SOLAR ELECTRIC AMBULANCE VAN TO ASSIST RURAL EMERGENCIES OF BANGLADESH

- A Complete Off-Grid Solution

A Thesis Submitted to the Department of Electrical and Electronic Engineering of BRAC University

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Declaration

We thus proclaim that our thesis titled "Solar Electric Ambulance Van to assist rural emergencies in Bangladesh- A complete off-grid solution", submitted to the Department of Electrical and Electronics Engineering of BRAC University in partial fulfilment of the Bachelors of Science in Electrical and Electronics Engineering, is our own work. The work has not been introduced somewhere else for evaluation. The materials gathered from different sources have been recognized here

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Abstract

Rickshaws are an essential method of transportation in Bangladesh. When it was altered to electrically assisted rickshaw, it attained popularity but was soon discontinued due to overconsumption of power. Therefore, Control and Applications Research Centre (CARC), BRAC University has proposed the concept to give a complete off-grid arrangement by utilizing the PV array, torque sensor pedal, and solar battery charging station and implementing it in a solar electric ambulance van as a significant part of individuals who live in the provincial zones, where the likelihood of reaching the hospital on time is very low due to lack of mode of transportation. The torque sensor pedal lessens the over-utilization of battery-bank. The intelligent control framework reduces the human force and diminishes the over-utilization of engine. PV panel is introduced on top of the van to share a part of the power and a solar battery charging station is installed to make the entire framework totally autonomous of national grid. This paper consists of the design and implementation of the idea proposed by CARC.

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LIST OF ABBREVIATIONS

CARC- Control and Applications Research Centre
PV- Photovoltaic
SOC- State of Charge
SBCS- Solar Battery Charging Station
DOD- Depth of Discharge
IDCOL- Infrastructure Development Company Limited
LVD- Low Voltage Disconnect
BRAC HNPP- BRAC Health, Nutrition and Population Program

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Bangladesh is a growing underdeveloped country comprising of lower to middle to higher class families. For any nation the method of transport is a noteworthy issue. In Bangladesh, everyone cannot manage the cost of an auto-rickshaw and it is not, by any means, feasible to travel everywhere with it, given the streets are typically narrow. This is when tri-wheeler rickshaw as shown in Fig 1.1 was presented as the fair was cheap and voyaging time was less also. Yet, traditional rickshaws require a ton of human exertion shown in Fig 1.2 which brought about them being changed to electrically assisted ones. These electrically assisted rickshaws eliminated the requirement of human effort completely whereas the target was just to reduce it. Partially reduced human effort vehicle was developed because the existing electric rickshaw puts huge pressure in the already overloaded national grid of Bangladesh. Along with that, Bangladesh is a country which is very prone to load shedding every other day during summer when all sorts of cooling machineries are being used at their peaks. The national grid of Bangladesh does not produce sufficient power to meet the demand of the ever-growing population. So when these electrically assisted rickshaws were used they caused even more load shedding in the country. Rural poverty is persistent in most of Bangladesh. Improving the mode of transportation can help with the deteriorating rural economic situation by providing them to more accessible services (finance, education, treatment), obtain goods and income, and participate in various activities. A permutation of proper transport infrastructure, better transportation means and reasonable modes of transport would be a necessity for mobility [1].

Fig 1.1: Traditional Rickshaws [1]

Fig 1.2: Traditional Rickshaws [2]

1.2 Impact of Rickshaws In Bangladesh

A huge percentage of people, every year, end up being illiterate and end up being rickshaw pullers since they can earn on a daily basis and can work according to their schedule and route. There is an estimation which revealed that a rickshaw puller earns Tk 446 a day and work on a normal 26 day a month. Subsequent to paying the rent to rickshaw proprietor, the net wage stays at Tk 368. Subsequent to deducting the rent, the wage of a rickshaw puller remains at Tk 384 in urban territories while Tk 331 in rustic ranges. [2]. A research revealed an astonishing fact that when a rickshaw puller shifted to another job, their income decline by 15% [3]. The reduction of load on national grid is achieved by installing the PV array on the rickshaw [3], replacing the fully throttled system by torque sensor pedal, and using the solar charging battery station [4] which is present on the rooftop of BRAC University.

1.3 Motivation

An off-grid solution was proposed by CARC [5]. The electrically assisted rickshaw has been further developed to implement into a new concept which was the human hauler [6]. The human hauler was then later modified to make our solar electric ambulance van as shown in Fig 2.1. In rural areas of Bangladesh people cannot afford the city ambulance and they cannot reach the destination right away which is why we have provided a different solution for it by designing and implementing our solar electric ambulance van. Such a case has been observed in Derbyshire where patients have died due to ambulances not being able to reach on time [7]. The paper represents the design and performance analysis of the rickshaw-van with PV array and torque sensor installed to determine the percentage of energy saved which is completely off the national grid.

The carts shown in Fig 1.3 is used in villages are not suitable to transport a patient from one place to the other, taking into consideration the conditions of the roads of Bangladesh and that it is totally open to outer world.

Fig 1.3: Local Carts used as ambulance in rural areas

The city ambulances as shown in Fig 1.4 are not affordable for the people of these rural areas and along with that they cannot reach the villages right away and travel in the narrow lanes.

Fig 1.4: City Ambulance

1.4 Overview of the Content

The following sections depict the work that has been accomplished, the disadvantages and proposed tentative future arrangements. The second chapter gives a diagram of the entire framework with existing components. The third section is the correlation between the solar electric ambulance van that we have utilized as a part of our test and the other existing model which is the solar electric ambulance van and the chronological development of the ambulance van. The fourth chapter describes the design of the existing system. The fifth chapter determines the torque sensor and PV array installed into the framework with control calculation. The torque adjuster designs and lab simulations are specified as well. The sixth part gives a review of the current solar battery charging station that has been utilized to charge batteries and the outline and idea of simple swapping procedure of the batteries from SBCS to ambulance van and the other way around keeping in mind the end goal is to make the framework a great deal more easy to use. The seventh section is the most essential section of our thesis where it shows the information acquired from field tests, data analysis and calculations of the energy saved from the battery. Section eight describes the difficulties faced during performing the field tests. The conclusion and the future work have been described in chapter nine.

Chapter 2

OVERVIEW OF THE WHOLE SYSTEM

2.1 Introduction

The solar electric ambulance van is a full throttle vehicle, manufactured by Beevatech Limited. Beevatech Limited is the first expert in making electric auto rickshaw maker in Bangladesh, built up in 2001 as a gathering organization of Prime Logistics Ltd [8]. The solar electric ambulance van is made with light steel body and an alternate structural engineering from the traditional rickshaw or vans. It is equipped for conveying the patient and two attendees as well. As the governing body has banned commercialization of such automated vehicle on account of consuming power from the already overloaded national grid [9] , organizations like Beevatech Limited has needed to hold up under misfortune and are experiencing issues in picking up endorsement once more. Hence CARC came up with the human hauler which was modified to solar electric ambulance van as shown in Fig 2.1, Fig 2.2 and Fig 2.3 from different views of the vehicle. The specification and details of the vehicle is mentioned in the following sections.

Fig 2.1: Side View

The solar electric ambulance van is a fully throttle controlled electric vehicle. Its light weighted body can carry the patient along with two attendees. Our target is to run the vehicle without drawing any power from the national grid. The solar electric ambulance van along with PV array and torque sensor is shown in Fig 2.1. The ambulance van is a five-wheeler consisting of two 500W brushless DC gear motor, eight 12V 25Ah lead acid batteries, motor controllers, a throttle, power key, mechanism for emergency motor stop, traditional front wheel brake and an extra rear wheel brake, charge controller, charge indicator, headlights, helical spring, stretcher, direction indicators, siren, light, first aid box, and a fan. The solar powered ambulance will bring a great change for the people living in the village. As it is a very cost effective and easy to construct it will be a perfect aid for the village dwellers. The country's electricity distribution board is failing to cope with the exponential growth in demand for power in the capital and all over the country. Therefore, the Government is trying to reduce the pressure on national grid and create awareness for using non-renewable energy; the solar powered ambulance will be the perfect example as it is eco friendly.

Not only for its cost efficiency and easy construction, the ambulance will help the villagers in various other ways as well. Bangladesh has a high mortality rate and infant mortality rate. Our ambulance can play a huge role in this. It can carry pregnant woman from the village to the health complexes where city ambulances are present to take them to hospitals in the cities. Road accident is very common in our rural areas. Sometimes the city ambulances cannot reach at the accident spot timely. In that case, our ambulance can carry injured person to the hospital. Moreover, the ambulance can also carry the sick person in case of an emergency. In special cases like political unrest in the village an ambulance can be an easy ride. Also, older people can be carried by the ambulance from one place to another by the ambulance. In most of the villages people are using battery related rickshaw van for transportation. That is why load shedding becomes very common in that region. As we are using non-renewable energy in our ambulance, pressure on national grid will be reduced.

Fig 2.2: Front View

Fig 2.3: Inside View

2.2 Components Used

The components used in the solar electric ambulance van have been described below.

2.2.1 Batteries

Fig 2.4: Batteries

Eight 12V, 25Ah Rechargeable batteries have been used in the ambulance. From eight batteries individually four of them are connected and later on these two sets are connected in parallel. These two sets of batteries supply 48 volts each to the two BLDC motor. These are lead-acid batteries. The batteries are placed under both the seats as shown in Fig 2.4.

2.2.2 Motor

Fig 2.5: BLDC Motors

There are two BLDC motors we are using in the ambulance. The features of the individual motors are 500 rpm, 48V, 500W each. These two motors are attached with the chassis as shown in Fig 2.5. For the speed and backup for the emergency we are using two BLDC motors. In case one of the motor stops working, there will always be another option as a back-up. The reason for using BLDC motor in our project is that the BLDC motors have permanent magnets and an electronically controlled rotating field stator, using sensors (rotary encoder or back-EMF) to detect rotor position.

2.2.3 Controller Box

Fig 2.6: Controller Box

There are two motor controllers as shown in Fig 2.6 we are using for our thesis. But due to the unavailability of proper resources, the controller wires were identified using some online resources, experiments, and exploring the connections in the system. Fig 2.7 shows identification of the controller cables.

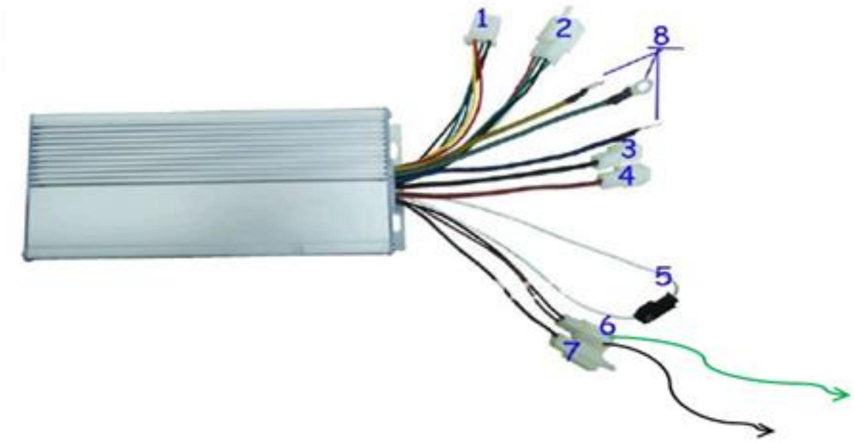


Fig 2.7: Identification of the controller cable [10]

2.2.4 Throttle

Fig 2.8 Throttle

The throttle shown in Fig 2.8 is a designed potentiometer. For controlling the speed of the motor, BLDC motor needs the throttle. Output voltage is controlled by the angle or position of the throttle. This output voltage goes to the motor controller. The motor speed increases as the output voltage increases.

2.2.5 The Power Key and Charge Controller

Fig 2.9: Charge Indicator

For operating the system manually, a power key as shown in Fig 2.9 is used to turn the whole system on and off. The puller has to turn it on before using the throttle to drive the motor. It was a mechanism to short two wires that go directly to the controller unit. Normally the wires are open switching ‘off’ the whole system. When it is keyed, the wires get shorted.

2.2.6 Solar Panel

Fig 2.10: Solar panel

In Fig 2.10 the solar panel is placed at the top of the van which is made of iron frame. Four 100W, 12V panels are connected in series that provides 96V to the batteries through the charge controller.

2.2.7 The Charge Controller

Fig 2.11: Charge Controller

For efficient charging and supply power to the load, we need two charge controllers in our project. The charge controller checks the current battery status and according to it, it sends right amount of charge to the battery. There are 4 terminals in a charge controller 'PV+' , 'PV-', '48V+' and '48V-'.The 'PV+' and 'PV-'terminals were to be connected with the positive and negative terminals of the 400-Watts Panel. The '48V+' and '48V-' were to be connected across the 48V battery terminals.

2.2.8 Torque Sensor

Fig 2.12: Torque Sensor

The torque sensor is a device which is used to measure and record the torque of a rotating system. Biasing voltage of 5V is needed which is supplied from a DC source. As the torque increases output voltage increases. The speed of the motor is directly proportional to the output voltage. Torque sensor after being installed is shown in Fig 2.12.

2.2.9 The Brake System

Fig 2.13: Traditional Hand Clutch

Fig 2.14: Rear Wheel Brake

Traditional hand clutch is used to stop the front wheels. Another hand-clutch is placed on the left hand-side shown in Fig 2.13 along the traditional hand-clutch. This hand-clutch stops the motor at once. When the hand-clutch is released, it returns to its original position and allows the motor to start again when required. A rear wheel brake pedal shown in Fig 2.14 which is introduced in the system to stop the rear wheels. The rear wheel brake is a mechanical brake similar to cantilever brake that helps in stopping the moving central shaft or axle and thus stopping the rear wheels.

2.2.10 Light System

Fig 2.15: Back Indicator lights

The indicator lights are shown as in the fig 2.15. Indicator lights are used while taking turns. There are six indicator lights in the van, two at the back, and two at the front.

2.2.11 Helical Spring

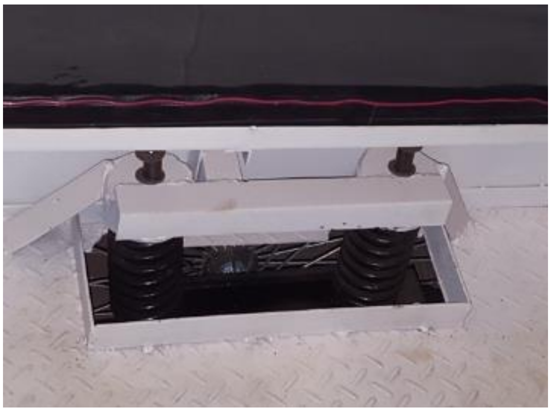
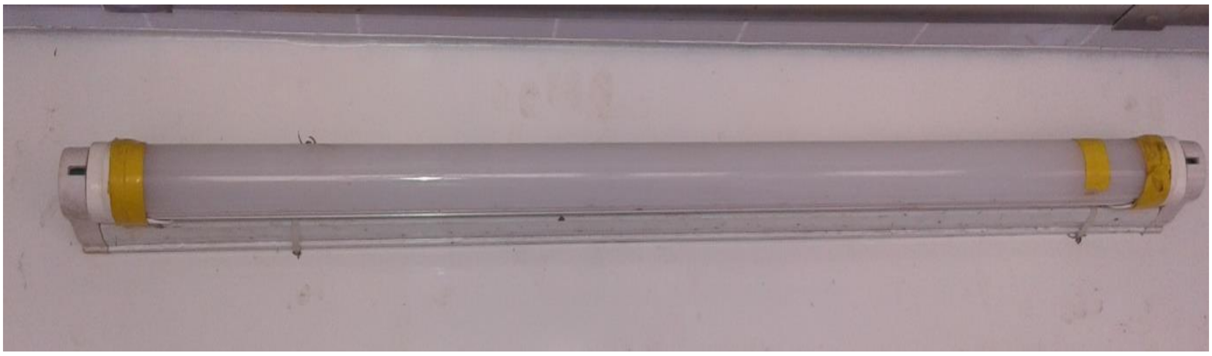


Fig 2.16: Helical Spring

The helical spring is installed in the vehicle as shown in Fig 2.16. The helical spring is to control the spring and suspension movement. They reduce any jolts and make it more comfortable for the patient.

2.2.12 Accessories of the Solar Ambulance Van

A headlight is placed in front of the van which helps to see the obstacle at night while driving. In side of the ambulance an LED strip light is also used which consume 31V and 9W. Siren is installed on top of the van. First aid box is placed inside the van as well. The regular accessories which are usually present in an ambulance are here, in the van, as well. They are shown below in the fig 2.17.



