARDON SHAFT 1 & 3	1
6	KENDA ATV K229 BEAR CLAW AT26X 10,000-12	4
7	RIM PART 1	4
8	RIM PART 2	4
9	RIM PART 3	8
10	DISC (BRAKE)	2
11	CLAM	4
12	CLAM 2	2
13	ENGINE FRAME	1
14	SHAFT	4
15	INNER HOLDER	4
16	HELICAL SPRING 2	4
17	BOTTOM HOLDER	4
18	HELICAL SPRING 1	4
19	COUNTER	4
20	BOLT	4
21	HOLDER	4
22	VOLANTE	1
23	PART 1	2
24	DIFFERENTIAL PART 1	1
25	DIFFERENTIAL PART 2	1
26	DIFFERENTIAL PART 3	1

27	DIFFERENTIAL GEAR	1
28	DIFFERENTIAL PART 7	1
29	SWING ARM	2
30	PART 4	2
31	MOTOR	1
32	MOTOR GEAR	1
33	CHAIN PART S2	37
34	CHAIN PART S1	37
35	Solar Panel	1
36	Solar Panel Controller	1
37	Lead Acid Batteries (12v , 80A)	4

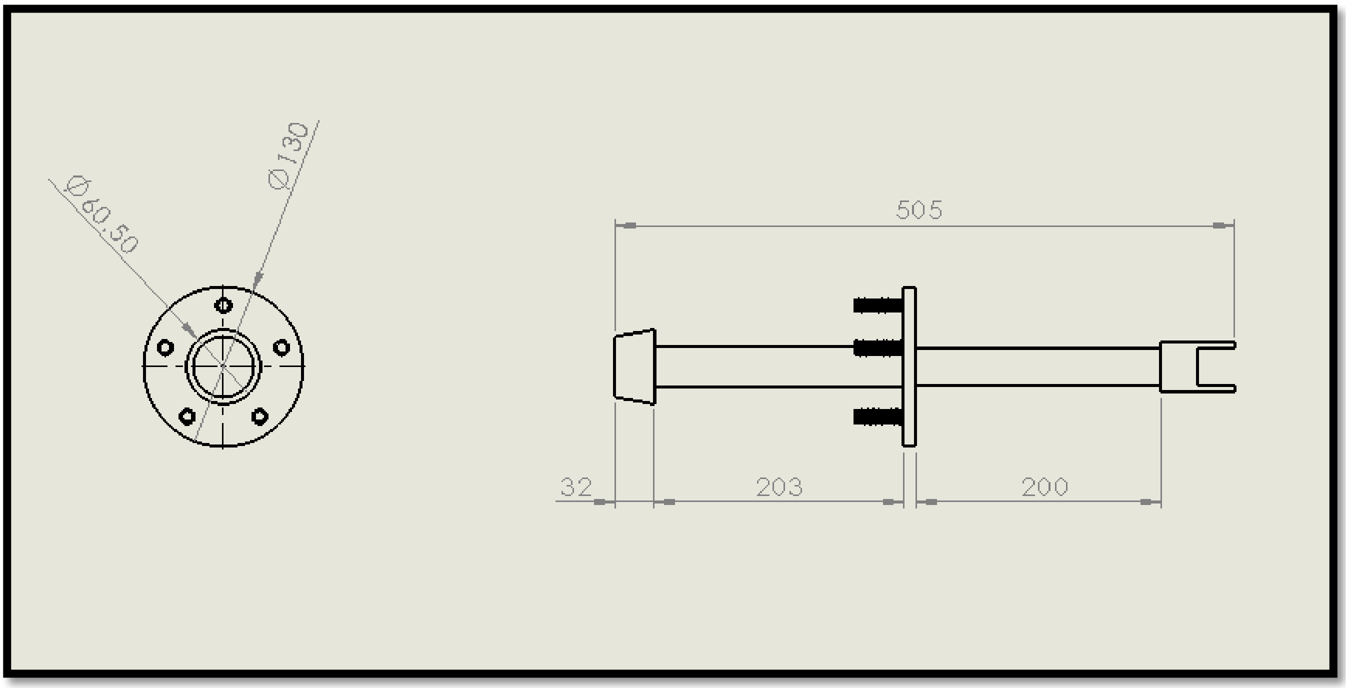
(Bill of Materials for the Exploded View of Car Components)



