Performance Investigation of a Solar Powered Electric Car

By

Md. Abir Hossain
14121020
Abdul Majid Saiful
14121058
Md. Nazmus Sakib
13321065
Ajmir Hossain Nion
13321049

A thesis submitted to the Department of Electrical and Electronics Engineering in partial fulfillment of the requirements for the degree of
Bachelor of Science in Electrical and Electronic Engineering.

Department of Electrical and Electronic Engineering
Brac University
April 2019

© 2019. Brac University
All rights reserved.

Declaration

It is hereby declared that

1. The thesis submitted is our own original work while completing degree at Brac University.
2. The thesis does not contain material previously published or written by a third party, except where this is appropriately cited through full and accurate referencing.
3. The thesis does not contain material which has been accepted, or submitted, for any other degree or diploma at a university or other institution.
4. We have acknowledged all main sources of help.

Student's Full Name & Signature:

Md. Abir Hossain 14121020	**Abdul Majid Saiful** 14121058
Md. Nazmus Sakib 13321065	**Ajmir Hossain Nion** 13321049

Approval

The thesis titled “Performance Investigation of a Solar Powered Electric Car” submitted by

1. Md. Abir Hossain (14121020)
2. Abdul Majid Saiful (14121058)
3. Md. Nazmus Sakib (13321065)
4. Ajmir Hossain Nion (13321049)

of Spring, 2019 has been accepted as satisfactory in partial fulfillment of the requirement for the degree of Bachelor of Science in Electrical and Electronic Engineering on 25.04.2019.

Examining Committee:

Supervisor:
(Member)

_____

Dr. Mosaddequr Rahman
Professor, EEE
BRAC University

Program Coordinator:
(Member)

_____

Dr. Saifur Rahman Sabuj
Assistant Professor, EEE
BRAC University

Departmental Head:
(Chair)

_____

Shahidul Islam Khan, Ph.D.
Professor, EEE
BRAC University

Abstract Summary

In today's world, the most threatening situation we are going towards is global warming. The main reason behind this threat is fuel consumption from which harmful chemicals are releasing into the air & causing a devastating effect on environment. To reduce it, alternative source of energy as a fuel source is the key where solar energy plays a vital role. The objective of this paper is to develop the infrastructure of the existing solar car so that it can cover more distance per hour at the same battery charge level by modifying the differential so that the overall efficiency in case of battery consumption, speed & longevity of the car can be up to its full potential. In this paper, it also illustrates the overall result of the reliability of the solar car & also gives a glimpse to its future development scope.

This paper also focuses on the side to side to comparison of the data that were previously collected & the recent data after the upgrades to screen the practicality of this project. This includes the data logging, solar panel efficiency, the overall speed of the solar car & the distance covered in one full charge in daily condition.

Keywords: Solar car, solar, renewable energy, solar panel car, solar powered electric car.

Dedication

To Our Beloved Parents

Table of Contents

List of Figures

Chapter 1

Introduction

1.1 Importance of renewable energy

Energy that are obtained from natural sources are mainly considered as renewable energy. which are additionally inexhaustible. Common renewable energies include sunlight, wind, water tides, waves, biomass. As harmless as these energies are to the environment, they are also good alternative to those degradable non-renewable energy source assets. Ozone layer is being continuously harmed due to the massive emission of CO_2. To save the environment from this harm, it is high time that we move to a safer alternative which will cause no harm to the environment as well as provide enough power to fulfill our fuel demand. Renewable energy is the future if we want to save pollutant from power plants, nuclear reactor and fossil fuels.

As natural gas is the main source of energy for the huge number of vehicles in Bangladesh, the pressure has been increasing day by day as people are getting more solvent to buy a car of their own. Also, there are numerous public vehicles in the mega cities to meet the demand of people's everyday commute which also depends on natural gas as their main source of fuel. However, natural gas in Bangladesh is on the verge of getting finish and we still don't have any alternative source to it. Moreover, Bangladesh is also suffering from Global Warming and if we cannot control the emission of CO_2 which mainly comes from the increasing number of vehicles in megacities then the long-time sufferings will be immense. Hence, shifting to zero emission vehicle is the only solution to all these problems for the world and also Bangladesh.

The most suitable renewable energy for vehicle consumption till now is the electricity produced by the solar panel. As it receives energy from the sun which is cost free and its storehouse of energy, we will utilize this energy through this process. Amazing it may seem but one-hour equivalent energy received from sun is enough to meet the demand of 12 months more or less. All we need is the photovoltaic module having solar cells, charge controller and a battery. The charge controller plays out the errand by conveying power to the battery and by ensuring the battery is safe at the same time. The battery stores energy and use it to provide power to the vehicle. The charge controller performs a noteworthy job to switch the power connections from

cells to battery. As it is a sustainable power source, so it doesn't utilize all those materials, which causes harm to the environment.

1.2 Previous Works on Solar Panel Car

The first solar powered vehicle was invented on August 31,1955. The primary solar vehicle invented was a small 15-inch vehicle made by William G. Cobb of General Motors. Called the Sunmobile, Cobb displayed the solar vehicle at the Chicago Powerama tradition on August 31, 1955. The solar vehicle was made up 12 selenium photovoltaic cells and a little Pooley electric engine turning a pulley which thus pivoted the back-wheel shaft. The principal solar vehicle in history was clearly too little to even consider driving [1].

Figure 1.1: The first Solar Car

The most recent development on solar car which will be hitting the road on 2019 is Lightyear One which has won the recent Climate Change Innovator Award. Designed by the Dutch startup Lightyear, the “car that charges itself” can supposedly drive for months without charging and has a 400 – 800 km range [2].

Figure 1.2: Lightyear One

1.3 Importance of Solar Car in Bangladesh

The vehicle that we see on the road mainly use compressed natural gas which is mainly known as CNG. In year 2002, there were only five CNG filling stations in Dhaka. By 2005 it grew to 75 and now approximately 500 stations are operating [3]. Although CNG consumes only 5 percent of the gas production [4], the continuous increase in the number of vehicles only in Dhaka city is alarming. The main reason behind this is the ability to own a private vehicle has increased over the years. Approximately *300,000* of the *1 million vehicles* on the road are now CNG-fueled [3].

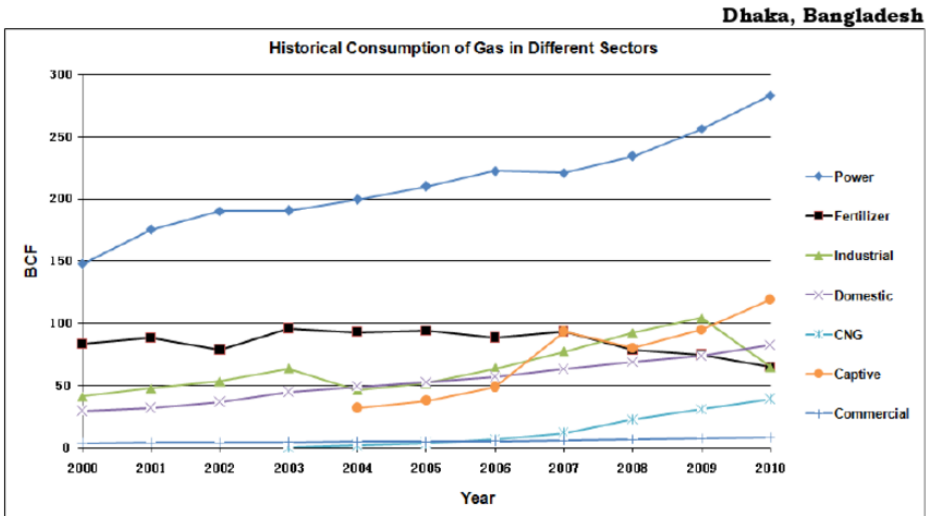


Figure 1.3: CNG consumption chart.

The main fuel reserve in Bangladesh is natural Gas. 815.98 billion cubic feet of gas had been extracted until June 2015. If the rate continues, Bangladesh will be able to use the reserve for around 16 more years, which means until 2040 [5].

So, we can see that the natural gas will not last forever for Bangladesh. Therefore, if we can lessen the consumption even by 1% by using solar powered vehicle in Bangladesh, it will protect us from both environment pollution and will be able to meet our needs of fuel from which we will be benefited both economically and we will save a lot of our resources for better use.

1.4 Advantages & disadvantages of Solar Panel Car

1.4.1 Advantages

- **Eco-friendly and Quiet:** As they are free of any utilization of non-renewable resources and fuel, so they have zero emission level. Also, neither pollutants or greenhouse gases are emitted by the electricity generated by the electric motors. Moreover, they don't produce any noise that conventional vehicle does as they are not powered by convention fuels.

- **Energy Availability:** As sun is unending power source, it always shines and provides unlimited energy, so solar cars can always derive their power from the sun. An efficient solar panel can produce and store more horsepower for the vehicle.

- **Zero Fuel Costs:** Unlike the conventionally fueled vehicles, solar vehicles have no fuel costs and a low cost of maintenance.

- **Driving Comfort:** Made up of aluminum and lightweight components, the solar powered cars run faster and more smoothly than petrol and diesel engine vehicles.

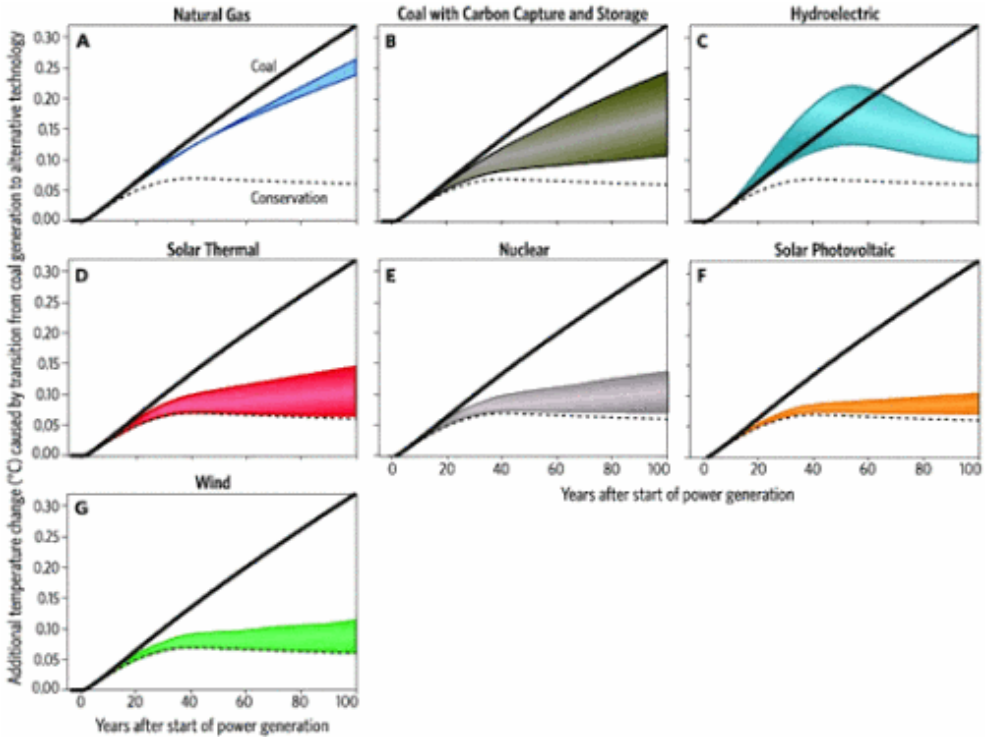


Figure 1.4: Clean Energy Sources

1.4.2 Disadvantages

- **Challenging Design:** It requires large surface area on the roof of the car to install the solar panels, have low wind resistance and space only for two passengers.

- **Poor Practicality:** These green vehicles don't have any driver security highlights and other gear, for example, wiper sharp edges, headlights and back view mirrors. Perspectives like suspension, chassis strength, steering, brakes, secured solar panels and batteries arrangement likewise should be paid attention to.

- **Expensive Batteries:** The efficient solar panels and batteries and their substitution are too costly that should be changed so frequently. This is the thing that makes the solar vehicles an expensive undertaking.

- **Energy Storage Capacity:** The photovoltaic cells or solar panels can convert 15-30% of sunlight into electricity, depends on the material used, which is quite limited.

1.5 Motivation

1.5.1 Air Pollution

The first motivation behind the solar panel car is the air pollution in Bangladesh. The main concern for the city dwellers of Dhaka city is the huge amount of air pollution that they have to face on regular basis. Broken vehicles, particularly diesel run vehicles, block furnaces, and residue from streets and building destinations and toxic fumes from industries add to air contamination. Industrialization and motorized vehicles are two noteworthy sources of air pollution in any nation. Those are unavoidable accompaniments of increased economic activity of any country. The quantity of vehicles has been expanding in Dhaka city at the rate of somewhere around 10 percent every year, which has been adding to air pollution from one perspective and traffic clog on the other. Diesel-run vehicles represent more than 80 percent of the air contamination in Dhaka as the greater part of them neglect to conform to the approved emission standard, said a recently published survey report [6].

Around 60 percent of the city inhabitants think about engine vehicles as the fundamental sources of air contamination, around 55 percent consider diesel-run transports to be most dirtying the air and 22 percent feel that diesel-run trucks cause the air pollution. Air pollution in Dhaka is serious because of expanding populace and related motorization. The city's normal SPM levels are around multiple times higher than the Bangladeshi standard of 200 µg/m3 in local locations and are in 10 times higher than the WHO rules of 120 µg/m3 (24hours) in business territories [6].

	Particulate matter (PM10)	Hydrocarbons	Carbon Monoxide	Nitrogen oxides	Lead	Carbon dioxide	Methane
Light duty vehicles	0.26	3.70	24.91	1.63	0.012	309	0.04
Mini bus	0.21	0.12	0.30	0.58	0.003	115	0.02
Diesel bus	0.64	0.42	1.40	2.65	0	324	0.02
Diesel truck	1.11	0.74	1.91	3.61	0	563	0.03
3-wheeler	0.93	13.52	16.37	0.07	0.011	147	0.19
2-wheeler	0.55	3.31	5.81	0.02	0.011	50	0.11
Total	3.70	21.80	50.70	8.55	0.037	1507	0.40

Fig 1.5: Baseline vehicular emissions inventory in Dhaka, 1996; Unit: 1,000 tons

Initial estimates reveal that motor vehicles annually emit 3,700 tons of particulate matters (PM10), 8,550 tons of nitrogen oxides, 50,700 tons of carbon dioxide, etc. TSEVs (mainly 3-wheeler baby taxis) are the significant contributors [7].

1.5.2 Global Warming

Global warming is one of the major motivations behind the solar powered vehicle. Bangladesh is one of the top countries to be suffering severely from global warming in the recent years. In recent years, we have seen untimely rain, extending winter since March, late coming of winter in November & excessive rain in the rainy season. These are all due to the effect of global warming.

CO_2 emission in Bangladesh has increased at an alarming rate due to industrialization and motorization which is affecting mainly Dhaka the most. Recently, we can see rid sharing companies are blooming in Dhaka city which is causing more CO_2 emission in Dhaka. Almost 5.2% of the total CO_2 are emitted by the public vehicle [8].

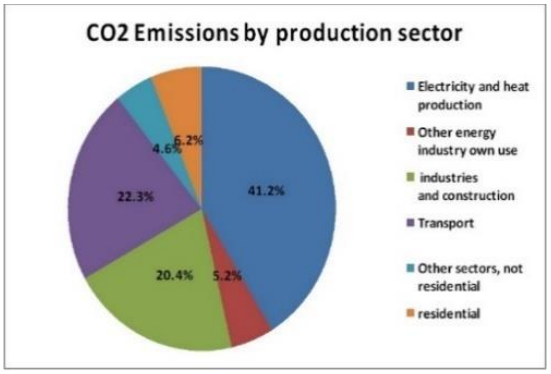


Figure 1.6: CO_2 emission by vehicle

1.5.3 Fuel Prices

The increasing amount of fuel prices has acted as our last motivation for solar powered vehicle. As day by day, the number of vehicles is increasing in Dhaka city, so it causing more demand of fuel which is having impact on fuel price.

In 2016, diesel price for Bangladesh was 0.84 US dollars per liter. Diesel price of Bangladesh increased from 0.26 US dollars per liter in 1998 to 0.84 US dollars per liter in 2016 growing at an average annual rate of 15.45 % [9].

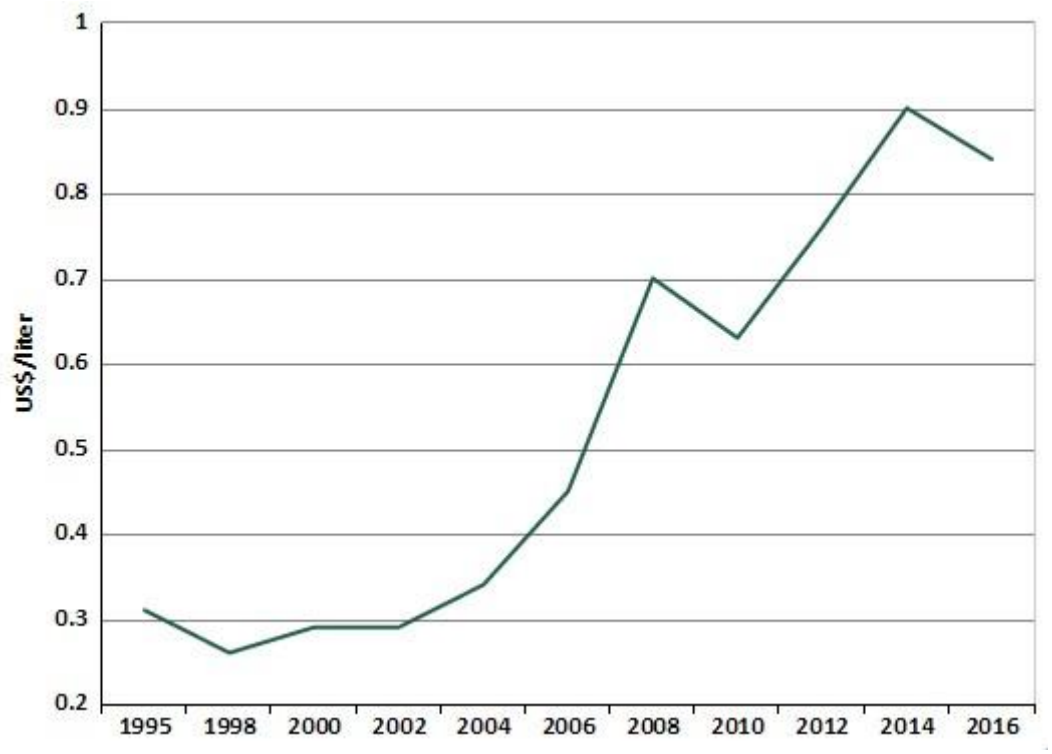


Figure 1.7: Fuel price increase in Bangladesh

To summarize, the main motivation behind solar car is the pollution of air, rising global warming and price hike of fuel. Once we can move to a fully functional and reliable solar car, the negative effect of present conventional vehicle towards the environment would reduce to a great extent. As it will have significant impact on reducing air pollution of Dhaka city as it does not emit any harmful chemical through its exhaust. Moreover, it will also help to reduce the greenhouse effect on Dhaka as there will be zero CO_2 emission. Lastly, there would be no fuel expense to think about after the major cost of the component's installations.

Hence, if we want to build a greener Dhaka city, moving to solar car has an immense role.

1.6 Project Objective

The objective of this thesis study includes the following topics:

- To increase the battery capacity of the existing car.
- To increase the total duration in one full charge battery condition.
- To increase the speed by modifying differential of the car
- To identify the existing hardware drawback and upgrade it.
- To know in detailed structure about the best way to design a solar car and make it more efficient in the future.

Chapter 2

Project Overview

2.1 Introduction

We can divide the whole system of the solar panel car into two parts:

1.Electrical.

2.Mechanical.

Here, electrical part is mainly considered as the input and the mechanical part as the output of the solar car system.

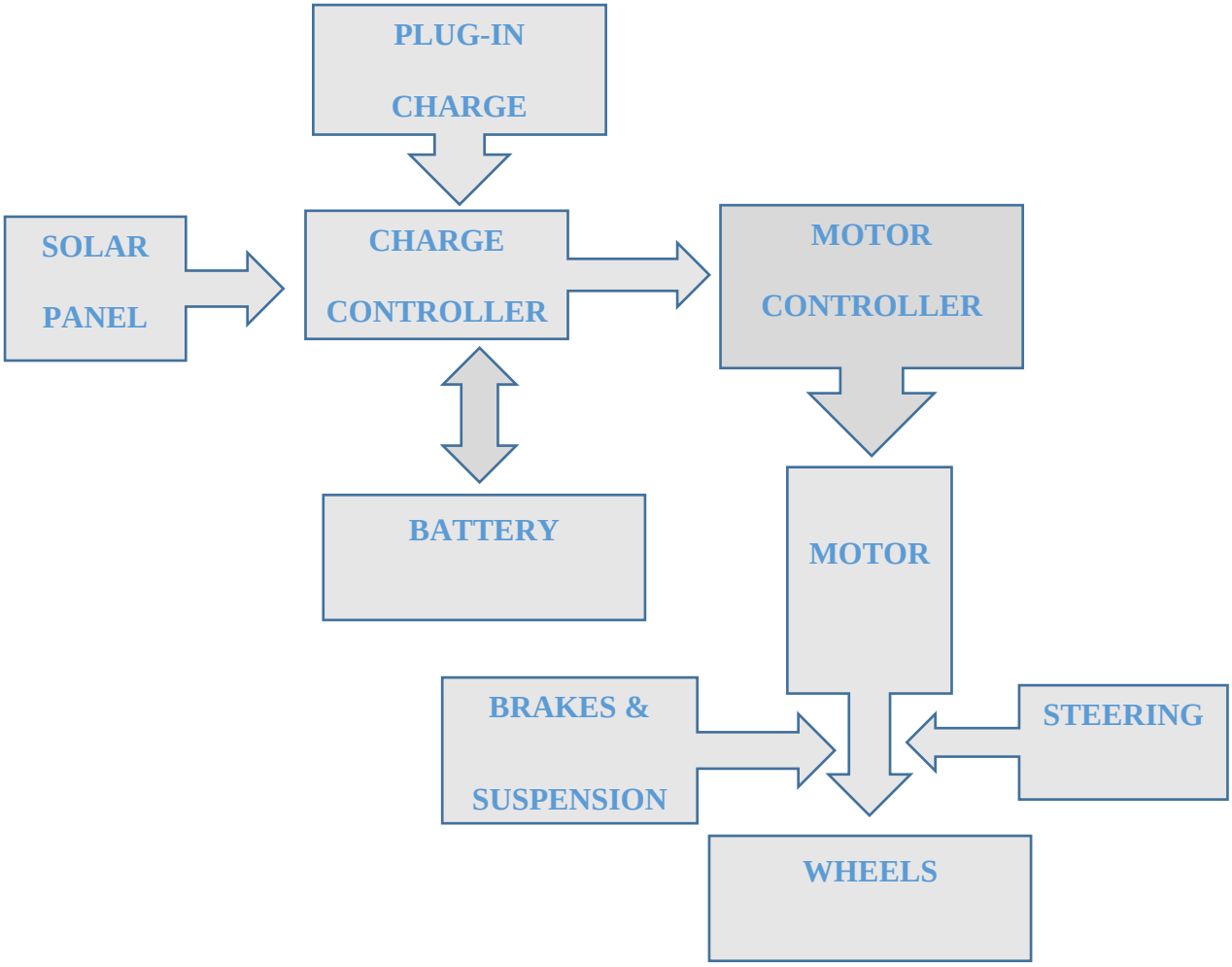


Figure 2.1 (a): System architecture of the solar car

Figure 2.1 (b): Solar Panel Car

2.2 Solar Panel

The development of solar panel is a continuous process since its first invention in 1954.In 1954, **Photovoltaic** technology is born in the United States when Daryl Chapin, Calvin Fuller, and Gerald Pearson develop the silicon **photovoltaic** (**PV**) **cell** at Bell Labs—the **first solar cell** capable of converting enough of the sun's **energy** into **power** to run every day electrical equipment. The initial efficiency was less than 8% of the total energy it could acquire from the sun ray. [10]

Since then, we have achieved a great success in increasing the efficiency. Right now, DS1, which is a satellite, has a solar panel which is the most advanced solar panel till now can convert up to 22% of their available energy into electrical power [11].