(a)

(b)

(c)

(d)

(e)

Fig 2.17: Tube light (a), Headlight (b), Fan (c), Siren (d), and First Aid Box (e)

2.3 Conclusion

This chapter describes all the components of the vehicle and have been showed respectively in the pictures.

CHAPTER 3

CHRONOLOGICAL DEVELOPMENT OF RICKSHAW

3.1 Introduction

Modernization of rickshaw has been one of the major reasons in the development of Bangladesh as making the transportation better leads to the development of the country as a whole. This chapter will describe the chronological development of the rickshaw from the traditional ones to the solar electric ambulance van. The six models traditional rickshaw, electrically assisted rickshaw, torque sensor based hybrid rickshaw, hybrid rickshaw with PV support, solar electric tri-wheeler van, and the latest model solar electric ambulance van will be described in this chapter.

3.2 Traditional Rickshaw

This vehicle as shown in Fig 3.1 is one of the most popular means of transportation in developing countries like Bangladesh. Despite being popular this is a very strenuous task for the pullers as it is completely based on human effort. Along with that, wages is low compared to the amount of labour required for this job. The main reason for this vehicle to gain so much popularity was because of its route flexibility and the flexible time availability for the puller. Developing this vehicle is one of the major contributions in the improvement of lifestyle for the working class people.

Fig 3.1: Traditional Rickshaw

3.3 Electrically Assisted Rickshaw

The traditional rickshaw was developed to the electrically assisted rickshaw as shown in Fig 3.2. This vehicle completely eliminated the requirement of human effort. It was made with a steel body which makes it look very different from the traditional rickshaw as shown in Fig 3.2. Four 12V, 20Ah lead acid batteries were used along with 48V, 500W brushless DC motor drive system but throttle position sensor to control motor speed. Traditional chain was present but the rickshaw puller barely used it. It was found that the throttle control system consumed too much power from the overloaded national grid and discharged pretty quickly as in within 5 or 6 hours. This mechanism reduced the battery life and motor as well due to high current flow from battery to motor. This vehicle was made by Beevatech limited. And it was also manufactured by Boraq limited which is a smaller company compared to Beevatech limited. They converted the traditional rickshaw to the electrically assisted one as well by accommodating expensive batteries which increased the run time and the motor but the problem of charging the batteries was still not solved.

Fig 3.2: Electrically Assisted Rickshaw

3.4 Torque Sensor Based Electrically Assisted Rickshaw

CARC, BRAC University proposed an off-grid solution in 2012 to modernize the fuel green rickshaw by installing the torque sensor in the Beevatech model of electrically assisted rickshaw shown in Fig 3.3[10]. To assist the rickshaw puller, a mechanism was implemented to ease the pressure of the puller. Four 12V, 20Ah lead acid batteries were used along with 48V, 500W brushless DC motor. To increase the longevity of the batteries and reduce the battery use the torque sensor was implemented. It was found that around 42% energy was saved. Despite that the batteries still got discharged pretty quickly and the problem of charging them from the national grid still persisted.

Fig 3.3: Torque sensor based Electric Rickshaw

3.5 Electric Rickshaw with PV Support

The electrically assisted rickshaw was further modified in a research conducted by CARC, BRAC University in 2013 to electrically assisted rickshaw with PV support [11]. A 360W panel was placed on the roof of the Beevatech model of electric rickshaw. Four 12V, 20Ah, lead acid batteries along with 48V, 500W brushless DC motor was used. The research mainly focused on the position of the panel for maximum sunlight to be incident on it and was found out that further development should be done in 'flat panel state'. The research showed that around 50% energy was conserved with the use of PV panel as a result reducing pressure from the national grid. The drawback of this vehicle as shown in Fig 3.4 was the structure of it as the 360W panel installed made the structure too heavy and the panel exceeded the maximum surface area of the rickshaw, making it unsafe in the roads of Dhaka city.

Fig 3.4: Electric Rickshaw with PV panel installed in 'flat state'

3.6 Solar Electric Tri-Wheeler Van

Motivated by the success from the result obtained in the research with torque sensor pedal in the system and PV support in the system separately, CARC has implemented the PV support and torque sensor pedal in battery operated rickshaw van shown in Fig 3.5 [12]. Solar battery charging station was set up was set up as well to make the system completely off-grid solution. Four 12V, 25Ah lead acid batteries along with a 500W DC gear motor was used along with four 100W solar panels. The primary focus of the research was to make a "green vehicle'' and making it completely off-grid and field tests were carried out accordingly.

Fig 3.5: Solar Electric Tri-wheeler Van

3.7 Solar Electric Ambulance Van

After the success of the tri-wheeler van, CARC, BRAC University modified this vehicle to the solar electric ambulance van shown in Fig 3.6. The details of this vehicle are mentioned in the following chapters.

Fig 3.6: Solar Electric Ambulance Van

3.8 Comparison of the Designed System with the Existing One

The two vehicles are compared to analyze the differences and similarities and find out more efficient options. The comparison is showed in the following table.

Fig 3.7 Solar Electric Ambulance Van **Fig 3.8 Solar Electric Tri-wheeler Van [12]**

Table of the comparison between designed system and the existing system:

SPECIFICATION	DESIGNED SYSTEM	EXISTING SYSTEM
Batteries	Two sets of Lead Acid • 12V, 25Ah	One set of Lead Acid • 12V, 25Ah
Brushless DC motor	48V, two 500W motors,	48V,750W
Torque sensor	Installed in pedal	Installed in pedal
PV Panel	• each 100W, 12V four panels are connected in series	• each 100W, 12V four panels are connected in series
Total distance travelled	• 12.45km	• 16.1km

Table 3.9: Comparison of the existing vehicle with the designed one

3.9 Conclusion

This chapter described the chronological development of rickshaw from the traditional rickshaw to solar electric ambulance van and the comparison of the designed vehicle with the existing one. Chronological development of the van is shown in a flow diagram attached in Appendix C. The main objective along with each development was to reduce pressure from the national grid and the overconsumption of the batteries.

Chapter 4

DESIGN OF SOLAR POWERED AMBULANCE VAN

4.1 Introduction

This chapter is solely based on the innovative five wheeler design that we came up with in the vehicle and how this design benefited us when it came to comfort of the patient inside and as well as maintaining good speed. Complications that were faced and how we solved them is also explained in this chapter.

4.2 Design

The five wheels are divided into 1 front wheel, 2 middle wheels and 2 rear wheels. Details of the design are shown in the figures below from Fig 4.1 to Fig 4.4.

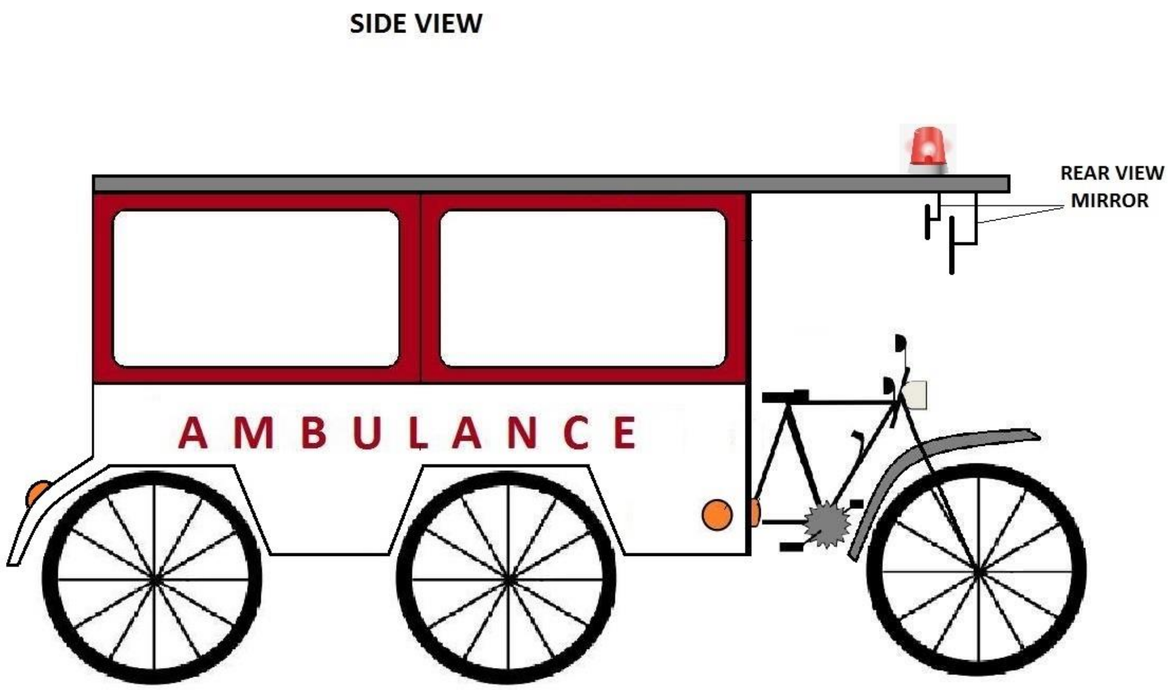


Fig 4.1: Side view of the Ambulance van

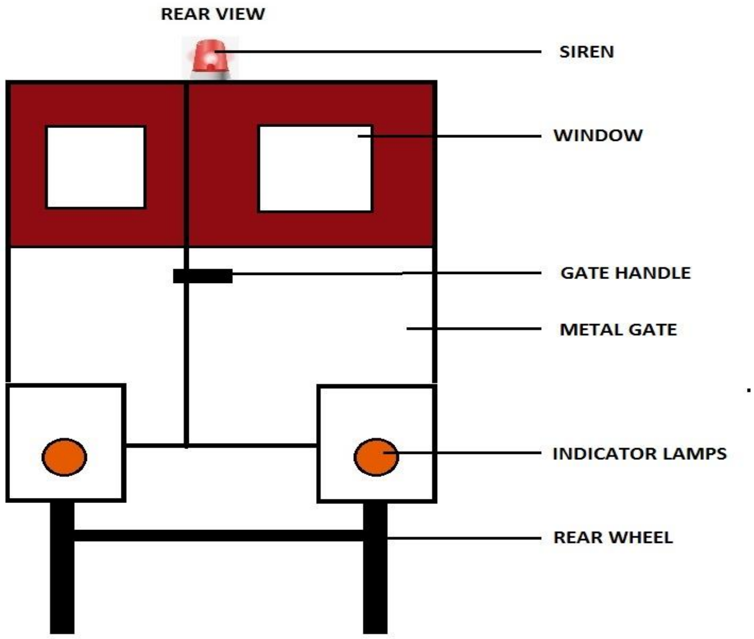


Fig 4.2: Rear view of the Ambulance van

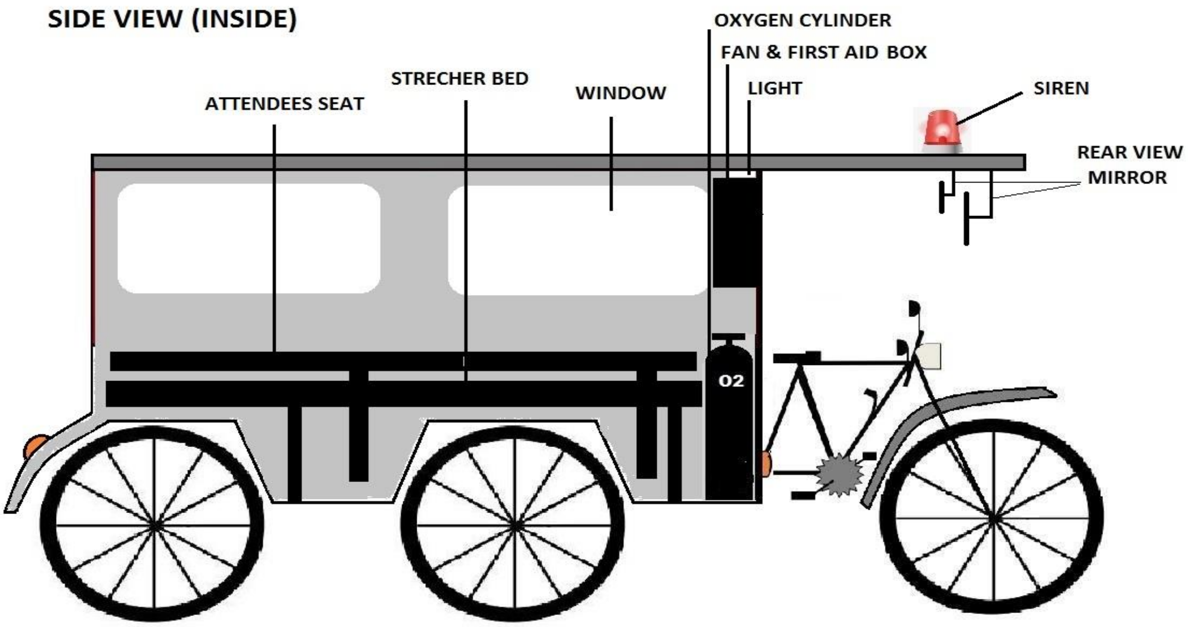


Fig 4.3: Inside view of the Ambulance van

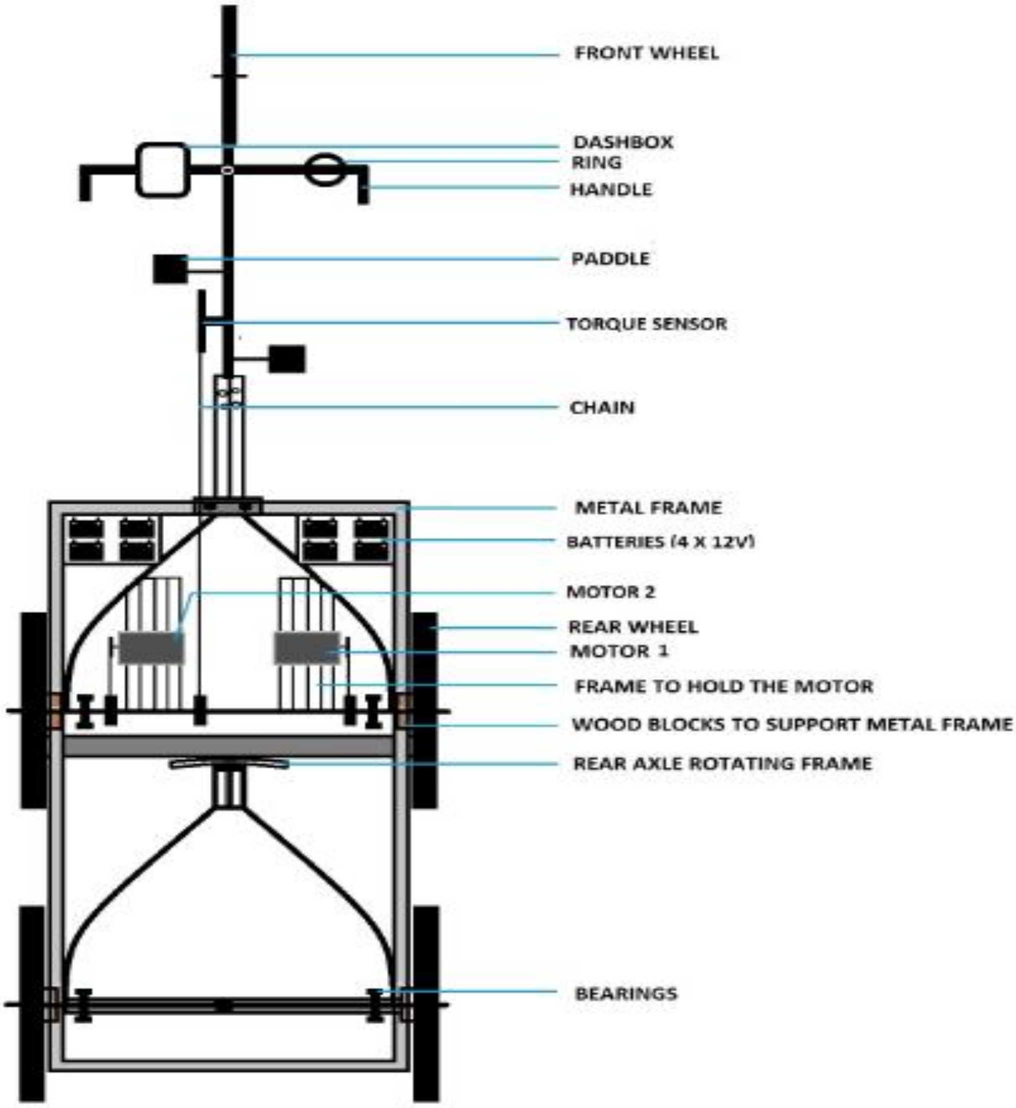


Fig 4.4: Skeletal Diagram of the Ambulance Van

The skeletal diagram gives a cross-sectional visual through the body of the vehicle. It gives an idea of how we achieved five-wheeler design while making it very stable for the comfort of the patient. Details on the skeletal diagram will be explained further in the next section.

