PERFORMANCE EVALUATION OF A SOLAR POWERED ELECTRIC VEHICLE

Submitted by:
Mohammad Tayef Hossain – 13121014
MdSolaimanBhuiyanAlave – 11321013
KaziMushfiqusSaleheen – 10321012
Syed AshrafulKarim - 13110002

Supervised by:
Dr. Md. MosaddequrRahman
Professor
Department of Electrical& Electronic Engineering (EEE)
BRAC University

A Thesis Submitted as the partial Fulfillment for the Degree of Bachelor of Science in Electrical and Electronic Engineering

Department of Electrical and Electronic Engineering
Fall 2017
BRAC University
Dhaka, Bangladesh

Declaration

Acknowledgement

We would like to express the most profound and most sincere appreciation to our Thesis Supervisor Dr. Md. MosaddequrRahman, Professor of Department of Electrical & Electronic Engineering (EEE), BRAC University, for his relentless direction and support throughout this work. Without his guidance and consistent help this dissertation would not have been achievable.

Abstract

Solar power is one of the key source in the field of renewable energy in current world. The solar energy is converted to electrical energy by means of photovoltaic cells like as Monocrystalline silicon, Polycrystalline silicon and Amorphous silicon. The objective of this paper is to measure the efficient solar electric vehicle performance and upgrade the vehicle as per need, for the daily office-goers of the Dhaka city, so that they can cover their required distance as per need on daily basis on a reliable, environment friendly and economical car that operates on free renewable solar energy. The paper gives a brief of how the charge created in the solar panels is obtained and is carried in and out of the battery pack and is controlled using a microcontroller based charge controller to make efficient storage of charge in the battery pack. And how the stored charges from the battery drives the DC motor of the vehicle to operate using a motor controller to drive the vehicle forward and reverse and to control its speed. The paper also illustrates the wiring and mechanical concepts of the electric vehicle from top to bottom and its modification and also provides graphical representation of the component testing results with calculation derived after evaluation.

Table of Contents

1.Introduction

1.1 Motivation

Renewable Energy:

Solar power energy is known as the radiant light and heat from the sun that is utilized using a range of ever created techniques such as the solar heating, photovoltaics, solar thermal energy. Solar power energy is a vital source of renewable energy, and according to the report of "International Energy Agency" published in "2011" mentioned that the inexhaustible and clean solar energy technology will have a huge longer terms benefits among the countries making them independent from the fuel consumption dependency and save natural resources for the future and also reducing pollution, increasing sustainability and lowering the cost of lessening global warming. The earth absorbs 174 petawatts (PW) of incoming solar radiation and among that 30% is reflected back to the space and the remaining is absorbed by the clouds, oceans and land masses.

Solar energy have been used from ages, it is known as the most sustainable and reliable energy source ever created by humans there are many reason why solar energy is so beneficial like it reduces the energy bills, it cuts off global carbon emissions, lowers carbon footprints which have great positive impacts in people's lives and in environment keeping healthy peoples, waterways, soil, animals and beyond. And also solar energy has been used to operate several appliances like calculators, cars, watches, heaters as its cheap and renewable.

As per geographical data it shows that the bright sunshine hours in the coastal region of Bangladesh differs from 3 to 11 hours daily. And the isolation differs in Bangladesh from 3.8 kWh/m^2 per day to 6.4kWh/m^2 per day at an average of 5 kWh/m^2 per day, this estimated results shows that Bangladesh have a good possibility for solar thermal and photovoltaic applications for mass implementation. It is estimated that around 40% of the mass population of Bangladesh have no electricity so according to the report of 2014 it elaborates how government of Bangladesh has implemented solar home system from 2009 to supply electricity to homes and factories which have no grid access and according to World Bank report it is the fastest growing Solar Home System in the world and the government of Bangladesh have been successfully able to supply as of now by 2017, 72 % of the total population have access to electricity and around 30 million people are benefitting from the SHS system , it is an example which shows the importance solar power as an alternative of natural nonrenewable resources.

Carbon footprint:

Carbon footprint is known as the overall set of greenhouse gas emission caused by any organization or any individual and is defined as total number of CO2 emission and Methane emission of a defined population, system or activity considering all the factors relevant to it. Greenhouse gas is produced for various reason such as due to clearing of land and making and consuming of products, foods, roads, Material, building, transportation .Carbon emission have a huge impact on climate change and results disastrous consequences for the human, animal and for the environment. The burning of the fossil fuels results emission of carbon dioxide in the atmosphere together with other greenhouse gasses, hence the emission of carbon dioxide increases the global temperature by trapping the solar energy in the inner space of the atmosphere which in turns increases the global temperature and effects the climate by changing water supplies and weather pattern, altering the growing season of food, crops and causing natural disasters and raising sea levels.

Climate change and Bangladesh are the two familiar name in the record when heard of any natural disaster, Bangladesh has been affected most due to climate change and its estimated that if sooner the global warming not controlled then Bangladesh will face lots of casualties and death as due to rise of sea level and super typhoons , keeping in mind according to the report published in 2006 by BDRC (Bangladesh development research center), Bangladesh emitted around one tenth of the world CO2 emission although its country population is 160 million represents 2.4 % of the world population. Bangladesh government has introduced lots of government and private sectors to enhance the use of alternative energy resources best known as SHS (solar home system) and lot of other similar projects, in order to decrease carbon footprint and bring people under national power grid who have faced scarcity of electricity.

1.2 Project overview

The rapid climate changes alongside with occasional price hike of fuels have paved the path for the research of solar charged automobile. A lot of solar car models have been introduced over the year. The campaign for affordable green cars is gaining weight over the years. Stella, the first completely solar car designed for normal road travel, reached the U.S. in 2014. TESLA, another leading automobile company, famous for the manufacturing electric vehicle is also on the run for affordable solar car. Though the mass population of Bangladesh is habituated with the use of renewable energy for domestic purpose but solar powered car is still a fresh idea here. As mentioned earlier aim of our project is to make the solar car efficient and affordable for mass production and frequent usage.

The vehicle has two parts, Electrical and Mechanical. Electrical parts are mainly the input whereas the Mechanical parts can be regarded as the output.

Figure 1.2a: Finished Solar Powered Electric Vehicle

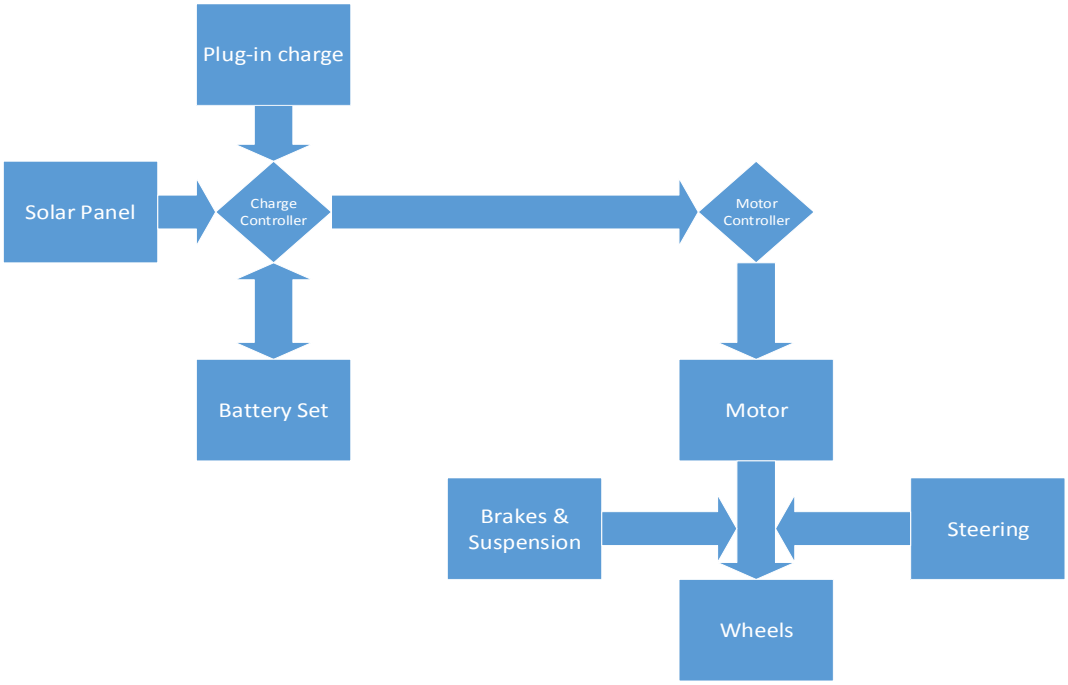


Figure 1.2b: Basic block diagram for the overall system

MOTOR AND MOTOR CONTROLLER

The motor we used is a DC-series excitation motor [brushless] which is rated at 2 kW, 60V, 36 A. This DC-series motor determines the car's speed. The motor controller is designed to control the speed of rotation of the motor. It also navigates the direction of the rotation. The Motor we used is capable of 3000 rotation per minute [rpm] without any load which is sufficient enough to make our car move and to reach expected speed. The manufacturer of the motor is Hong Kong Dong Hui Motor Industrial Co. Ltd.

Figure 1.2c: Motor and Motor Controller

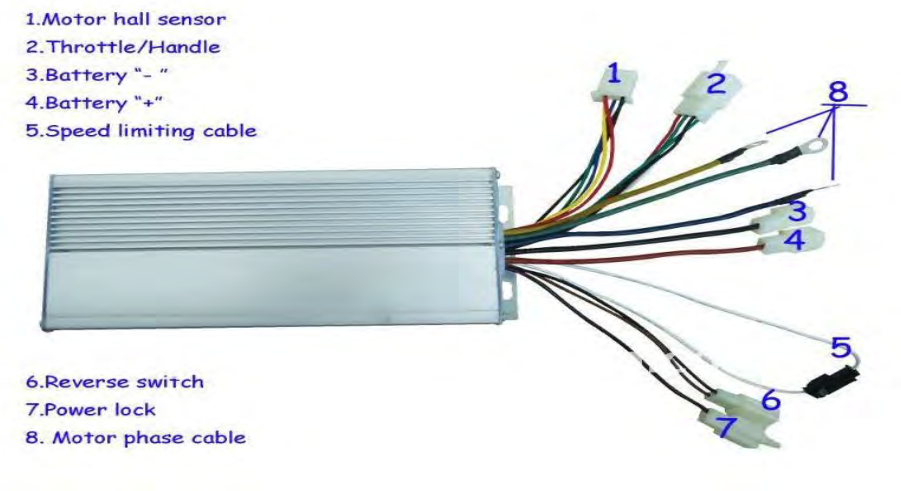


Figure 1.2d: Motor Controller

STEERING, SUSPENSION, BRAKES, WHEELS

These components sum up the whole mechanical part of the solar car. Front wheel steering is used for better stability and safety. Though there is room for improvement the suspension used is good enough to protect the car and panels from sudden shocks and blows. We used a drum braking system as used in typical fossil fueled cars. Rolling resistance of a wheel determines how far it can travel with the provided energy. We had to go for a thinner but strong wheels since thicker wheels tend to have higher rolling resistance.

Battery Set

We used five batteries of twelve voltages. All the batteries were connected in a series connection. The Batteries being a bit heavy for the car sit behind the vehicle so that we can balance it with miscellaneous parts of the car in the front part. The capacity of the battery is 180Ah.

Figure 1.2e: Battery Set

SOLAR PANEL

Solar panel being the most important part of the car collects the energy from the light source. The solar panels used in this project are mono crystalline. They can be mounted and fitted on top of the car or on the bonnet easily.The Solar panel is semi flexible.

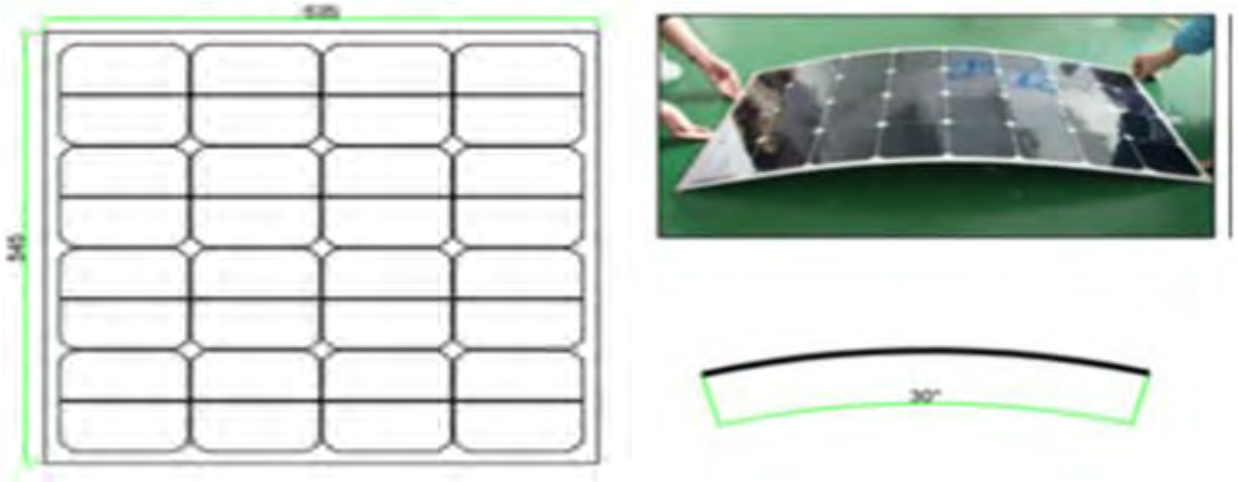


Figure 1.2f: 50W Semi-flexible Monocrystalline Solar panel

Charge controller

The batteries are connected to a charge controller .The controller monitors the battery condition. It keeps the batteries fit by preventing it from over charging and over discharging. A microcontroller is programmed to detect the voltages at the battery terminal and/or the solar panel terminals. According to that voltages it determines the charging current the battery needs.