At present, there are mainly four types of solar PV technology subsists. They are-

- Single crystalline or mono crystalline
- Multi crystalline or poly crystalline
- Thin film
- Amorphous silicon
- Single Crystalline or Mono Crystalline

Among these 4 cells, the most efficient one is the mono crystalline silicon cells. One of its advantage is that, it is high efficiency and sleeker aesthetics. To make solar cells for monocrystalline solar boards, silicon is shaped into bars and cut into wafers. These sorts of boards are designated "monocrystalline" to show that the silicon utilized is single-crystal silicon. Since the cell is made out of a solitary single crystal, the electrons that generate a flow of electricity have more space to move [12].

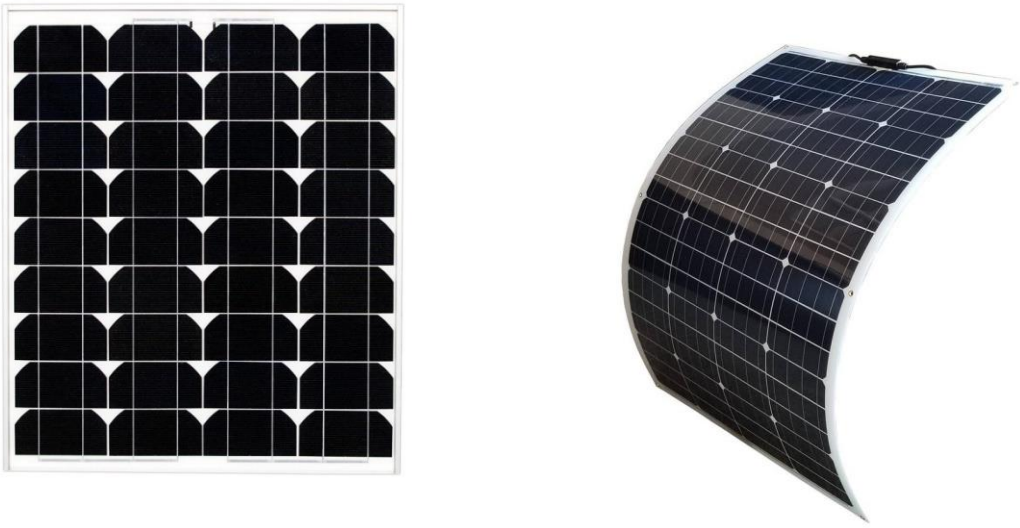


Figure 2.2 (a): Monocrystalline PV Cell.

The solar panel that have been chosen for this project is monocrystalline PV cell. The reason behind this is their nature of flexibility and the highest efficiency among the rest. Due to this, we can easily set it on the roof and bonnet of the car by flexing it. To be specific, it is a 50w semi flexible solar panel. By taking into consider the overall cost, longevity, durability, warranty, size and wattage, five monocrystalline flexible solar panels, bought from

Chinese based company “Shenzhen Shine Solar Co. Ltd”, was used in the making of the solar car [13].

The rating of the 5 solar panels that were provided by the company is as follows:

50 Watt Monocrystalline Bendable Photovoltaic Module

Made with high efficiency back-contact solar cells

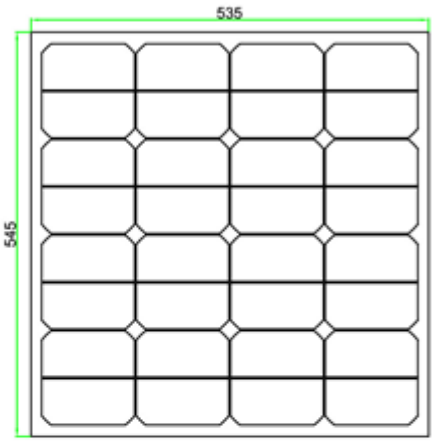
Electrical Characteristics

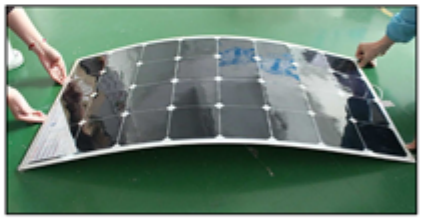
Max Power	Pmax	50W
Max Power Voltage	Vmp	17.6V
Max Power Current	Imp	2.84A
Open Circuit Voltage	Voc	21.2V
Short Circuit Current	Isc	3.05A
Maximum System Voltage		600V
Series Fuse Rating		10A
Temperature Co-efficients		
	Power	-0.38%/℃
	Voltage	-60.8mV/℃
	Current	2.2mA/℃
Cell Efficiency		21.5%
Number of Cells in Series		32
Max Power tolerance		±5%

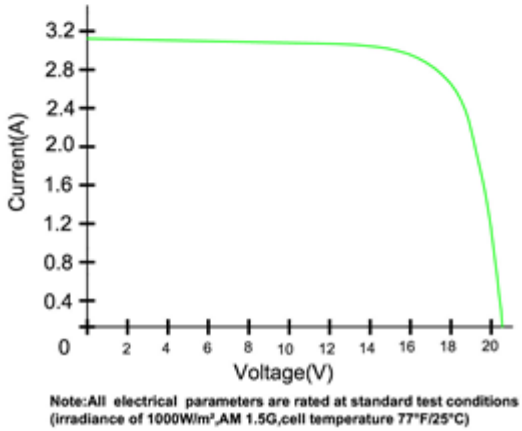
Mechanical Characteristics

Weight	0.7KG
Dimension	545*535*3

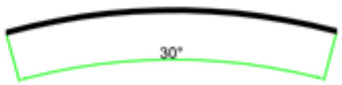
Dimensions







Note:All electrical parameters are rated at standard test conditions (irradiance of 1000W/m²,AM 1.5G,cell temperature 77°F/25°C)



Maximum recommended bending degree:30 degree

Figure 2.2(b): The ratings and specifications of the solar panels used

2.3 Battery

A device which is a collection of one or more cells whose chemical reactions create a flow of electrons in a circuit. It consists of mainly three components: an anode (negative side), a cathode (positive side) and some kind of electrolyte (a substance that reacts chemically with the anode and cathode).

For providing uninterrupted output to the solar car, we are using battery as a media for storing energy. There are mainly two types of battery on the basis of charging capability-

- Primary
- Secondary

2.3.1 Primary Battery

Primary batteries are non-rechargeable battery which is mainly used for single time purpose and then are rejected. When the material in the cathode or anode is consumed or no longer able to be used in the reaction, the battery is unable to produce electricity, they are considered as dead. There are many types of primary battery. The most noteworthy are-

- Alkaline battery
- Aluminum-air battery
- Aluminum ion battery
- Bunsen Cell
- Dry cell
- Zinc-air battery
- Lithium battery etc.

Figure 2.3: Some type of Primary Batteries

As we need something which can us reusable as well as rechargeable for long time use, so we did not consider the primary batteries.

2.3.2 Secondary Battery

The batteries which are rechargeable and can be used over and over again unlike primary battery are known as secondary battery. Some of the most common secondary batteries are-

- Flow battery
- Fuel Cell
- Molten Salt battery
- Nickel-Cadmium battery
- Potassium ion battery
- Lithium ion battery
- Lead Acid Cell battery

As we will be needing a battery which are rechargeable and can store the extra charge from the solar panel to a battery so we go with secondary battery. Among all these types of battery, we have chosen Lead Acid Cell Battery as it is able to supply high surge current although it has low energy to weight and low energy to volume ratio. Below, we have described in a nutshell what lead acid battery is.

Lead Acid Cell Battery

It is one of the oldest types of battery and it was the first rechargeable battery for commercial use. It is not supported by first charging. To charge this, it takes almost 8 to 16 hours. Deep cycling is not recommended for it. A full discharge causes extra strain and each cycle cuts off some service life of the battery. To prevent the battery from being stressed through repetitive deep discharge, a larger battery is recommended. The self-discharge is about 40% per year, one of the best on rechargeable batteries. [14]

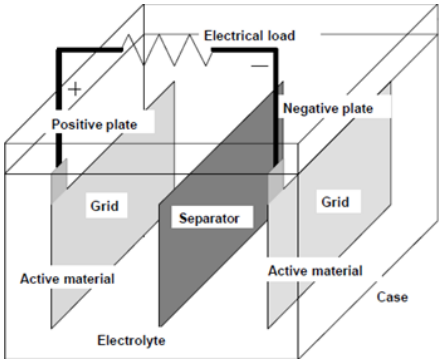


Figure 2.4: Lead Acid Cell Battery

Here are some of the advantage and disadvantages of lead acid cell battery-

Advantages

- Inexpensive and simple to manufacture.
- Mature, reliable and well-understood technology - when used correctly, lead-acid is durable and provides dependable service.
- The self-discharge is among the lowest of rechargeable battery systems.
- Capable of high discharge rates.

Disadvantages

- Low energy density - poor weight-to-energy ratio limits use to stationary and wheeled applications.
- Cannot be stored in a discharged condition - the cell voltage should never drop below 2.10V.
- Allows only a limited number of full discharge cycles - well suited for standby applications that require only occasional deep discharges.
- lead content and electrolyte make the battery environmentally unfriendly.
- Transportation restrictions on flooded lead acid - there are environmental concerns regarding spillage.
- Thermal runaway can occur if improperly charged.

Therefore, considering all this pros and cons, even after 150 years after its invention, there is not a single better alternative to lead acid cell battery considering the cost effectiveness. Hence, we have utilized 5 lead acid cell battery for the solar panel car where each of them is of rating 12V/180Ah. Each of the batteries has a weight of around 15 kilograms.

2.4 Charge Controller

A charge controller or charge regulator is essentially a voltage or potentially current controller to shield batteries from overcharging and discharging. It controls the voltage and current originating from the solar panel heading off to the battery. Most "12 volt" boards put out around 16 to 20 volts, so if there is no guideline, the batteries will be harmed from overcharging. Most batteries need around 14 to 14.5 volts to get completely charged. [15]

The main purpose of the charge controller is to work as a battery management system (BMS) where it is responsible for managing the charging and discharging of the battery. A PIC 16F876A microcontroller chip has been used to manage it.

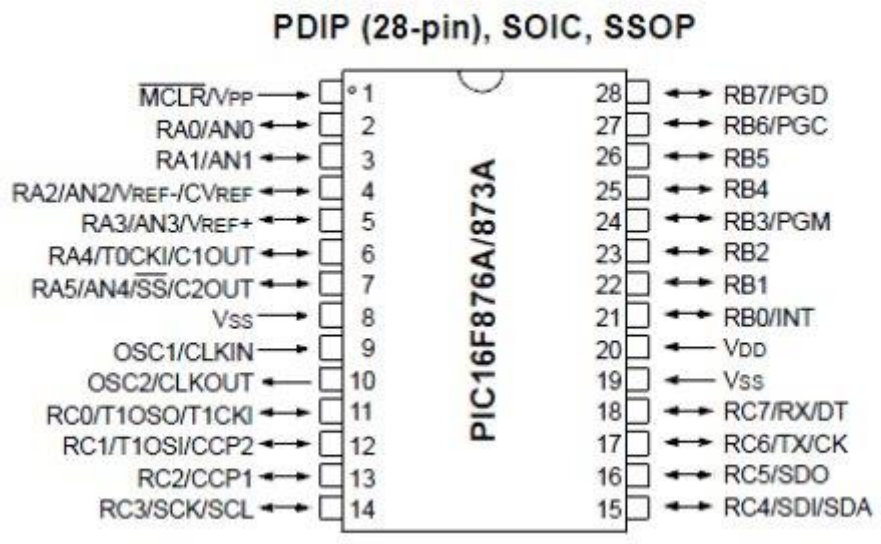


Figure 2.5: PIC 16F876A microcontroller chip

While charging, if the battery charges above 100%, it will show that it is over charged, also when the battery is discharged below 20%, it will show that it has over discharged. To ensure the overall longevity of the battery, the battery charging range should remain between 20% to 100%. Similarly, it will disconnect the solar panel from the charger as soon as it crosses the ranges during both over charging and discharging.

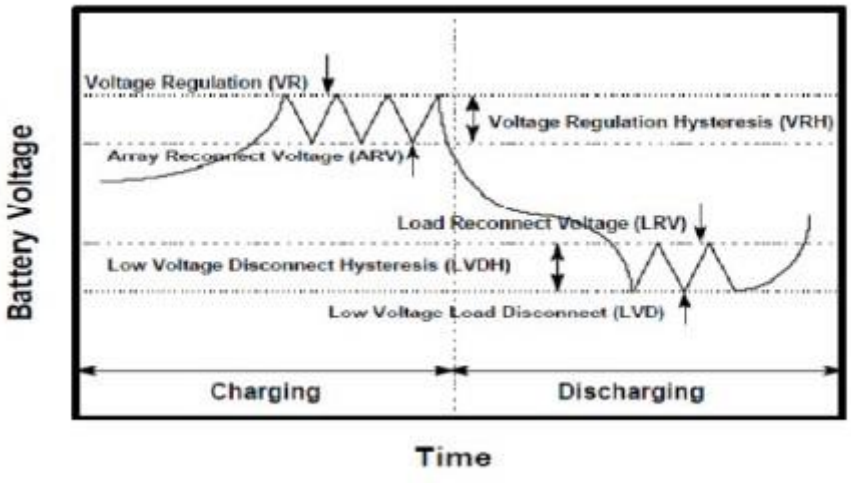


Figure 2.6: Charge Controller Set Points.

Figure 2.7: Charge Controller of the Solar Panel Car.

The charge controller parameters that were set are [16]-

1.

□AC (3 steps, due to high charging current):

- Stage 1: 0-14V : 90% PWM charging
- Stage 2: 14-14.2V : 50% PWM charging
- Stage 3: 14.2-14.3V : 10% PWM charging

0% PWM above 14.3V

2.

□Solar panel (2 steps, due to high charging current):

- Stage 1: 0-13.4V : 90% PWM charging
- Stage 2: 13.4-13.7V : 10% PWM charging

0% PWM above 13.7V

3.

□Low voltage disconnect at 10.8V and reconnect at 12.4V.

□Max charging currents:

- 4A for charging via solar panel
- 8A for charging via AC.

□Charge controller input voltage and current range for

- Solar panel charging are 75V and 10 A respectively

□AC line charging are 90V and 10 A respectively

2.5 Plug in Charging

As there might not be the perfect weather for the solar car to charge itself from sunshine, so we have also allowed it to have an option to AC charge the batteries from any AC power source during foggy or rainy weather. It can be charged simply by plugging in the AC power source. This allows the flexibility of the user when this type of condition arises. Moreover, it also allows the increase in overall utility of the car.

2.6 Motor and Motor Controller

The motor that has been used is a DC series excitation motor which is rated at 2 kW, 60V. Its rated RPM rating is 3000 rpm. The controller used in the solar car has an input and output rating of 48 to 60 volt and has a current rating of max 30 ampere. There are two outputs from the motor controller, one for the acceleration pedal and other for the motor [13].

Figure 2.8: Motor

DC series excitation motor is considered as one of the simplest types of motor. The reason behind the brushed type was chosen is that it is simple to work with and it produces torque directly from DC power supplied to the motor which makes it convenient to control its speed and direction of rotation.

The basic working principle of the electric motors is that when current flows through, magnetic flux is generated which allows the rotor coils to interact with the magnetic flux of the magnet which causes rotational motion of the coil.

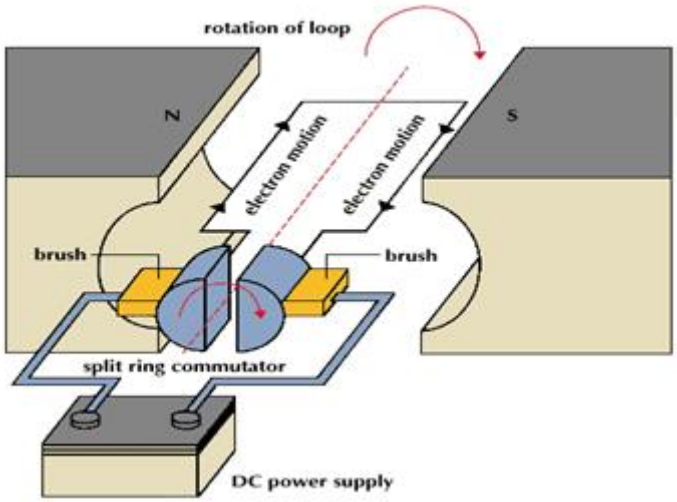


Figure 2.9: Basic Motor Working Principle.

In case of DC series motor, another coil winding called the armature winding which generates a magnetic field when current flows through it replaces the permanent magnet.

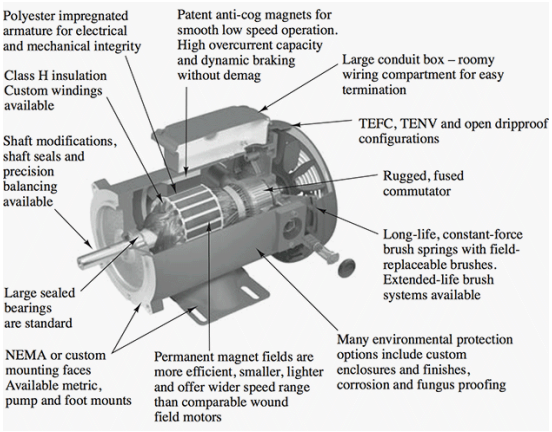


Figure 2.10: Internal Construction of DC Series Motor.

In the internal circuit of the DC series motor, the armature and field windings are in series with DC voltage to be applied. Here, the rotational speed in equally proportional to the DC applied voltage which means more the applied voltage, more the speed.

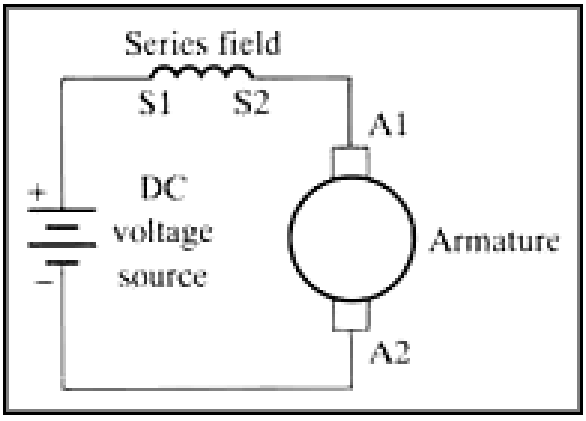


Figure 2.11: Internal Circuitry of DC Series Motor.

2.7 Steering, Suspension, Brakes, Wheels

The mechanical part of the car consists of these four parts which includes the steering, suspension, brakes and wheels.

Front wheel steering is used as it provides more stability and safety while riding the car.

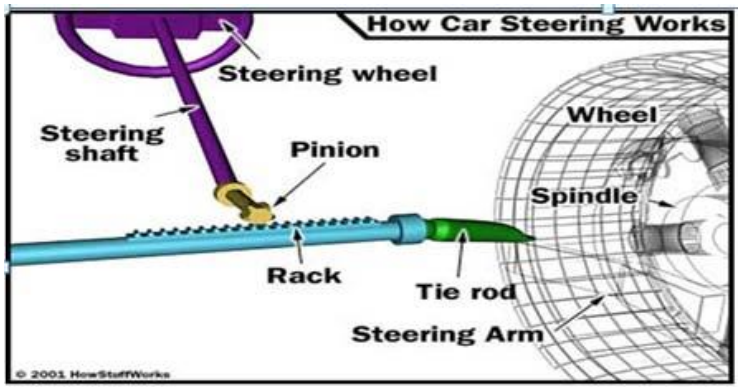


Figure 2.12: Car Suspension Working Mechanism.

The suspension that has been used here is good enough to allow the rider a smooth ride and protect the car and the solar panels from unwilling shocks and blows. Carbon suspension used in this car serves three special purposes namely road isolation, road holding, cornering.

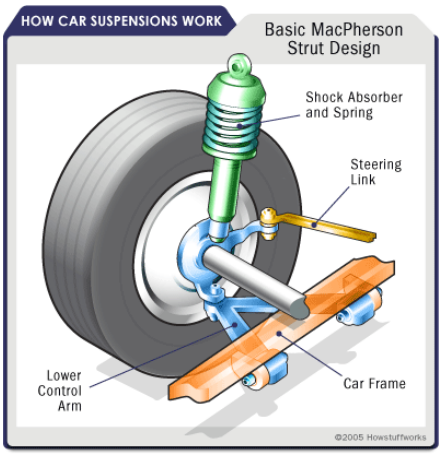


Figure 2.13: Car Suspension Working Mechanism.

In case of braking system, drum braking system has been installed to provide smooth and safe brake while travelling in the car. Moreover, to have minimum rolling resistance, a thinner in dimension but strong wheels were preferred as thicker wheels have more rolling resistance which causes the reduction in speed.

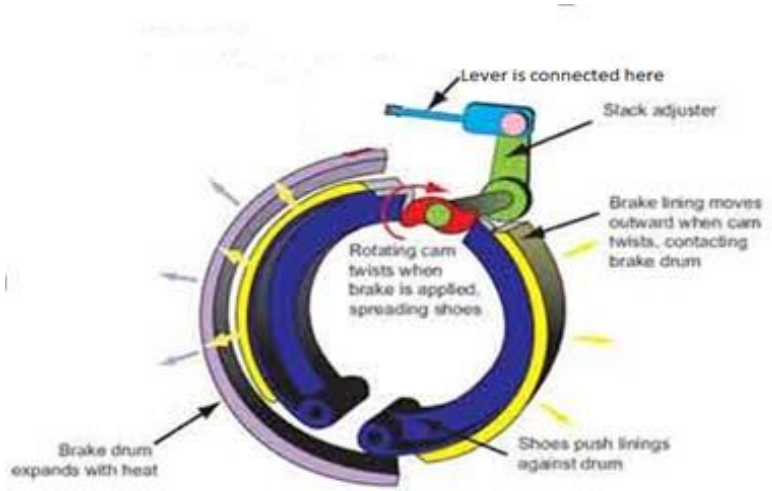


Figure 2.14: Drum Braking System Working Principle.

2.8 Summary

There are mainly two part of the solar car which includes mechanical and electrical part. For providing power to the car and storing charge from the solar panel, it was decided to go with lead acid battery as they are inexpensive and self-discharge rate is low. Also, mono crystalline cell is installed due to its flexibility and highly efficient among the rest. Moreover, charge controller has been used for controlling over charge and low charge problem. Furthermore, drum braking system is used for better break and also, good quality steering, suspension is there for smoother ride. Lastly, thin wheel is installed for low friction and better efficiency.