4.3 Explanation

Working with the five wheeler van was a difficult job to accomplish. Since we did not have any previous reference to five wheelers we had to build it up from scratch. The front three wheels are a single rickshaw chassis and rear two wheels are being attached to the front three wheels. Attaching the rear two wheels directly gave rise to a problem. The problem was the lifting up of the middle two wheels during turning. This was a critical issue since the vehicle needed support from all the five wheels all the time for stability purposes. To eliminate this problem we came with the idea of separating the rear two wheels from the front and attaching them by means of a system that lets the rear wheel axle to move independently. This enables the van to turn and move in a way that is similar to container trucks. The inside of the van is spacious enough to be lied down comfortably. It can hold one patient and two attendees. It is fully equipped with emergency medical instruments. Along with that the addition of the helical spring gives the patient a pleasant and bumps free ride.

4.4 Dimensions

Length of the box	6 feet (72 inches)
Length from end to end	4 feet (48 inches)
Width of the box	4 feet 4 inches (52 inches)
Height of the box	10 feet 9 inches (129 inches)

Table 4.5: Dimensions of the Solar Electric Ambulance Van

4.5 Features

- Five wheeler to accommodate long structure
- Turning mechanism at rear to separately move rear most wheels.
- Comfort for patient with big windows and fan
- Back up motor to run when one motor dies
- Compact design
- Comprises stretcher bed, seat and oxygen cylinder

4.6 Conclusion

The design was critical for us since it revolutionize the pedal-van business. We have done our research and developed many ideas. Some of them were simulated, some were discarded and some were actually made. In the future, more development will be done on this foundation of design we have created today.

Chapter 5

TORQUE SENSOR AND PV ARRAY OF THE SYSTEM

5.1 Introduction

This chapter describes the torque sensor, the PV array and how both of this in combination results in saving energy consumption from the batteries. It will give a in depth explanation regarding torque sensor and PV array including specifications, circuit diagrams, block diagrams, mechanical assembling, lab test results as well as simulation results. This chapter will also cover the control algorithm of the whole system.

5.2 Introduction to the Torque Sensor

The torque sensor shown in Fig 5.1 is manufactured by Suzhou Victory Sincerity Technology Company Limited from Suzhou, China. Fig 5.2 shows the torque sensor after being implemented. Its main purpose is to be used in electronic bikes. Our ambulance van runs with the same mechanism as electronic bike so we decided to purchase it from them. The company produced this torque sensor which is European standard - EN 15194 qualified.

Fig 5.1 Torque Sensor with module

Fig 5.2 Torque sensor after being integrated

The basic operation of torque sensor is to convert mechanical energy provided on the pedal to electrical energy. This electrical energy is further conditioned before going to the motor controllers and eventually to the motor. There are two types of torque sensors and they are rotary which measures dynamic torque and reaction that measures static torque. The whole system is powered by the existing set of battery sets.

5.3 Features of Torque Sensor

- Compatible with brush or brush-less motors
- Its aluminium alloy body makes it impact resistant
- Its structured as ordinary wheel crank so installation is easier
- Water and dirt resistant
- Gives accurate and instant response to pedal pressure
- Additional parts are highly accessible
- Data collection per crank rotation from 18 to 96 times

5.4 Specifications

- Vcc = 5.15 V (+/- 0.15V)
- Output, linear, zero-start, 0.5~4.5V
- Output torque >15N-m
- Delay time < 50ms

5.5 Advantages of Torque Sensor Circuit

- The circuit does not require any complex hardware
- The driver can fine tune the ease of paddling
- The circuit needs very small voltage
- The op-Amp LM358 requires no negative biasing
- The components are minimal
- It ensures no sudden thrust
- The circuit will keep on giving its maximum 3.6V when paddling is stopped
- Its PCB design ensures its resistance to shocks and bumps
- The circuit becomes independent from power keys and hand clutch

5.6 Integration of Torque Sensor into the System

The full set of torque sensor consists of torque adjuster, brushless motor controller, chain wheels and the crank. Integrating the sensor in the circuit requires mechanical work as well as making some electrical connections. The torque sensor circuit does not come with the spindle with which it will attach to the vehicle so it had to be purchased separately. Number-12 wrench is required to fit into the vehicle. Pliers and screw drivers are required to connect the external circuit to the battery sets. To test its performance, voltmeter and ammeter is required.

5.7 Power Distribution

The components required for the torque sensor circuit is DPDT switch, LM7805, LM358 and voltage divider circuit. The torque sensor circuit requires very small voltage to be powered. The voltage comes from the battery set. 12V is taken from the any of the battery set and converted to 5V by means of LM7805. The 5V is fed into the op-Amp LM358 and torque sensor module. The function of DPDT is to switch between the battery sets to power the torque sensor circuit. In this way if a battery is observed to be in stress, DPDT can be used to switch to the other battery set to power the torque sensor circuit. The block diagram of power flow distribution and signal flow is shown in Fig 5.3.

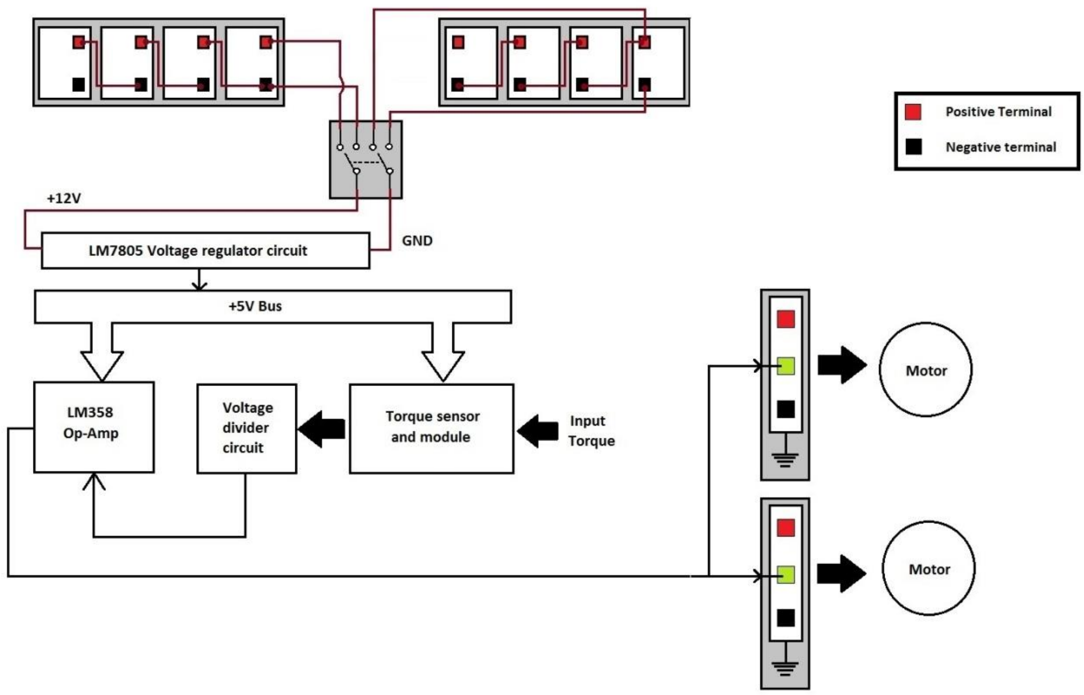


Fig 5.3: Block diagram of power distribution and signal flow

The torque produced by paddling will be fed into the torque sensor and its module. The module will process the input torque and give it to the voltage divider circuit. The objective of the voltage divider is to provide the small voltage to the torque sensor circuit. This reduction of voltage will be amplified by the op-amp before it is fed into the control unit. The input of control unit is in parallel connection to get the output voltage from the op-amp. Parallel connection is preferred because voltage remains same across all the parallel connection. The gain of the amplifier can be altered using a feedback resistor R_f which will help the driver to tune his ease of driving.

5.8 Design of Torque Sensor

The objective behind the design we went for is to make the travel safe. Since it is an ambulance, safety and speed is our primary objective. The design includes a voltage divider circuit which limits the incoming voltage produced due to paddling. The output of the voltage divider is 0.6 times the voltage coming from the torque sensor. This low voltage ensures two things and they are the following:

1. Prevents the circuit being burned by high voltage.
2. Prevents the motor from running faster than the safety limit.

Several designs have been made during testing but this is the one which give optimum results keeping our objectives intact.

5.8.1 Circuit Diagram

The circuit diagram is shown in Fig 4.4.

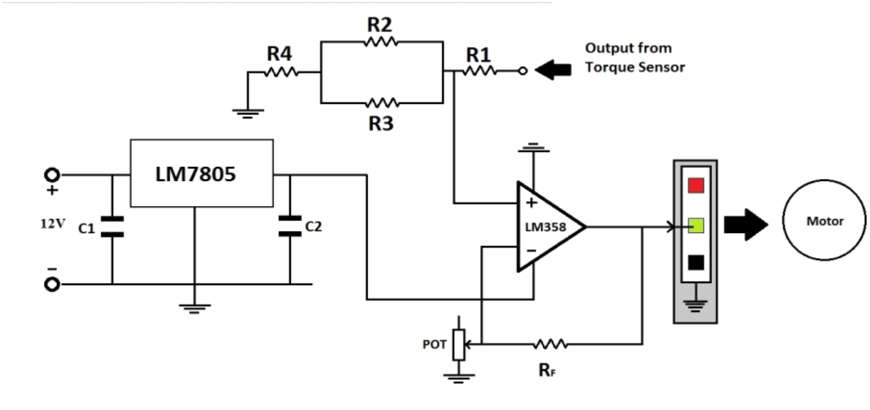


Fig 5.4: External circuit of Torque Sensor

5.8.2 Explanation

The input voltage from torque sensor gets through the voltage divider circuit and gets reduced to 0.6 of its input value. This reduced voltage gets fed into the LM358 op-amp which amplifies it before sending it to the motor controllers. The op-amp is set in non-inverting state and the gain is altered by changing the feedback resistor R_f. This changing of gain is introduced because not all drivers have the same strength of paddling and that is why the driver can adjust the gain according to his ease of driving. Powering the whole circuit requires only 5V. We did not use any additional batteries to power it separately rather we went for a voltage regulator device which can 12V from our existing batteries and convert it to 5V to power the circuit.

5.8.3 Torque Sensor Simulation Data

Torque sensor input voltage	Torque sensor output voltage	Torque sensor input voltage	Torque sensor output voltage
0.1	0.78	4.4	3.14
0.5	0.071	4.1	2.93
1	0.357	4	2.86
1.5	0.71	3.9	2.78
1.8	1.3	3.5	2.6
2	1.43	3	2.15
2.1	1.51	2.5	1.79
2.5	1.78	2.2	1.57
3	2.14	2.1	1.6
3.1	2.21	2	1.43
3.5	2.5	1.5	1.08
4	2.86	1	0.8
4.1	2.93	0.5	0.081
4.5	3.21	0.1	0.071

Table 5.5: Table showing the simulation results of the torque sensor

5.9 Design-II of Torque Sensor

The second design was made with an intention of improving the longevity of the circuit itself. It is possible that high amount of current and voltage can get in to the circuit from the battery sets. This high amount of current and voltage can burn the circuit and make the torque sensor module to be unusable. This is why we have come to a solution to minimize the voltage that goes into the circuit. The circuit diagram is shown in Fig 5.6.

5.9.1 Circuit Diagram

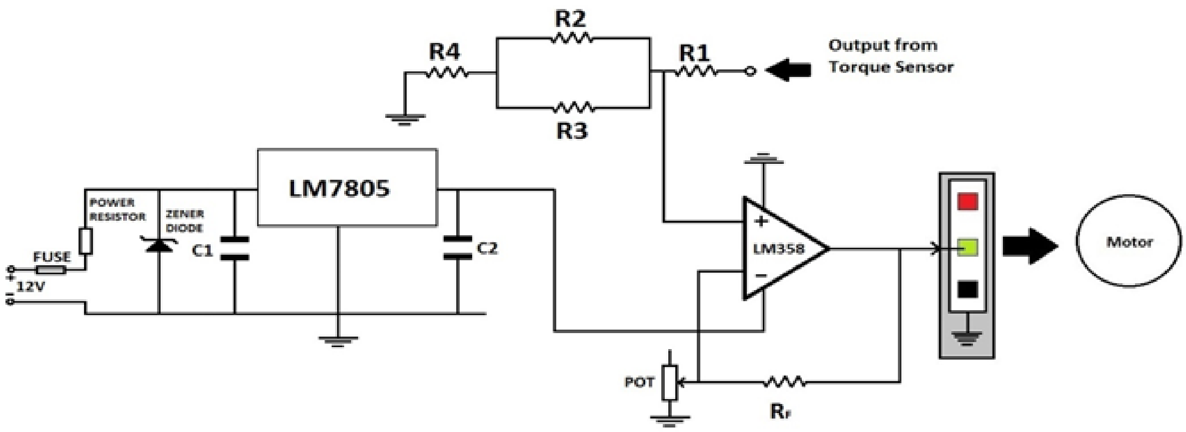


Fig 5.6: Circuit diagram of design- II

5.9.2 Explanation

We have added zener diode and power resistor in parallel with the voltage regulator to minimize the incoming voltage. The zener diode has a rated voltage of 10V and the power resistor is of 100Ω and 1W power. In forward bias mode zener diode works the same as the normal diode. In reverse bias when the incoming voltage is higher than the rated voltage then the diode's breakdown voltage is reached and avalanche breakdown occurs in the depletion layer which causes a current to flow through the diode to limit further increase in voltage. This is how zener diode limits high voltage to enter the circuit. To save the circuit from high current, a fuse of 1A is used which will breakdown when incoming current is over 1A. The reason behind 1A fuse to use was because the maximum current the circuit can tolerate is 1A. This is how both zener diode and fuse increases the life span of the circuit in a cost effective manner and also serves a improvement over design-I.

5.10 Introduction to PV Array

In an emergency case, power failure is unacceptable. To further increase our distance and to reduce the power drawn from the batteries, we have integrated the PV array into our system. The PV array has high power, 400W in total. Basically it consists of four 100W PV panels connected in series. The constant sharing of power with the batteries will give the battery longer operating time between two charging periods.

5.10.1 Specifications

- Maximum power output (5%) – 100W
- Open circuit voltage - 21.6V
- Short circuit current - 6.46A
- Voltage at MPP – 17.2V
- Current at MPP – 5.8A
- Nominal operating voltage – 12V
- Max system voltage – 600DC
- Cell type - Mono-Crystalline
- Dimension – 51cm*118cm
- (+-3%) at STC ; Irad-1000w/m2 ; AM=1.5 ; Cell temperature = 25

5.10.2 Charge Controllers

The charge controllers are the devices that connect both PV panels to the two battery sets. Since we are using two battery sets, we are using two charge controllers. The two polarity of PV panel is paralleled and connected to both charge controllers while the positive and negative polarity of each battery set connects to each of the charge controllers as shown in Fig 5.7.

Fig 5.7: Charge controllers

One of the biggest concerns with the batteries in our country is that it becomes unusable very soon. The main reason is that the batteries get fully discharged before being charged again. This full discharge reduces the batteries life span. Since it is going to be used in rural areas and for emergencies, those people cannot afford to change batteries that often and also a worn out battery can cause power failure during transporting a patient. To solve this problem we must ensure that the batteries never get discharged completely and here is where the new feature of the charge controller comes in action, which is called the Low Voltage Disconnect (LVD). LVD stops supplying voltage to the motor when the battery voltage drops to 50% of its SOC. In that way the batteries never fully discharge and its longevity increases.

5.11 Block Diagram of the Whole System

The battery set and the PV panel is connected by means of the charge controllers to ensure the constant sharing of power. The torque sensor circuit is connected to 12V from ach of battery states by means of DPDT in order to switch between battery sets when one of them is in stress. The entire mechanism is shown in a block diagram in Fig 5.8.