Figure 1.2g: Charge controller

Moreover the charge controller is available with an additional input that to charge the batteries from an AC power supply. Thus the solar car will have this plug-in charging system for using in case of gloomy weather. This facility for an external plug-in system to charge the batteries would increase its' overall utility.

2.Component testing

Electric vehicles have fewer major components compared to internal combustion engine vehicles. However, it is imperative at the design stage that the electrical systems have precise calculations of the ratings of these major components. The ratings of the 3 major components of the vehicle that will be determined are:

- The motor performance ratings required to achieve the necessary speed and acceleration.
- The battery capacity which can support the distance required to be travelled.
- The solar panel specifications needed to keep the battery sufficiently charged for the journey.

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

2.1 Motor Performance

The force provided by the motor determines the speed of the vehicle. We used the 3000rpm rated motor provided to us and install it to replace the older 2000rpm one that was faulty. After fittings and the vehicle was taken for field test.

The major objectives of the field test were:

- To see how the whole system behaves on road (i.e. is it really comfortable for both the rider and passenger?)
- To see if the motor control system is working properly and safely (i.e. if any hazardous situation takes place, like losing the control of the car etc.)
- To analyze performance under different conditions (i.e. performance on different days, different road conditions, etc.)
- How quickly the battery discharges

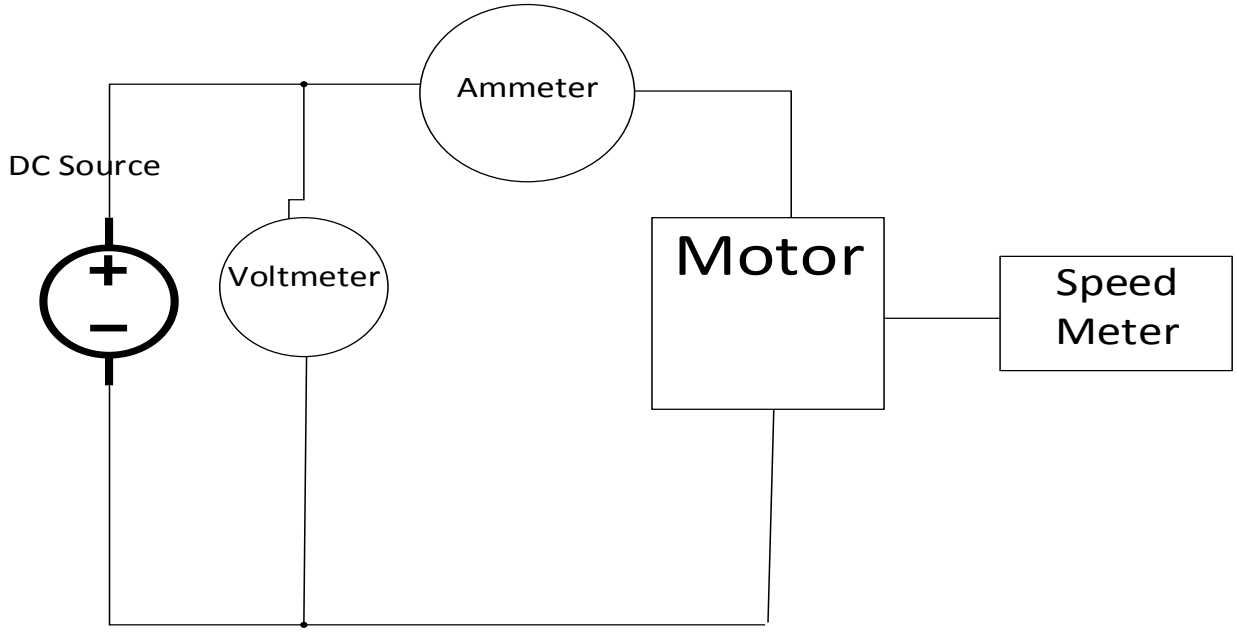


Figure2.1a: Circuit design used to analysis the motor's performance
(DC Source is the "battery set" in this case)

Qualitative Analysis

During the two hours of test, no hazardous condition took place like losing the control over motor and stopping it on emergency basis etc. From the passengers' point of view, it

Quantitative Analysis

Data taken to analyze motor performance:

- The output voltage pattern analysis of the battery to motor
- The pattern of current drawn from battery to motor
- The speed pattern analysis of the car
- What is the percentage of battery-charge after each of run

From the current-drawing pattern, the following data were achieved.

- The power consumption pattern by the motor (the other power-consumptions are negligible)
- The total-energy consumption by the motor in a particular time-interval
- A comparison between each run.

Data Acquisition Technique

Due to the unavailability of modern data acquisition techniques, a video camera was used to record the data from multi-meters and then replayed and paused in regular intervals of approximately 1 second or 5 seconds, depending on the condition used, are noted. Multiple runs were taken each lasting approximately 1kilometer of length. Then the recorded data were plotted to represent in figures for better understanding.

2.2 Battery Capacity

Capacity is the measurement of how much energy the battery can store (in Ampere-hours), analogous to the amount of water in a jug. The capacity contributes to the vehicle's acceleration and speed as well as the total distance the vehicle can cover before the battery charge is depleted. For our experiment we used charge-discharge method to measure the capacity for each battery individually from the battery set.

The major objectives for this charge-discharge experiment were:

- To determine how fast the battery fully charges and fully discharges

Circuit design for:

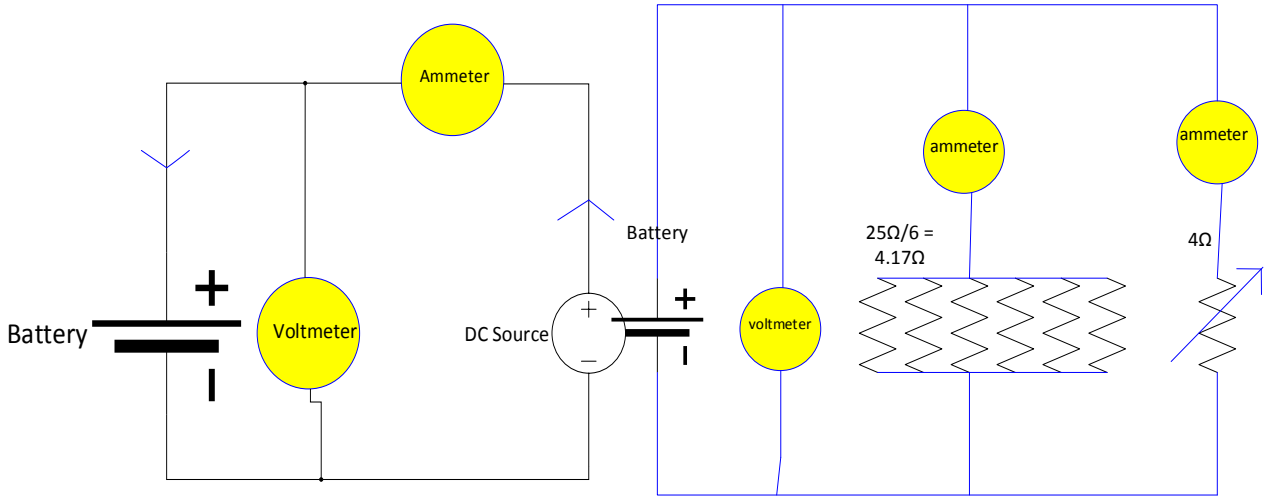


Figure2.2a: Charging **Figure2.2b: Discharging**

Qualitative analysis

During the experiment the batteries performed as expected with no noticeable defects such as overheating, fluid leakage or getting shock while handling the electrical components.

Quantitative analysis

Data taken to analyze battery capacity:

- Open circuit voltage of the battery before starting the experiment and at certain time intervals during the experiment
- Terminal voltage during the experiment in regular intervals of ten minutes

Data Acquisition Technique

Assumption:

State of Charge	12 Volt battery
100%	12.7
90%	12.5
80%	12.42
70%	12.32
60%	12.20
50%	12.06
40%	11.9
30%	11.75
20%	11.58
10%	11.31
0	10.5

Figure2c: SOC vs open circuit/no-load terminal voltage

Typically in a 12V lead-acid battery system the voltage varies from 10.7V to 12.7V. Although the actual state of charge of each battery is unique. Thus the actual charge/discharge characteristic of a battery has to be determined by testing the battery for at least one charge/discharge cycle.

The appliances provided by the BRAC University Thesis Laboratory were used.

For charging:

- Controllable DC power supply
- Voltmeter
- Ammeter
- Connecting wires
- Switch

The current across the circuit was kept constant while the voltage applied to the battery was increased gradually using the controllable DC power supply. The circuit was disconnected using the switch at every 3 hours interval and 10-15 minutes were allowed for the battery to rest before taking the open circuit voltage to determine the state of charge of the battery. Then the experiment is continued and the process repeated until the open circuit voltage had crossed the 12.7V mark.

For Discharging:

- variable resistors
- Voltmeter
- Ammeter
- Connecting wires
- Switch

The current across the circuit was kept constant using the variable resistors. The circuit was disconnected using the switch at every 3 hours interval and 10-15 minutes were allowed for the battery to rest before taking the open circuit voltage to determine the state of charge of the battery. Then the experiment is continued and the process repeated until the open circuit voltage had dropped to 11.8V. Multiple charge-discharge cycles data were taken to improve the accuracy of the result. Then the recorded data were plotted to represent in figures for better understanding.

2.3 Solar Panel

The solar panel is the ultimate source of energy for this vehicle so to ensure that the panels were functioning as intended an experiment was performed to analyze its output power.

The major objective of this experiment is:

- To determine the amount the panels can generate
- To determine the amount of time it will take for the panels to fully charge the batteries

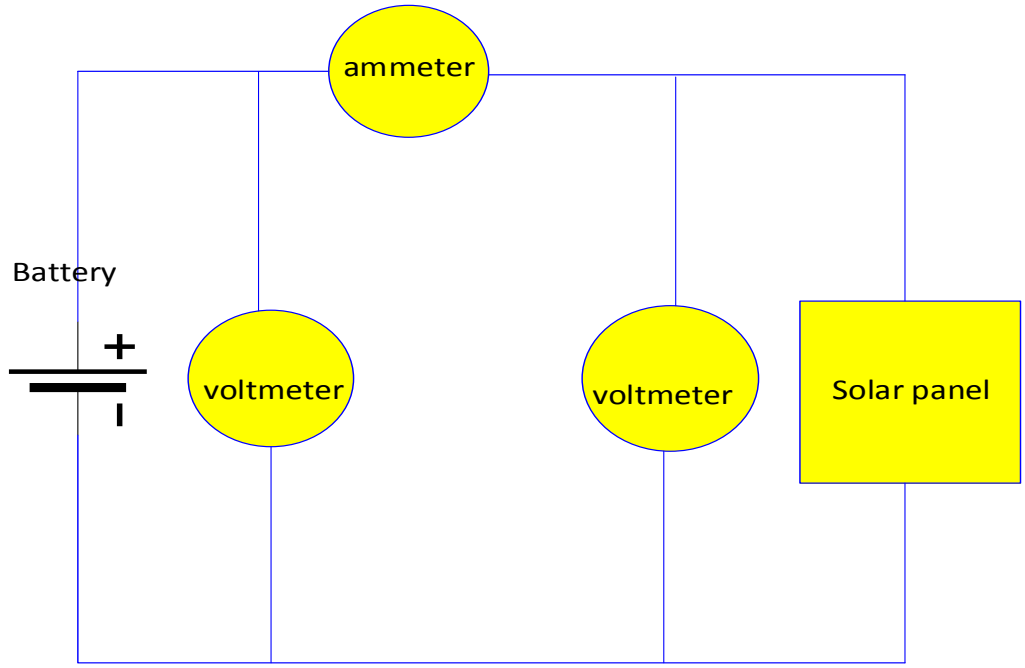


Figure2.3a: Circuit design for charging using the Solar Panels

Qualitative analysis

During the experiment the components performed as expected with no noticeable defects such as overheating or getting shock while handling the electrical components.