Chapter 3

Component Checking and Upgrades

3.1 Introduction

Components of electrical vehicle and combusting engines are not same. Electrical engine has few major components but the calculation is more precise. From the beginning of our project we have the only goal to enhance the efficiency of the solar car. Main three components we worked with the solar car and compared to the previous works are:

- Compare the motor performance ratings required the necessary speed and acceleration.
- Compare the battery capacity which will determine the longer distance required to be travel.

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

3.2 Motor Performance

The motor determines the speed of the vehicle after getting the necessary voltage from the battery. In our project, we used 3000 rpm rated motor which was already preinstalled during previous thesis work.

Motor controller provides the right amount of voltage and current and also provides isolation. When we evaluated the existing motor controller, we saw that it lacked some wire which could be used for adding necessary features to the car like forward and reverse gear function. Also, it was less efficient. So, it was decided that an upgraded motor controller is needed to add the full functionality of the solar car. Hence, for providing the necessary functionality, we replaced the 48-60V, 1200W motor controller with a new one but with all preinstalled wire.

Figure 3.1: Upgraded Motor Controller.

The motor controller usually has different wires for different purpose. The wire purpose of the motor controller that has been used is given below.

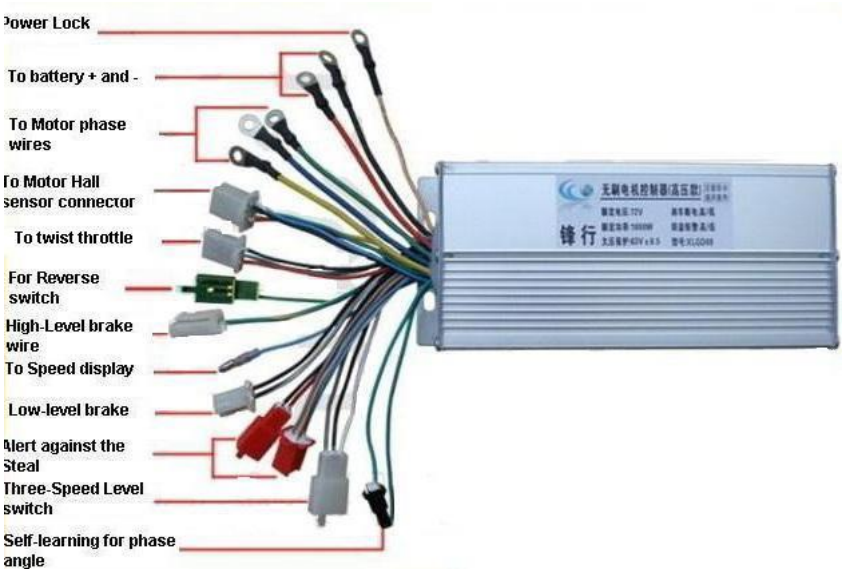


Figure 3.2: Motor Controller wire functionality.

Moreover, a forward and reverse speed control switch which will make the solar car go forward and reverse was installed for the ease of driving it.

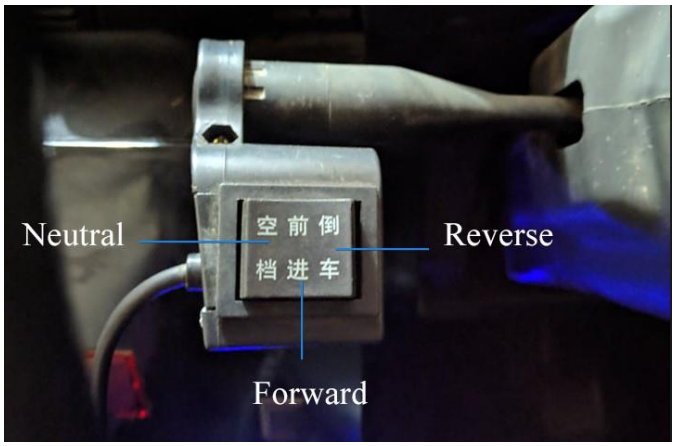


Figure 3.3: Forward and reverse control switch.

Furthermore, a new hand throttle was installed replacing the previous one on the accelerator wiring point in the engine room of the car to make it easy for accelerating.

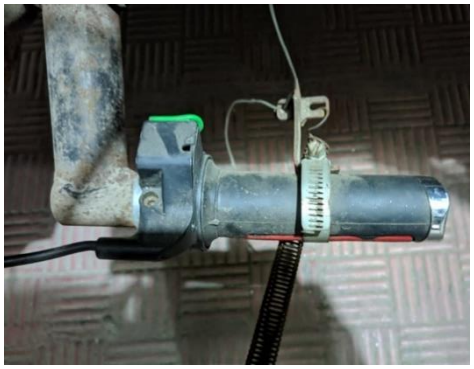


Figure 3.4: Hand throttle on the accelerator wiring point.

3.3 Battery Capacity

Battery capacity is the measurement of units of amp-hour (Ah.). The capacity of the battery determines the vehicles' acceleration, speed and also contributes how far the vehicle moves and how much battery charge will consume. The capability of the battery is proportional to efficiency of the car.

The existing battery of the car has gotten very weak over the time. As a result, the car was not getting sufficient energy from the battery to make it run. Also, it was uncapable of storing the charge for long time. Moreover, carbon was getting infused on the connecting point of the batteries which was not allowing it to get charge from the AC source. Hence, it was decided to get a new set of battery for enhancing the overall efficiency and for getting the best performance from the battery.

The preinstalled battery had a rating of 180 Ah but it could barely give output up to 100 Ah. So, 5 set of new and high capacity battery was brought from Rahimafrooz company to install it in the solar car.

Figure 3.4: Previous battery (left) Vs. New battery(right)

3.3 Differential

Differential is a gear train with three shafts that has the property that the rotational speed of one shaft is the average of the speeds of the others, or a fixed multiple of that average [17].

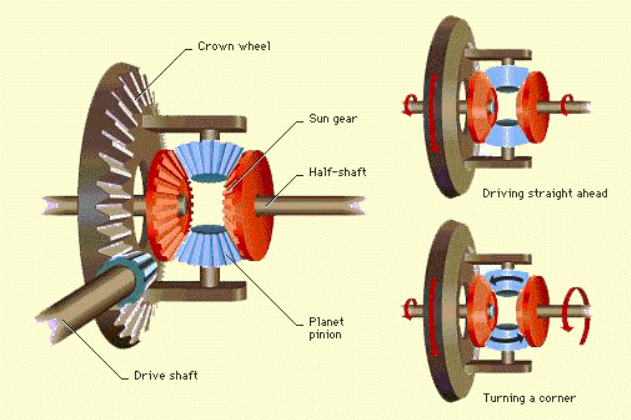


Figure 3.5: Diffraction.

To increase the efficiency of the solar car, one thing that was not possible to do was to modify the other part of the car as they were all in pristine condition. So, the only way the overall speed can be increased was to modify the differential part of the car. Hence, it was decided that the differential can be modified to reach the target speed of 45 kmph.

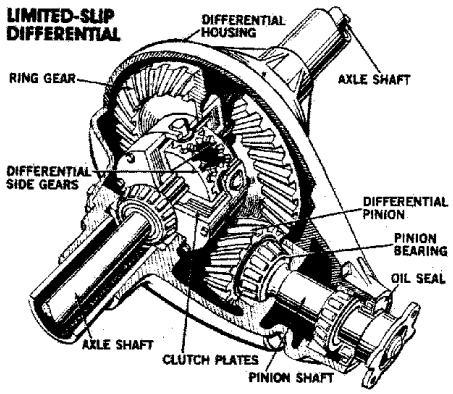


Figure 3.6: Inside differential.

The way it was modified is that the teeth of the pinion were increased using lathe machine so that it can rotate more. Hence, the overall speed was increased from 35 kmph to 45 kmph.

3.4 Battery Level Indicator

The existing battery level indicator of the car that is prebuilt in the black box does not show the perfect reading of the battery level. That is why a new battery level indicator was built to measure the battery level and battery voltage perfectly with the help of Arduino.

Figure 3.7: Battery Level Indicator.

Here, the positive and negative end of the wire was connected with connection of the car. It was built based on the voltage divider rule. As Arduino cannot measure voltage more than 5v, so this rule was used in the code to measure the values. Things that was used to create it:

1. Arduino Pico.
2. Resistor.
3. 10k Potentiometer.
4. Wire.
5. Copper board.

It has to be powered by a power bank which can provide 5v to the Arduino. It was calibrated to measure the voltage of the battery and charge percentage.

3.5 Summary

Firstly, the differential was modified to increase the speed. Later on, it was found out that the car was unable to run due to low battery performance, hence the battery was changed to a better one with better Ah rating. Also, the motor controller was changed to a new one as the present one lacked some important wire. Furthermore, a new Arduino powered battery controller was installed to measure the battery voltage and battery percentage as the present built in battery level indicator does not show as accurate value as it.

Chapter 4

Data Acquisition and Analyzing

4.1 Introduction

The main objective of this chapter is to find the change of speed, change of voltage both with respect to time. Then the voltage and current of both battery and solar panel was found out from using multi meter to find out the power and energy rating of both solar panel and battery respectively. Finally, comparing with the previous data before the upgrades were discussed and shown how the efficiency has been increased.

4.2 Required components:

Location:

The road that we used to test the vehicle is at 300 feet, beside the Purbachol Pragati Sharani-Debgram high road. It was a road of almost 900 meter in length with no speed breaker.

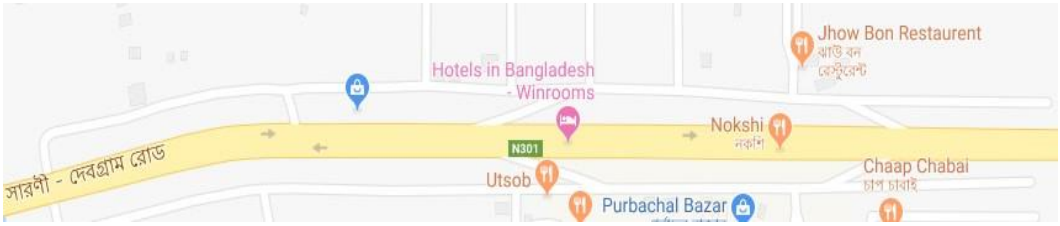


Figure 4.1: Field testing location.

Tools:

1. Four crocodile wire.
2. Two multimeters.
3. One clamp meter.
4. Speedometer app.
5. Smart phone.

Duration:

All the data were taken in bright sunlight with almost no cloudy weather. The duration that was needed to acquire all the data were 5 hours. It was ensured that the solar panel is exposed to the brightest sunlight it can have. As a result, the solar panel's output was nearly the best that it could output.

4.3 Vehicle Field Test Analysis

Field Test No.1

1. Speed of the vehicle:

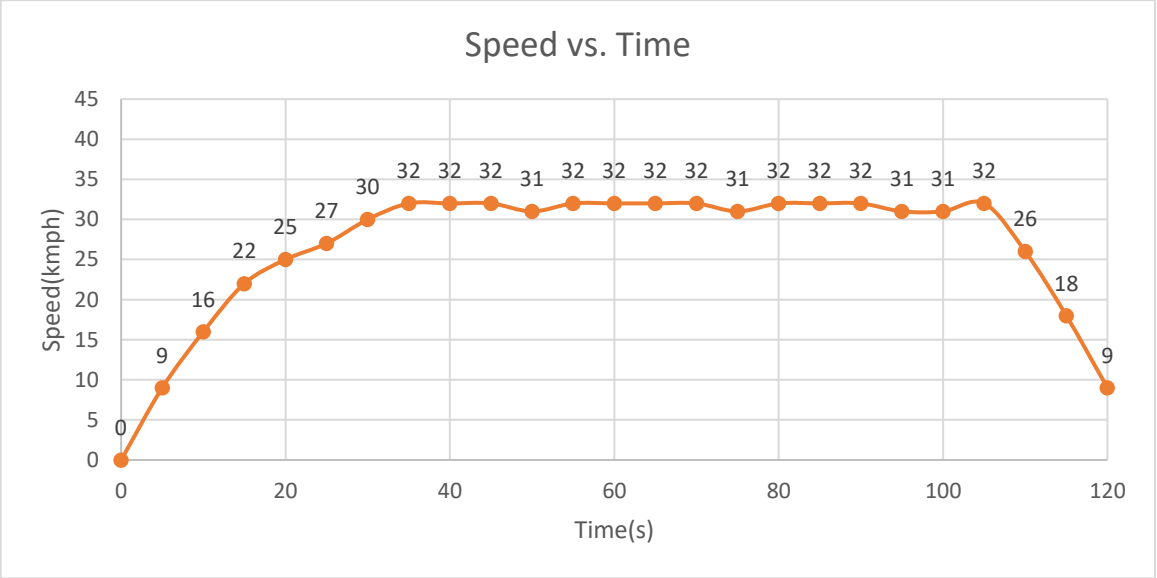


Figure 4.2: Speed vs. time 1

Maximum speed: 32 kmph

2. Distance travelled by the vehicle:

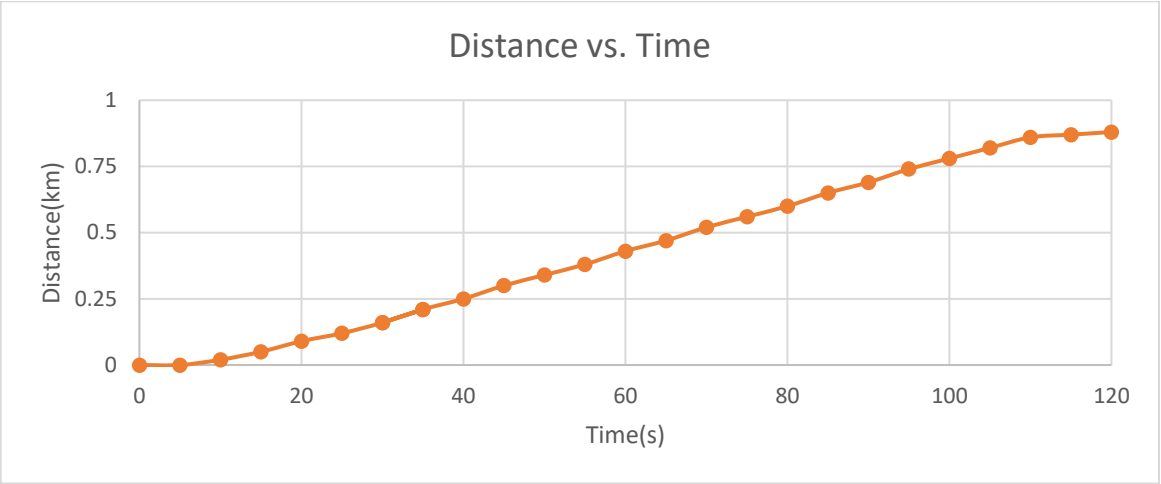


Figure 4.3: Distance vs. time 1

3. Speed vs. Distance comparison:

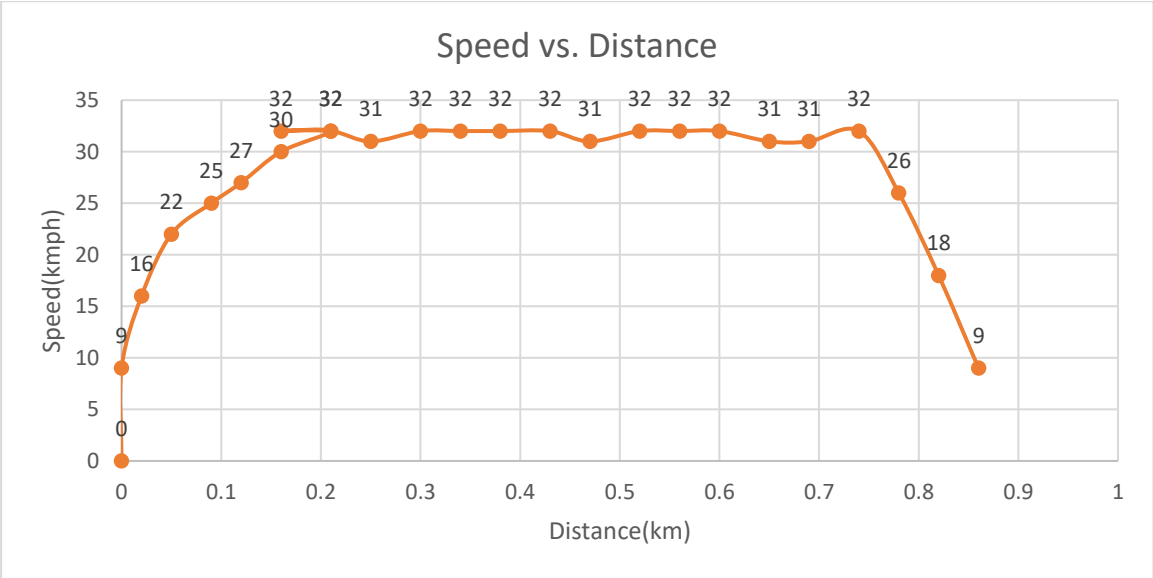


Figure 4.4: Speed vs. distance 1

Field Test No.2

1. Speed of the vehicle:

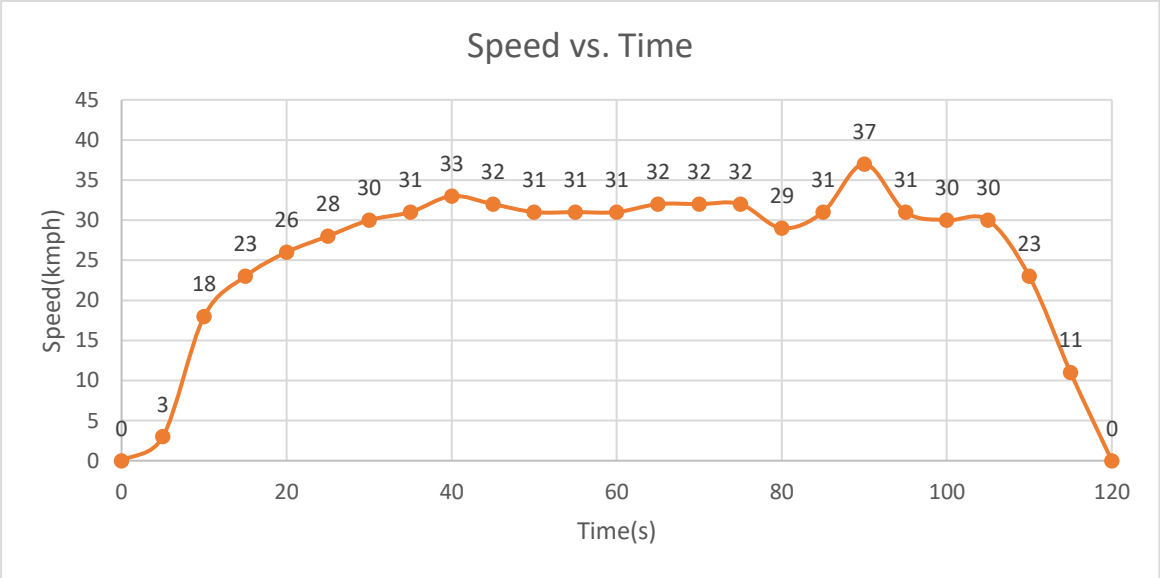


Figure 4.5: Speed vs. time 1

Maximum speed: 37 kmph.

2. Distance travelled by the vehicle:

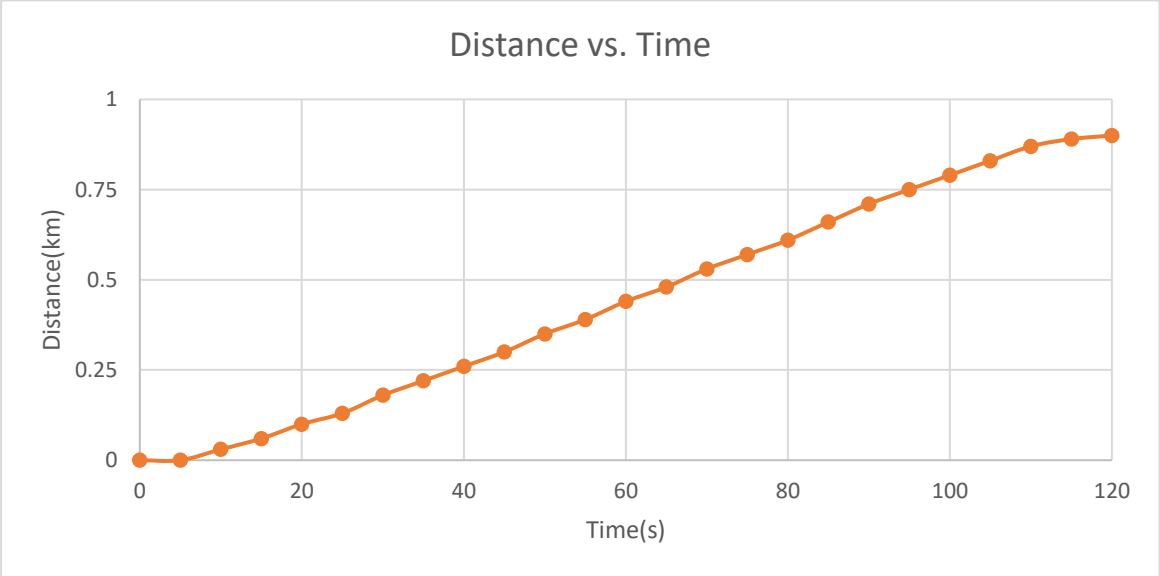


Figure 4.6: Speed vs. time 2

3. Speed vs. distance comparison:

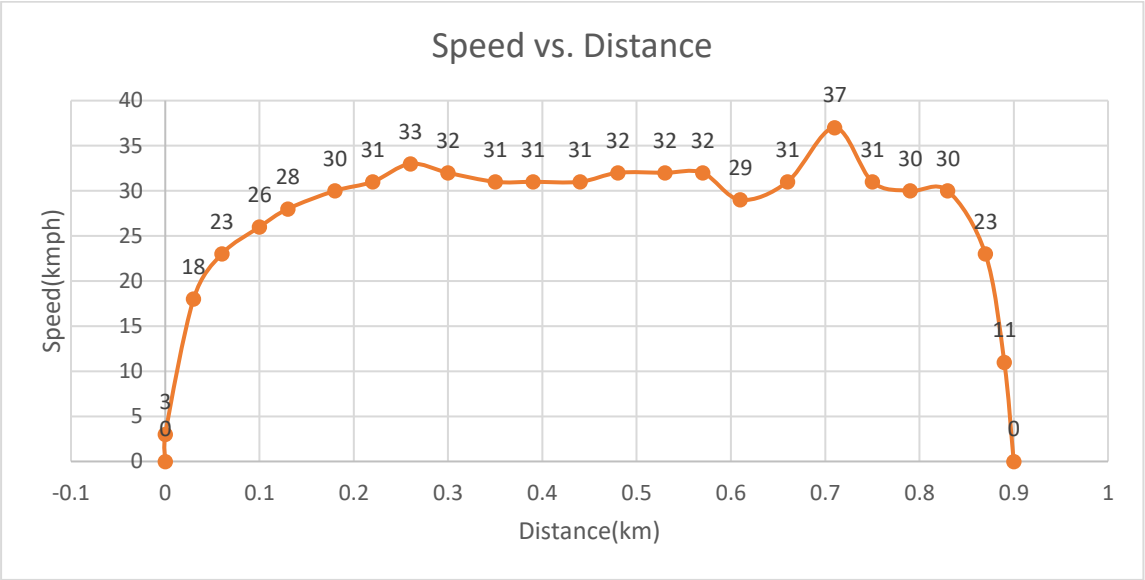


Figure 4.7: Speed vs. distance 2

Field Test No.3

1. Speed of the vehicle:

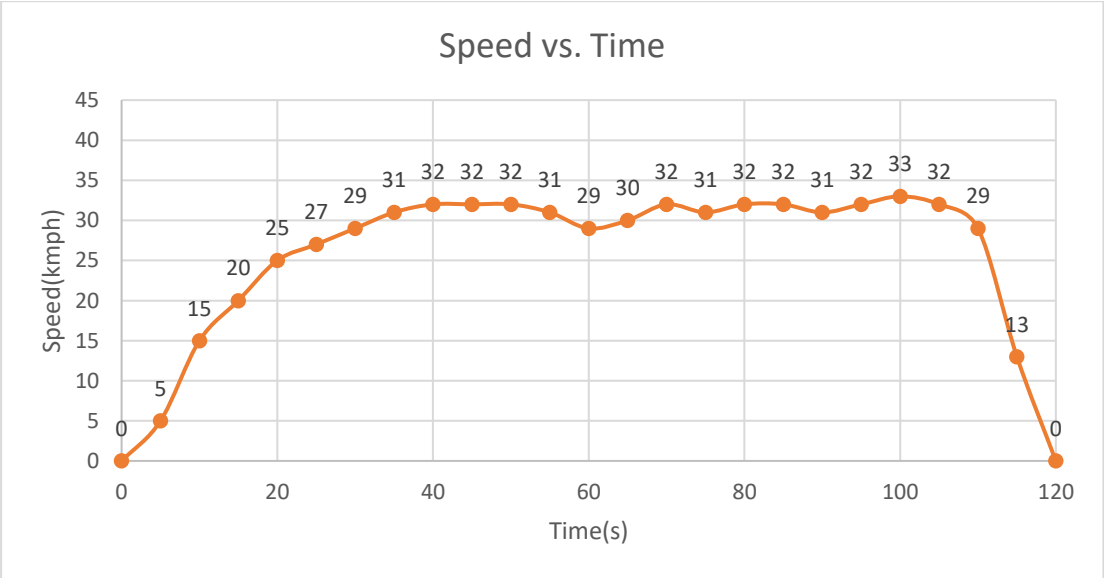


Figure 4.8: Speed vs. time 3

Maximum speed: 33 kmph.