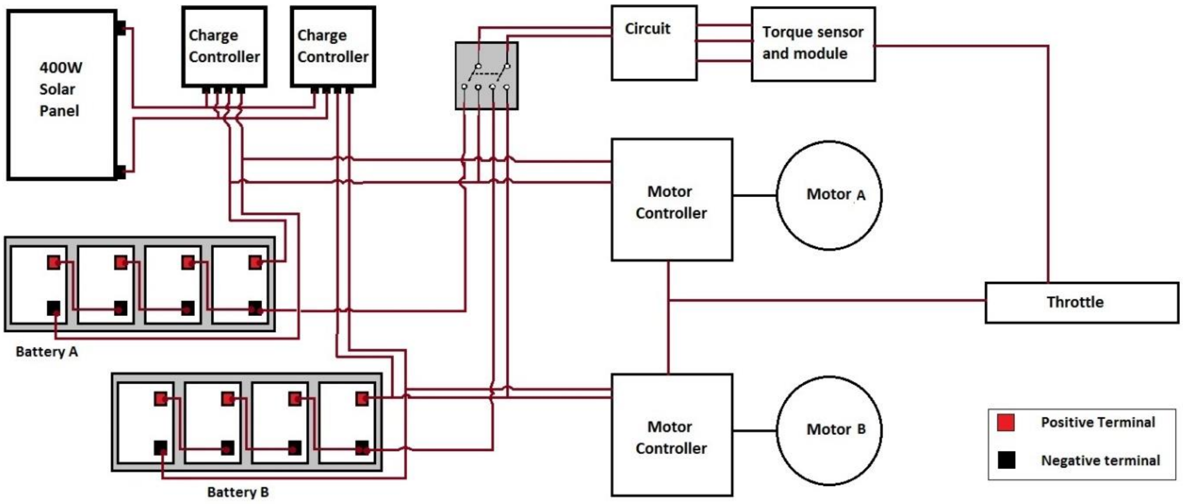


Fig 5.8: Block diagram of integration of torque sensor and PV array into the system

The motor controllers are directly connected to the battery sets at one end and to the motors on the other. The throttle is connected to both the torque sensor module and also to the motor controllers.

5.12 Explanation of Control Algorithm

The control algorithm is mainly based on the comparison between current values from throttle, torque sensor, PV panel, motors and the battery sets. It is shown in a flow diagram in Fig 5.9. At first we consider the throttle and sensor currents; if they exist then we proceed with the panel, motors and battery currents. If there is a current from PV panel and it is greater than motor current then battery current will be equal to the summation of panel current and motor current otherwise motor current will be equal to the summation of battery current and panel current. If there is no current from PV panel then motor current and the battery current will be equal. If there is no current flowing from torque sensor but there is some panel current then battery current and panel current will be same otherwise we go back to take throttle current and torque sensor current.

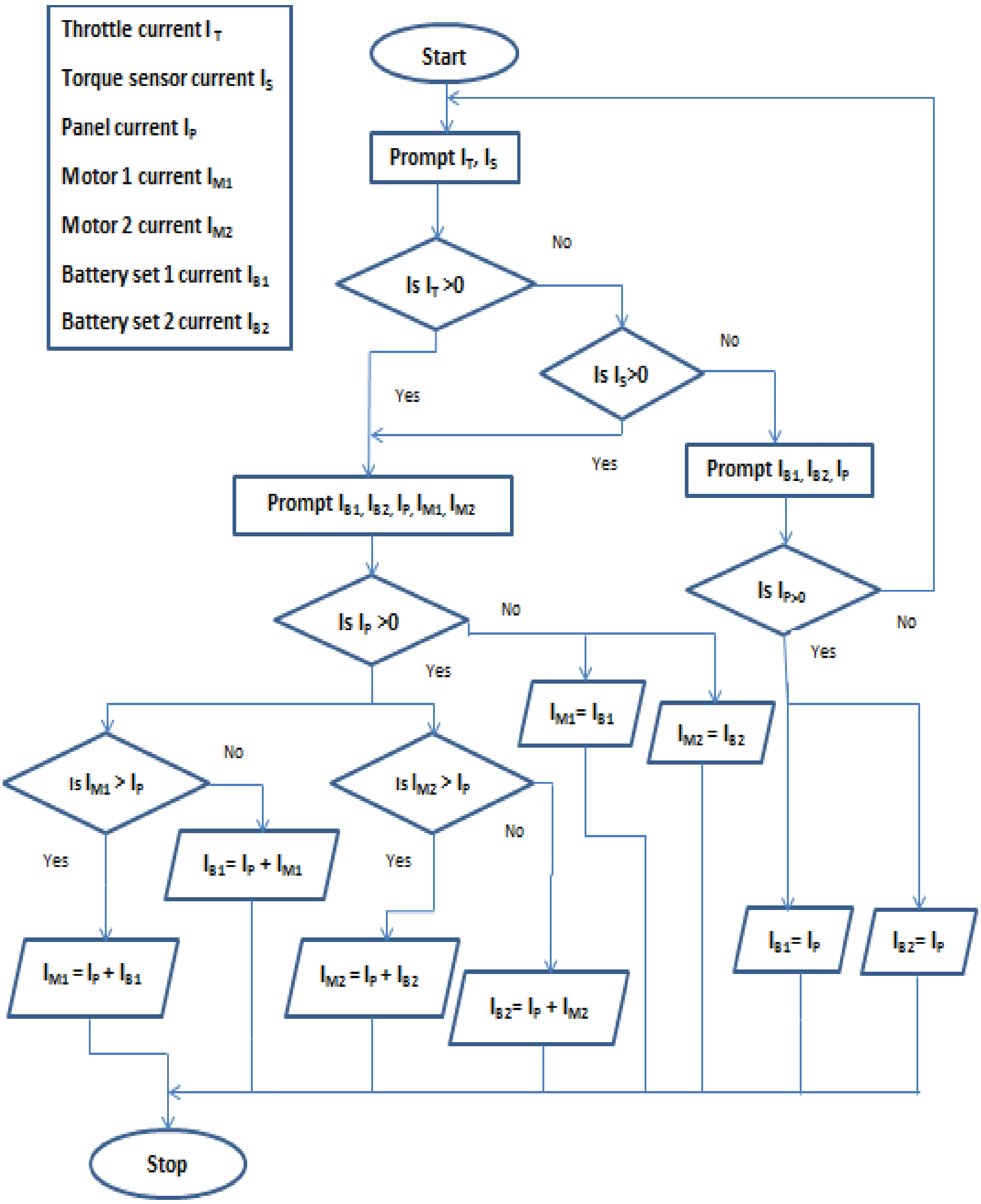


Fig 5.9: Flowchart of control algorithm

5.13 Conclusion

The torque sensor circuit gave excellent results when it was tested in the lab. For such a low powered component, it has done a tremendous job in reducing energy consumption from batteries. The PV panel supported significantly as well. 28% of battery energy reduction was found with the integration of PV panel. Combining both the torque sensor and PV panel we have managed to reduce up to 74% of energy consumption from batteries. In the near future with further development with the torque sensor module, the torque adjustor circuit and higher efficiency solar panel we may be able to decrease more energy consumption and make a greener solution.

Chapter 6

OVERVIEW OF THE SOLAR BATTERY CHARGING STATION

6.1 Introduction to the Solar Battery Charging Station

The solar electric ambulance van is a fully throttle controlled electric vehicle. The ambulance van is complete, having installed a photovoltaic array and a torque sensor pedal. Our target is to run the vehicle without drawing any power from the national grid. The ambulance van is a five-wheeler consisting of eight 12V 25Ah lead acid rechargeable batteries, in sets of two, with each set having four batteries connected in series to supply 48V. Also, a pair of charge controllers or charge regulators is located along with the dual sets of batteries to keep the batteries from over-charging or over-discharging. Four 100W PV panel combined together and is implemented on the roof of the ambulance van, shares electrical energy with the batteries. This decreases the consumption from the batteries and increases battery cycle span. The panel also charges the batteries when the van is stationary, which lessens the need of charging the batteries by any other means.

In order to ascertain the working procedure and the practicality of the solar battery charging station, a charging station has been installed on the rooftop of BRAC University. Fig 6.1 mentioned below, displays the existing system of the University. The core reason behind this implementation was to charge the batteries for the van and hence keep them entirely off the national grid. Although the solar panel and the torque sensor have been merged for energy saving of the van, the batteries yet demand for charging. And charging these batteries via the national grid overloads the already overloaded national grid of the country [13]. Hence, the solar battery charging station is setup which utilizes just the solar energy and is completely independent of the national grid.

Fig 6.1: Solar panels being charged on the rooftop of BRAC University

At the BRAC University solar battery charging station, a minimum of two sets batteries, each set having four batteries in series, can be accommodated to set for charge and to service the van with fully 100% charged batteries. This is done once the van has travelled enough so that a set of batteries has discharged down to 50% of its SOC. The discharged batteries set is replaced with fully charged batteries set from the station and the discharged set is further set to charge at the station. This is the basic working procedure of a solar battery charging station. Fig 6.2 below represents the concept of the procedure.

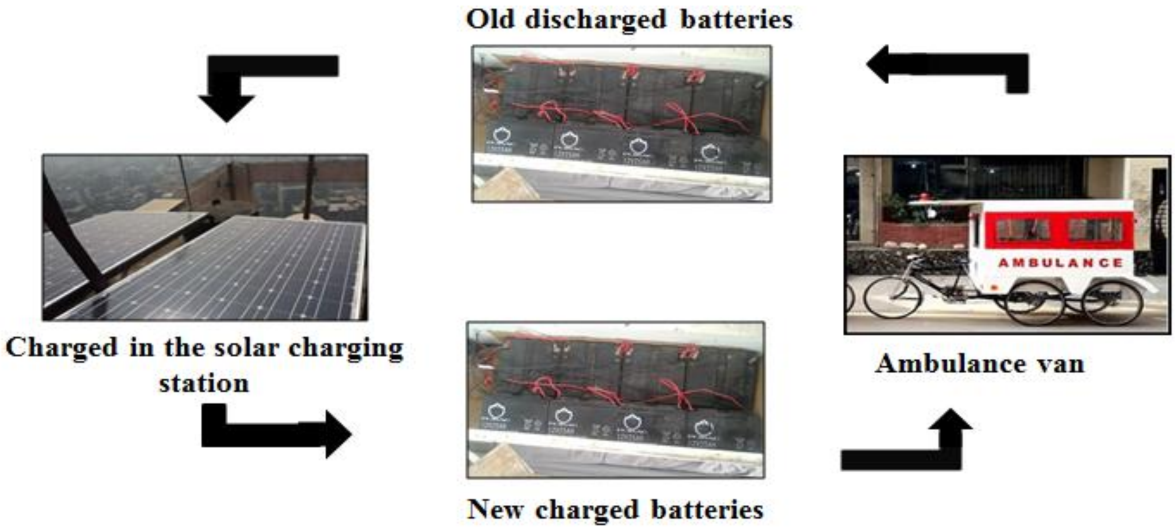


Fig 6.2: Working procedure of solar battery charging station

The current system has two PV panels, each of 200W power, installed at the University station. The two modules of the 400W array, in series, power a DC bus which connects to two charge controllers. These controllers then provide for the two set of batteries to be charged. The specification of the PV modules is mentioned below:

- Maximum power- 200W
- Nominal power- 34.92V
- Nominal current- 5.7A
- Open circuit voltage- 44.64V
- Short circuit current- 6.2A
- Number of cells- 72
- Weight- 14.5kg
- Dimensions- 1580*808 (MM*MM)
- Max system voltage- 600DC
- Power tolerance- +-3%

The functional operation of the solar battery charging station is presented below in Fig 6.3

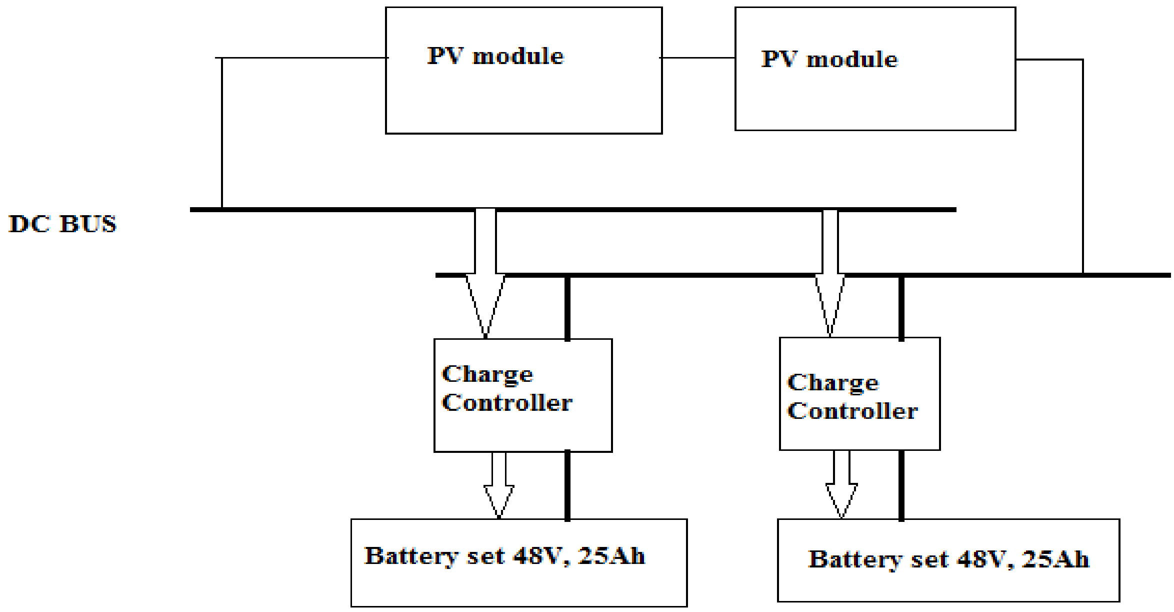


Fig 6.3: Operation of Solar battery charging station

6.2 SOC: State of Charge of the Battery

In order to learn about the current condition of the battery, the following variables, mentioned below, are required to be familiar with to summarize battery specification.

Stage of Charge (SOC) (%) - An expression of the present battery capacity as a percentage of maximum capacity. SOC is generally calculated using current integration to determine the change in battery capacity over time [14].

Depth of Discharge (DOD) (%) – The percentage of battery capacity that has been discharged expressed as a percentage of maximum capacity. A discharge to at least 80% DOD is referred to as a deep discharge [14].

To check for the SOC of the battery, measuring the battery's voltage is an approximation and does not give accurate results. The voltage of the battery is monitored by determining the flow of current in and out of the battery, when current value is approximately zero during battery being charged. A web-guideline contains an SOC chart, Table 6.4 given below, which specifies that a 100% charged 12V battery has an open-circuit voltage of 12.73V and a 50% discharge battery has 12.10V across its terminal.

Percentage of Charge (%)	12V Battery	48V Battery
100	12.73	50.93
90	12.62	50.47
80	12.5	49.99
70	12.37	49.49
60	12.24	48.96
50	12.1	48.41
40	11.96	47.83
30	11.81	47.26
20	11.66	46.63
10	11.51	46.6

Table 6.4 SOC of battery [15]

The 50% discharged batteries are charged to full at the solar battery charging station. The batteries are charged during the day hours when the solar is at its peak. With the concept of a solar battery charging station, a decent amount of energy can be contributed, hence saving energy from the national grid of the country.

6.3 Replacement and Restoration of the Five-Wheeler's Solar Batteries

In the solar electric ambulance van, eight lead-acid batteries are installed in sets of two. These batteries are quite heavy and require much strength to lift and handle. Hence, it becomes difficult to simultaneously carry all the discharged batteries of the van to the charging station and replace those with new sets from the station. To alleviate the task, simple swapping method has been acquired.

The design of the ambulance van includes a small door, next to the puller's seat, which exposes the sets of batteries. Although, the batteries are placed inside a channel under the patient's bed, the small gate system at the front side of the vehicle allows access to the batteries. Instead of upholding the heavy batteries to and from the charging station, conventional trolleys can be used. Fig 6.5 below shows a conventional trolley used to transport these batteries. These trolleys have long handles attached to base support platforms where the battery sets can rest when the trolley is in move. However, one still has to lift the batteries manually just before the charged batteries are to be installed inside the van after the batteries are being carried from the station to the van on the trolley.

Fig 6.5 Conventional trolley used for transport purpose

To eliminate such a drawback, new design has been proposed. This system facilitates both the carrying of the batteries on a trolley and swapping the sets to and from the van. A roller system wheel can be adjusted under the battery sets inside the van. Another roller system wheel can be attached on the trolley so that the roller wheels can easily rotate to shift the batteries from the trolley to the van. The roller system wheel resembles a conveyer belt carrying medium; Fig 6.6 below shows a belt conveyer. Also, the trolley base platform can be custom-made to meet the height of the van base where the batteries are placed.

Fig 6.6: Conveyer belt that can be used for roller system purpose [16]

6.4 Conclusion

Easier ways of swapping the batteries need to be found out in the future to make the whole system much easier and more effective. This belt will make it easier for old people to swap the batteries as well without much difficulty.