Quantitative analysis

Data taken to analyze charging capabilities:

- Open circuit voltage of the battery before starting the experiment
- Terminal voltage of the battery during the experiment in regular intervals of five minutes
- Terminal voltage of the solar panel output terminals during the experiment in regular intervals of five minutes
- Current across the circuit during the experiment in regular intervals of five minutes

Data Acquisition Technique

Due to the unavailability of modern data acquisition techniques, and road safety concerns a street with minimum traffic (people and vehicle) during the time slot 11:00am – 2:00pm. Multiple sets of data were taken to account for different weather conditions over several days and improve the accuracy of the result. Then the recorded data were plotted to represent in figures for better understanding.

3.Performance Evaluation

3.1 Upgrades

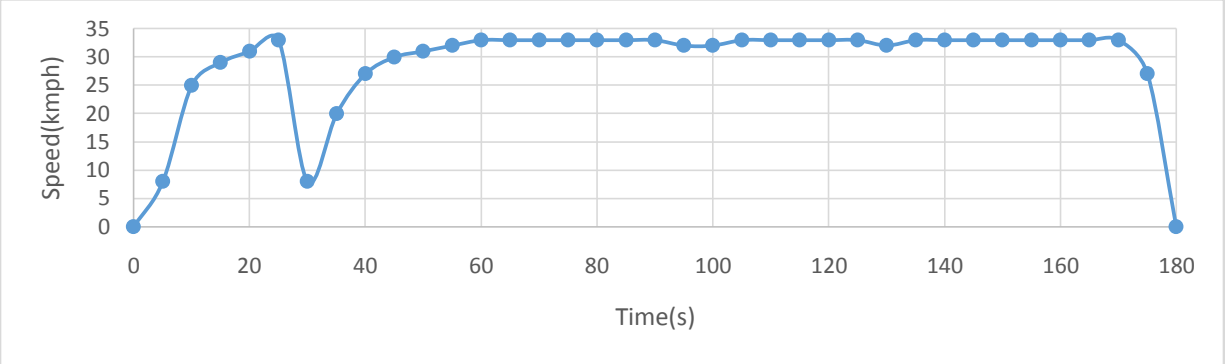
The previous recorded speed was approximately 20kmph. A new motor of greater rpm rating was purchased in order to increase the speed of the vehicle. Although the actual purpose of the upgrade was that the previous model was faulty. Its' no load rotation speed was approximately 1400rpm whereas it was rated at 2000rpm. Thus a new model was purchased of 3000rpm rating. During its' test the no load rotation speed was approximately 3000rpm and after installment the loaded rotation speed measured using the vehicle wheel was approximately 2600rpm which was acceptable.

Also, a new set of batteries were purchased in order to increase the maximum travelling distance the vehicle can cover. The battery capacity was increased from 70Ah to 180Ah in order to double the maximum travelling distance.