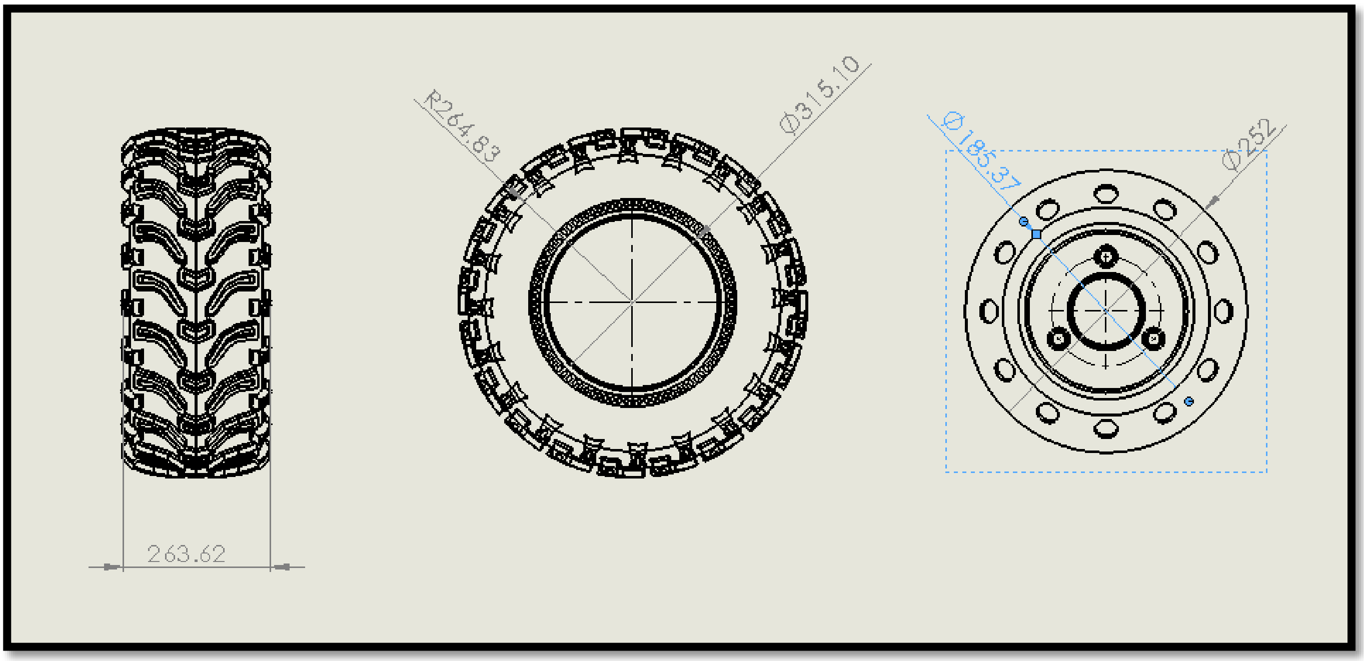
(2D drawing for the Hub & Front axle)



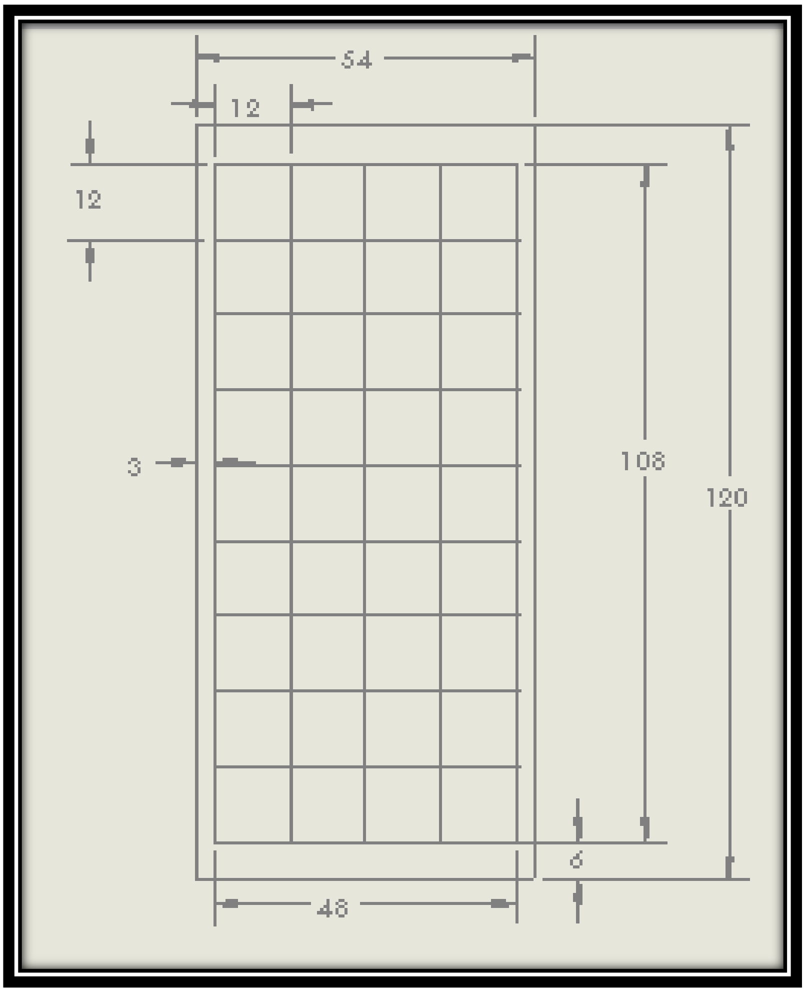
(2D drawing for the Chassis)