Chapter 7

FIELD TEST

7.1 Objective

The objectives of the field test were to retrieve data for the ambulance van's battery supply profile, the load profile, and the solar supply profile; to check for the efficiency of the braking system and check for the over-all reliability of the system. However, the core objective was to find the actual percentage of power saved from the batteries when torque sensor pedal and solar panel were introduced to the ambulance van. Data were extracted in the day-time during the peak sun hours. The field tests were conducted mostly on less traffic-packed roads in order to run the ambulance van freely.

The field tests to be performed are divided into four steps:

1. Test data without any PV array assistance or aid from torque sensor pedal – The objective of this particular field test is to account for the total distance the ambulance van can travel when the batteries are discharged down to 50% of battery SOC. Also, data is obtained to determine the load power consumed solely from the batteries.

2. Test data with only PV array assistance and no aid from torque sensor pedal – The objective of the second stage of field test is to determine the total distance covered when the ambulance van runs on PV support only. The distance is again measured for batteries discharged down to 50% SOC. Data is obtained here to determine the load power that is contributed and shared between the batteries and solar panel.

3. Test data with only aid from torque sensor pedal and no assistance from PV array – The objective here is to determine the total distance travelled for the batteries to discharge down to 50% SOC when the ambulance van runs on the torque sensor pedal. Data too is obtained to check for power consumed from the batteries.

4. Test data with both PV array assistance and aid from torque sensor pedal – This specific field test accounts for the total distance covered when the ambulance van is supported by both the PV and the torque sensor pedal installed on the van.

7.2 Procedure for Attaining Data

Certain techniques and instruments are used to acquire data and accomplish the objective of the field tests performed on the ambulance van. Multi-meters, in the form of voltmeters, are used to measure the voltage across the solar panel and the batteries. Two multi-meters are required, each connecting in parallel across the two 48V sets of batteries. A further two multi-meters are used across the junctions of the two batteries sets connected to two charge controllers. Two clamp-meters, in the form of ammeters, are attached to the wires that are connected in series with the two battery sets and the two motors. Another clamp-meter is connected in series with the solar panel to the charge controllers. Google map distance and tracking software called Endomondo application are used to measure the total distance travelled and the average speed reached by the ambulance van. During the field tests, data results are obtained and retrieved using a video camera which also records for instantaneous data readings. Fig 7.1 below displays the data attaining method.

Fig 7.1: Data Attaining Procedure

7.3 Test Data without any PV Array Assistance or Aid from Torque Sensor Pedal:

This is an initial stage of the research where test is done to determine the energy consumed by the dual sets of batteries installed in the ambulance van. Impacts from the solar support and the torque sensor pedal are not present. The battery voltage and current drawn from the battery by the load have been recorded. These data are shown in a graph of van's dual battery sets supply profile in Fig 7.2 and Fig 7.3. Also, the power (voltage*current) supplied by the dual battery sets to the load is given in Fig 7.4 and Fig 7.5. Since this test only consumes energy from battery, battery power equals the load power; load power is represented in graphs Fig 7.6 and Fig 7.7. The data obtained from test data records are placed in **Appendix F.**

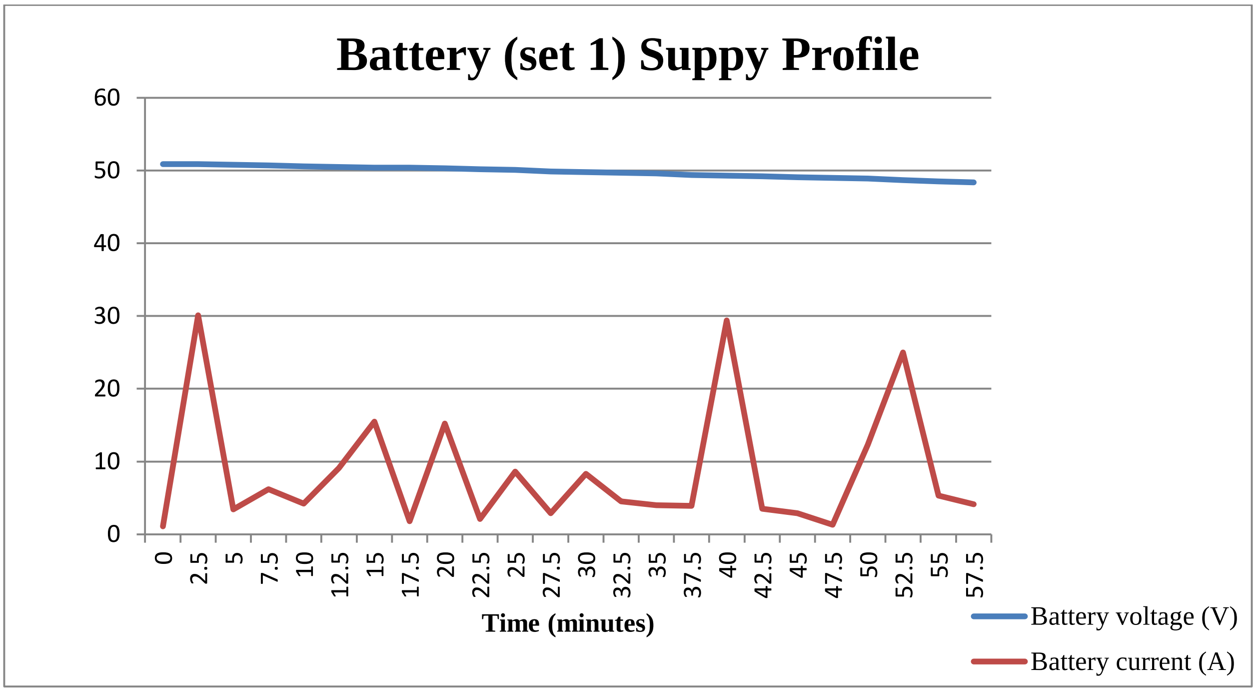


Fig 7.2 Voltage and current from first set of batteries

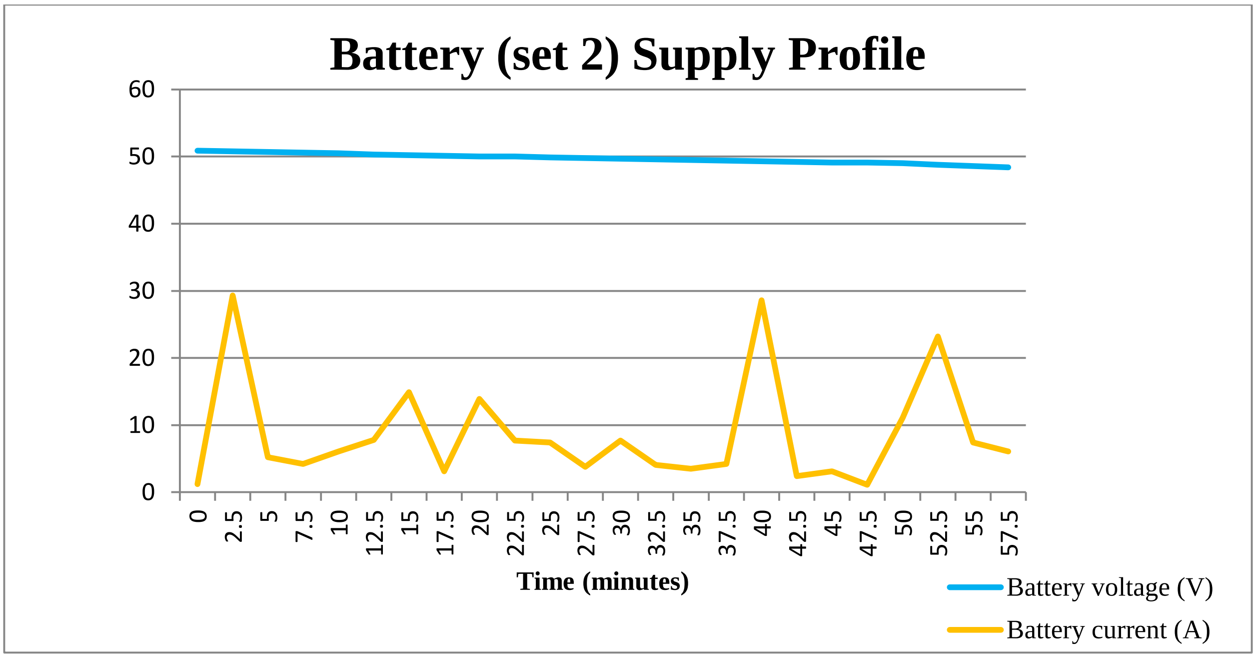


Fig 7.3 Voltage and current from second set of batteries

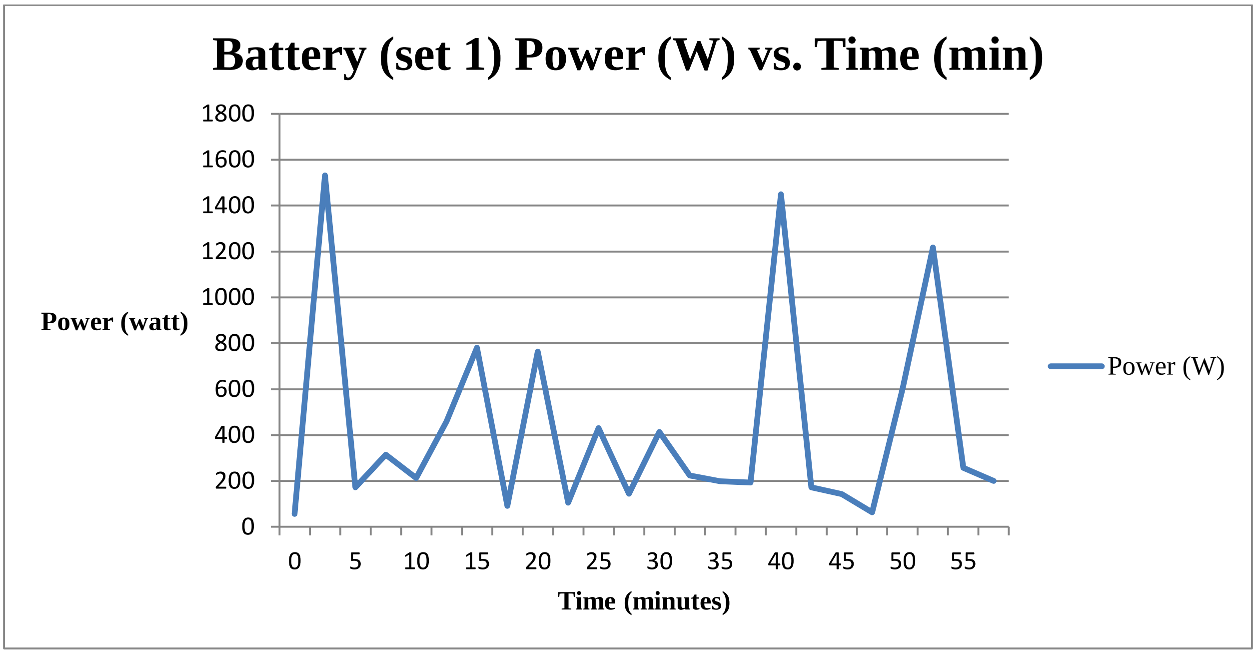


Fig 7.4 Power supplied by first set of batteries

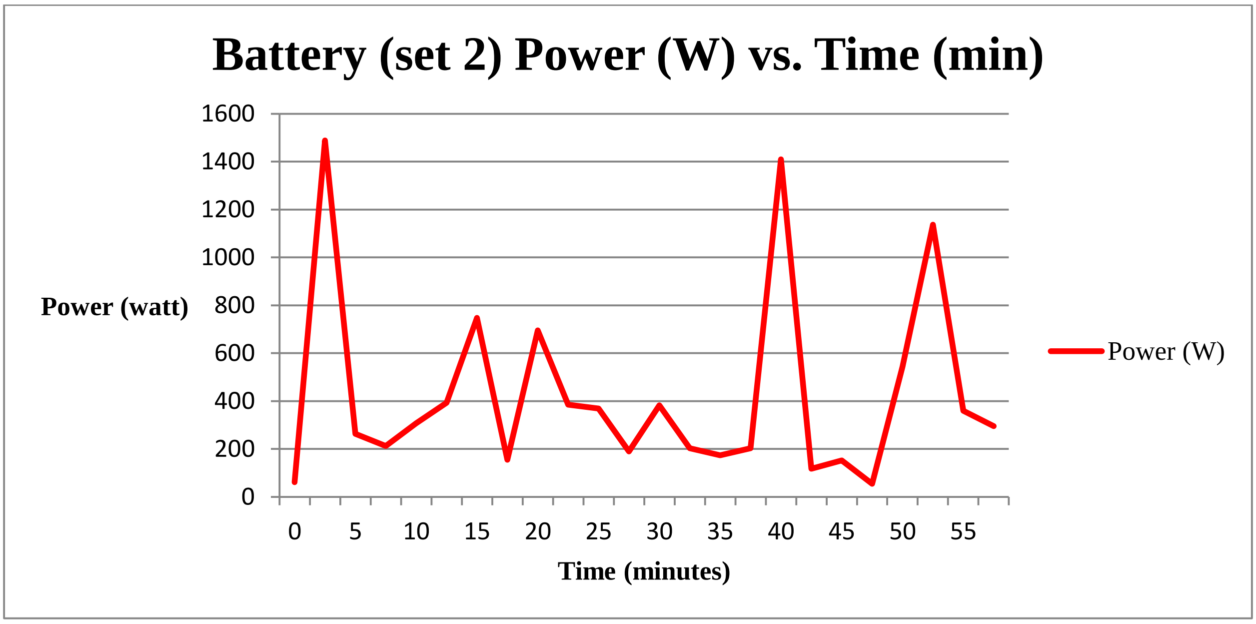


Fig 7.5 Power supplied by second set of batteries

7.4 Test Data with Only PV Array Assistance:

For the second stage, field test is carried out using support from the PV. Performance on the ambulance van due to solely PV impact is evaluated here. This test is carried out in the day-time during the sun peak hours, around 12 pm to 3 pm. Also, it is efficient to carry out the test in areas where solar exposure is sufficient in amount to determine the effect of solar panel support on the vehicle. Data is mined for the voltage across PV array and battery sets, current supplied by the panel, and current drawn from the battery by the load. The total distance covered for a total time is recorded for the battery to discharge down to 50% of battery SOC. The average power supply and energy supply by the panel, the average power supply and energy supply by the battery and the average power supply and energy consumed by the load are recorded for this particular field test. The sharing of total power supplied by PV panel and the batteries is estimated to be the following, 20.1% energy is supplied by PV panel and the rest 79.9% energy is supplied by the battery. Hence, 20.1% energy is saved and 79.9% energy is consumed.

7.5 Test Data with Only Aid from Torque Sensor Pedal:

For the third stage, field test is carried out using torque sensor pedal. For this test, the use of the vehicle throttle is expelled since the vehicle puller has to paddle the torque sensor based pedal to run the vehicle. Voltage across the battery and current drawn from the battery are recorded. The power supply by the battery and the energy consumed by the load from the battery are both determined. The total distance travelled for a total time is calculated for the battery to discharge down to 50% SOC. The input voltage of the torque sensor to the controller unit and the output voltage from the torque sensor pedal to the torque regulator or adjustor are retrieved as-well. From test with only torque-sensor pedal, the system saves 45.9% energy and consumes 54.1% energy of the throttle controlled design. Hence, it can be said that 45.9% energy is supplied from the integrated torque sensor pedal on the ambulance van.