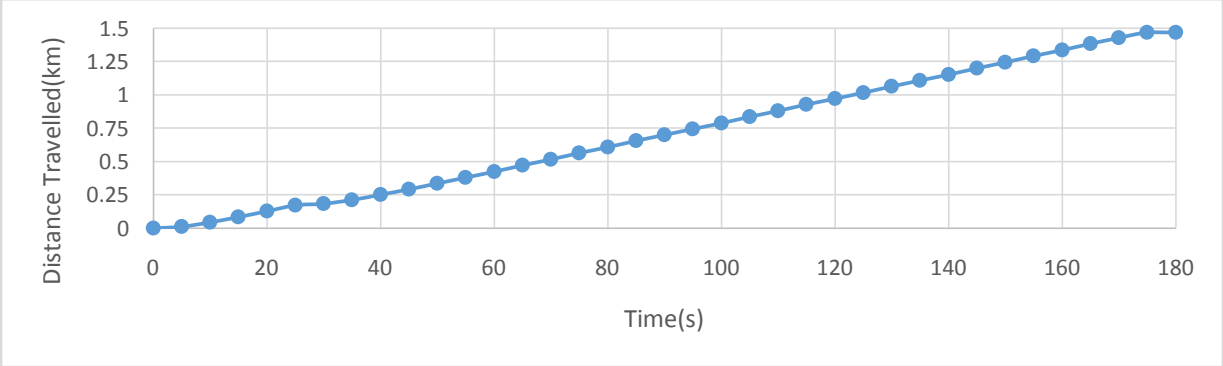
3.2 Vehicle Field test analysis

Field Test No.1

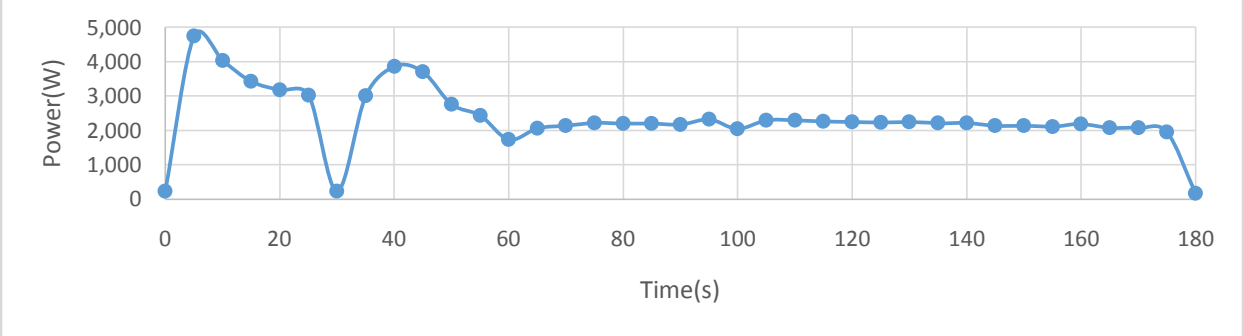
Speed of the vehicle



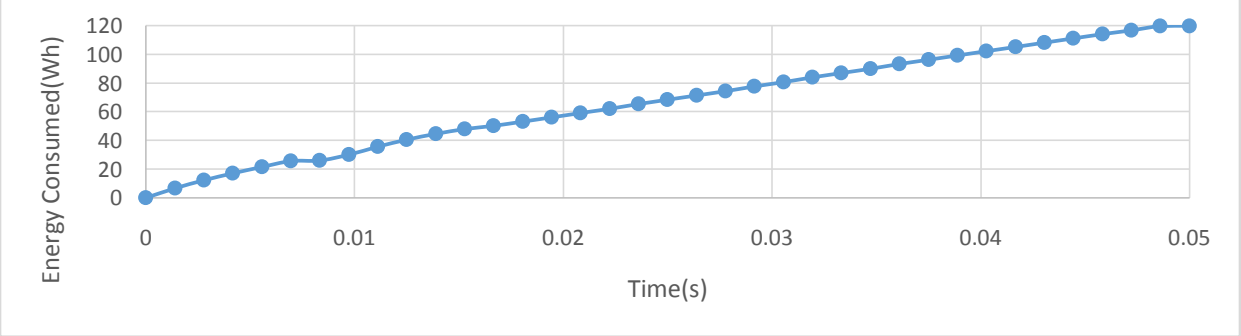
Distance travelled by the vehicle



Power rating of the motor

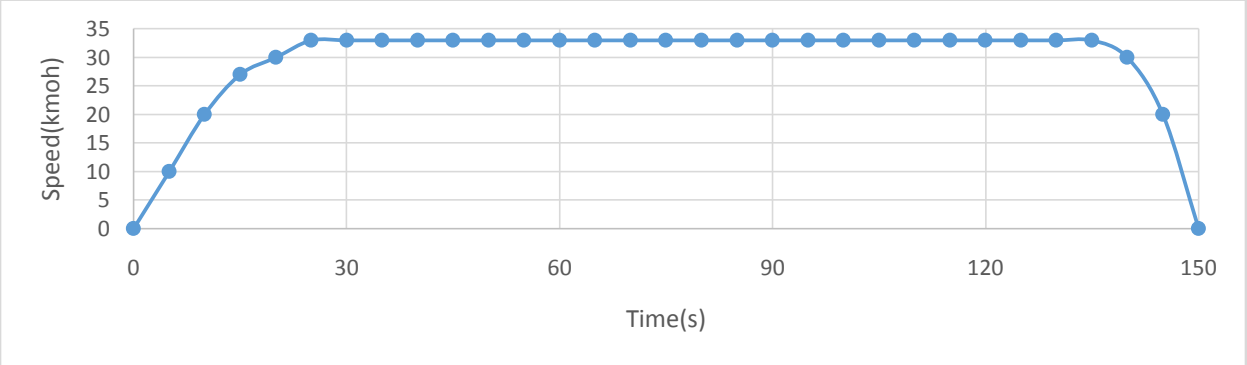


Energy Consumed by the motor

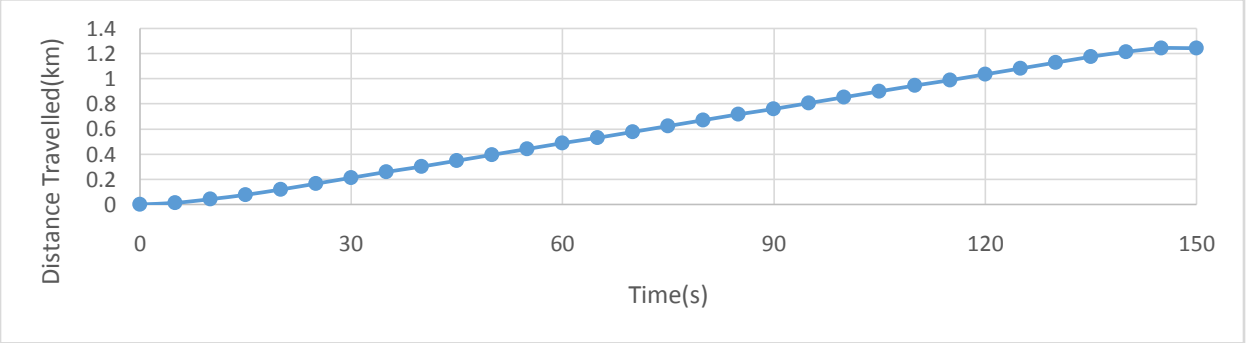


Field Test No.2

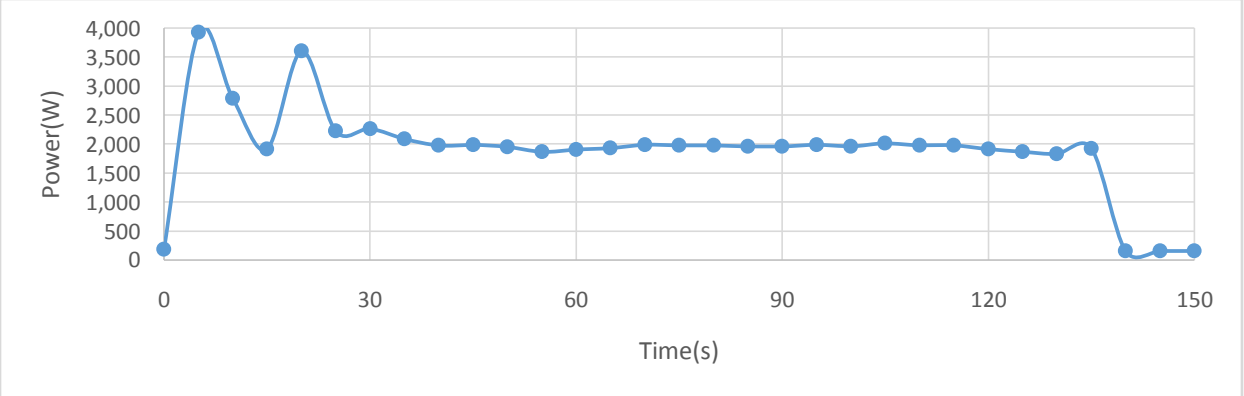
Speed of the vehicle



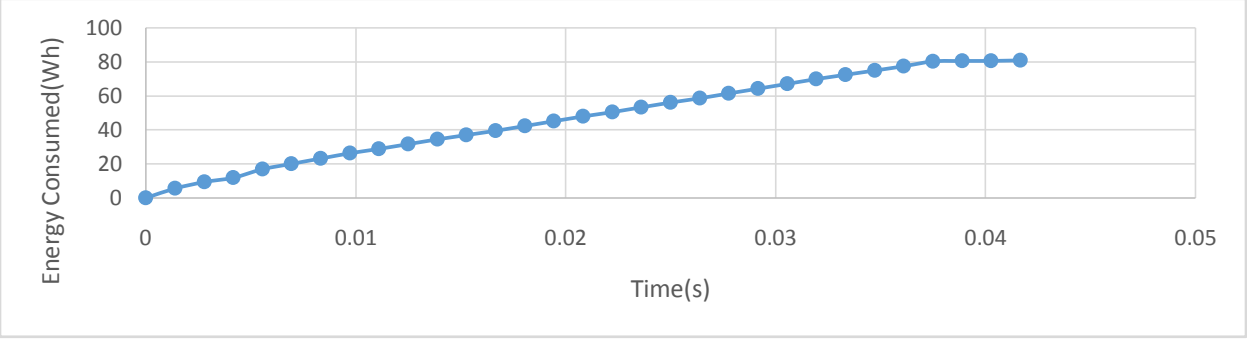
Distance travelled by the vehicle



Power rating of the motor

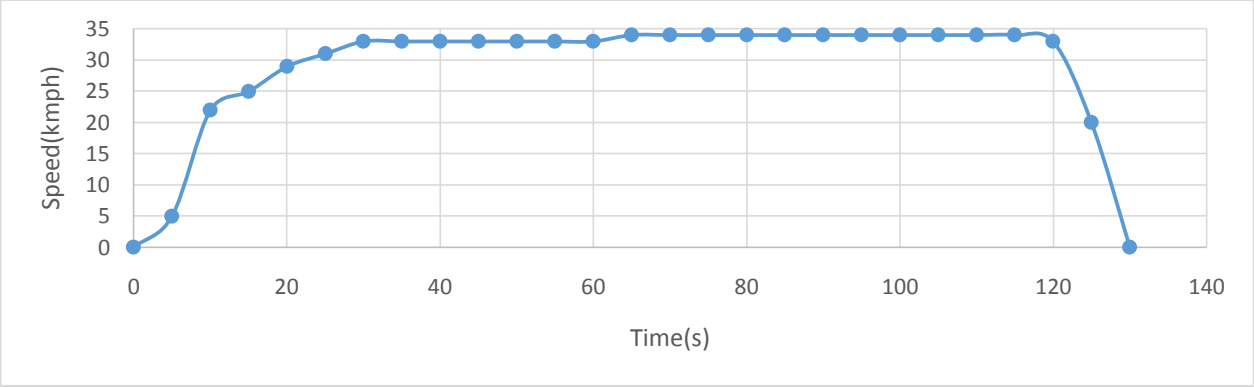


Energy Consumed by the motor

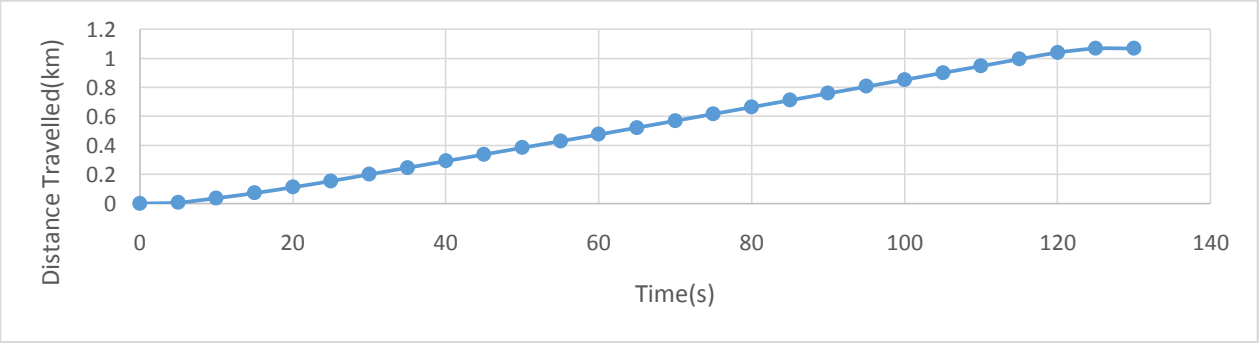


Field Test No.3

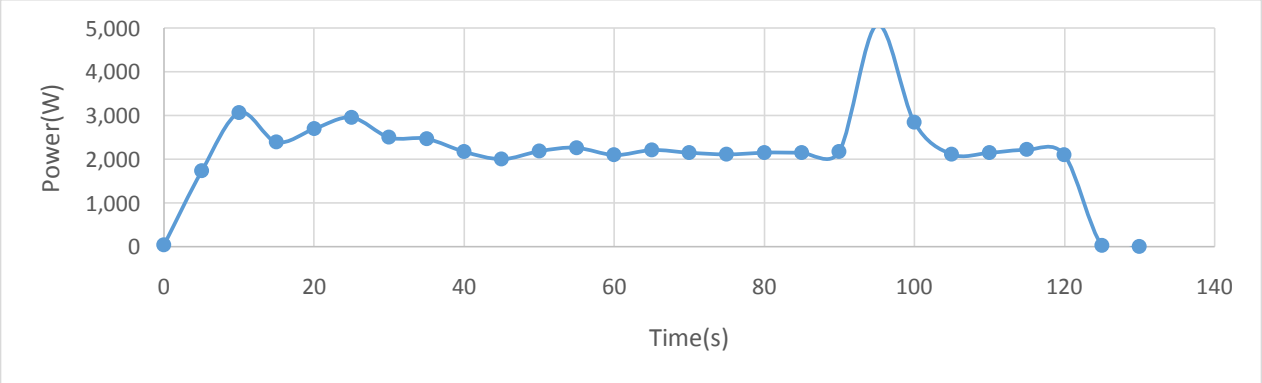
Speed of the vehicle



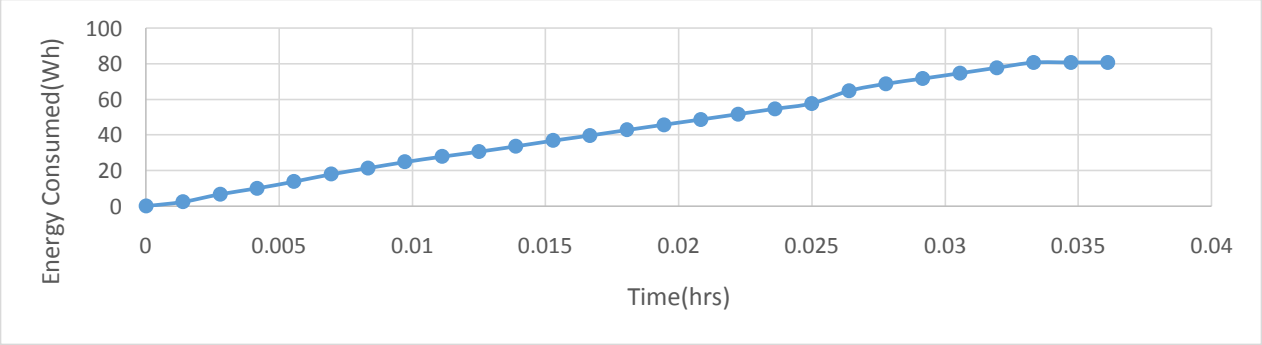
Distance travelled by the vehicle



Power rating of the motor

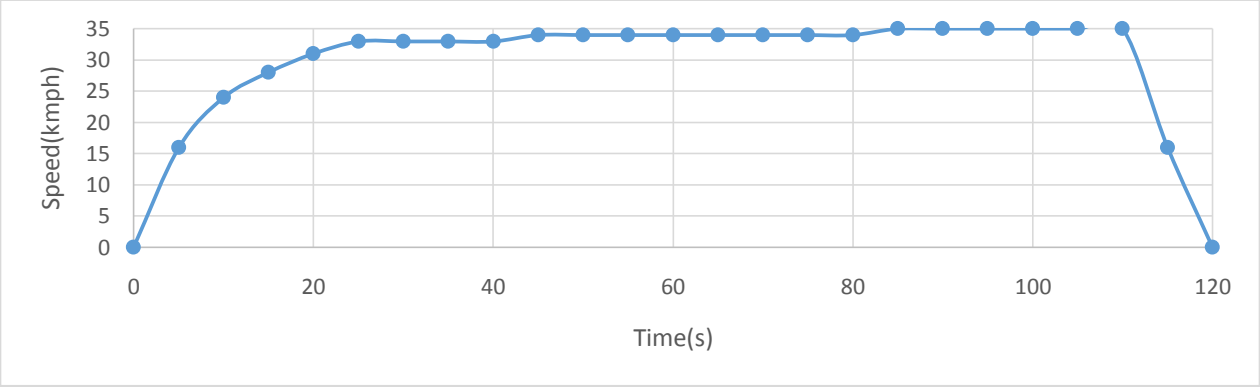


Energy Consumed by the motor

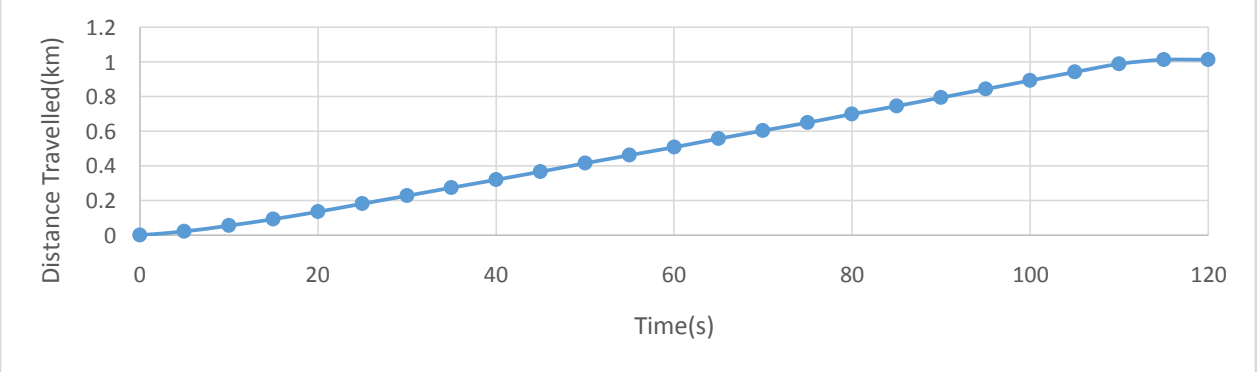


Field Test No.4