2. Distance travelled by the vehicle:

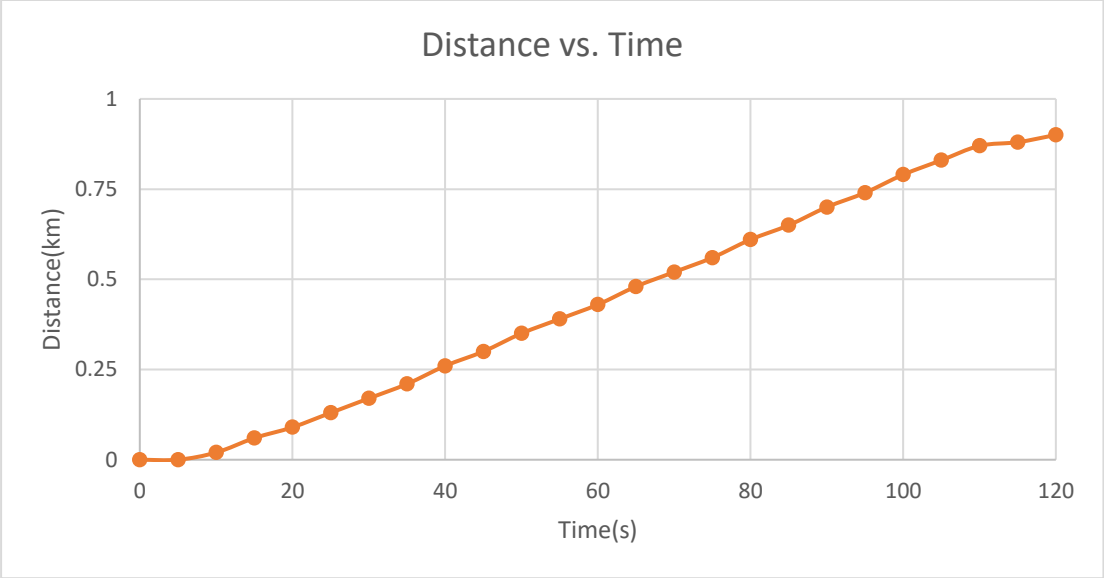


Figure 4.9: Distance vs. time 3

3. Speed vs. Distance comparison:

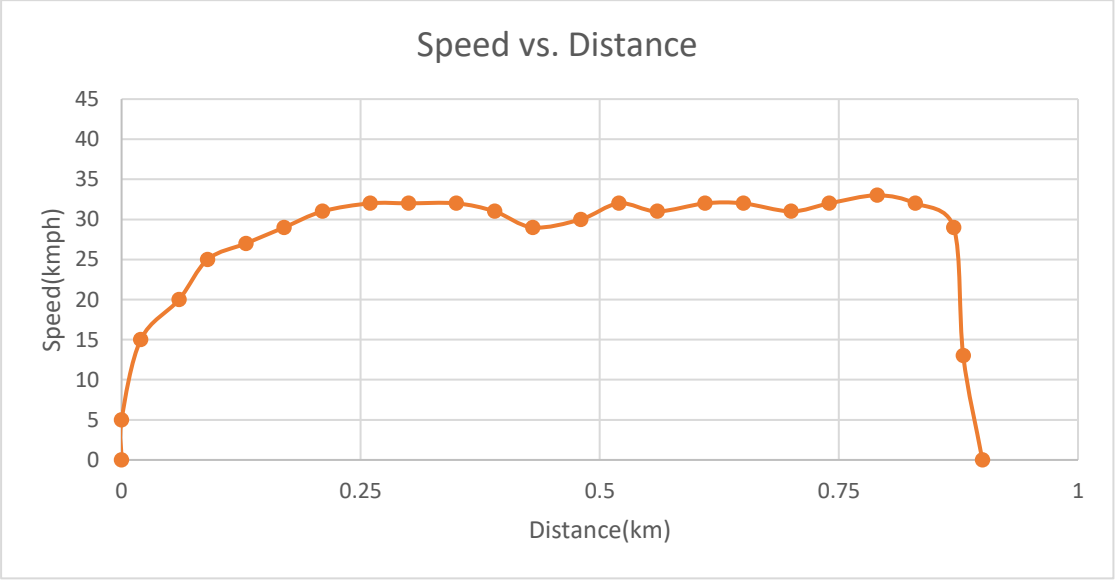


Figure 4.10: Speed vs. distance 3

Field Test No.4

1. Speed of the vehicle:

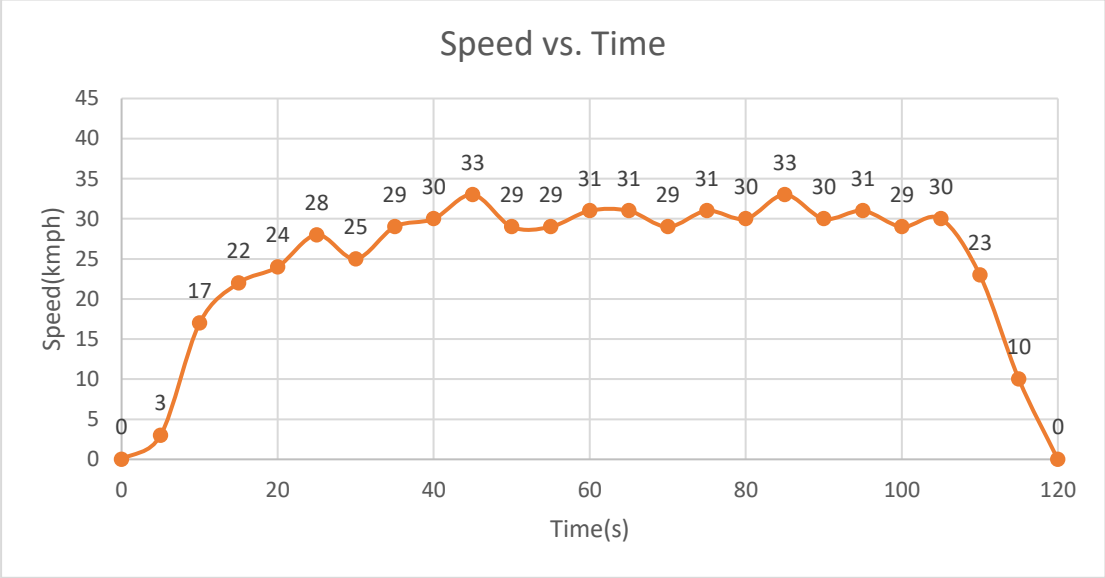


Figure 4.11: Speed vs. time 4

Maximum speed: 33 kmph.

2. Distance travelled by the vehicle:

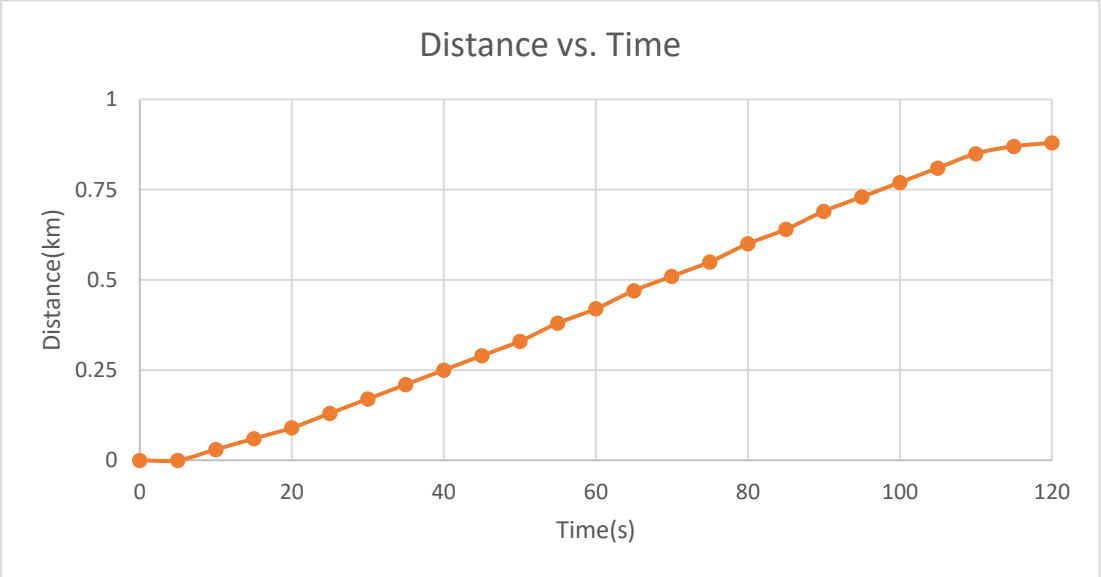


Figure 4.12: Distance vs. time 4

3. Speed vs. distance comparison:

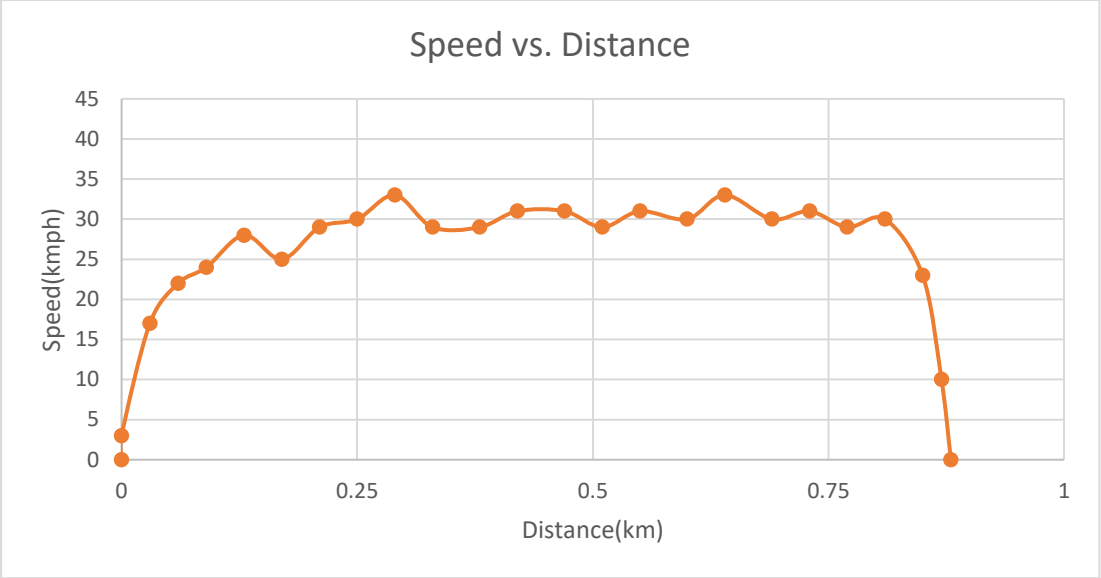


Figure 4.13: Speed vs. distance 4

Field Test No.5

1. Speed of the vehicle:

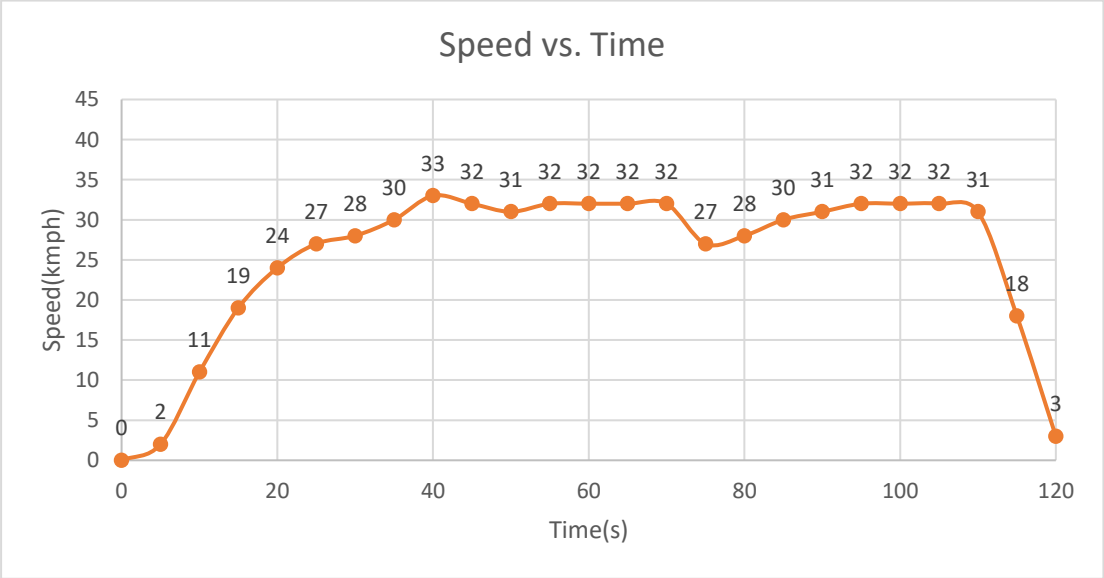


Figure 4.14: Speed vs. time 5

Maximum Speed: 33 kmph.

2. Distance travelled by the vehicle:

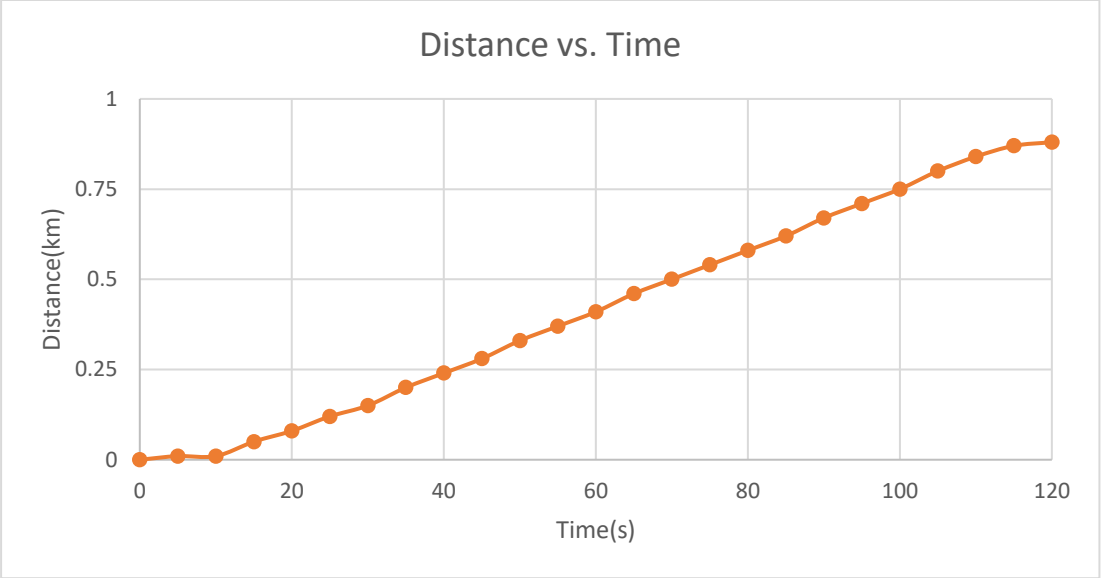


Figure 4.15: Distance vs. time 5

3. Speed vs. Distance comparison:

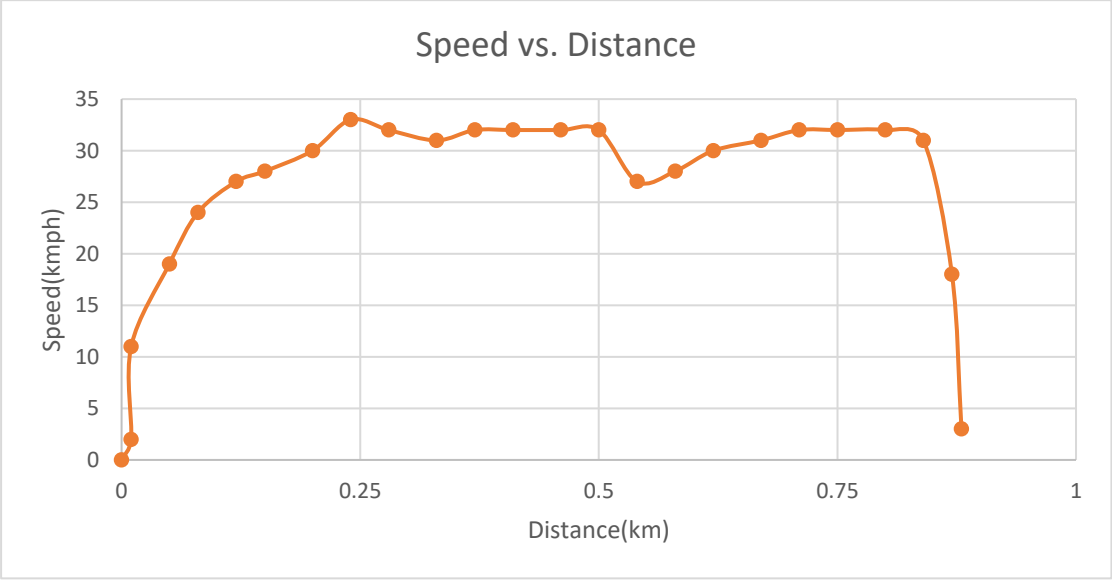


Figure 4.16: Speed vs. distance 5

Field Test No.6

1. Speed of the vehicle:

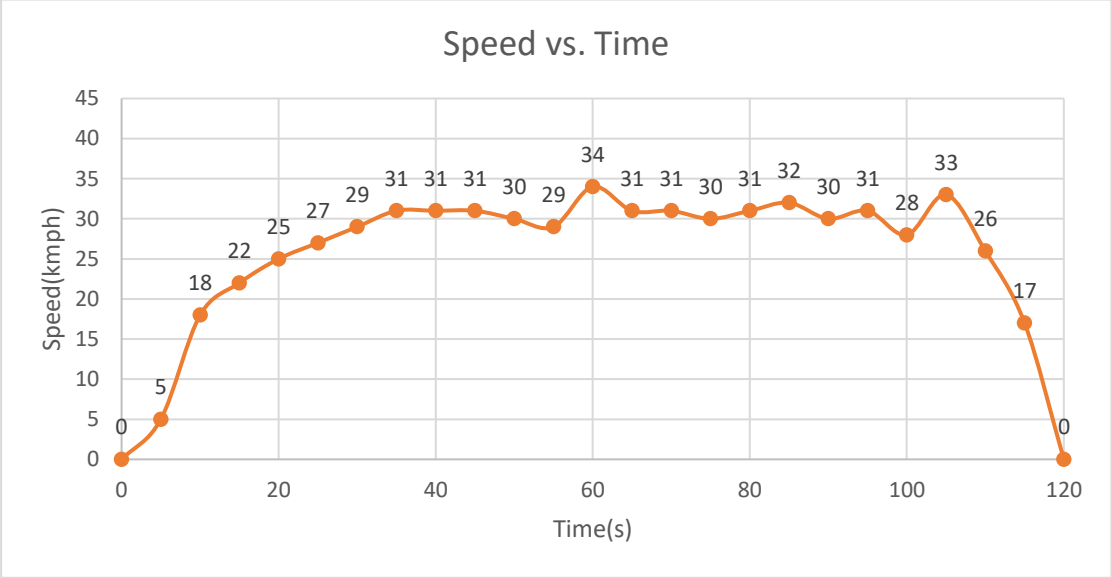


Figure 4.17: Speed vs. time 6

Maximum speed: 38 kmph.