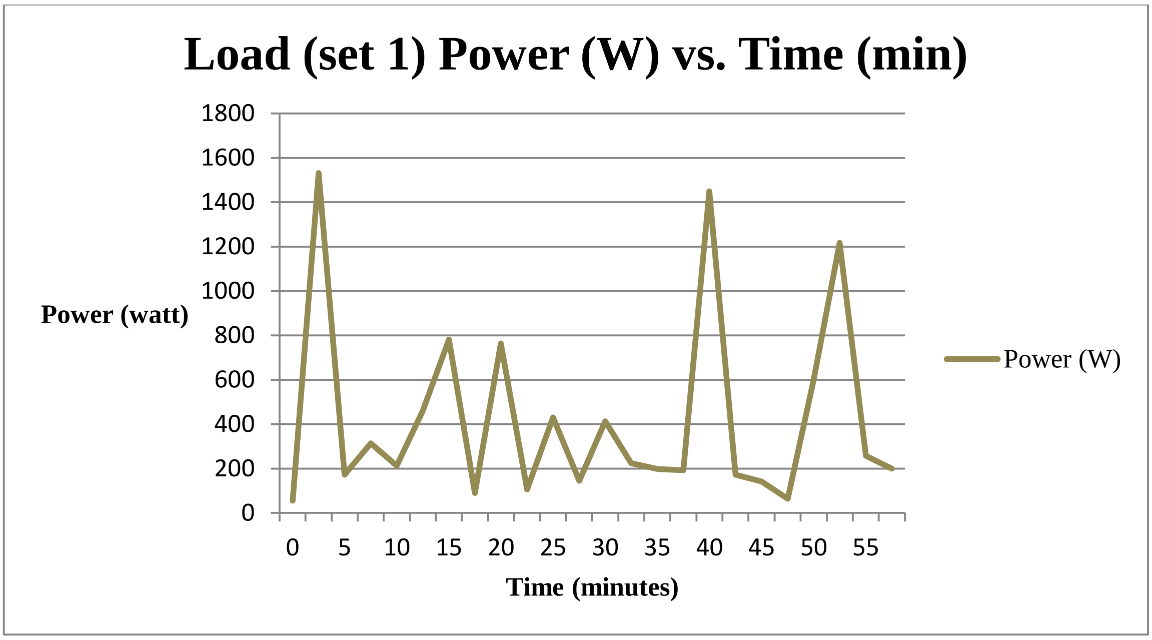


Fig: 7.6 Load power for first set of batteries without PV support and torque sensor

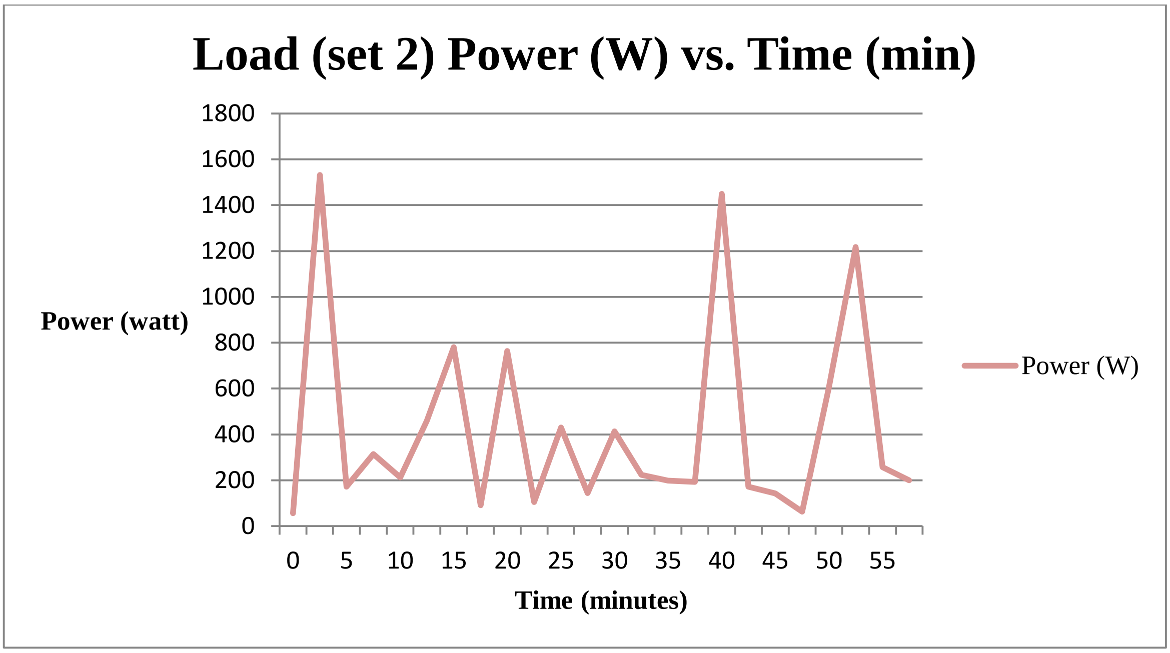


Fig 7.7 Load power for second set of batteries without PV support and torque sensor

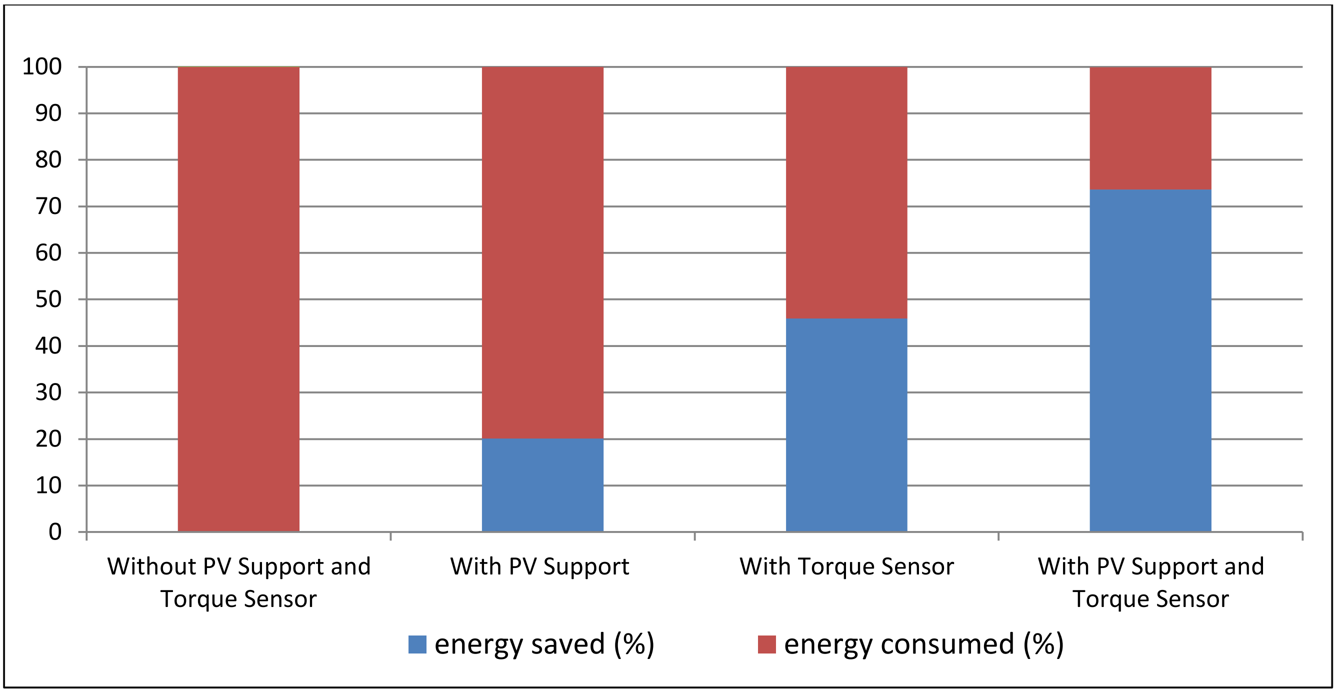
The energy consumed by the load of the van is calculated from the area under the curve of battery power versus time. From the following curves, the average power supplied by the battery and the average energy supplied by the battery to the load are approximately 427.002 Watts and 1.4732 M Joules respectively.

As per the data collected, for field test without PV or torque sensor, following the SOC chart of the battery, the total distance travelled, for the batteries to discharge down to 50% of SOC, is 16.1 km in the time 57.5 minutes. The field test with PV and torque gives an average speed of 16.8 km/hr for the batteries to discharge down to 50% of SOC. Maximum speed attained by the ambulance van during field test is 32 km/hr.

7.6 Test Data with Both PV Array Assistance and Aid from Torque Sensor Pedal:

For the fourth and the final stage of the research, field tests are carried out using both solar and torque sensor pedal supports. This test is done during the peak sun hours for results. Voltage across the PV panel and current supplied by it are retrieved. Voltage across the batteries and current drawn from the batteries by the load are also retrieved. The input voltage of the torque sensor to the controller unit and the output voltage from the torque sensor pedal to the torque regulator or adjustor are recorded. The total distance travelled for a total timed is calculated for the battery to discharge down to 50% SOC. The batter, solar panel and load power supply and energy supply profiles are determined. Combining the torque sensor and PV in the system supplies 73.6% energy to the design and saves this entire 73.6% energy by only consuming 26.3% energy from the battery.

A chart and a table represented in Fig, Table: 7.8 represent a comparison of energy savings from the four different field tests. Fig: 7.9 show the energy contribution of battery, PV support and torque sensor pedal in the form of a pie-chart.



Field Tests	Energy saved (%)	Energy consumed (%)
Without PV Support and Torque Sensor	0	100
With PV Support	20.1	79.9
With Torque Sensor	45.9	54.1
With PV Support and Torque Sensor	73.6	26.3

Fig, Table 7.8: Comparison of energy saving from different field tests

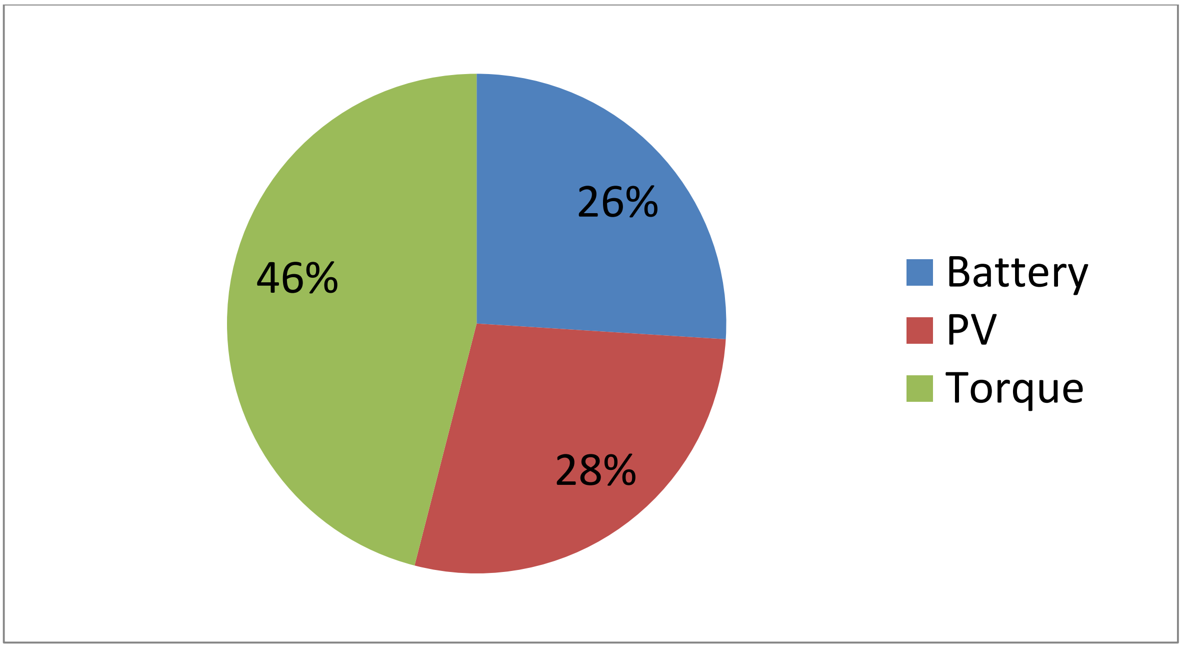


Fig 7.9 Energy contribution of battery, PV panel and torque sensor

7.7 Comparison with the Solar Electric Tri-wheeler Van:

Data has been extracted for only the first and foremost test; that is, test without any PV array assistance or aid from torque sensor pedal has been carried out. The rest of the three field tests types have been carried out but only in approximation. Numerical data has not been collected under the tests of only PV support, only torque sensor pedal and both PV and torque sensor for the ambulance van since similar field tests have been done in these categories on the tri-wheeler rickshaw van [12].

The core objectives behind initiating the project of solar electric ambulance van have been to create a complete efficient system, to make a comparative study with the electrically assisted rickshaw van to create a more developed version of it and implement the improvements in the ambulance van.

A comparative study has been done from the impact of the elements, torque sensor pedal and PV array, installed in the system which determines the power conservation from each criterion and the energy saved and contributed when these elements are performed on the ambulance van individually and on different combinations. A projection has also been made for the distance coverage and time elapsed to give the ultimate average speed for the ambulance van.

This comparative study has been done in reference to the solar electric tri-wheeler van. The human hauler travels 12.455km in 1.24hrs without any PV support or aid from torque sensor pedal for an average speed of 10.044 km/hr for battery to discharge down to 50% SOC. The maximum speed attained by this tri-wheeler van is 25 km/hr.

Whereas, the ambulance van travels 16.1km in 57.5 minutes for the same test, without PV support or torque sensor aid, with an average speed of 16.8 km/hr. This distance coverage is determined with the battery discharge down to 50% of SOC. And the maximum speed attained by the ambulance van is 32 km/hr. Table 7.10 summarizes the comparison between the ambulance van and rickshaw van for test with solely throttle control and no PV support or torque sensor pedal for battery discharge down to 50% SOC.

	Tri-wheeler Van	**Ambulance Van**
Distance travelled	12.455 km	16.1 km
Runtime	1.24 hr	57.5 min
Average Speed	10.044 km/hr	16.8 km/hr
Maximum Speed	25 km/hr	32 km/hr

Table 7.10 Comparison with tri-wheeler for test without PV or torque sensor

Also, in comparison to the rickshaw van which is composed of a set of four batteries giving 48V, supporting a 700W motor [12], the ambulance van is composed of dual sets of four batteries, each giving 48V, and supporting two 500W motors. The double number of batteries and motors of the ambulance van indicate to better performance compared to single battery set and motor of the rickshaw van.

As a result, the ambulance van is expected to give similar data pattern as that of the rickshaw van and even meet better results and further technical improvement. Fig 7.11 represents the projected distance of the ambulance van for 50% DOD (Depth of Discharge) of battery, in comparison to the tri-wheeler rickshaw van.

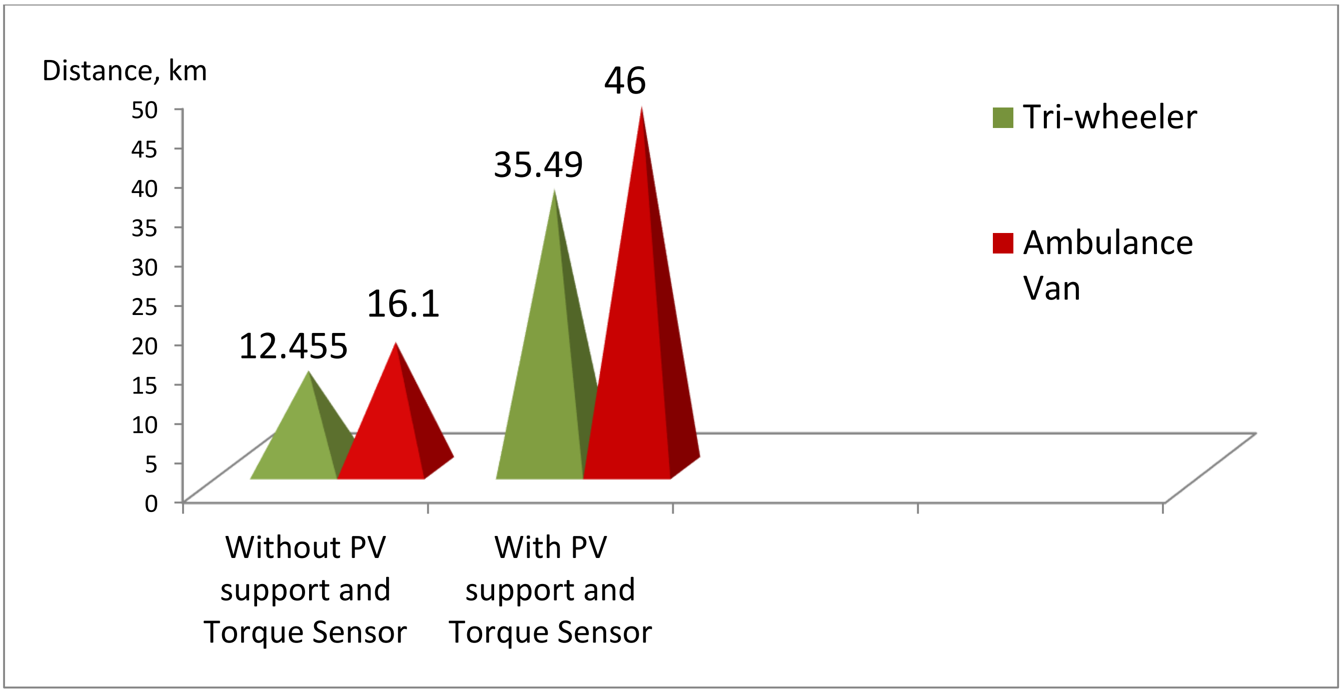


Fig 7.11: Projected distance of ambulance van for 50% DOD, in comparison to the ambulance van.