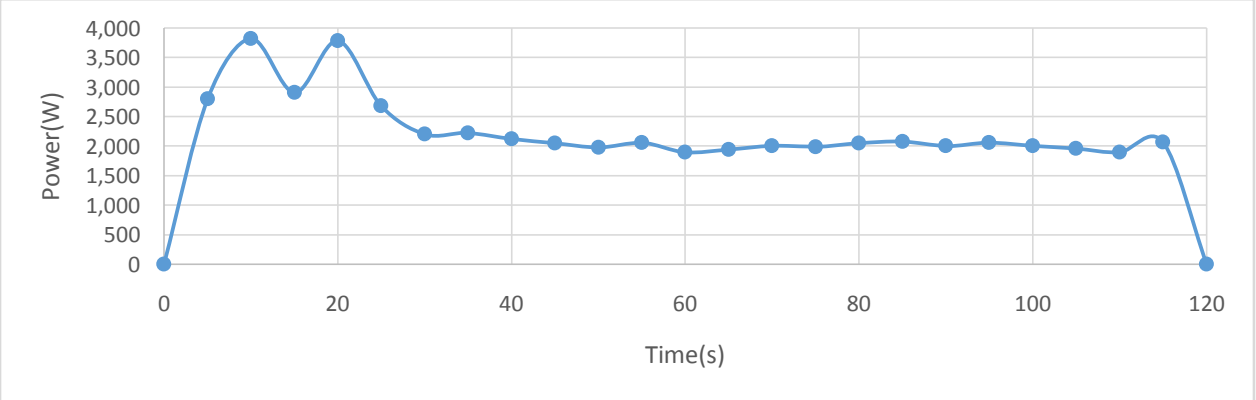
Speed of the vehicle



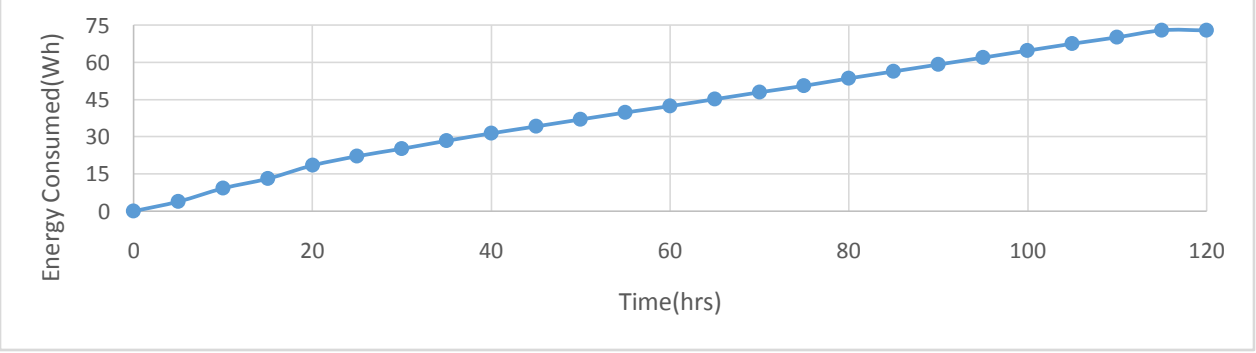
Distance travelled by the vehicle



Power rating of the motor

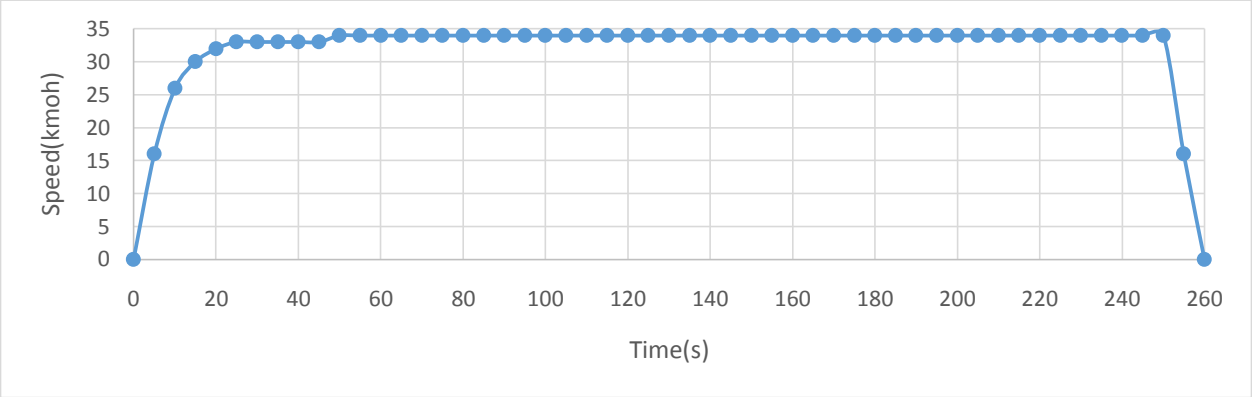


Energy Consumed by the motor

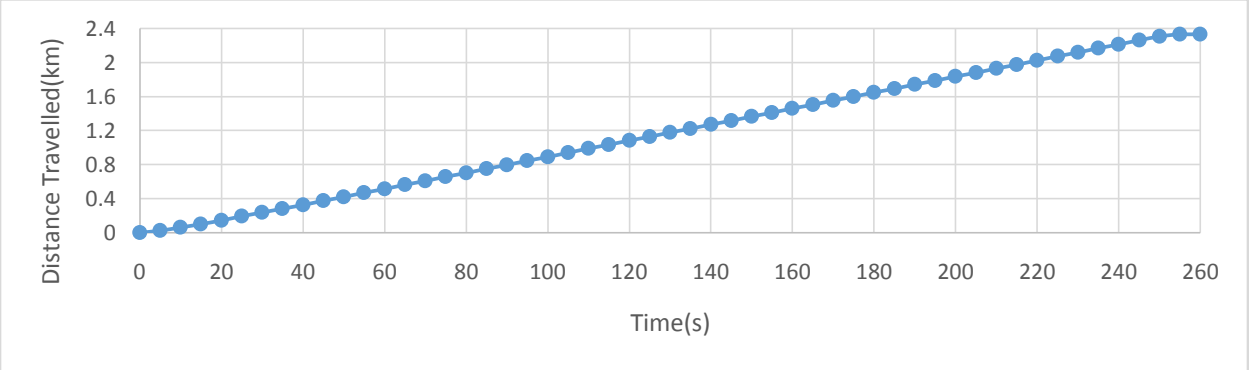


Field Test No.5

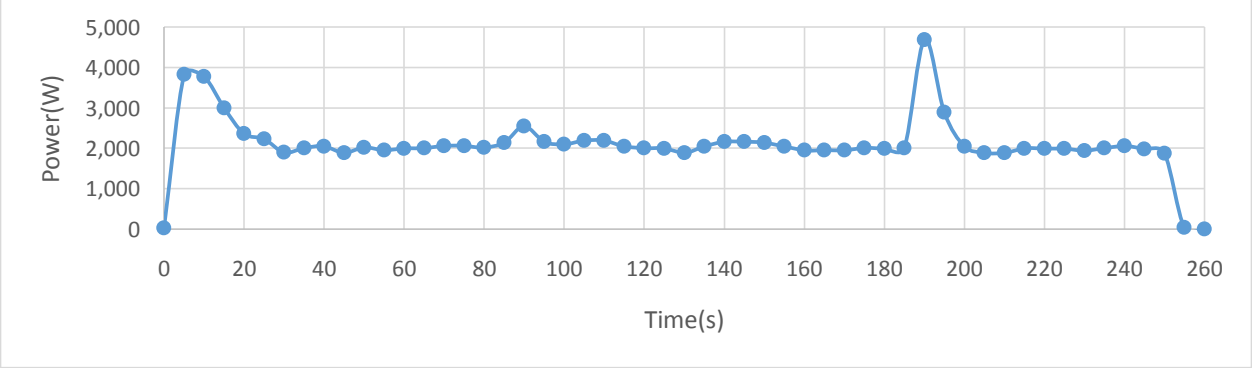
Speed of the vehicle



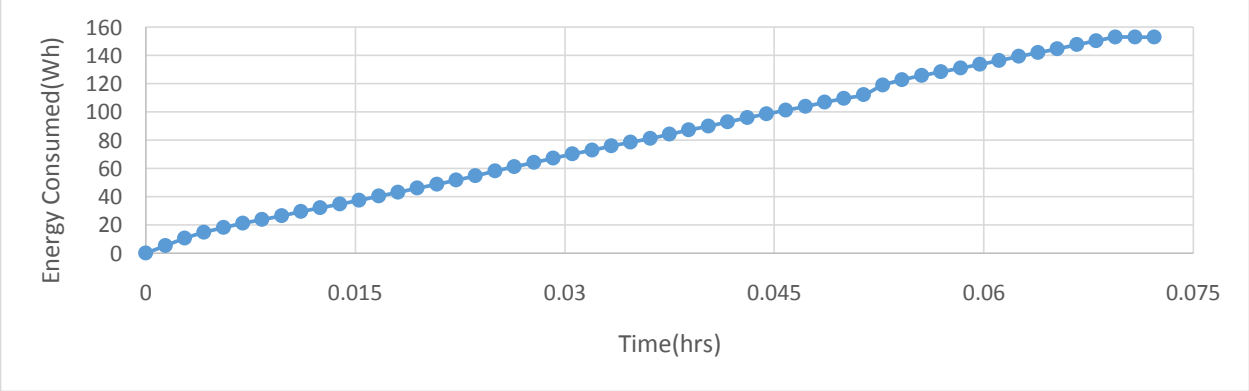
Distance travelled by the vehicle



Power rating of the motor



Energy Consumed by the motor



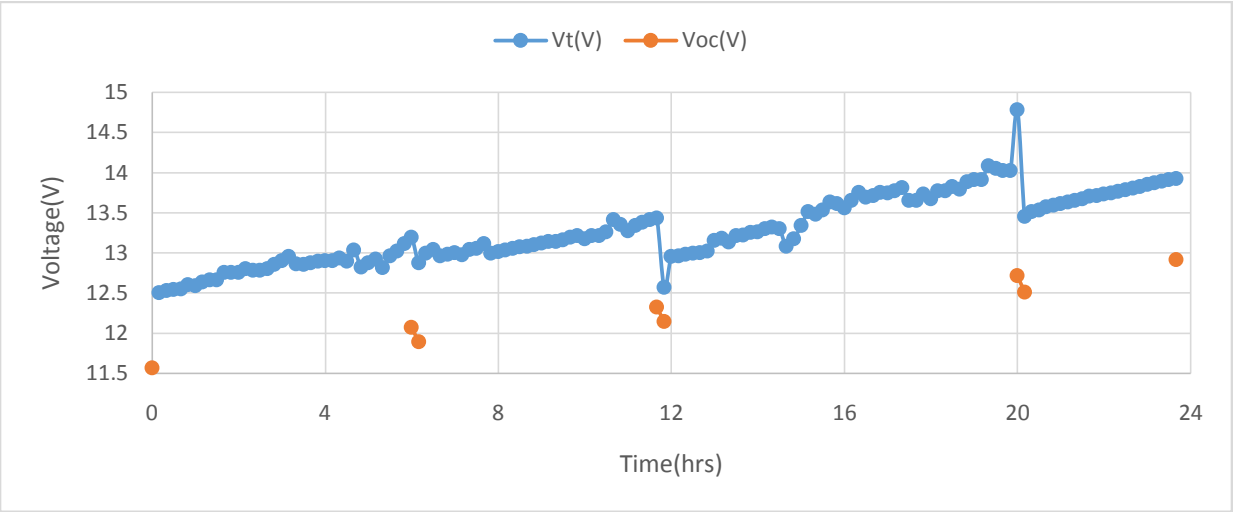
Field test summary

- Top Speed reached : 35kmph
- Average Speed of the vehicle: 32kmph
- Acceleration of the vehicle: 0-20kmph in 7.2 sec (2.78 km/s^2)
- Duration of operation: 2.1min (0.035hrs)
- Distance covered each run during operation: 1km
- Average Energy consumed during operation: 80Wh
- Operating Power of the system: 2300W
- Maximum Startup current of the system: 85A
- Operating Current of the system: 40A
- Operating Voltage of the system: 58V