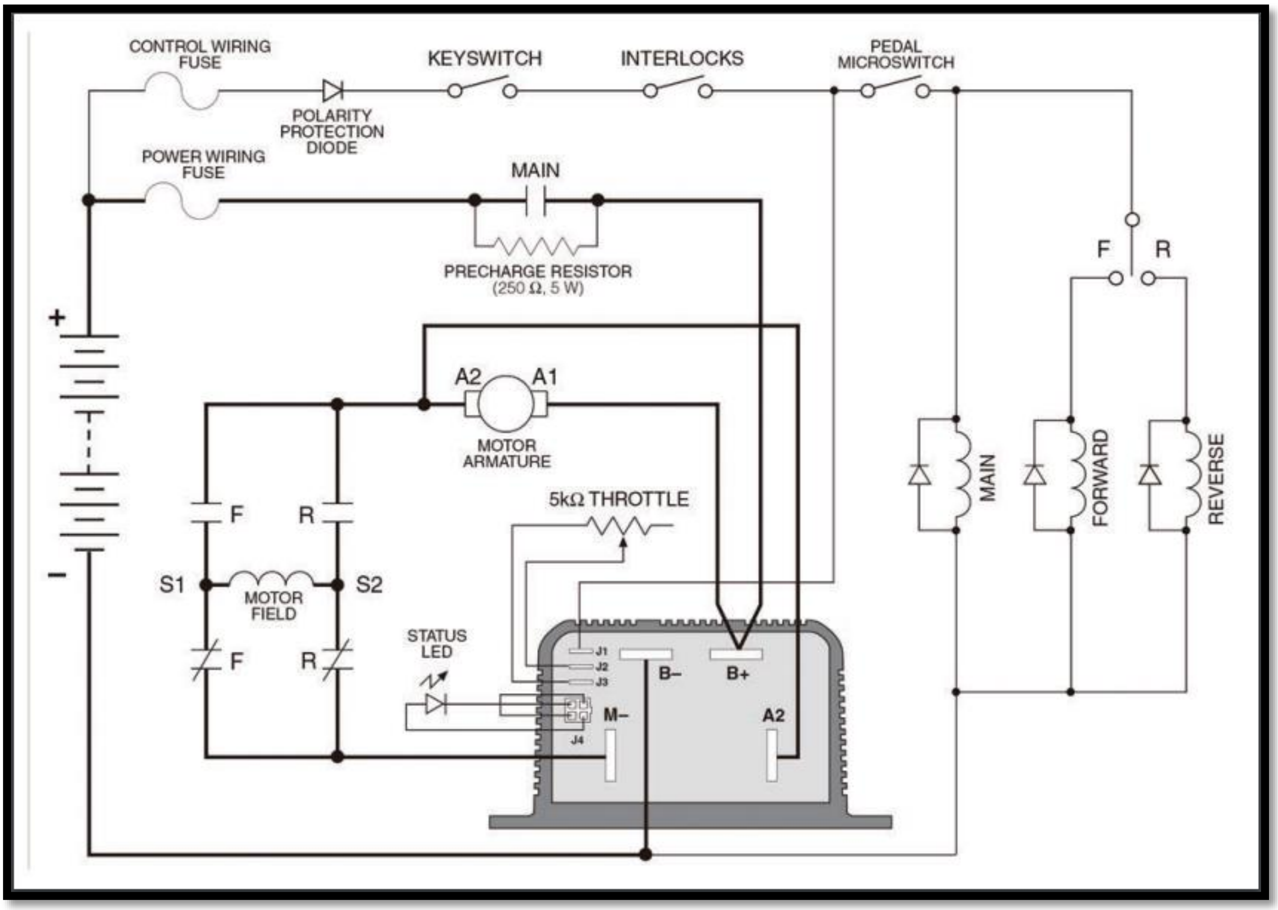
(2D drawing for the Hub and Rear axle)