2. Distance covered by the vehicle:

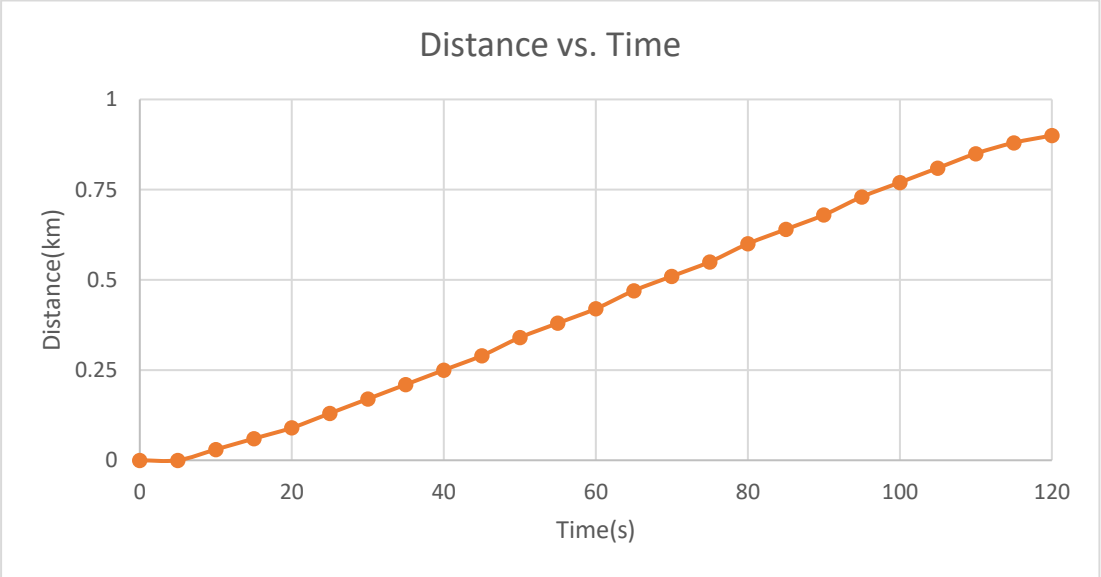


Figure 4.18: Distance vs. time 6

3. Speed vs. Distance comparison:

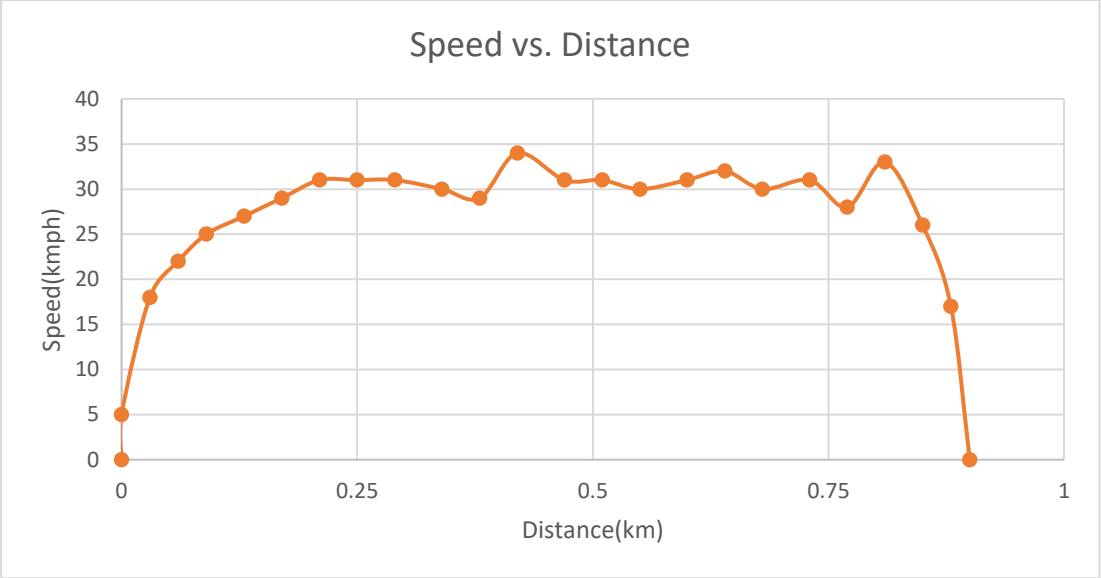


Figure 4.19: Speed vs. distance 6

Field Test No.7

1. Speed of the vehicle:

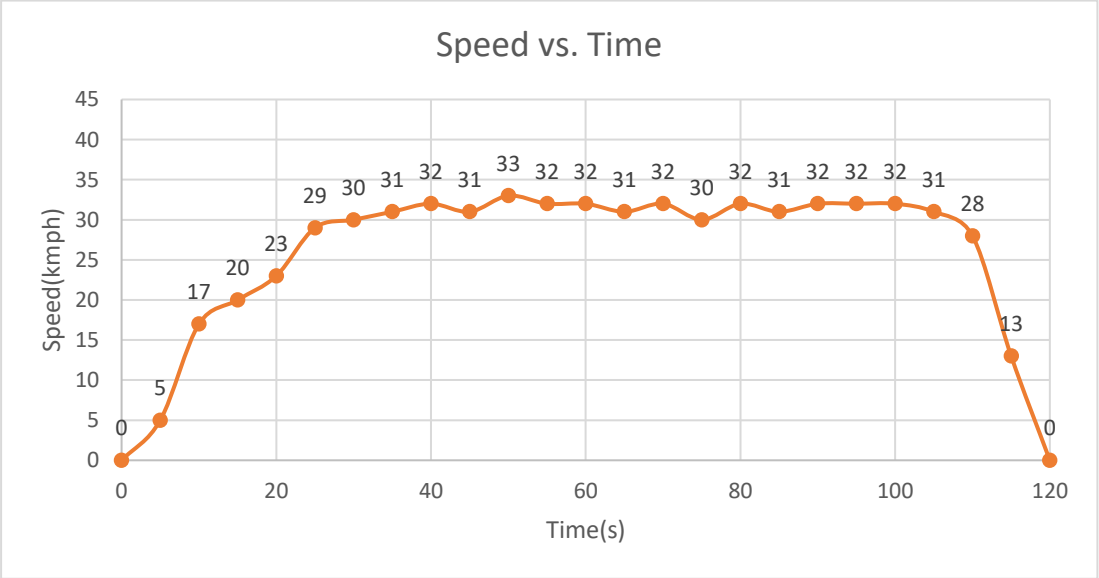


Figure 4.20: Speed vs. time 7

Maximum speed: 37 kmph

2. Distance covered by the vehicle:

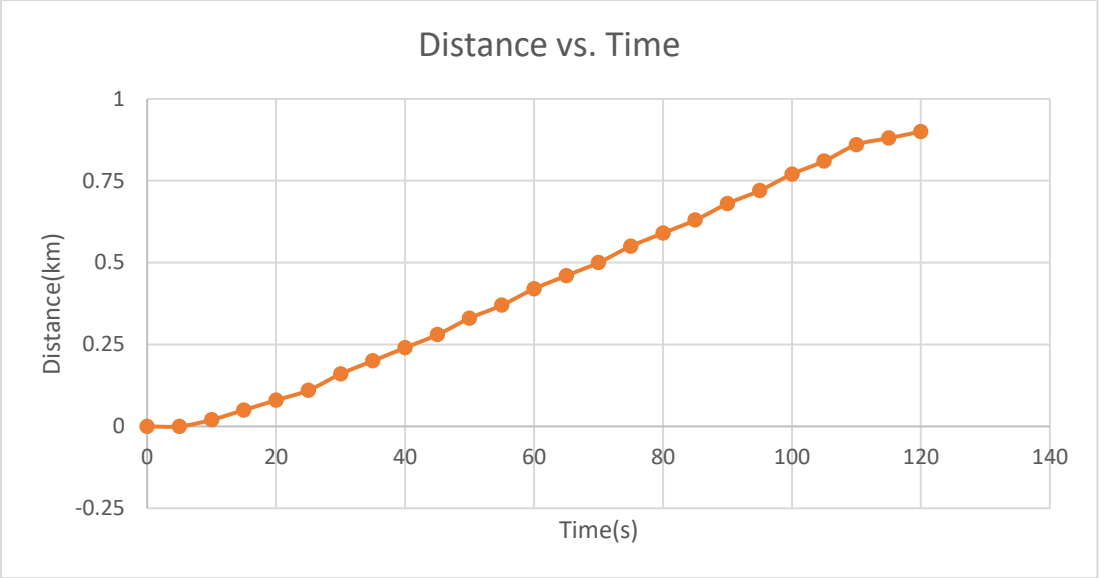


Figure 4.21: Distance vs. time 7

3. Speed vs. Distance comparison:

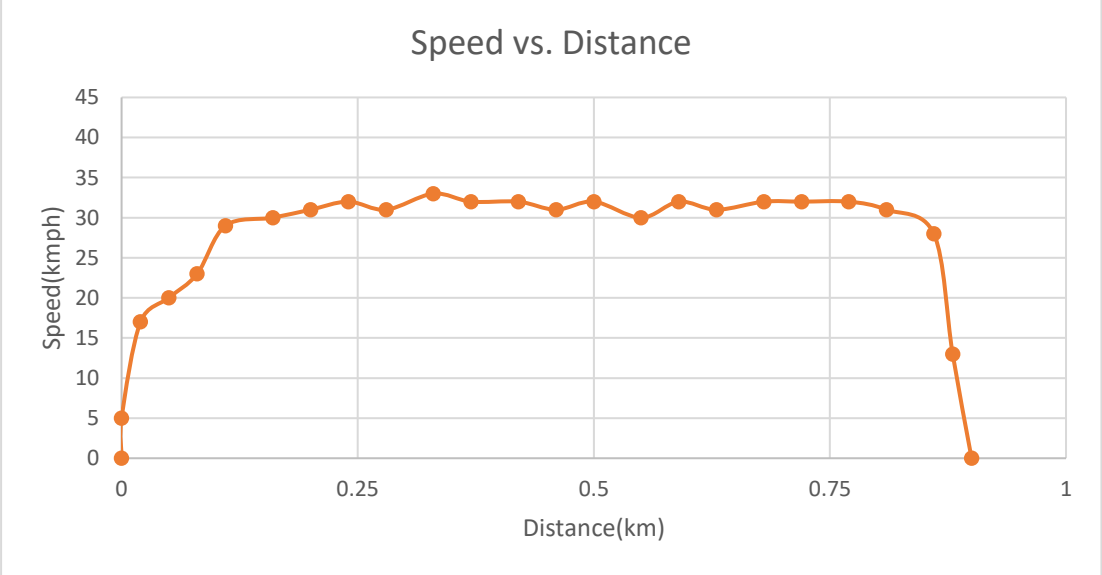


Figure 4.22: Speed vs. distance 7

Field Test No.8

1. Speed of the vehicle:

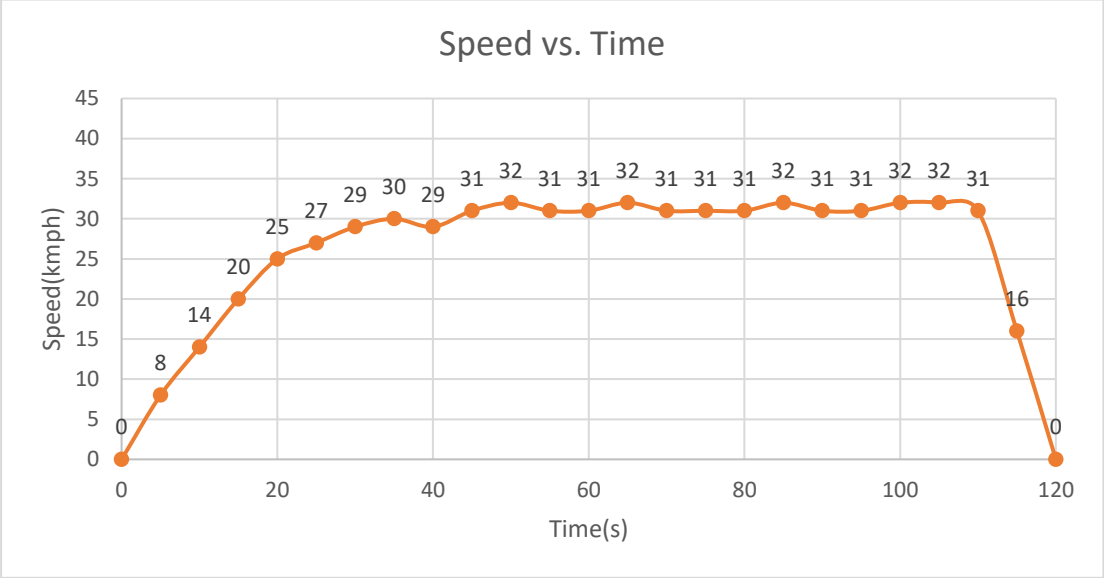


Figure 4.23: Speed vs. time 8

Maximum speed: 34 kmph

2. Distance covered by the vehicle:

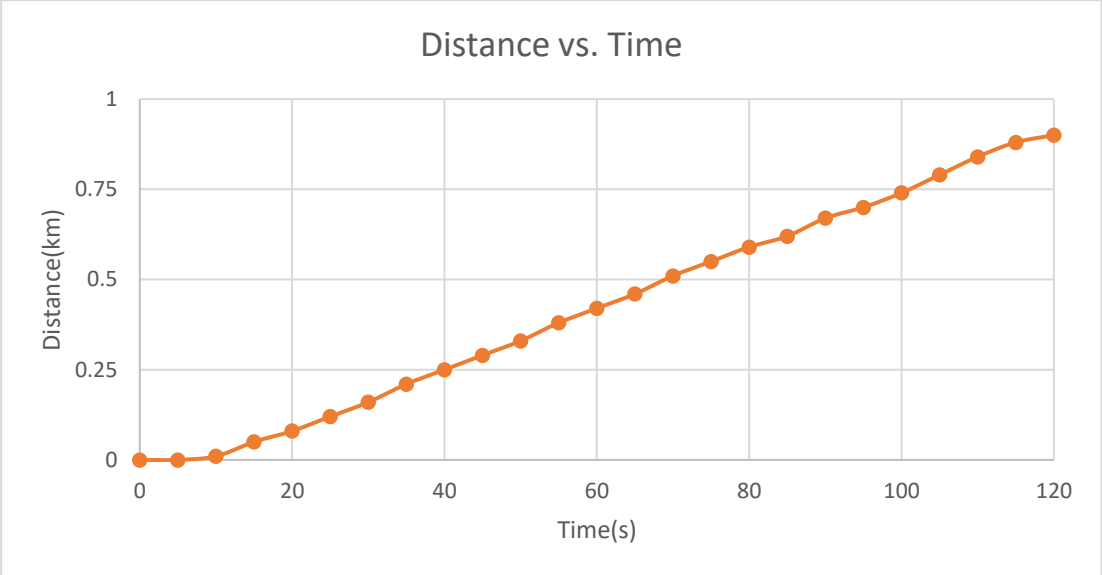


Figure 4.24: Distance vs. time 8

3. Speed vs. Distance comparison:

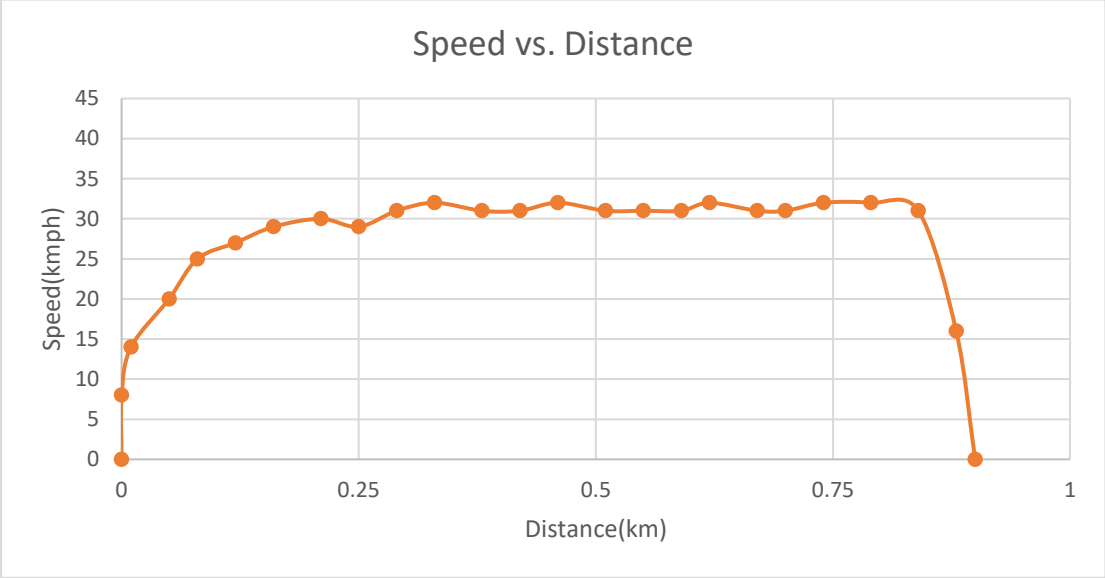


Figure 4.25: Speed vs. distance 8

Field Test No.9

1. Speed of the vehicle:

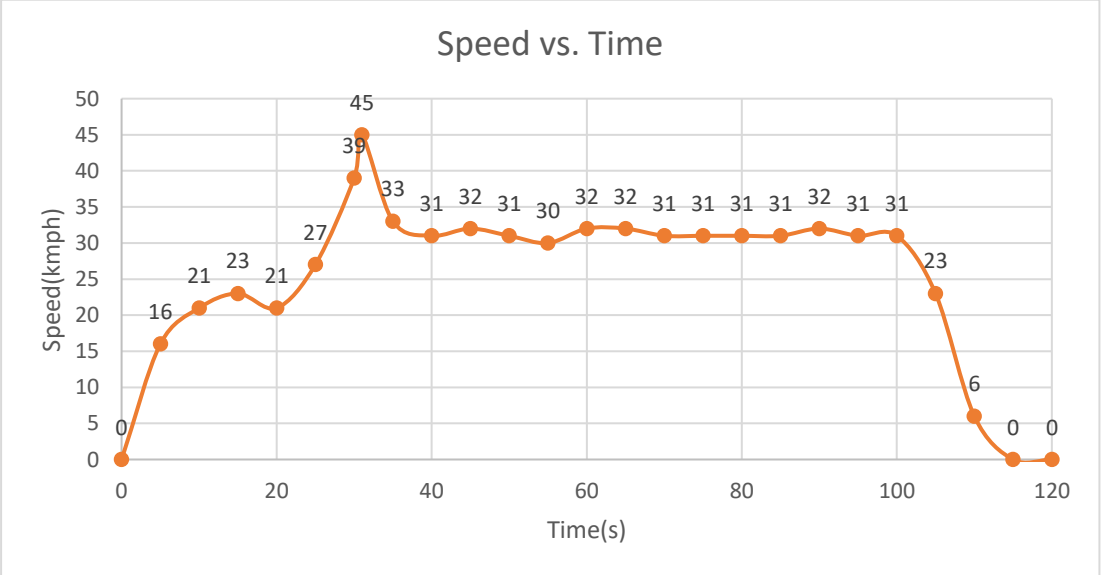


Figure 4.26: Speed vs. time 9

Maximum speed: 45 kmph.

During the 9th test run of the solar car; the expected speed was reached.