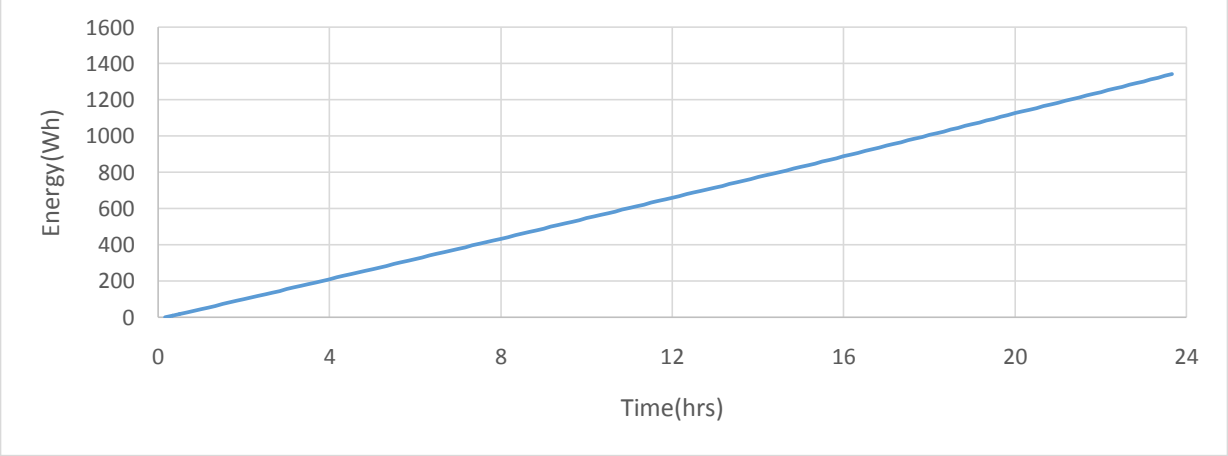
3.3 Battery Capacity

Charging curve No.1

Voltage change at I=4.3A

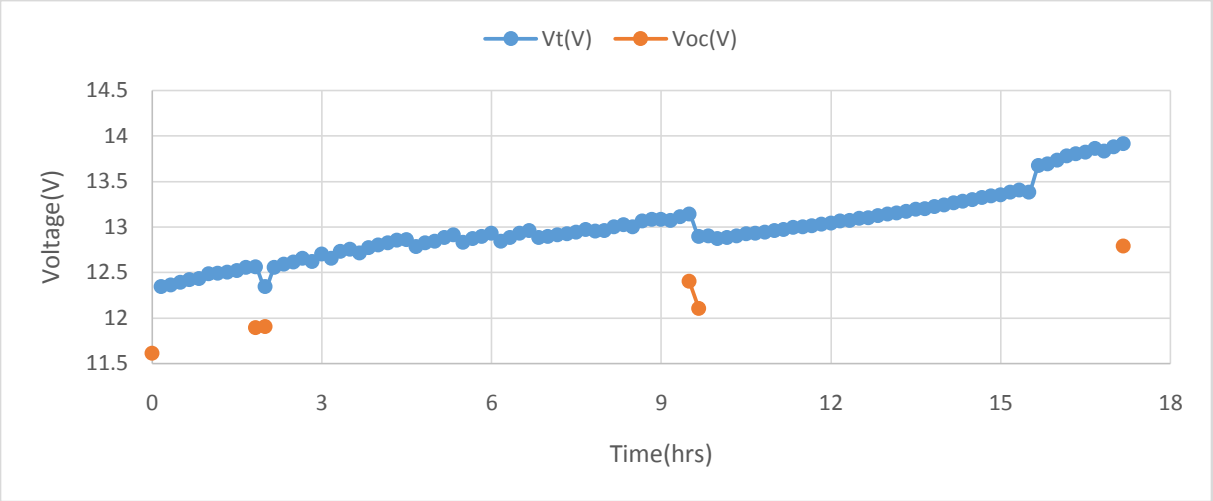


Energy supplied to battery

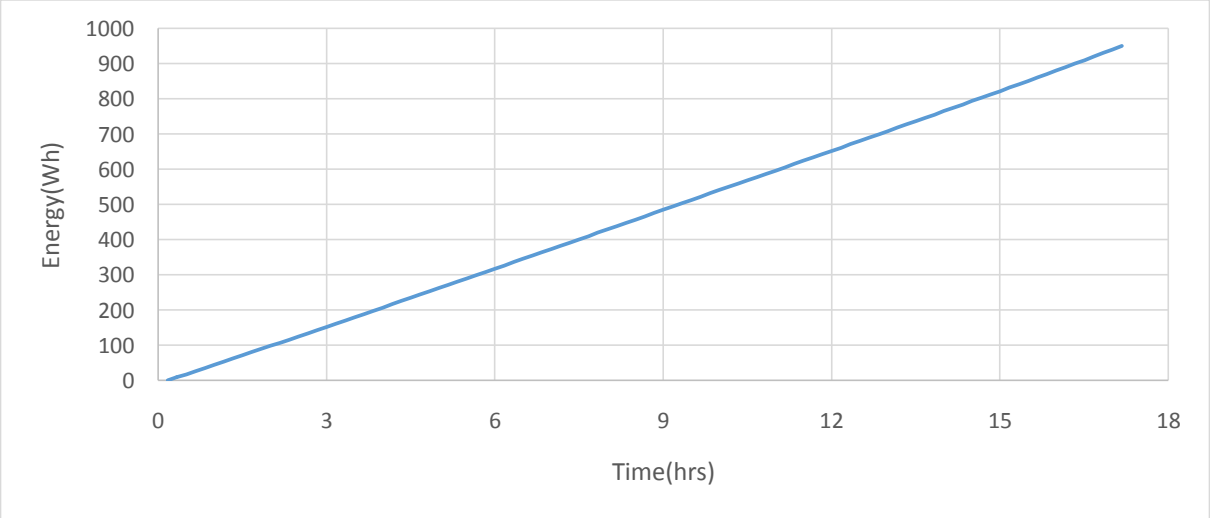


Charging curve No.2

Voltage change at I=4.3A

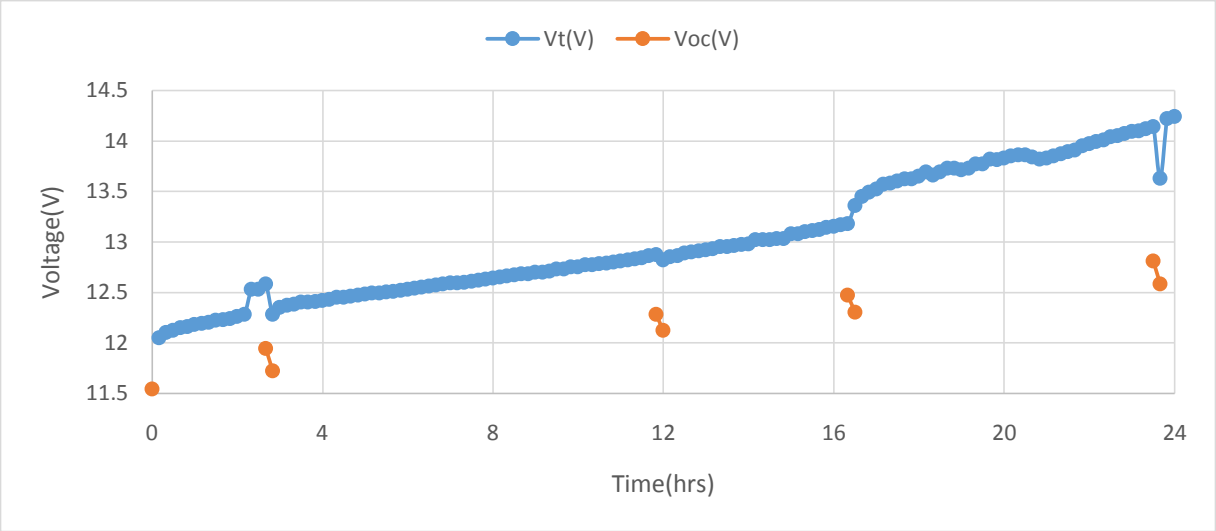


Energy supplied to battery

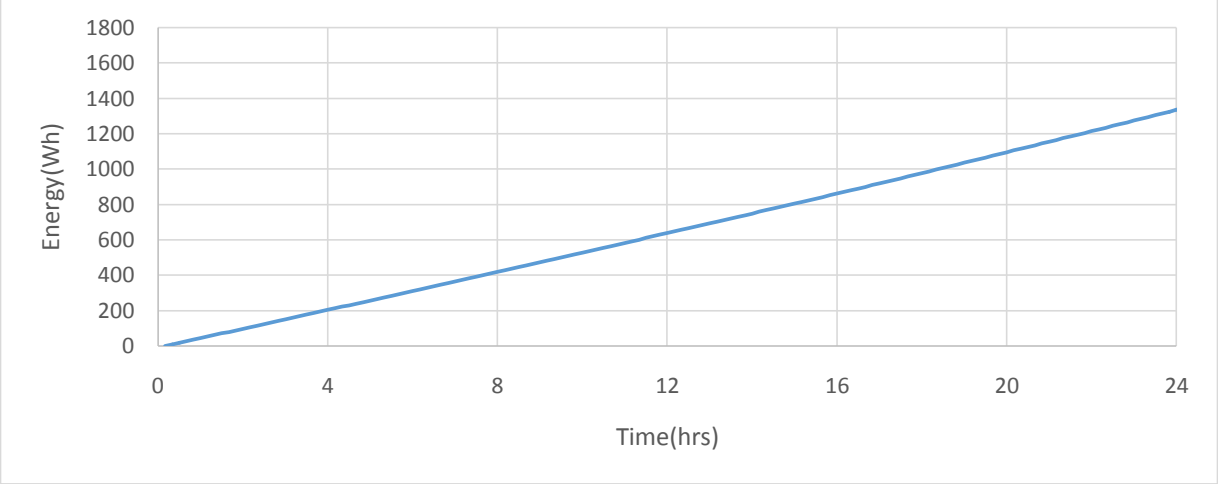


Charging curve No.3

Voltage change at I=4.3A

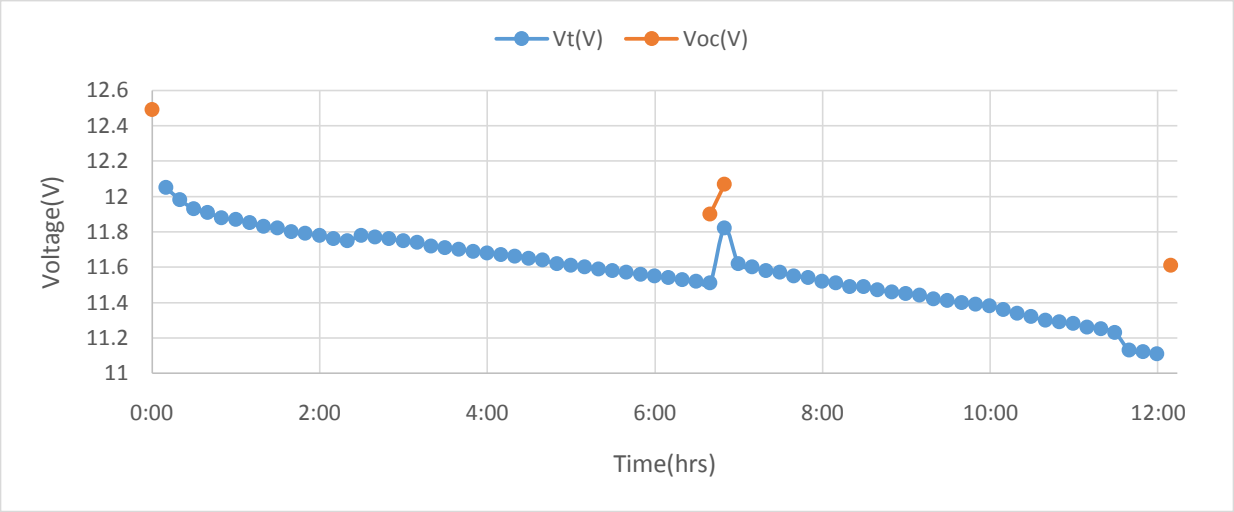


Energy supplied to battery

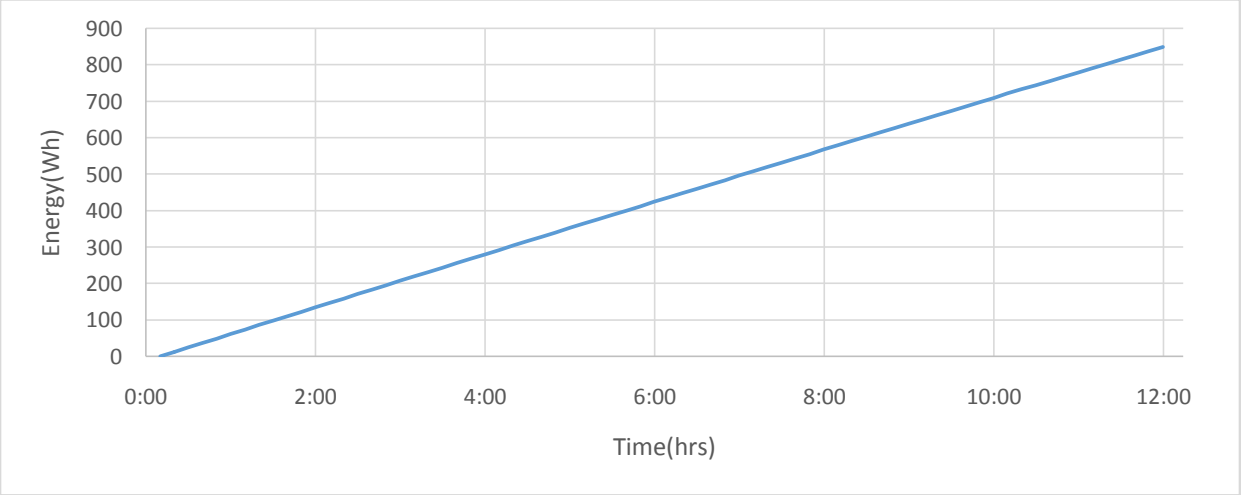


Discharging curve No.1

Voltage change at I=6.2A

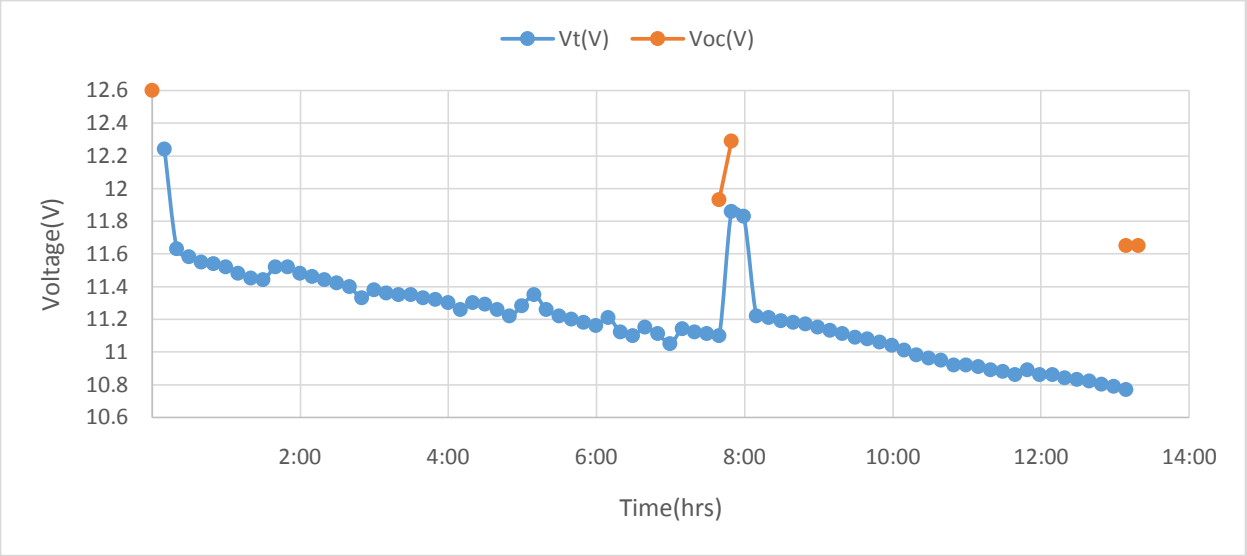


Energy consumed from battery

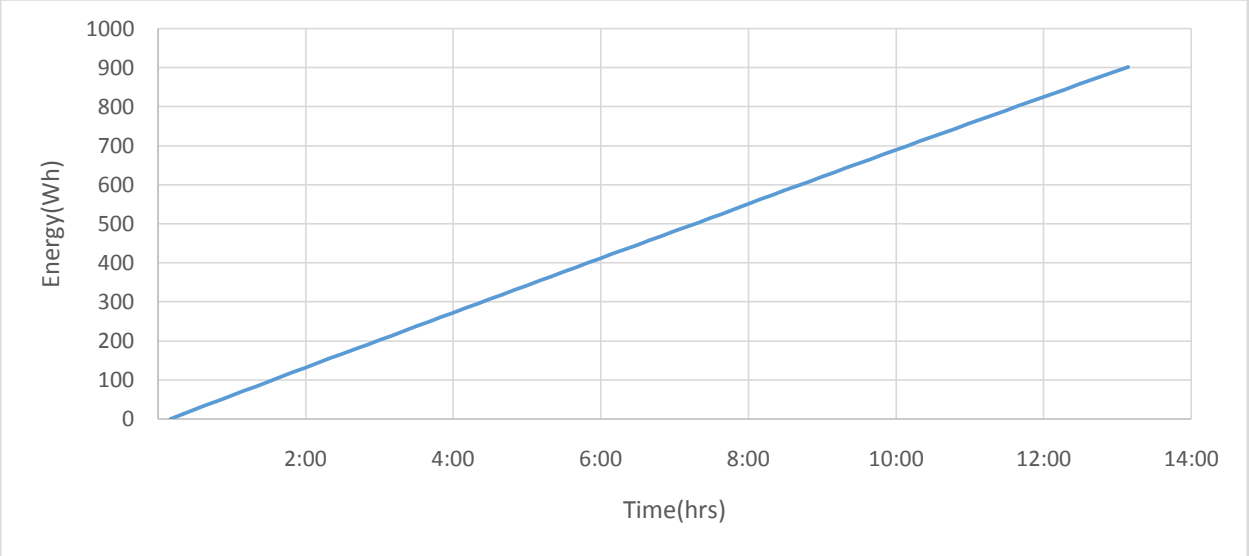


Discharging curve No.2

Voltage change at I=6.2A



Energy consumed from battery



Battery capacity summary

Charging results

- Average Charge Time: 16hrs
- Average Current: 4.3A
- Energy Supplied to battery: 850Wh