7.8: Conclusion

This chapter shows that the use of torque sensor and PV array significantly improves the performance of the vehicle. The distance travelled increases and the overconsumption of batteries decreases as well.

Chapter – 8

IMPROVEMENTS ON EXISTING DESIGN

8.1 Introduction

Five wheeler ambulance van is totally a new concept; we have faced some small problem during our field test. To make it more feasible it is important to solve this problem and add some extra features. Some of the problems were solved immediately whilst others are yet to be executed. The problems we faced during field test and as well as their solutions are discussed in this chapter.

8.2 Inability to Take Reverse Gear

Our present five wheeler van cannot take reverse movement using its throttle and motor. This problem can easily be overcome if we can make the perfect use of pin-6 and pin-5 of the motor controller. From the Fig 8.1 below of the motor controller we can see that pin-6 is for reverse gear in it. If we can connect it to a switch and give some throttle, our van can easily take reverse movement.

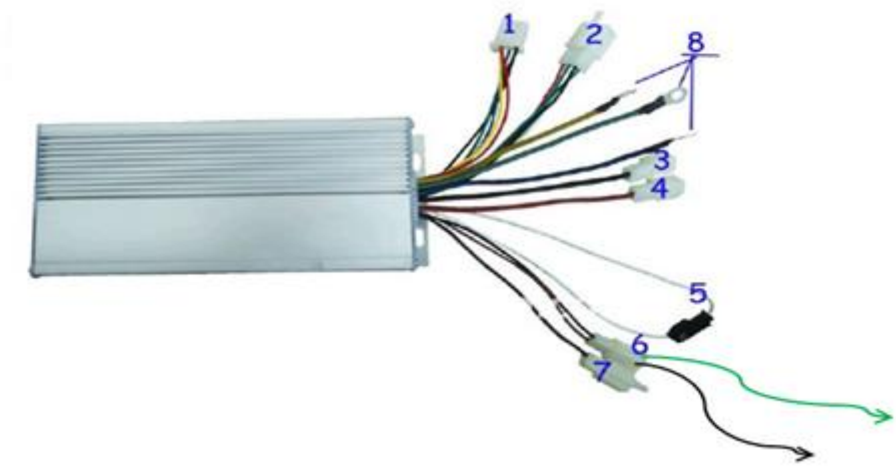
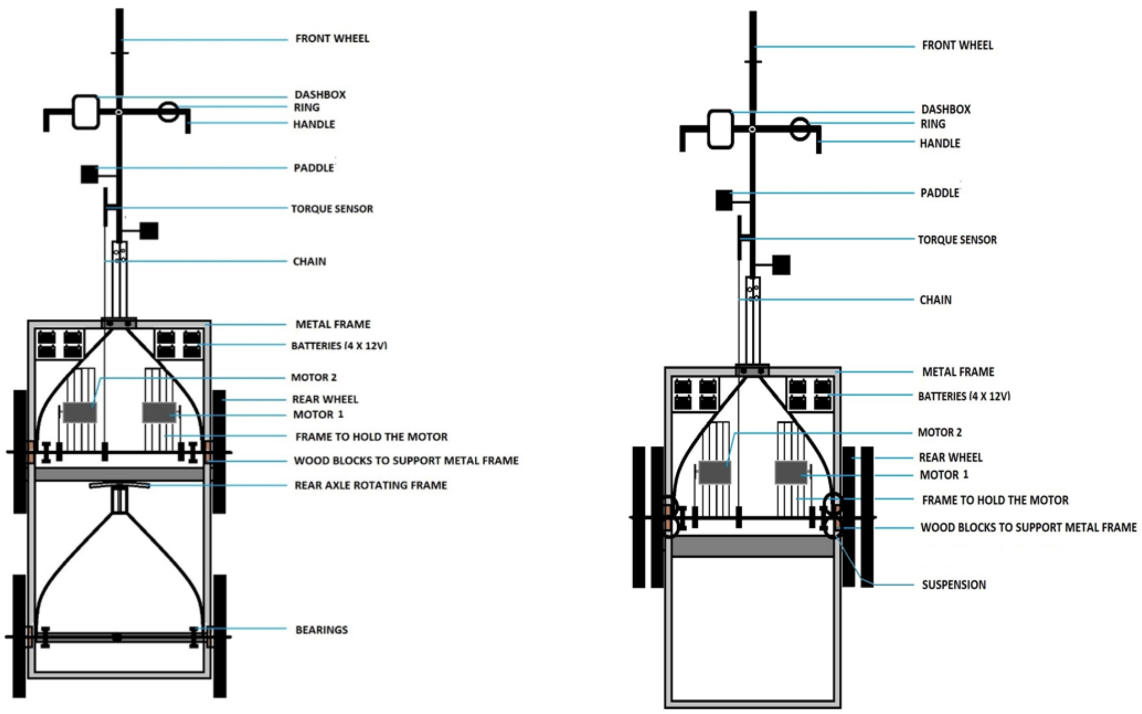


Fig 8.1: Motor controller [10]

However, in that case speed limiting cable in pin-5 should also be connected for safety reasons. This is one of those problems that we have already solved and implemented in our vehicle.

8.3 Inability to Take Sharp Turn

It has been observed during our tests that the vehicle needs longer arcs in a situation of taking turns. Since that is not an efficient way to go we have modified our design even further to achieve fast and sharp turning. Sharp so that it can travel through narrow lanes in the village and fast so that in case of an emergency, the vehicle can reach the destination faster.



(a) **(b)**

Fig: 8.2(a) Initial built skeletal diagram (b) Modified design skeletal diagram

In our initial design in part (a) of Fig 8.2, we have introduced the rear wheel rotating axle system. The rear wheel axle system enables the rear two wheels moves separately as a reaction of the direction of the front three wheels. This design solved the problem of lifting of the middle two wheels but the vehicle in this system required a longer arc to take turn. In our latest design in part (b) we have got rid of the rear two wheels and rather went for the custom made axle. This custom made axle is longer than any axle found any other found in the local shops. The reason we had to go for longer axle was because the vehicle is 4 feet long and it had to incorporate two wheels side by side on each side as shown in the Fig 8.3.

Fig 8.3: New chassis design

This design enabled the vehicle to take sharper turns due to its shorter chassis holding the same weight and dimensions as before. This is one of those problems that has been solved and successfully implemented.

8.4 Lack of Grip on Slippery Road

During our field test we observe that in rainy days, we observed that the vehicle got hard to steer. This happened because of the lack of grip in tyres. We started with close inspection on the existing tyres. At the end of the inspection we came to a conclusion that the existing tyres are not gridded enough.

Fig 8.4: Grid tyres for optimal grip

The tyres in the fig 8.4 are found in the local shops and usually used for mountain bikes where grip is of prime importance. This tyres will permit the driver to steer impeccably even on a rainy day when the road is slippery.

8.5 Impact Protection

Alike most vehicles, our ambulance van's body is made out of metal sheet. On the contrary to most vehicles, the inside of our ambulance van is lined with soft material which can cause injury if an accident occurs.

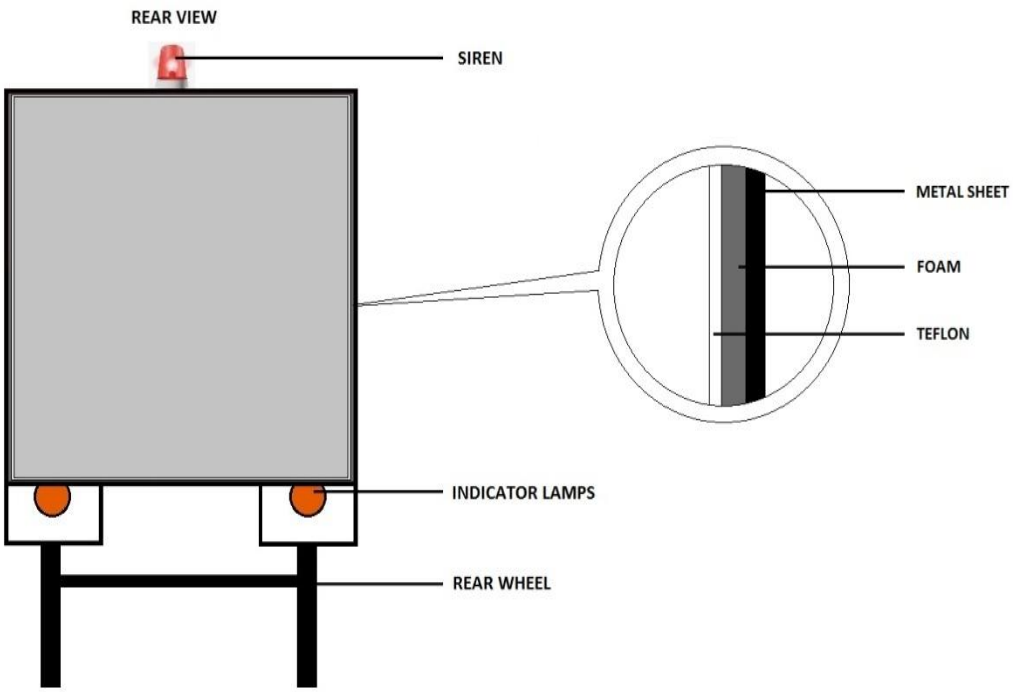


Fig 8.5: Using foam and Teflon in frame

We have decided to go with an extra layer of foam on the inner walls of the vehicle and cover it with Teflon as seen in the cross-sectional diagram in Fig 8.5. Teflon was chosen because of its strength as a polymer as well as being non-reactive to most chemicals that can be present inside the ambulance.

8.6 Inefficient Breaking System

In our five-wheeler ambulance van there are two types of brakes being used. These are the traditional brake shoes and rear wheel brake. With the power of two 500W motors combined and with the intention of emergency, these brakes are inadequate for their purposes.

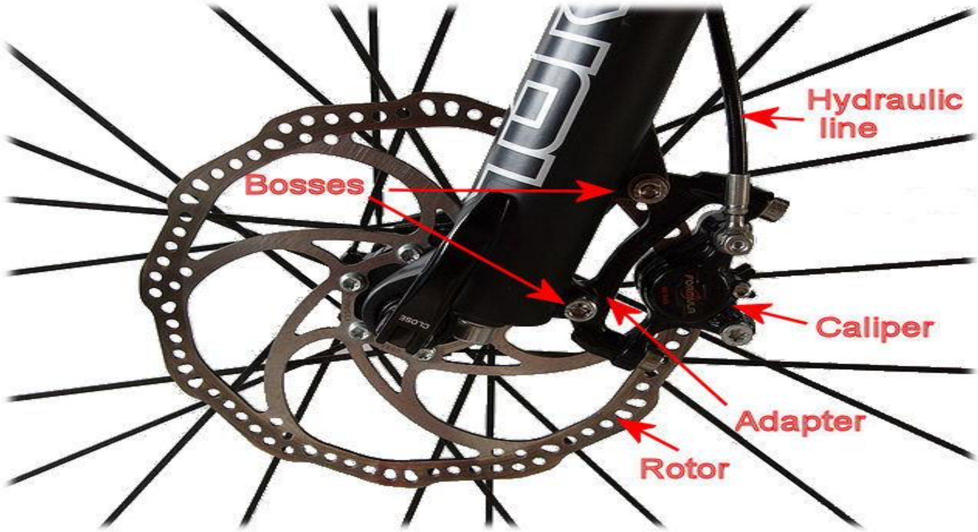


Fig 8.6: Disk brakes

To improve upon our current brake solution, we have decided to go with disk brakes shown in Fig 8.6. Disk brakes are famous among bicyclists for their smooth and precise braking, no heat generation, no wear and tear also for their consistent performance no matter what the weather condition is. This is one of those solutions yet to be implemented.

8.7 Conclusion

Our focuses on the problems and coming to the solutions has opened a gate improvements in overall performance of the ambulance van as well as providing persistence service to our customers. All the solutions mentioned above are low cost and will not affect the budget of manufacturing of the final product. Some of them are already fixed and others are soon to be done.

CHAPTER 9

CONCLUSION

9.1 Conclusion

People in the rural areas will be getting a huge support when the solar electric ambulance van gets commercialized and it is great advancement economically for Bangladesh as majority of the population are from rural areas. This will bring a huge change in the lifestyle and income of the rickshaw pullers. The high speed and the architecture of these vehicles would be beneficial for the patients of the rural areas as it would be safe and would take lesser time to reach the hospital. The five-wheeler causes zero pollution to the environment; hence it is a green project. It does not consume power from national grid for charging batteries. Instead, it uses renewable energy that is inexhaustible and thus the whole system is a complete off grid solution that can be sustainable.

Therefore, it can be said that the research work on the project “Solar electric ambulance van to assist rural emergencies in Bangladesh- A complete off grid solution, has been very efficient and has approached success. The target has been to develop the already existing such vehicle and make a complete useful system which have been achieved with our project. With the development of this vehicle, there can be opportunities of future work projection.

9.2 Work Projection

The ambulance van can be further improved with the installation of the following features Fig: 9.1:

- Better swapping system for the batteries- With the new proposed design of roller system wheels to transport batteries between the van and solar battery charging station, the whole working system of the solar battery charging station will be efficient.
- Wind shield- The wind shield can give protection from a weather situation.
- Better headlights- When there is heavy fog on the road, better light system will help the puller.
- Spare wheel and tool box compartments- These features are to be available in the vehicle for case of emergency when wheel tire can get deflated or when unavoidable

circumstance may arise. Tool box can include items such as tire-inflator, tire-lever, flash light, multi-tool package, umbrella etc.

- Good casings for motor controllers and torque sensor circuit module- Casings can be used to protect these components from getting damaged in extreme weathers

Fig 9.1 Extra features to assist future development

9.3 Project Recognition

Our meaningful partners are:

1. CARC- Control and Applications Research Centre

2. IDCOL- Infrastructure Development Company Limited

3. BRAC HNPP- BRAC Health, Nutrition and Population Program

4. IEEE USA

CARC helped us in initiating the idea of this project and bringing up this project from scratch. IEEE USA funded for this project. IDCOL approved our project and helped in commercializing it. This project will initially run in collaboration with BRAC HNPP in one of their sectors called "Manoshi program".

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REFERENCES

[1] P.Starkey, S.Ellis, J.Hine and A.Ternell (2002) ‘’Improving Rural Mobility: Options for Developing Motorized andNonmotorized Transport in Rural Areas
http://www-wds.worldbank.org/external/default/WDSContentServer/WDSP/IB/2002/10/18/000094946_02100304105088/Rendered/PDF/multi0page.pdf

[2] http://newagebd.net/91997/a-rickshaw-puller-earns-tk-446-a-day-bbs-report/, Accessed on 10/11/2015

[3] T. Faraz and A. Azad, “Solar Battery Charging Station and Torque Sensor Based Electrically Assisted Rickshaw”, Global Humanitarian Technology Conference (GHTC), 2012 IEEE, vol. no., pp. 12,22, 21-24 Oct. 2012

[4] Chowdhury, S.J.; Rahman, R.; Azad, A., "Power conversion for environment friendly electrically assisted rickshaw using photovoltaic technology in Bangladesh," *Transportation Electrification Conference and Expo (ITEC), 2015 IEEE* , vol., no., pp.1,6, 14-17 June 2015

[5] R. Rahman and A. Azad, "Power Conservation for Electrically Assisted Rickshaws with PV Support in Bangladesh”, IEEE Global Humanitarian Technology Conference (GHTC2014), Silicon Valley, San Jose, California, USA. -

[6] Azad, A., ‘’The Solar Assisted Rickshaw Van: A complete off grid solution’’http://tec.ieee.org/2015/01/08/solar-assisted-rickshaw-van-complete-grid-solution/

[7] http://www.bbc.com/news/uk-england-derbyshire-26887953. Accessed on 10/11/2015

[8] Beevatech Limited Homepage: http://www.beevatech.com/index.php

[9] M. Asaduzzaman et al., “Power from the sun: An evaluation of institutional effectiveness and impact of solar home systems in Bangladesh,” Bangladesh Inst. Dev. Stud. (BIDS), Dhaka Bangladesh, Final Rep. to the World Bank Report, May 30, 2013.

[10] Rachaen Mahfuz Huq, Numayur Tahmid Shuvo, Partha Chakraborty, Md. Anamul Hoque ‘Development of Torque Sensor Based Electrically Assisted Hybrid Rickshaw’,2012

[11] Shadman Shabaab Haque, Sabrina Hoque, Sanam Sabnin, Shah Omer Zahid. ‘Energy Conservation of Electric Hybrid Rickshaw wth PV support’,2013

[12] F.R.Khan, A.T.Aurony, A.Rahman, F.Munira, N.Halim, A.Azad, "Torque Sensor Based Electrically Assisted Hybrid Rickshaw-Van with PV Assistance, and Solar Battery Charging Station," Submitted to 3rd International Conference on Advances in Electrical Engineering (ICAEE) 17-19 December 2015, IUB Campus, Dhaka, Bangladesh

[13] http://www.dhakatribune.com/bangladesh/2015/mar/22/load-shedding-wont-improve-year. Accessed on 28/11/2015.