2. Distance covered by the vehicle:

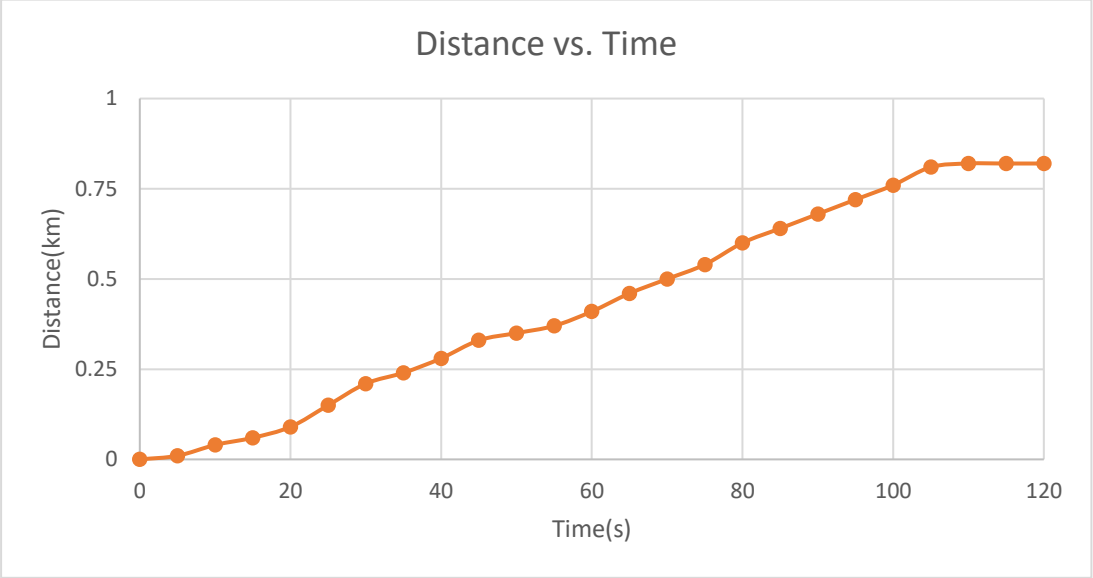


Figure 4.27: Distance vs. time 9

3. Speed vs. Distance comparison:

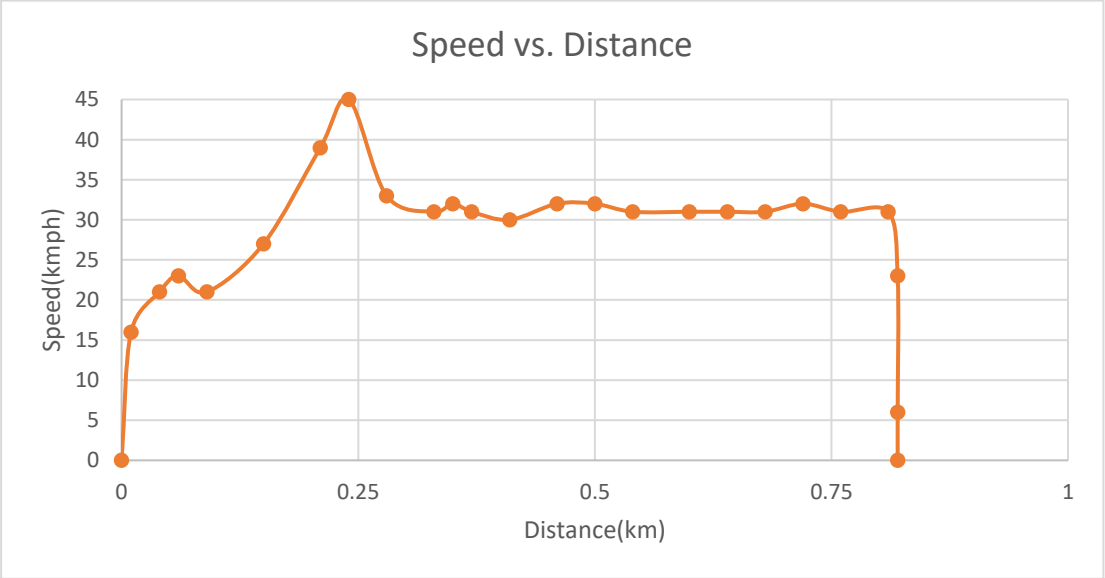


Figure 4.28: Speed vs. distance 9

Field Test No.10

1. Speed of the vehicle:

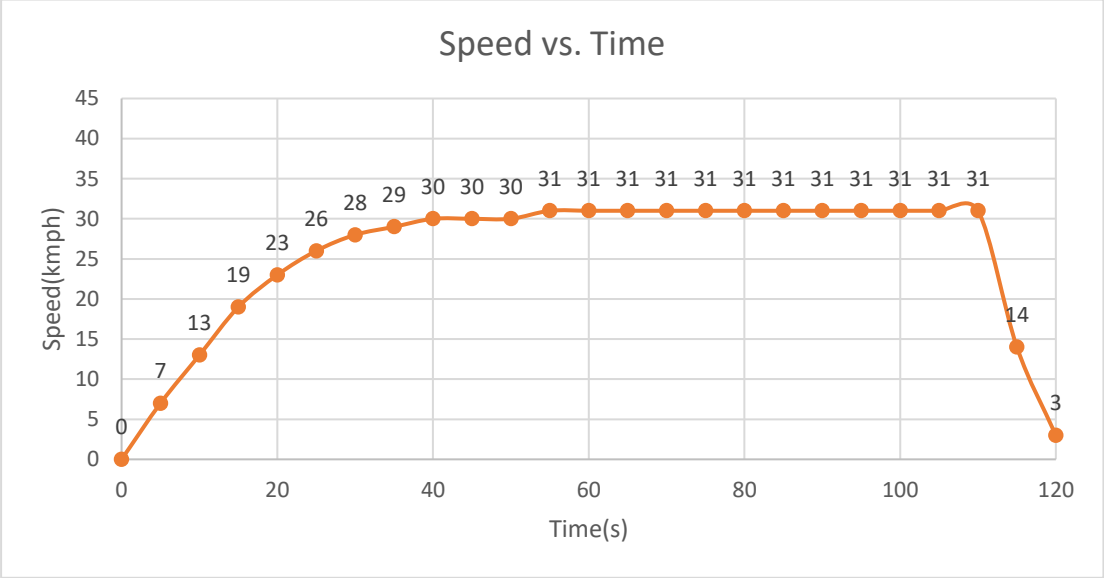


Figure 4.29: Speed vs. time 10

Maximum speed: 32

2. Distance covered by the vehicle:

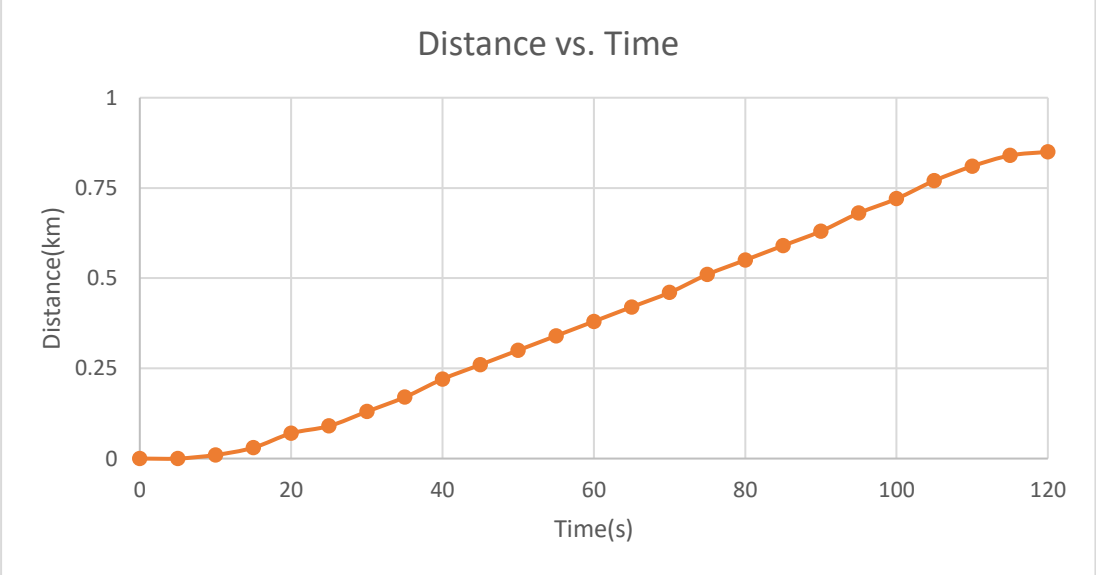


Figure 4.30: Distance vs. time 10

3. Speed vs. Distance comparison:

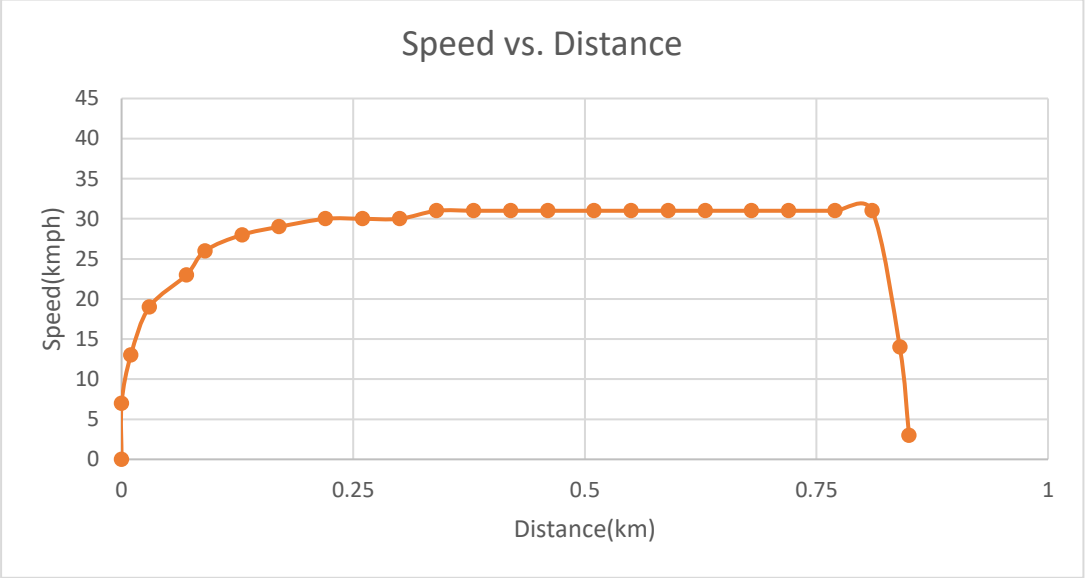


Figure 4.31: Speed vs. distance 10

4.3.1 Field test summary

- Top Speed reached: 45 kmph
- Average Speed of the vehicle: 35.4 kmph
- Acceleration of the vehicle: 0-20kmph in 13 sec (13 m/s2)
- Duration of operation: 2.0 min (0.033 hr)
- Distance covered each run during operation: 900 m approximately
- Maximum Startup current of the system: 60 A
- Operating Current of the system: 59~60 A
- Operating Voltage of the system: 58 V