(2D drawing for Tire)



(2D Drawing for Solar Panel)



(DC Series Motor Controller Wiring Circuit)

NEW OCEAN TECHNOLOGY CO., LTD.

Proforma Invoice

Date: 14/Apr/17 Invoice No.: 2017041400001

Customer: **Contact: Amar** **Contact Info: ammar884435@gmail.com**

Item No.	Description	Model	Quantity	Unit Price	Total Price	Remark
1	DC Series Motor	XQ-3-4	1	$545.00	US$545.00	48V DC, with square flange
2	CURTIS DC Series Motor Controller Assemblage	1204M-5203	1	$505.00	US$505.00	48V DC
				Domestic Logistic Fee:		
				Port Operational Fee:		
				FOB Price:		
				International Logistic Fee:	US$0.00	Expedited Service
				Document Fee:		
				CFR Price:		
	Insurance Rate:	0.10%		Insurance Fee:	US$0.00	
				CIF Price:	**US$1,050.00**	**Through PayPal Service**

NEW OCEAN TECHNOLOGY CO., LTD.

Address: 2304-2511, Morgan 100 Plaza, Downtown, Wuhu, China Postal Code: 241000

Email: info@nocoev.com Website: http://www.nocoev.com/

(Quotation for DC motor and Motor Controller Assemblage)

Appendix D: Program Codes

Microcontroller code

```
constintpwm = 2 ;             //initializing pin 2 as pwm
constint in_1 = 8 ;
constint in_2 = 9 ;

//For providing logic to L298 IC to choose the direction of the DC motor

void setup()
{
pinMode(pwm,OUTPUT) ;           //we have to set PWM pin as output
pinMode(in_1,OUTPUT) ;          //Logic pins are also set as output
pinMode(in_2,OUTPUT) ;
}

void loop()
{
//For Clock wise motion , in_1 = High , in_2 = Low

digitalWrite(in_1,HIGH) ;
digitalWrite(in_2,LOW) ;
analogWrite(pwm,255) ;

/*setting pwm of the motor to 255
we can change the speed of rotaion
bychaningpwm input but we are only
usingarduino so we are using higest
value to drive the motor  */

//Clockwise for 3 seconds
delay(3000) ;

//For brake
digitalWrite(in_1,HIGH) ;
digitalWrite(in_2,HIGH) ;
delay(1000) ;

//For Anti Clock-wise motion - IN_1 = LOW , IN_2 = HIGH
digitalWrite(in_1,LOW) ;
digitalWrite(in_2,HIGH) ;
delay(3000) ;

//For brake
digitalWrite(in_1,HIGH) ;
digitalWrite(in_2,HIGH) ;
delay(1000) ;
 }
```