Discharging results

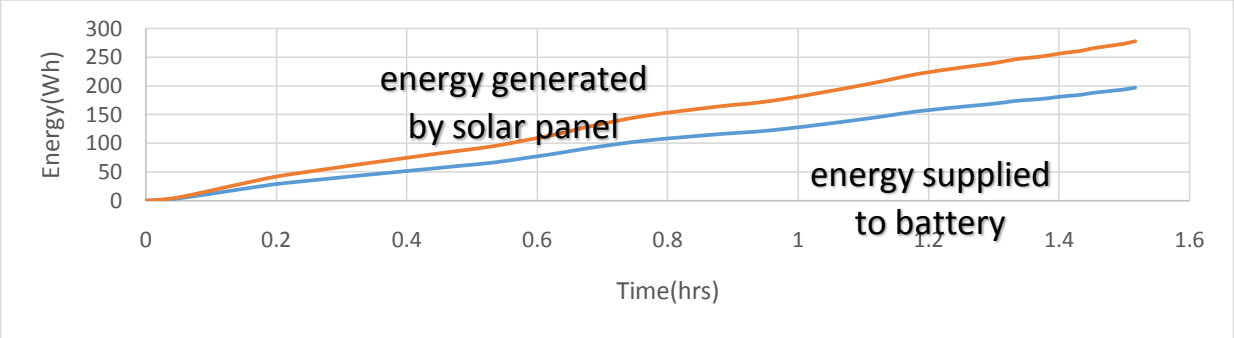
- Average Discharge Time: 11.5hrs
- Average Current: 6.2A
- Energy Consumed from battery: 830Wh

Overall Capacity: 70Ah

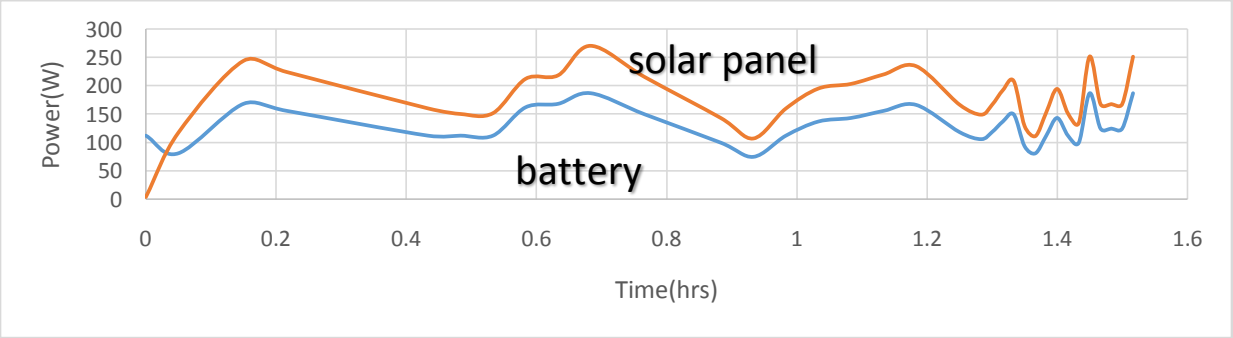
3.4 Solar Panel Recharge Rate

Charging Graph Day 1

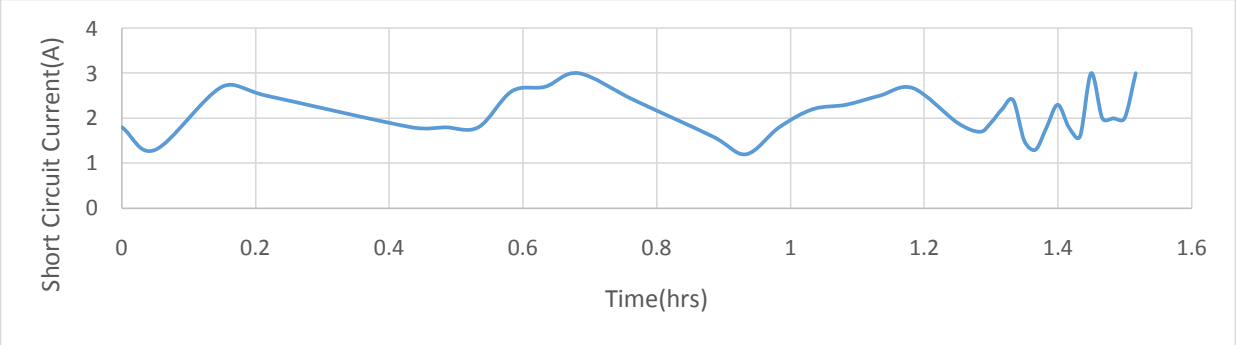
Energy generated and supplied during operation



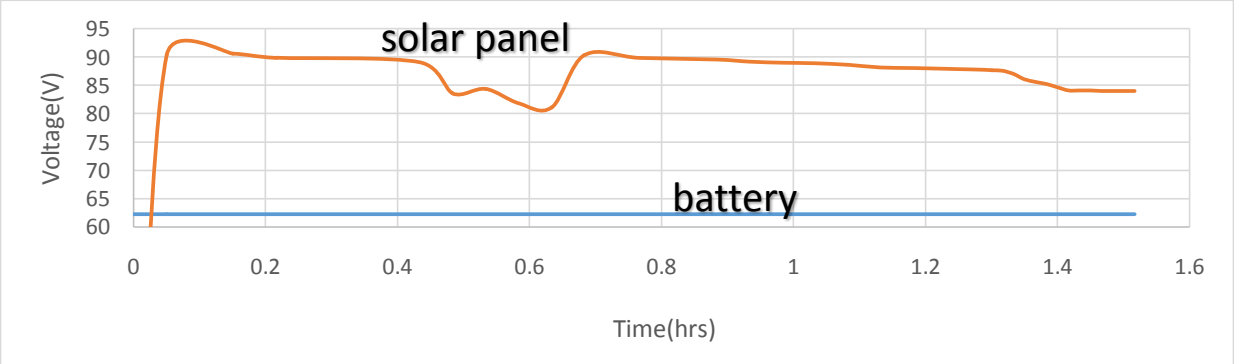
Power Ratings of the system



Current across the system

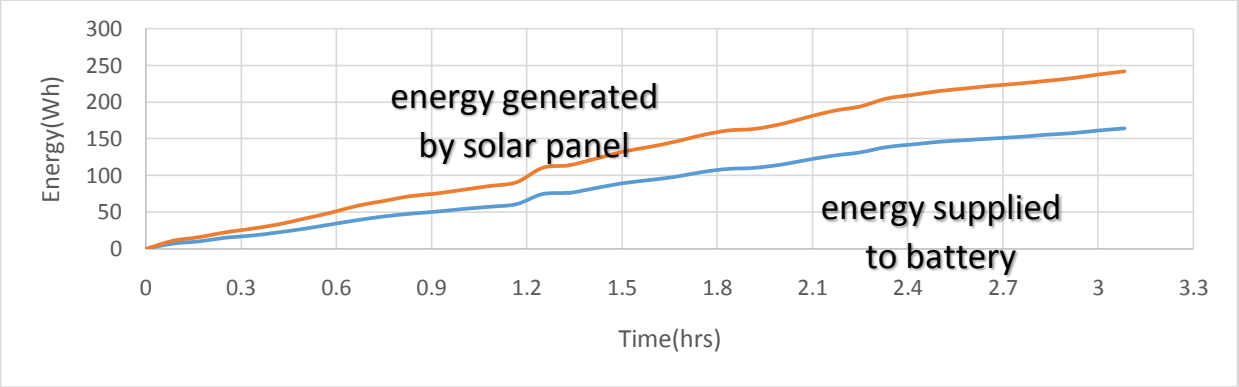


Voltage change during operation

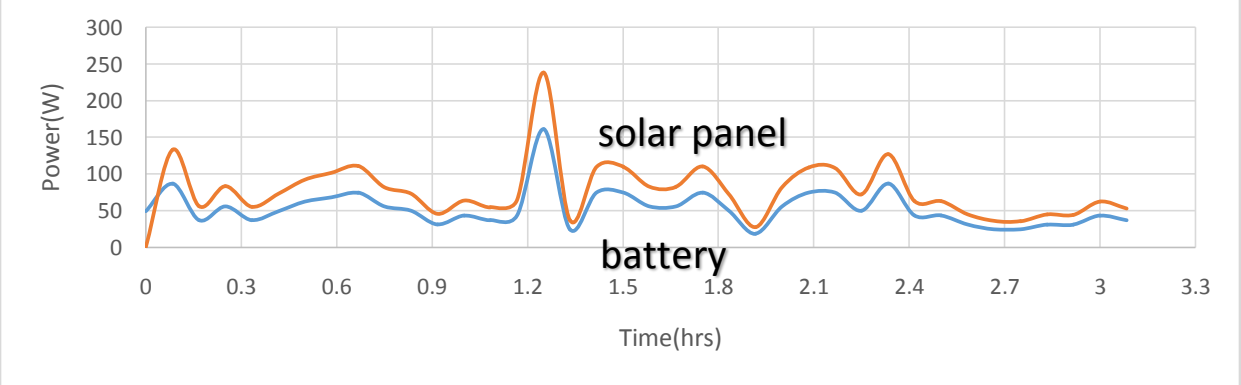


Charging Graph Day 2

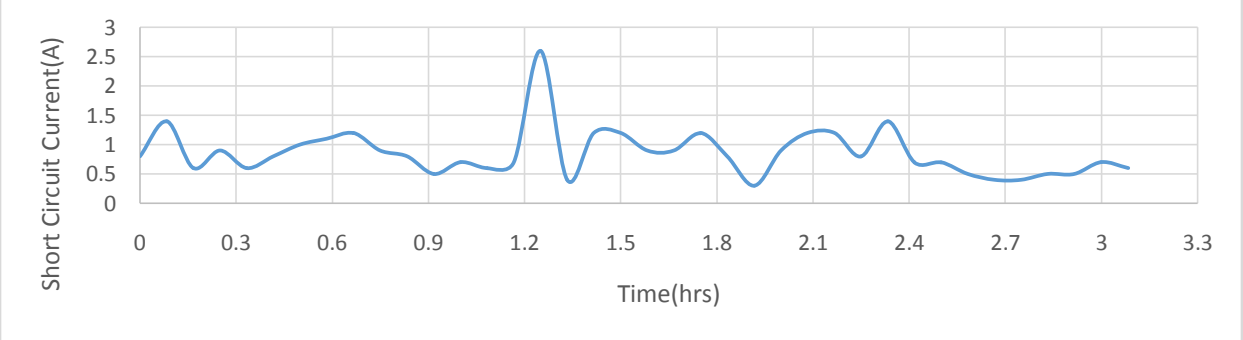
Energy generated and supplied during operation