4.4 Battery Data

4.4.1 With load data

Battery Data No.1

1. Battery Voltage:

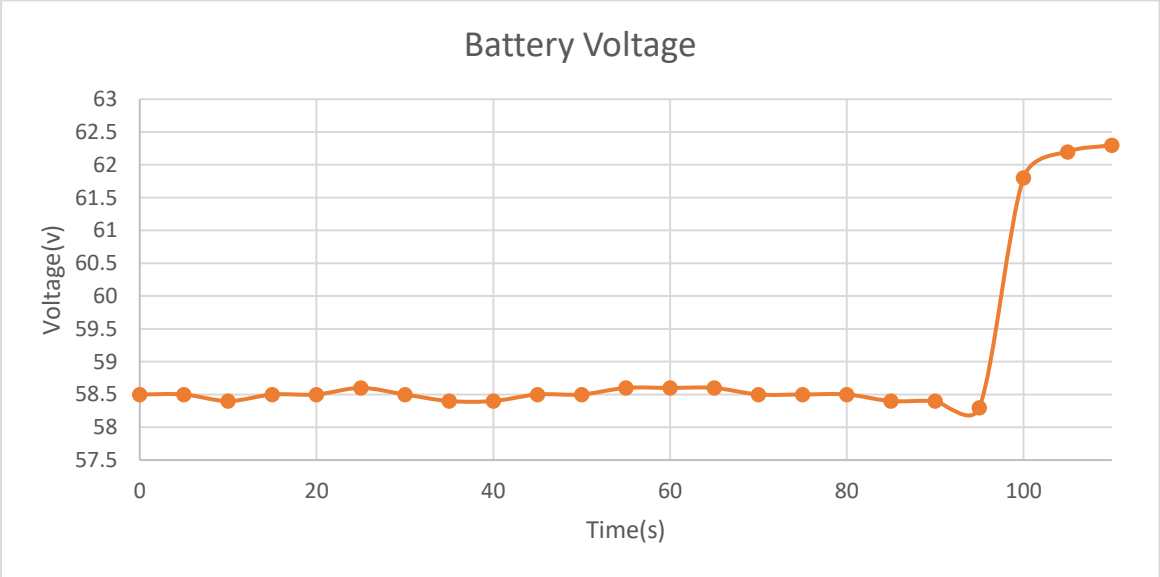


Figure 4.32: Battery Voltage 1

2. Battery Current:

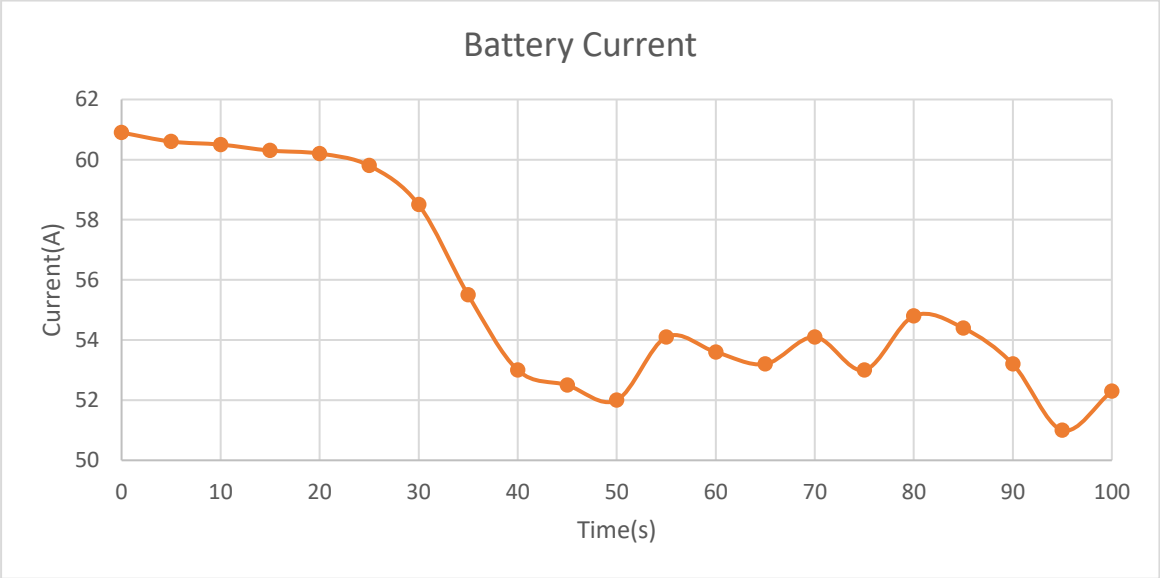


Figure 4.33: Battery Current 1

2. Power of Battery:

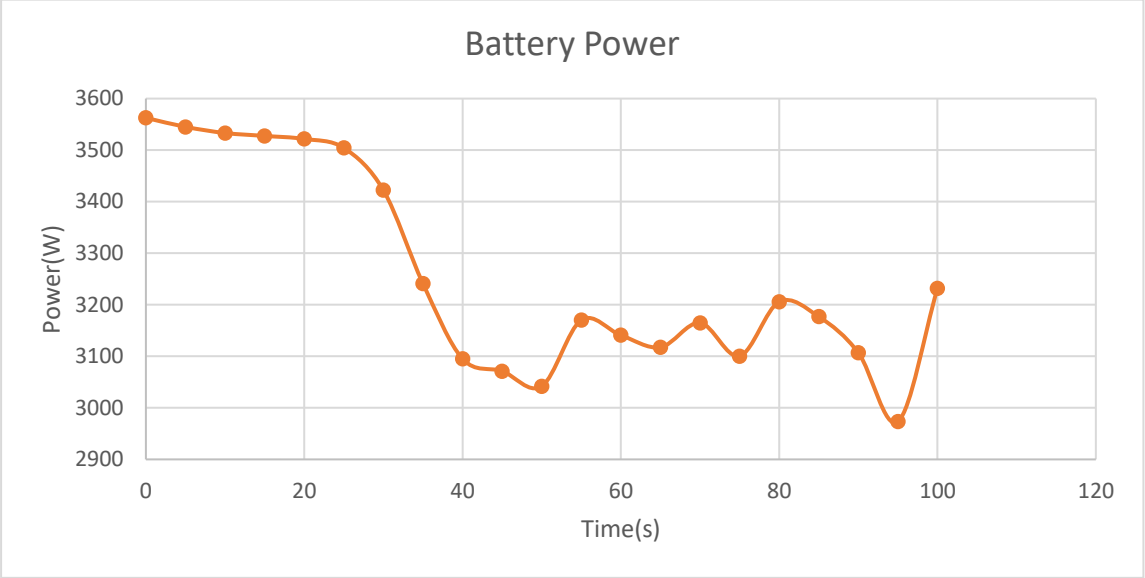


Figure 4.34: Battery Power 1

3. Energy of Battery:

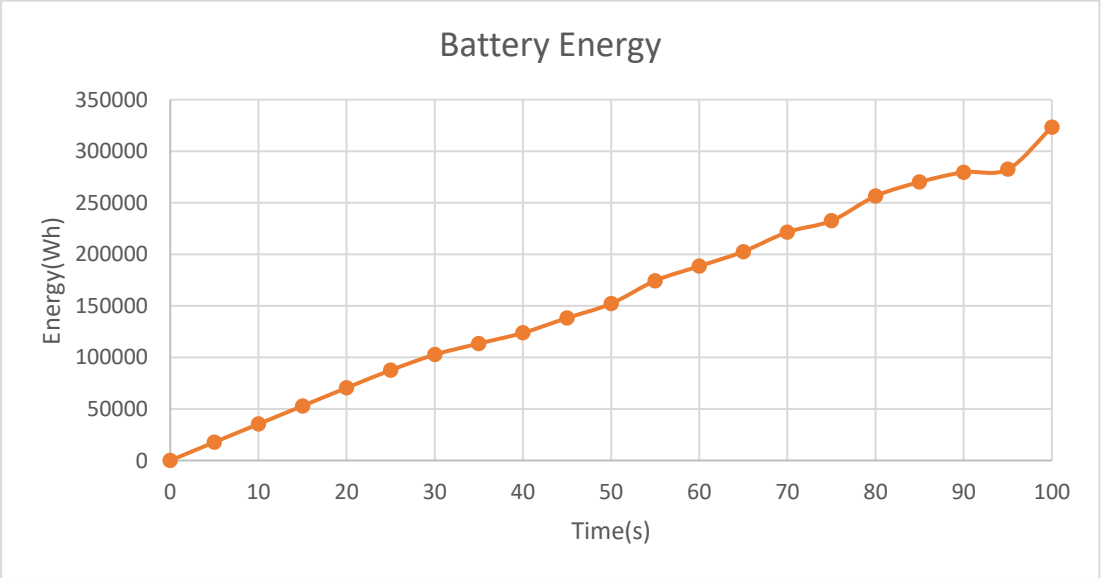


Figure 4.35: Battery Energy 1

Battery Data No.2

1. Battery Voltage:

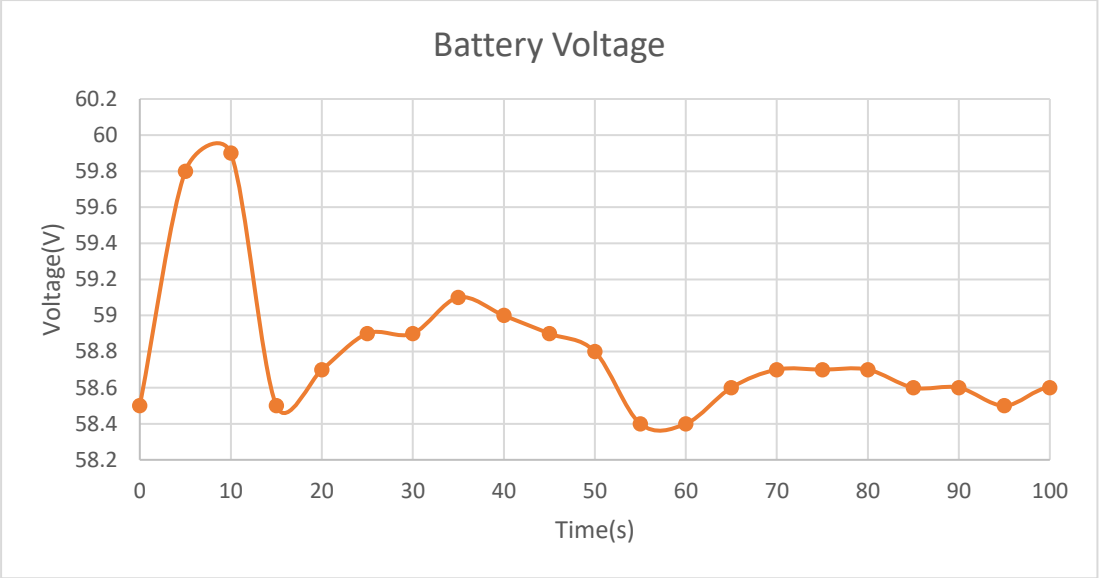


Figure 4.36: Battery Voltage 2

2. Battery Current:

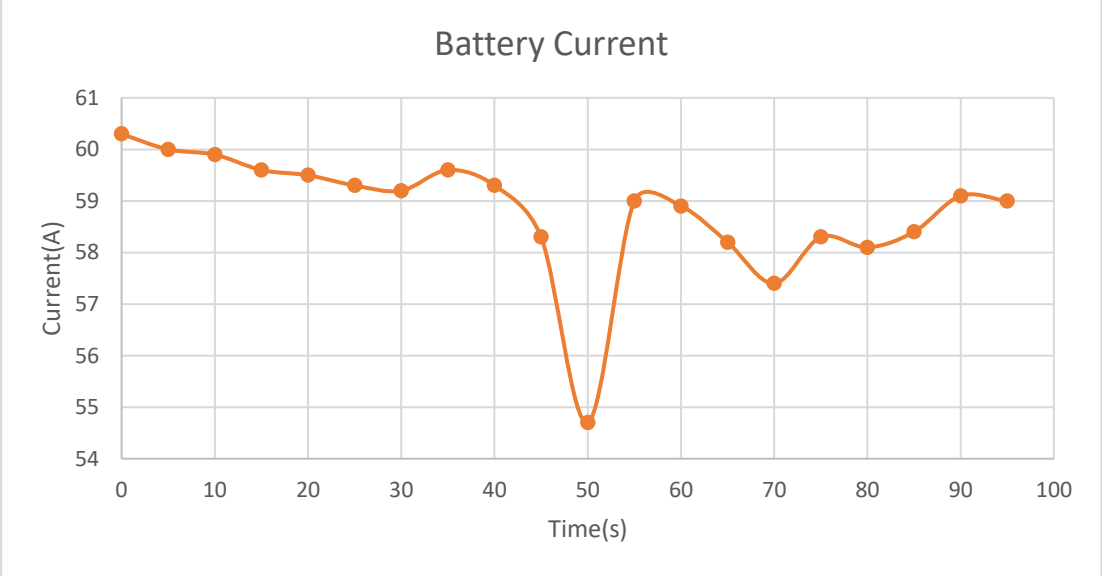


Figure 4.37: Battery Current 2

3. Battery Power:

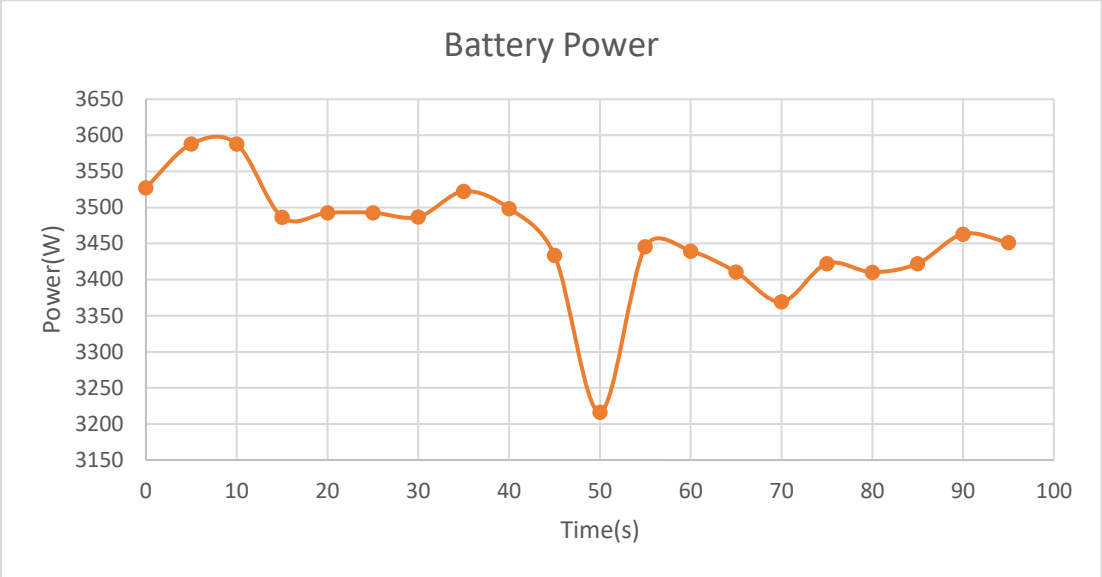


Figure 4.38: Battery Power 2

4. Battery Energy:

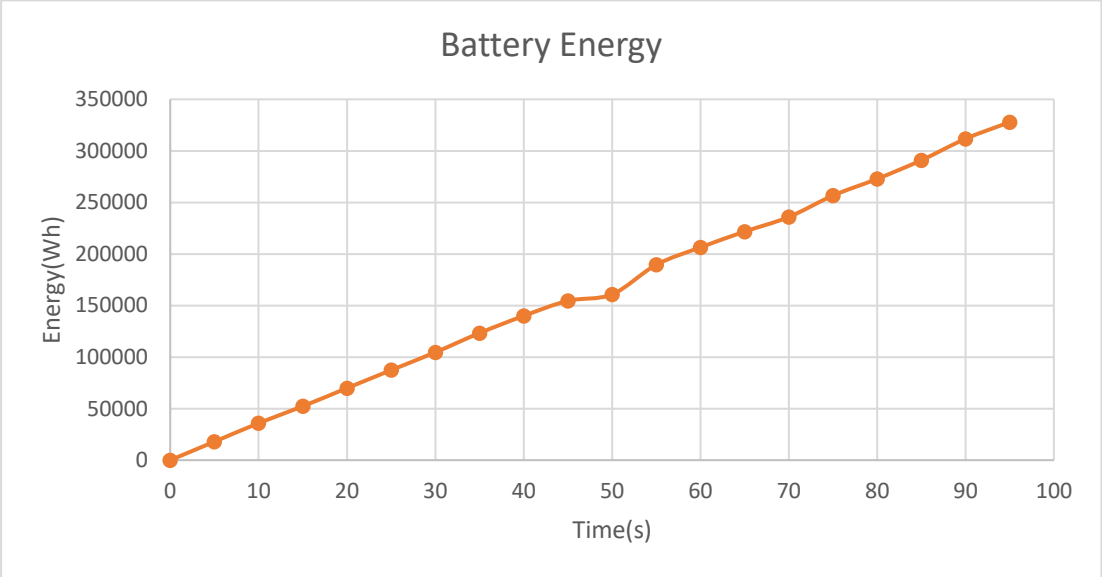


Figure 4.39: Battery Energy 2

Battery Data No.3

1. Battery Voltage:

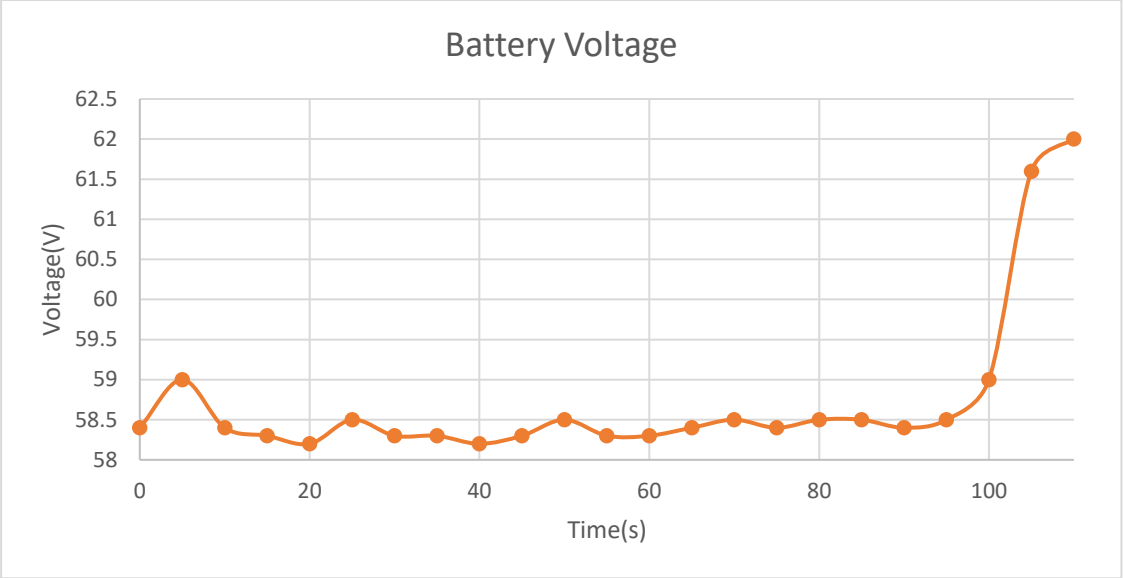


Figure 4.40: Battery Voltage 3

2. Battery Current:

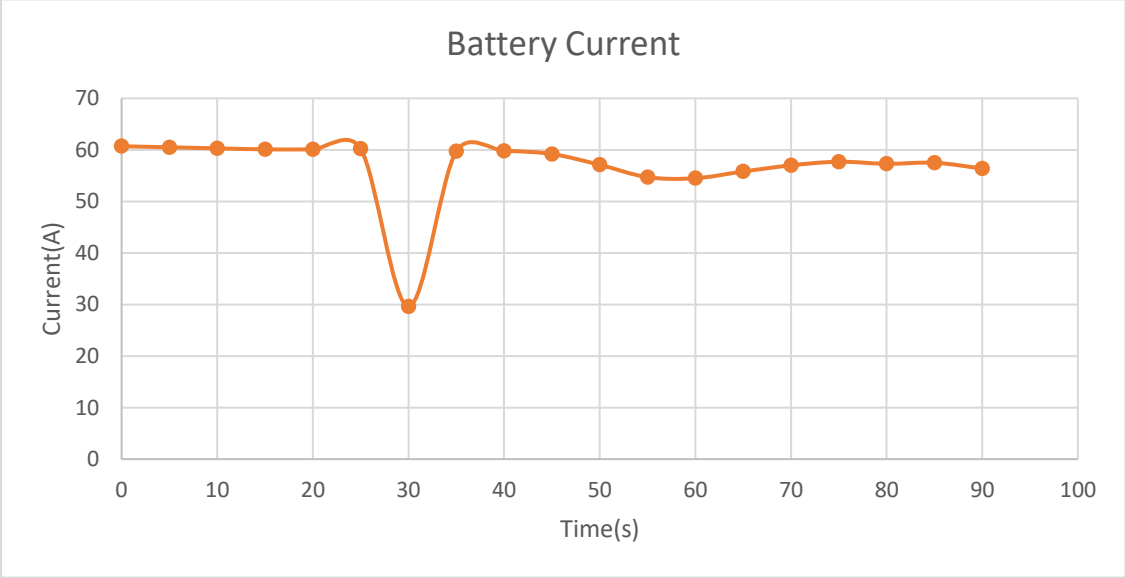


Figure 4.41: Battery Current 3

3. Battery Power:

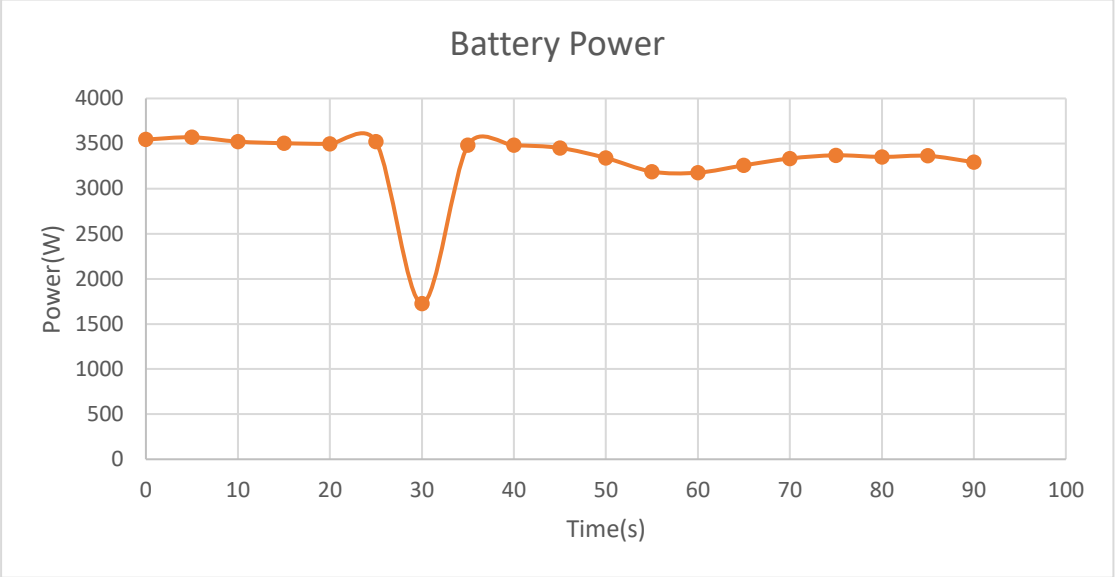


Figure 4.42: Battery Power 3

4. Battery Energy

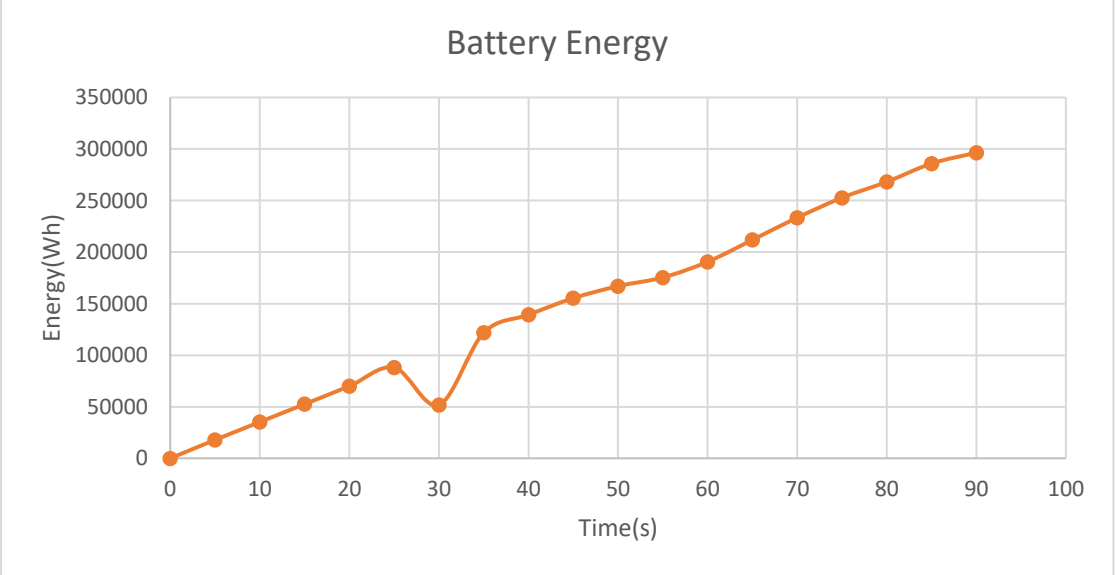


Figure 4.43: Battery Energy 3

4.4.2 Without load data

1. Battery voltage:

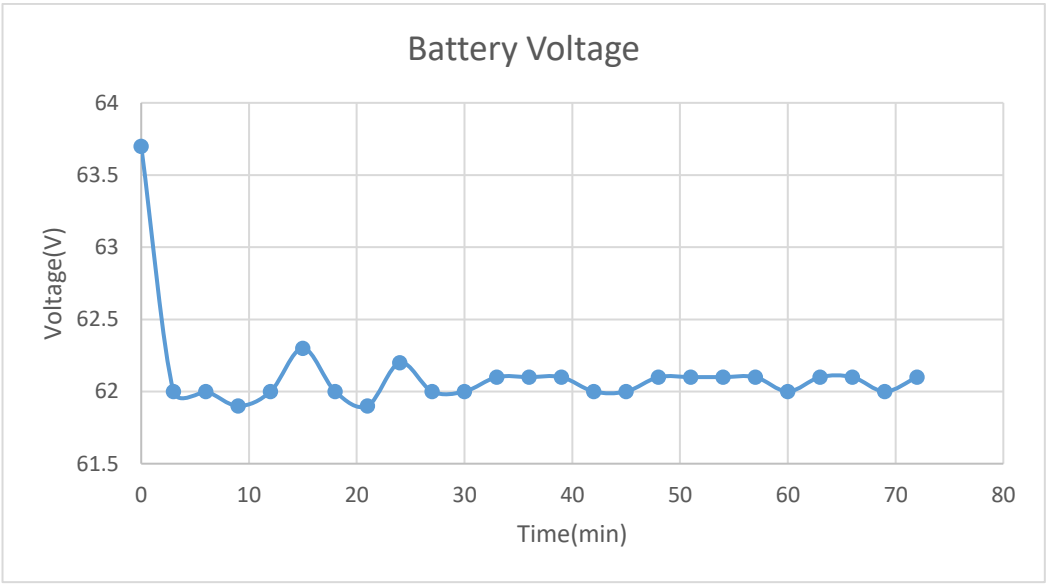


Figure 4.44: Battery Voltage 4

2. Battery Current:

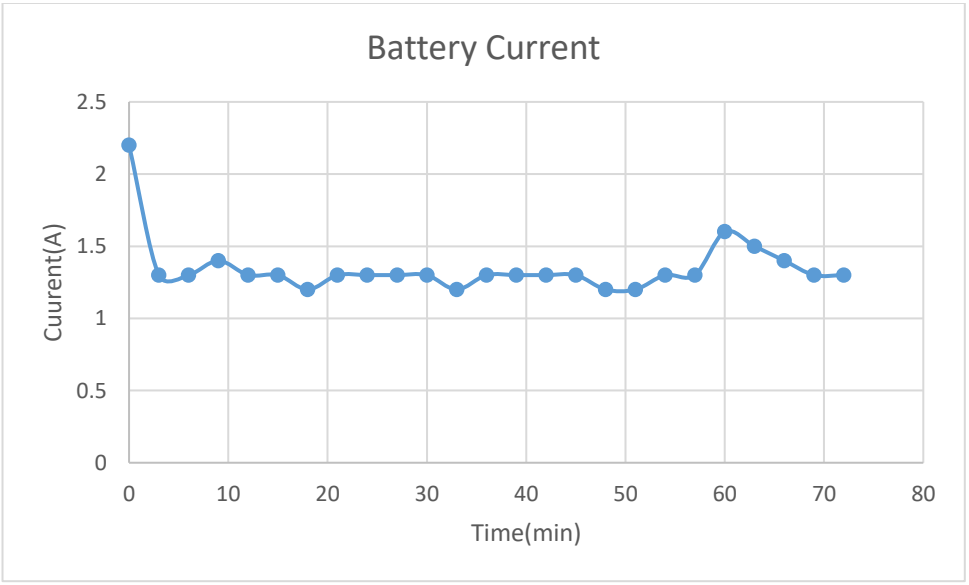


Figure 4.45: Battery Current 4

4.4.3 Discussion

Initially, two types of data were taken, one with load and another without load. Both of the data condition is discussed briefly here.

Battery Voltage:

One noticeable thing during the running condition is that every time, the initial voltage of the battery when the car was accelerated was 58.5 V. As the battery set is new and was fully charged, it stayed within 63 V, with an average of 58.5 volt.

Whereas, during the no load stage, the initial voltage was 63.7 which later got around 62.3.

Battery Current:

During the running condition, the battery current started with 61.5A and got fixed around 54A. For the rest two, the value stayed within 59A to 60A.

Whereas, during the no load condition, the voltage started with 2.25A but later stayed within 1A to 1.5A.

Battery Power:

While it was in running state, the initial power when it was accelerated was around 3500W but after a few moment later, it got stable between 3100W to 3200W. For the rest of the data, it was seen that, the value stayed between 3400W to 3500W

Battery Energy:

During the 120 second running condition of the car, the energy stayed between 0Wh around 320000Wh.