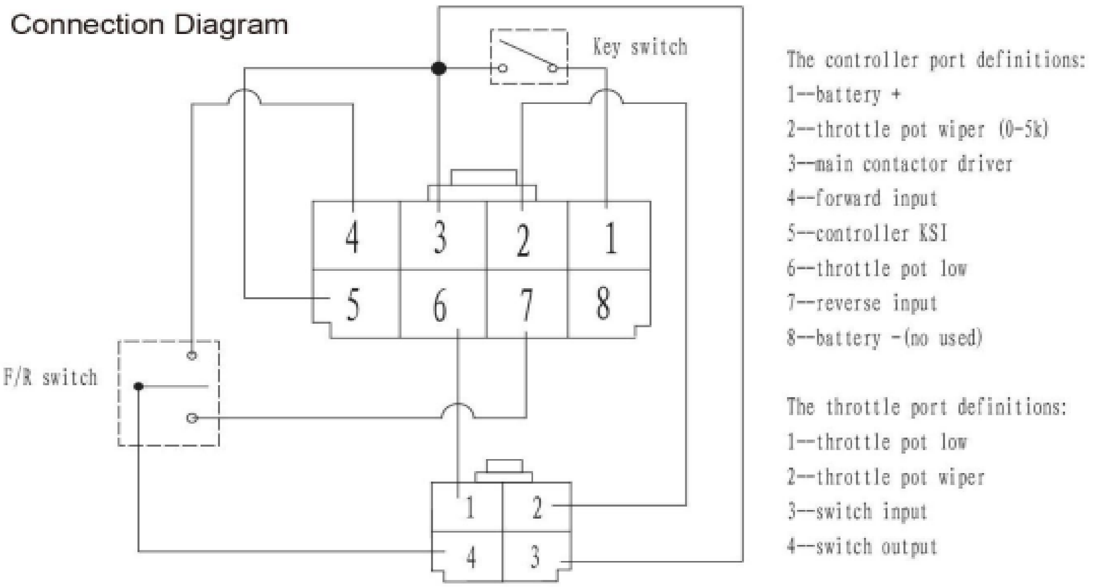
Appendix E: Operation Manual

Installation Instruction for CURTIS DC Series Motor Controller Assemblage

noco®
EV & Forklift Parts

CURTIS DC Series Motor Controller Assemblage

1. Checking the controller assemblage, battery system and motor:
   a) The whole assemblage status
   b) Installation kit & mating connectors
   c) Battery charging status
   d) Motor status (turning manually 2-3 rounds)
   e) The cables' length and insulation conditions
2. Preparing the mating connectors (please identify the wire number corresponding to the connectors on assemblage and throttle, as shown in the diagram):



   a) Throttle connector:
      i. If there is a throttle switch before the key switch, link the No. 3 wire to the throttle switch output; If not, link the No.3 wire to the key switch output
      ii. Link the No.4 wire to the Forward / Reverse switch "Power In" terminal (possibly marked as "B+" or "Input", please verify your F / R switch codification)
      iii. Link the No.1 wire to the assemblage mating connector No.6 wire
      iv. Link the No.2 wire to the assemblage mating connector No.2 wire
   b) Assemblage connector:
      i. Link the No.1 wire to key switch input terminal
      ii. Link the No.2 wire to the throttle mating connector No.2 wire
      iii. Link the No.3 wire to the key switch output terminal
      iv. Link the No.4 wire to F / R switch Forward output terminal
      v. Link the No.5 wire to the key switch output terminal
      vi. Link the No.6 wire to the No.1 wire of throttle mating connector

   vii. Link the No.7 wire to F / R switch Reversing output terminal
   viii. The No.8 wire could be linked to "0V" (B-), or be spared
  c) Try to connect and disconnect the connectors, making sure the all terminals are well contacted.
3. Mounting the assemblage and throttle on board. If there is an earth line, connect it to the assemblage aluminum plate.
4. Connecting all cables of battery and motor to the assemblage.
   a) Do not supply power to assemblage till confirming there is no "B+" and "B-" connection reversed. The reversed power poles' connection could cause an immediate system damage.
   b) Keep the F / R switch at neutral position, and the throttle at low end without output. Keep the vehicle braked.
   c) There are labels on the assemblage, indicating the connecting position, "B+", "B-", "D1", "D2", "A1" and "A2".
      i. We use "D1" and "D2" for motor field studs, while some DC series motor manufacturer use the symbols "F1" and "F2" (or "S1" and "S2").
      ii. "B+" and "B-" for battery positive and negative poles.
      iii. "A1" and "A2" for motor armatures.
5. Deliver power to the assemblage. Normally there should be a "click" sound of main contactor at the moment of power arriving.
6. Turn on the key switch, and keep the throttle at low end without output. Moving the F / R switch handle (or pushing the Forward / Switch buttons), check if the F / R contactor works by hearing the "click" sounds.
7. Release the vehicle brakes, put the F / R switch at "forward" position, step down a little the foot pedal (throttle) to start the motor. If the motor works, stop the motor, and try the same to reverse the motor.
8. Increasing slowly the motor speed till its max limit, run the vehicle for 5 minutes. Stop the vehicle, turn off the power, check the motor situation (if there is any overheating) and the assemblage (overheating or over-current).
9. By identifying there is no abnormal noise or smell, the system is installed correctly.