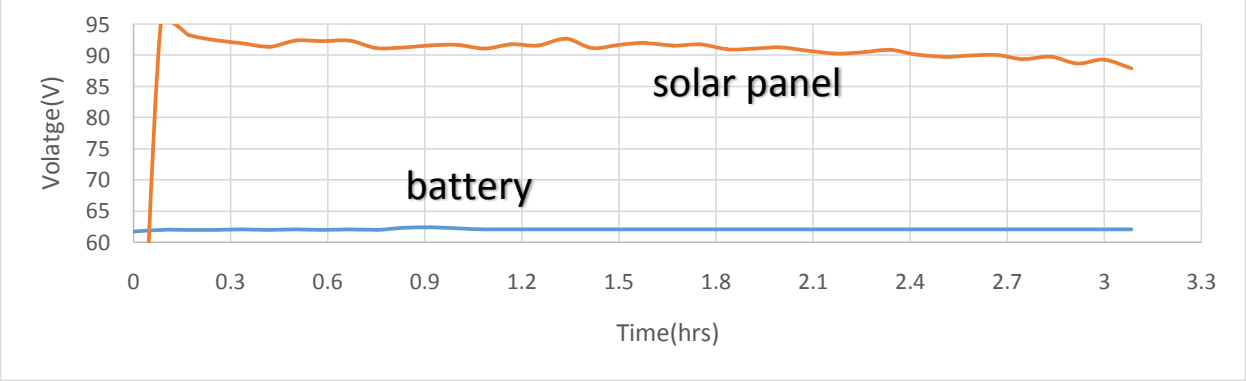
Power Ratings of the system



Current across the system

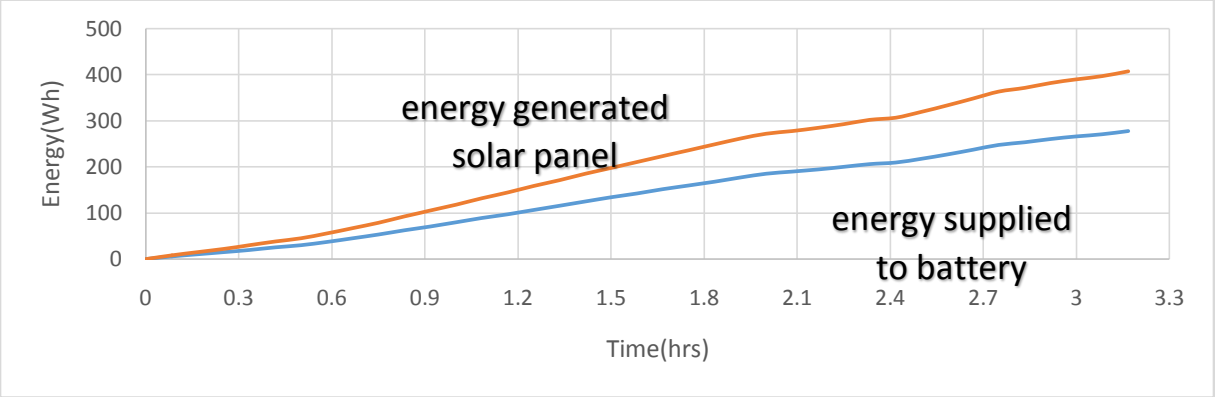


Voltage change during operation

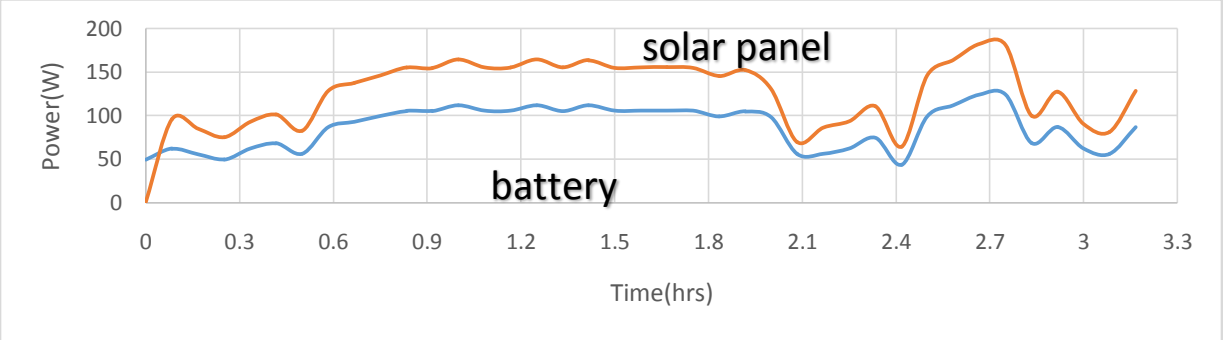


Charging Graph Day 3

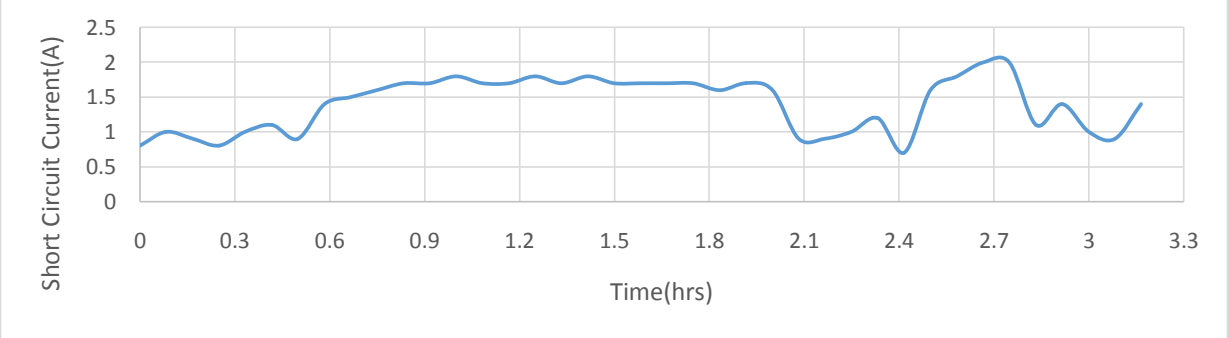
Energy generated and supplied during operation



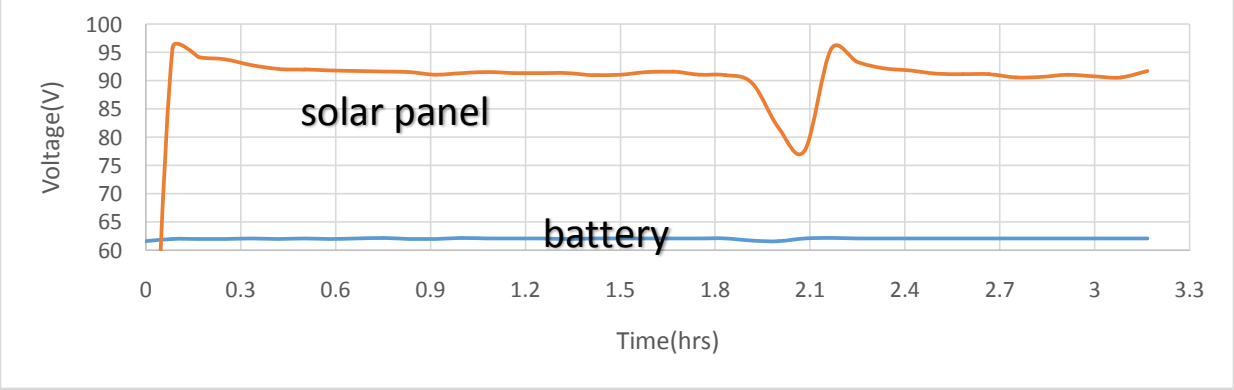
Power Ratings of the system



Current across the system



Voltage change during operation



Solar panel recharge rate summary

Weather Condition 1:

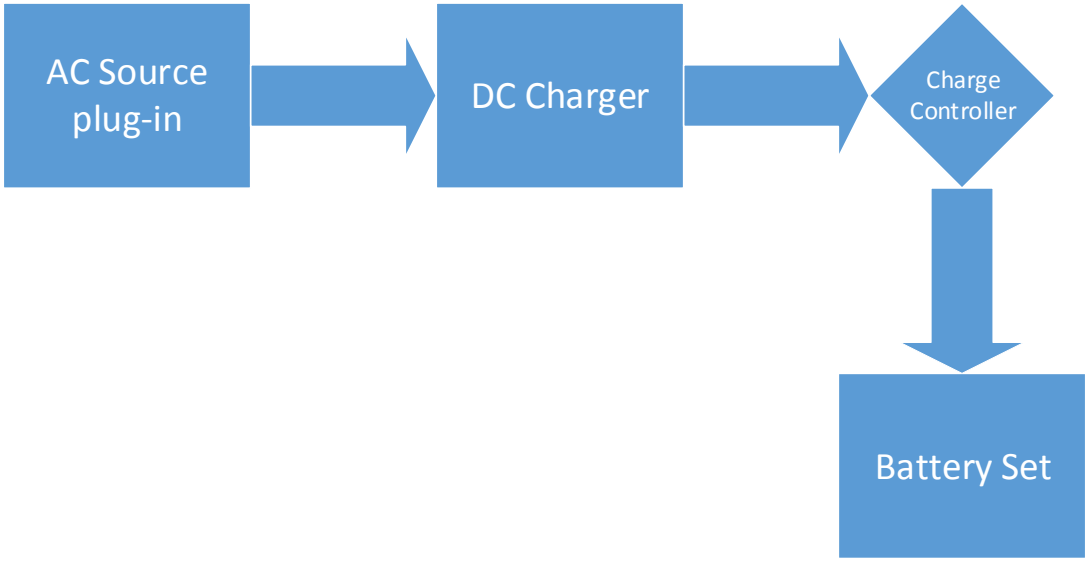
- 27°C (Mostly Sunny)
- Panel output voltage: 90V
- Battery input voltage: 62.2V
- Current across the system: 1.5A
- Average Power rating of the system: 100 W
- Experiment Duration: 3hrs
- Energy Stored in battery: 280Wh

Weather Condition 2:

- 27°C (Sunny/Hazy)
- Panel output voltage: 88V
- Battery input voltage: 62.2V
- Current across the system: 1A
- Average Power rating of the system: 50 W
- Experiment Duration: 3hrs
- Energy Stored in battery: 160Wh

3.5 Power Grid Recharge Rate

Block diagram of the system for recharging using the power grid



Recharge rate summary

- Average Charging time from 40% SOC to 100% SOC: 8hrs
- Average Current across the system: 10A
- Average Voltage across the battery: 70V
- Average Power rating of the system: 700W
- Max Energy stored in battery: 4800Wh

4.Limitations

4.1 Physical Limits

The current chassis design was implemented to minimize the vehicles weight. In doing so there is less or no room to apply any more appliances for experimental purposes.

Also, the chassis used is of a very old model street vehicle. Therefore, many components specific to that model are either unavailable or incompatible with the currently available ones.

4.2 Resources

The project is very expensive as the system is still at the development stage so everything had to be developed from scratch.

Furthermore, the lack of access to open field or a track made exclusively for vehicle testing prevented any further experimentations with the vehicle.

4.3 Safety Concerns

The vehicle is not well insulated so it limits the usage of the vehicle to dry weather only.

The vehicle is not sturdy enough to handle higher speed.

5.Conclusion

5.1 Future Works

- As from the above discussions and data, we can come to a point to state that due to severe environmental pollution and rising demand of fuels and its cost it is very essential to shift to new source of energy which is renewable, cheap, efficient, and environmental friendly, and in that case solar power energy based vehicle is the best known option. As the sun power appears as one of the most reliable renewable sources of energy that can be used to produce continuous flow of energyto solar automobiles.

- Solar power based vehicle is the best compared to any other because it is ecofriendly, the vehicle works on the same concept as any building power by solar panel. Photovoltaic cells are unique type of cells that is made up of semiconductors and are highly efficient in absorbing light, the absorbed light later converted to electrical energy and these solar panels are set up on the exterior of the vehicle.

- The solar power vehicle is fuel independent, hence its pollution level is zero and donot release any harmful emissions in the environment. The solar vehicles are quiet, so it does not cause any noise pollution unlike any fuel-driven vehicle. The solar vehicles have longer life time, solar vehicles can easily last for decades without any expensive regular service.

- The solar vehicles need low maintenance, the solar vehicles are modelled to be low maintenance which can last for years only general cleaning of the solar panels, solar vehicles are environment friendly, which is one of the most significant character of this vehicle, causes no harm to the environment. Solar power vehicles have renewable and infinite source of energy, it does not require any other natural resources other than sunlight.

- From the relevant information, results and data, we can conclude that solar power vehicles are perfect match for today's world and it is also advanced in technology and that days are not long enough when people will start using solar power vehicle in daily basis and the whole transportation system will be based on solar power rather than fuel-driven and which will be more advanced in technology and high speed and people will be using it for high efficiency, and for reasonable price and from the concern of healthy living and for a green environment.

References

1) https://en.wikipedia.org/wiki/Solar_energy
2) http://www.dhakatribune.com/tribune-supplements/tribune-climate/2017/08/12/bangladesh-towards-100-renewable-energy/
3) https://usgreentechnology.com/importance-solar-energy-economy/
4) https://en.wikipedia.org/wiki/Renewable_energy_in_Bangladesh
5) https://en.wikipedia.org/wiki/Solar_energy#Molten_salt_technology
6) https://en.wikipedia.org/wiki/Carbon_footprint#The_carbon_footprint_of_energy
7) http://education.seattlepi.com/consequences-carbon-emissions-humans-4138.html
8) http://www.bangladeshstudies.org/files/WPS_no10.pdf
9) https://www.solarpoweredcar.org/benefits-of-solar-powered-vehicle/