4.5 Solar Panel Data

4.5.1 With load data

Solar Panel Data No.1

1. Panel Voltage:

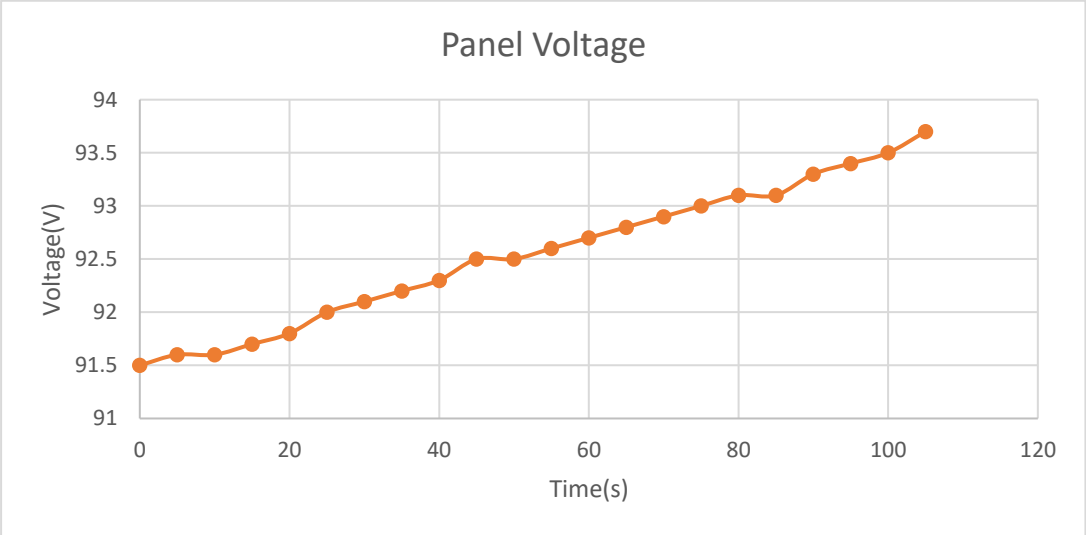


Figure 4.46: Panel Voltage 1

2. Panel Current:

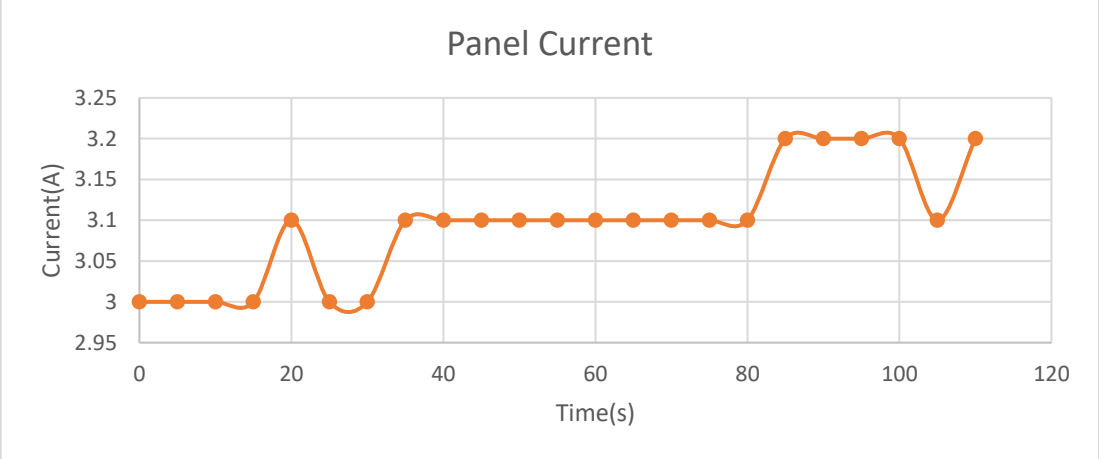


Figure 4.47: Panel Current 1

3. Panel Power:

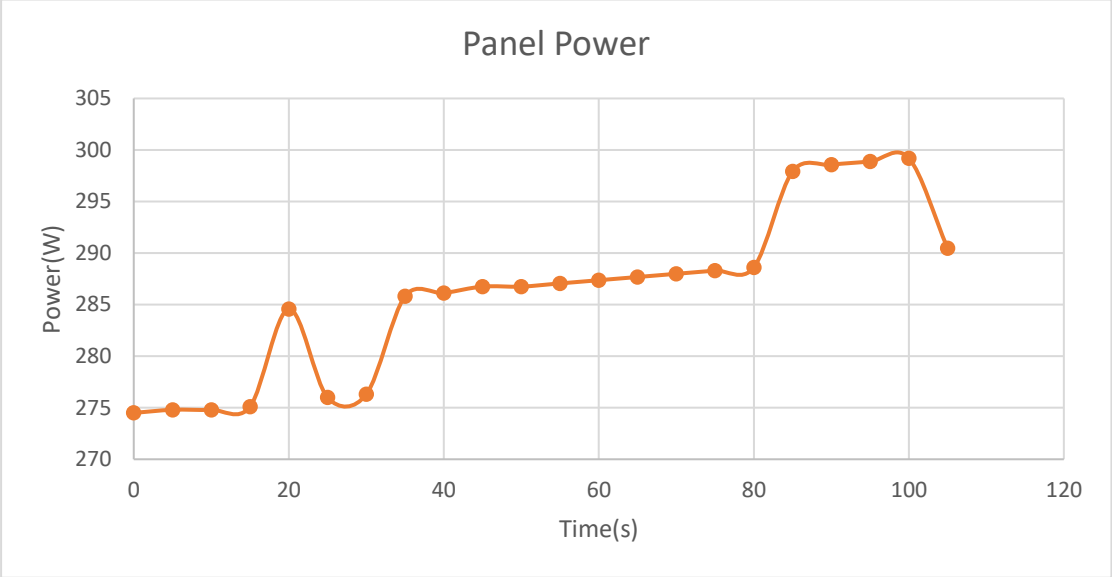


Figure 4.48: Panel Power 1

4. Panel Energy:

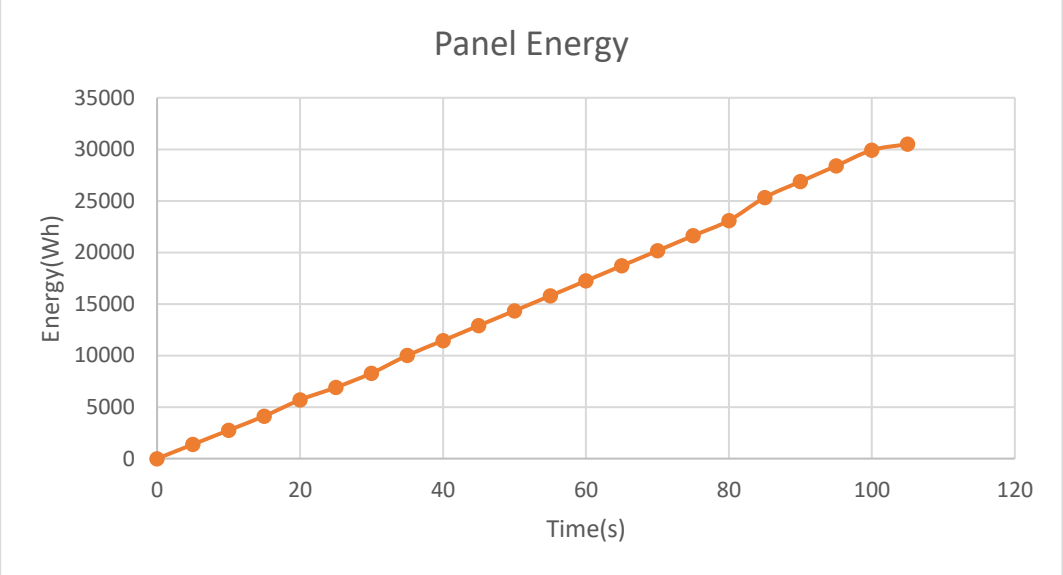


Figure 4.49: Panel Energy 1

Solar Panel Data No.2

1. Panel Voltage:

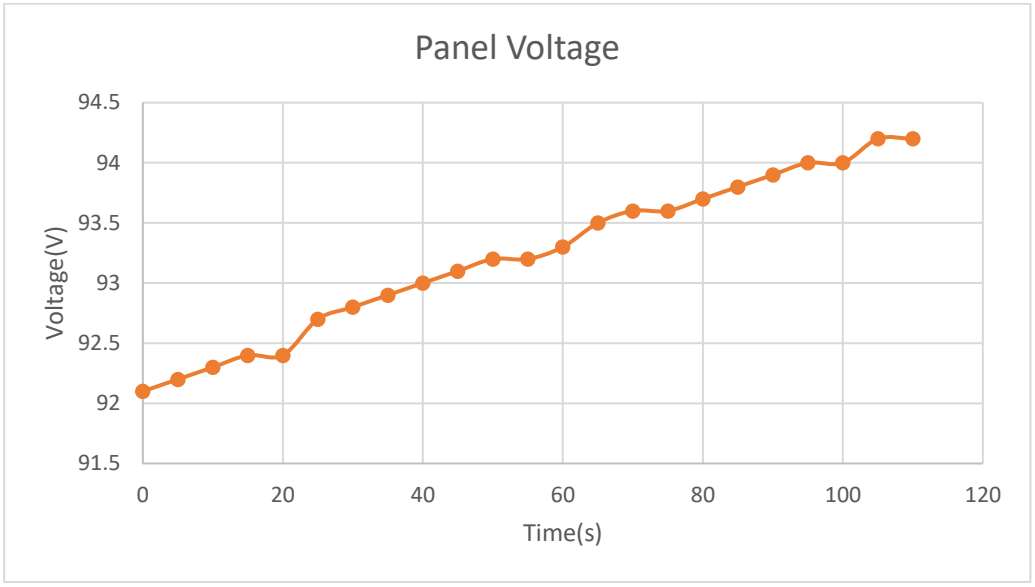


Figure 4.50: Panel Voltage 2

2. Panel Current:

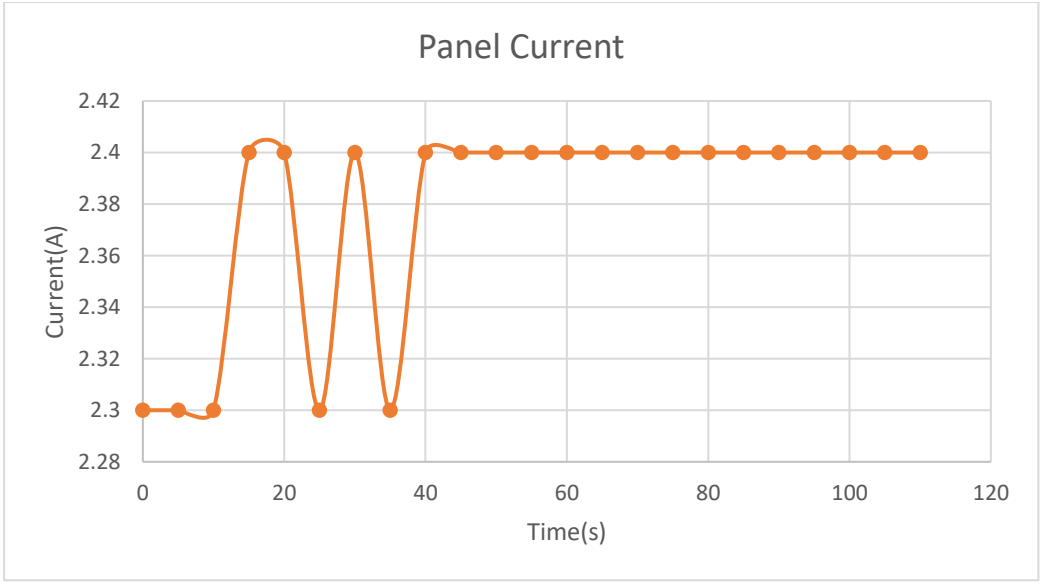


Figure 4.51: Panel Current 2

3. Panel Power:

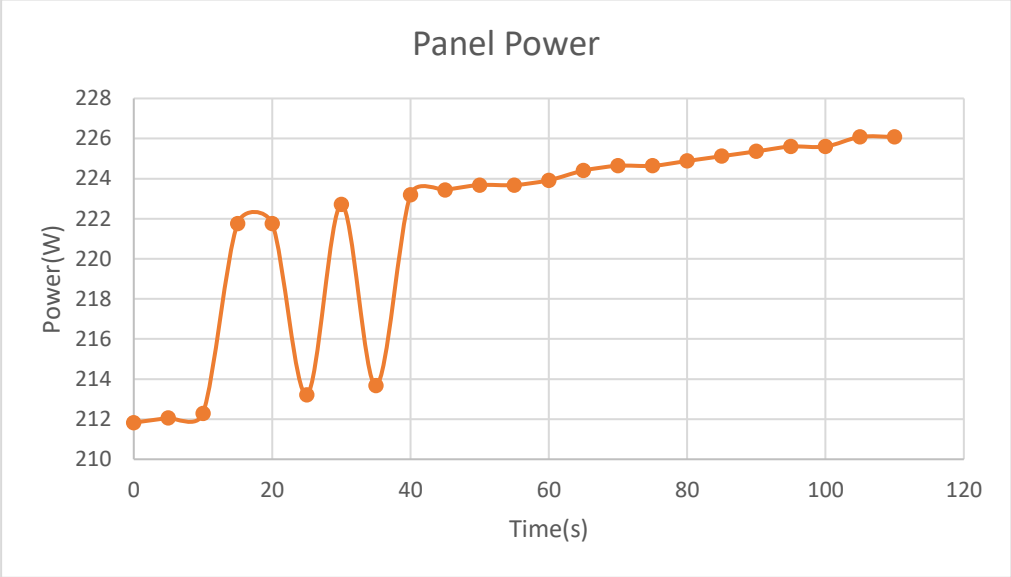


Figure 4.52: Panel Power 2

4. Panel Energy:

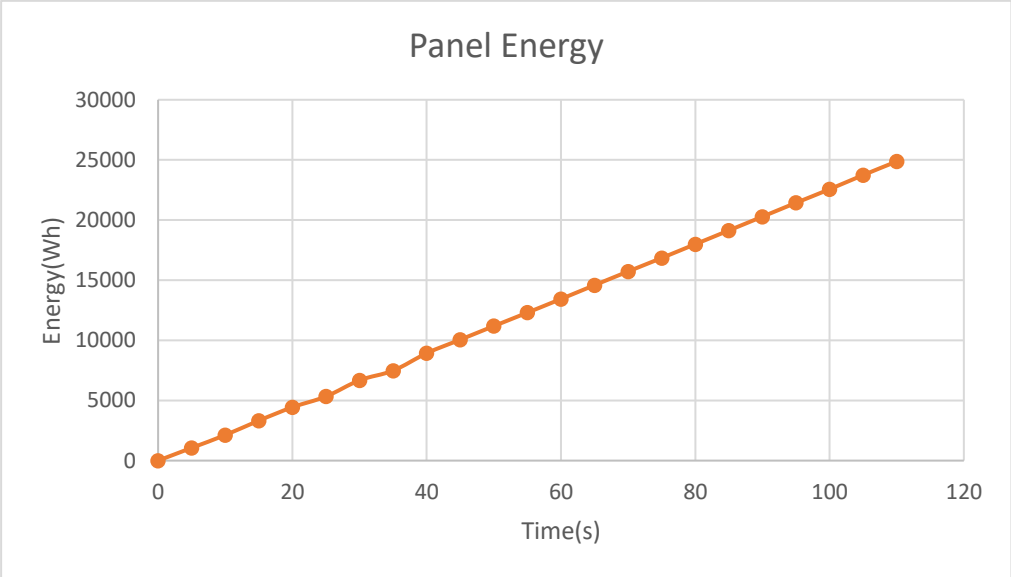


Figure 4.53: Panel Energy 2

Solar Panel Data No.3

1. Panel Voltage:

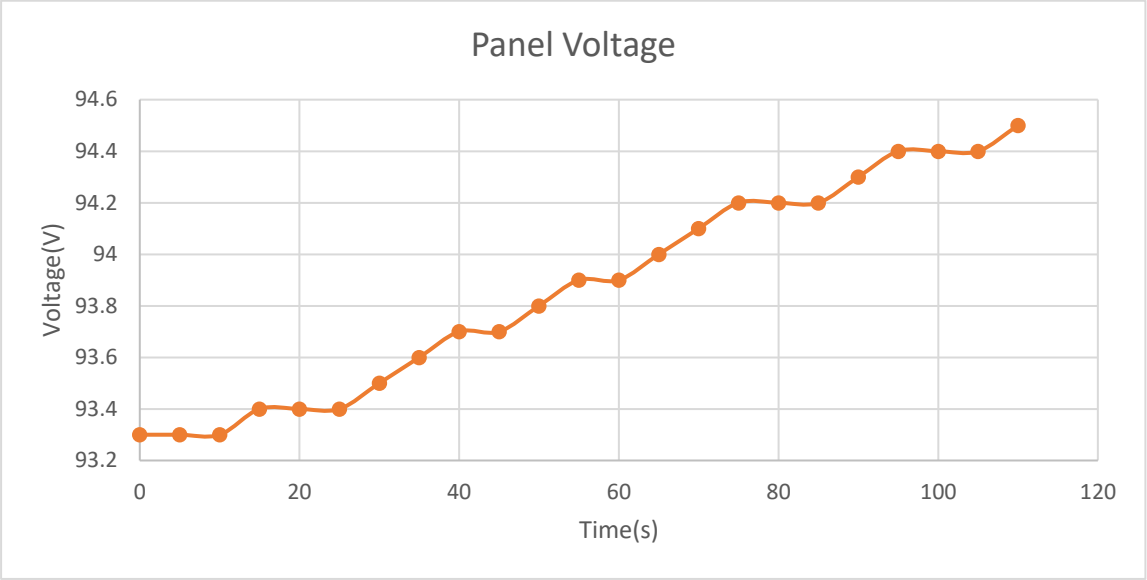


Figure 4.54: Panel Voltage 3

2. Panel Current:

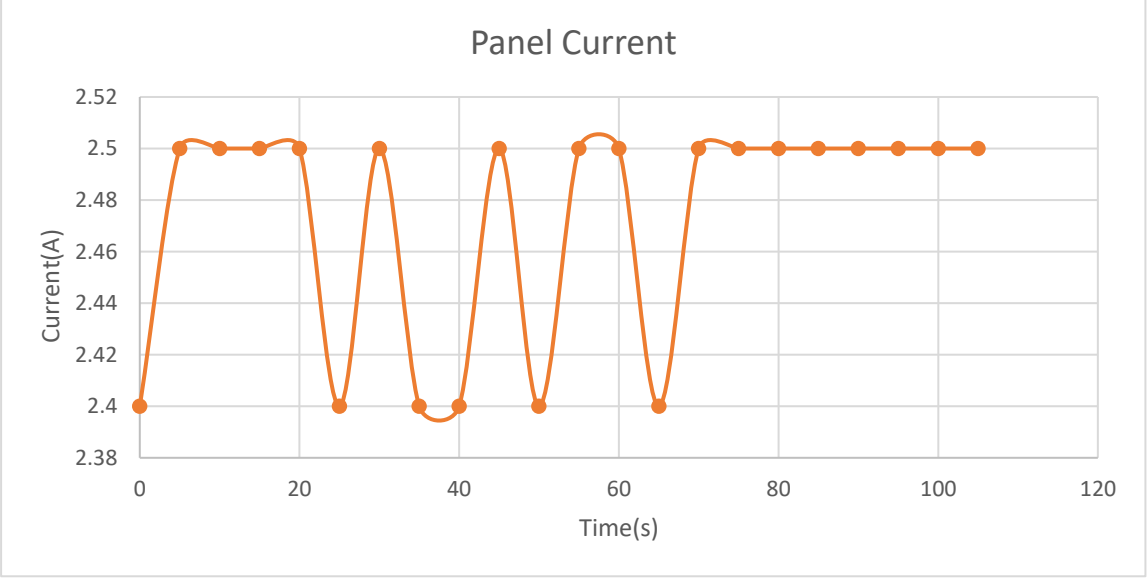


Figure 4.55: Panel Current 3

3. Panel Power:

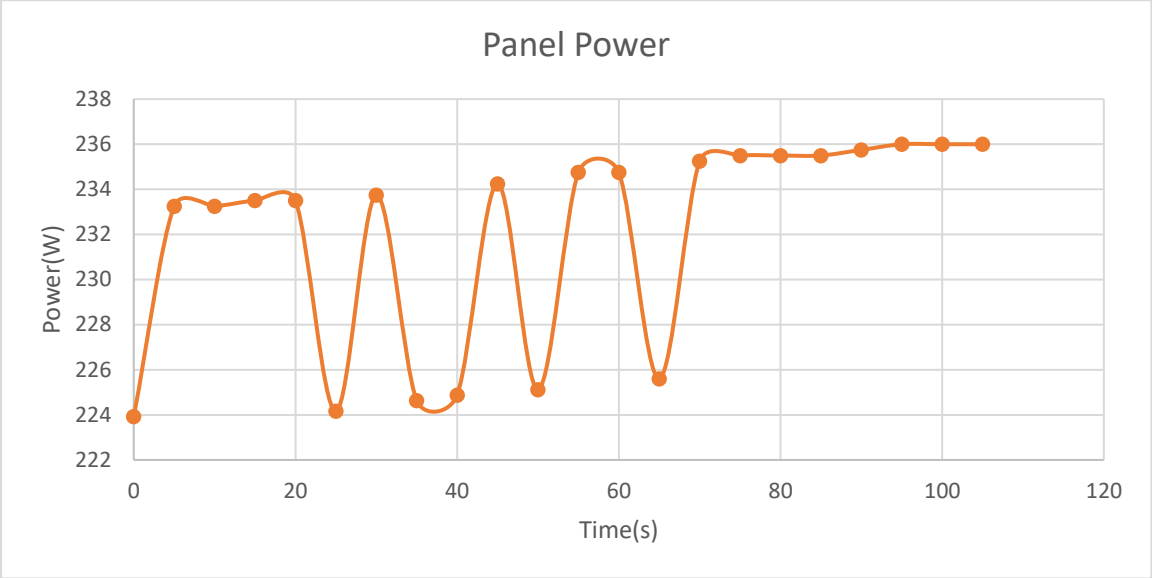


Figure 4.56: Panel Power 3

4. Panel Energy:

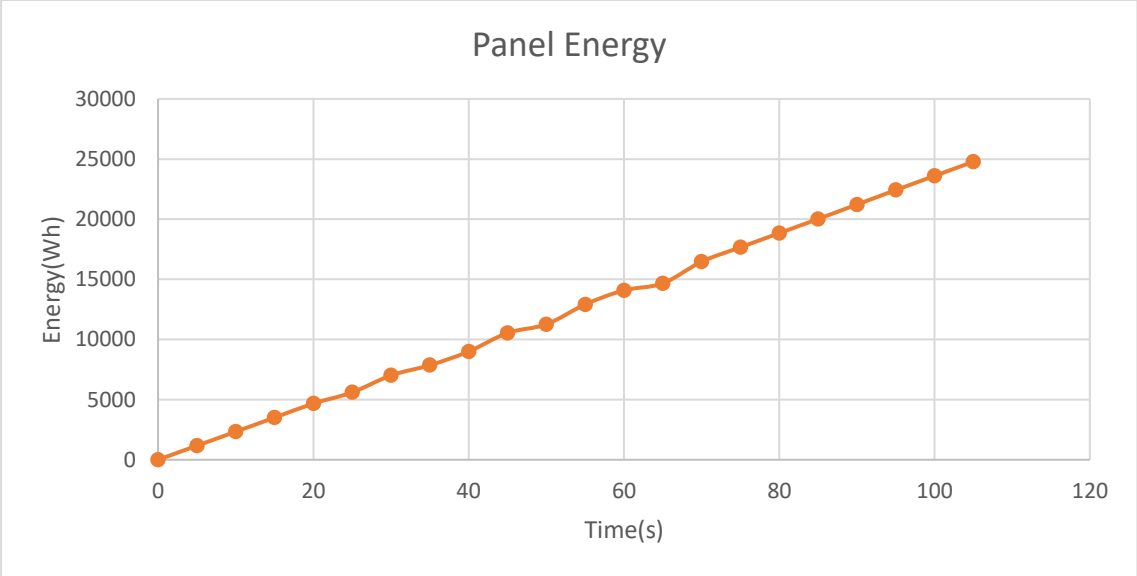


Figure 4.57: Panel Energy 3

4.5.2 Without load data

1. Panel voltage:

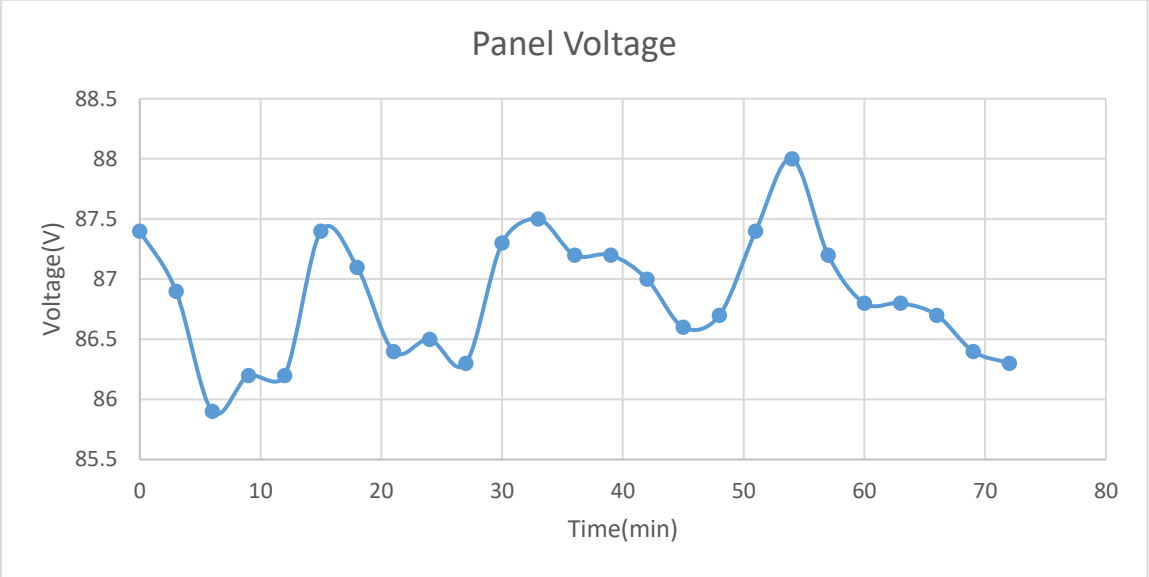


Figure 4.58: Panel Voltage 4

2. Panel current:

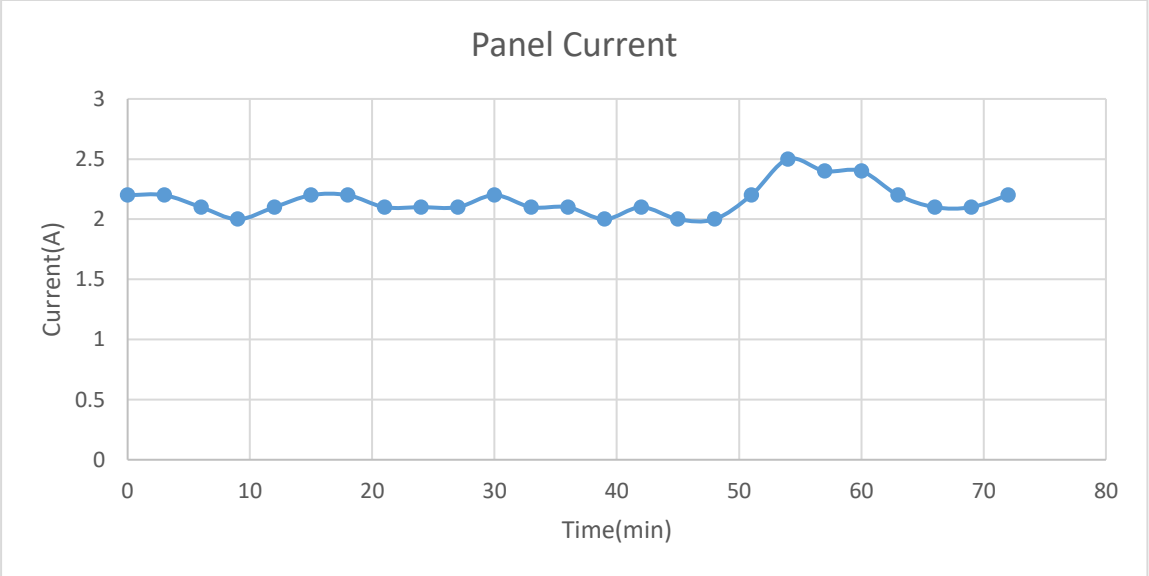


Figure 4.59: Panel Current 4

4.5.3 Discussion

Mainly, here two types of data were taken, one with load and another without load.

Panel Voltage:
During the running condition, the voltage of the panel remained within 92 to 94 volts. It did not fluctuate much due to panel's exposure to bright sunlight continuously. However, during idle condition the voltage stayed within 86V to 88V as the battery did not discharge so the voltage stayed less than the running condition.

Panel Current:
While the car was in running condition, the first panel current data showed that it peak current was 3.2A starting from 3A but for the rest two, the valued stayed within 2.3A to 2.5A. This happened because the voltage was high in the panel which resulted into higher panel current.
However, during the no load condition the current almost remained same as the load condition which is within 2.2A to 2.5A.

Panel Power:
In running condition, the power of the panel started with high watt of 275W to 299.2W but later, the power came down and stayed within 212W to 236W as the voltage and current was not as high as the first data.

Panel Energy:
During the whole duration of the car in running state, the energy initially had a watt hour of 30000Wh but during the second and third trial, the energy stayed within 0-25000 Wh.

4.6 Summary

From the field test data, it can be said that, it was not possible to achieve 45 kmph frequently as it was expected due to the structural reason but it is very much achievable as an average speed.

Secondly, from the battery voltage and current in both loaded and unloaded condition, it can be said that, the battery voltage decreased from the initial value during the loaded condition but during the idle state, the voltage got higher. In case of current, during loaded condition, it stayed around 60A but at idle state, the battery current was very low which is around 1A to 3A.

Thirdly, the panel voltage did not fluctuate much during both loaded and unloaded state. During loaded, it was slightly higher that is above 90V but during unloaded state, it was below 90V. Similarly, from the current reading, we can see that in loaded state, it was slightly higher than the no load state.

Chapter 5

Drawback and Opportunities

5.1 Drawback

5.1.1 Physical Drawback

The physical drawbacks that were found out during experimentation are:

- As the current chassis of the car is very congested so there is no more room for adding any extra features to it for experimentation.
- Being a very outdated chassis, compatible parts of it, in case of any failure, is very hard to find in the market.
- The average solar panel efficiency ranges from 15-18 percent only which makes it dependable on AC source charging.
- Dust makes the solar panel unusable if not cleaned regularly.
- Limited sunray availability during the day and its uneven intensity makes it difficult to charge the battery at a time without any interrupt.

5.1.2 Resources

The resource drawback that were found out during experimentation are:

- Unavailability of open area or field for testing purpose is responsible for carrying out experiment at any time.
- Outdated car parts are very expensive as they are hard to find which makes the modifying of the solar car harder.
- The battery of the car is very expensive to be replaced. It does not last long as it does not get charged every day.

5.1.3 Safety Concerns

The safety concerns that were found out during experimentation are:

- As the car is not water proof or wind proof, so this makes it exclusive for only dry weather.
- High speed makes the car sturdy as the inner parts are not fully attached with the chassis.

5.2 Economic Opportunities

Although the car has several drawbacks, it also has many economic opportunities.

- An average fuel car needs almost 1k fuel consumption per week whereas the solar car needs only to be recharged by the solar panel which is free of cost.
- The maintenance cost is very low for the car as one doesn’t need to change Mobil oil, gear oil and no issue with the engine.
- A full charge solar car would serve up to 140 km whereas a regular fuel fed car would not go more than 40 km.
- One never gets out of fuel in the solar car as it gets charge with the sunlight with free of cost.
- Long ride is easily possible with the solar car as the travel cost is very low compared to the fuel fed car.
- Solar panel has a durability of 20 years which makes it even more pocket friendly for the user.

Conclusion

Nowadays the world is going for Renewable Energy because natural resources like oil, natural gas are finishing slowly. Besides these, oil used engines produce high amount of carbons which pollutes our environment very badly. On the other hand, solar is renewable energy which has limitless supply as well as eco-friendly. Solar powered vehicles produce zero amount of carbons also noiseless, low maintenance and cost efficient. Solar powered car is compatible with today's and as well as future technology and we sincerely hope that it would not be much long before most of the people would change to driving this advanced vehicle and accordingly realize a positive change in their lives and the earth. This is simply the start of another innovation and it is ensured that future improvements will make solar powered cars the overwhelming method of transportation over vehicles with internal combustion engine.

To make the solar car more compatible in road the chassis has to be changed because when the speed is increases the whole body of the car begin to vibrate continuously. Besides, the brakes of the car are not that much good in crucial moments. The brake drums need some repair works. The acceleration cable is very much hard due because it has not been changed in years. The speedo meter of the vehicle needs to be calibrated with the front wheel properly. The suspensions can be changed due to stiffness.

References:

[1] http://www.automostory.com/first-solar-car.htm

[2] https://futurism.com/fully-solar-powered-car-hitting-road-2019

[3] http://www.ebangladesh.com/2801

[4] https://www.researchgate.net/figure/Historical-consumption-of-gas-in-different-sectors_fig3_289374730

[5] https://www.scribd.com/doc/101017237/Present-Future-prospects-of-Natural-Gas-in-Bangladesh

[6] https://www.bangladeshenvironment.com/index.php/polution-s/air-polution/291-air-pollution-in-dhaka-city

[7] https://leafsaversfoundation.wordpress.com/2016/08/28/be-eco-friendly-reduce-air-pollution/

[8] http://energybangla.com/carbon-emissions-forecast-to-hit-record-levels-this-year/

[9] https://knoema.com/atlas/Bangladesh/Diesel-price

[10] https://www1.eere.energy.gov/solar/pdfs/solar_timeline.pdf

[11] http://www.qrg.northwestern.edu/projects/vss/docs/power/2-how-efficient-are-solar-panels.html

[12] https://www.energysage.com/solar/101/monocrystalline-vs-polycrystalline-solar-panels/

[13] http://dspace.bracu.ac.bd/bitstream/handle/10361/3228/09221020.pdf?sequence=1

[14] https://batteryuniversity.com/learn/archive/can_the_lead_acid_battery_compete_in_modern_times

[15] https://www.solar-electric.com/learning-center/batteries-and-charging/solar-charge-controller-basics.html

[16] http://dspace.bracu.ac.bd/xmlui/handle/10361/4212

[17] https://en.wikipedia.org/wiki/Differential_(mechanical_device)