[14] http://web.mit.edu/evt/summary_battery_specifications.pdf. Accessed on 29/11/2015.

[15]http://www.trojanbattery.com/BatteryMaintenance/Testing.aspx. Accessed on 29/11/2015.

[16]https://www.google.com/search?q=conveyor+belt&source=lnms&tbm=isch&sa=X&ved=0ahUKEwj1psnqsrPJAhWSG44KHe3gCMwQ_AUIBygB&biw=1366&bih=657#imgrc=eahcliqX9YX7LM%3A. Accessed on 28/11/2015.

APPENDIX

Appendix A

Wiring Diagram

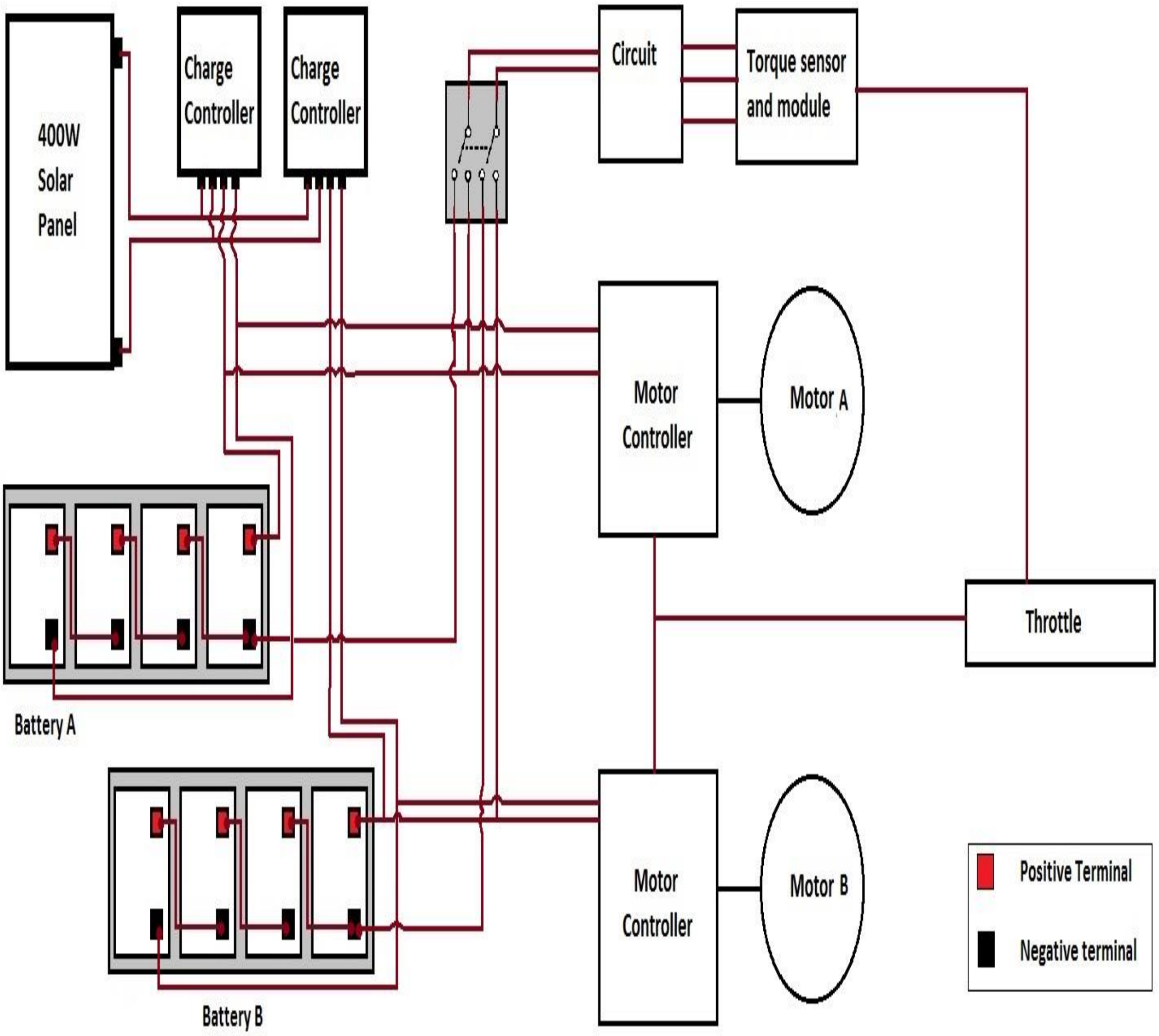


Fig: Total System Design

Appendix B

Torque Sensor Proteus Diagram

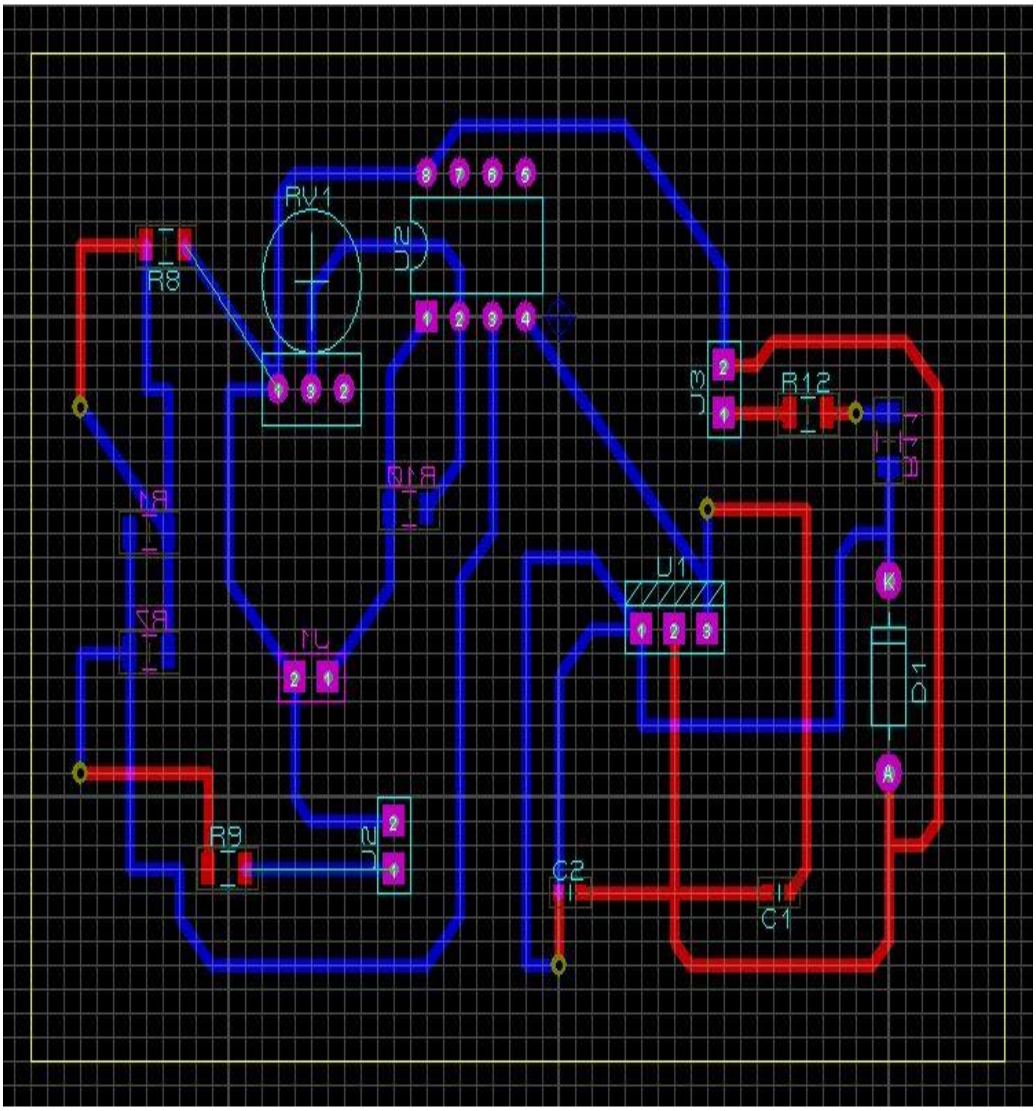


Fig: Torque Sensor

Appendix C

Chronological Development of the Solar Electric Ambulance Van

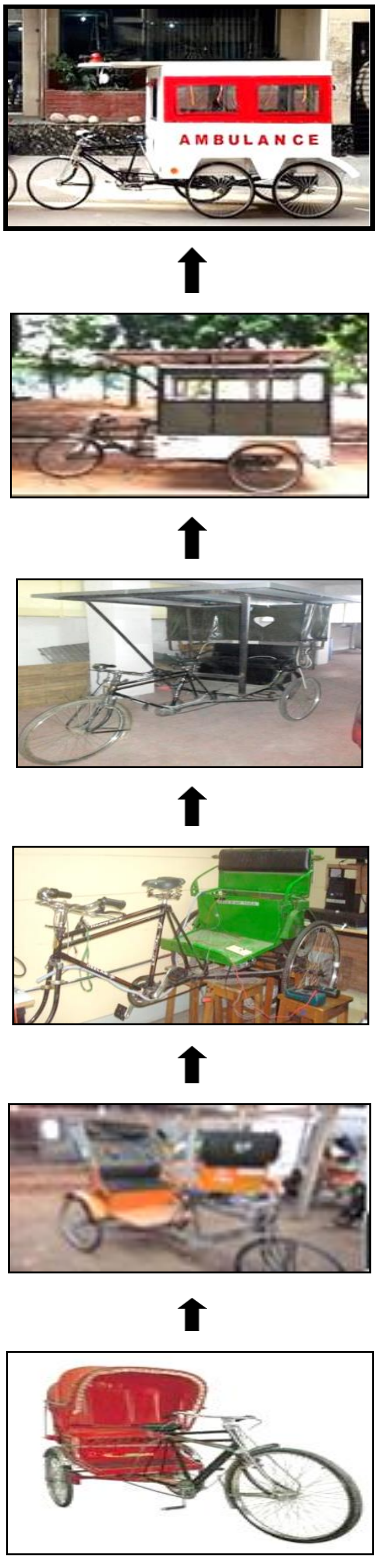
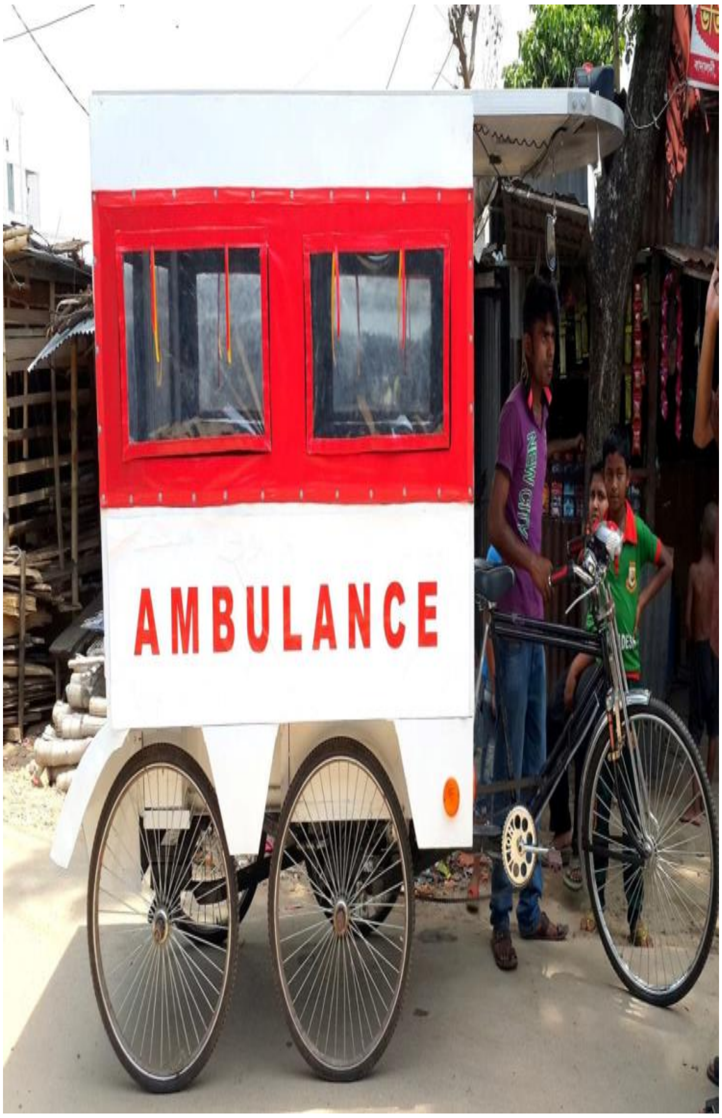


Fig: Flow Diagram of chronological development of solar electric ambulance van

Appendix D

The Vehicle at a Glance



Side view of the vehicle

Front view of the vehicle

Inside view of the vehicle

Appendix E

Components

The Batteries

Fig: Two Batteries

Eight 12V, 25Ah Rechargeable batteries has been used in the ambulance. From eight batteries individually four of them are connected and later on these two sets are connected in parallel. These two sets of batteries supply 48 volts each to the two BLDC motor. These are lead-acid batteries. The batteries are placed under both the seats as shown in the figure.

The Motors

Fig: Motors

There are two BLDC motors we are using in the ambulance. The features of the individual motors are 500 rpm, 48V, 500W each. These two motors are attached with the chassis as shown in Fig 2.5. For the speed and backup for the emergency we are using two BLDC motors. In case one of the motor stops working, there will always be another option as a back-up. The reason for using BLDC motor in our project is that the BLDC motors have permanent magnets and an electronically controlled rotating field stator, using sensors (rotary encoder or back-EMF) to detect rotor position.

The Controller Box

Fig: Controller Box

There are two motor controllers as shown in the figure we are using for our thesis. But due to the unavailability of proper resources, the controller wires were identified using some online resources, experiments, and exploring the connections in the system.

The Throttle

Fig: Throttle

The throttle shown in the figure is a designed potentiometer. For controlling the speed of the motor, BLDC motor needs the throttle. Output voltage is controlled by the angle or position of the throttle. This output voltage goes to the motor controller. The motor speed increases as the output voltage increases.

The Power Key and Charge Indicator

Fig: Power Key and Charge Indicator

For operating the system manually, a power key as shown in the figure is used to turn the whole system on and off. The puller has to turn it on before using the throttle to drive the motor. It was a mechanism to short two wires that go directly to the controller unit. Normally the wires are open switching ‘off’ the whole system. When it is keyed, the wires get shorted.

The Solar Panel

Fig: Solar Panel

The solar panel is placed at the top of the van which is made of iron frame. Four 100W, 12V panels are connected in series that provides 96V to the batteries through the charge controller.

The Charge Controller

Fig: Charge Controller

For efficient charging and supply power to the load, we need two charge controllers in our project. The charge controller checks the current battery status and according to it, it sends right amount of charge to the battery. There are 4 terminals in a charge controller ‘PV+’ , ‘PV-‘, ‘48V+’ and ’48V-‘.The ‘PV+’ and ‘PV-‘terminals were to be connected with the positive and negative terminals of the 400-Watts Panel. The ‘48V+’ and ’48V-‘were to be connected across the 48V battery terminals.

The Torque Sensor

Fig: The torque sensor after being implemented

The torque sensor is a device which is used to measure and record the torque of a rotating system. Biasing voltage of 5V is needed which is supplied from a DC source. As the torque increases output voltage increases. The speed of the motor is directly proportional to the output voltage. Torque sensor after being installed is shown in the figure.

The Brake System

Traditional hand clutch is used to stop the front wheels. Another hand-clutch is placed on the left hand-side shown in the figure along the traditional hand-clutch. This hand-clutch stops the motor at once. When the hand-clutch is released, it returns to its original position and allows the motor to start again when required. A rear wheel brake pedal shown in figure which is introduced in the system to stop the rear wheels. The rear wheel brake is a mechanical brake similar to cantilever brake that helps in stopping the moving central shaft or axle and thus stopping the rear wheels.

The Light System

The indicator lights are shown as in the figure below. Indicator lights are used while taking turns. There are six indicator lights in the van, two at the back, and two at the front.

Fig: Back indicator lights

Helical Spring

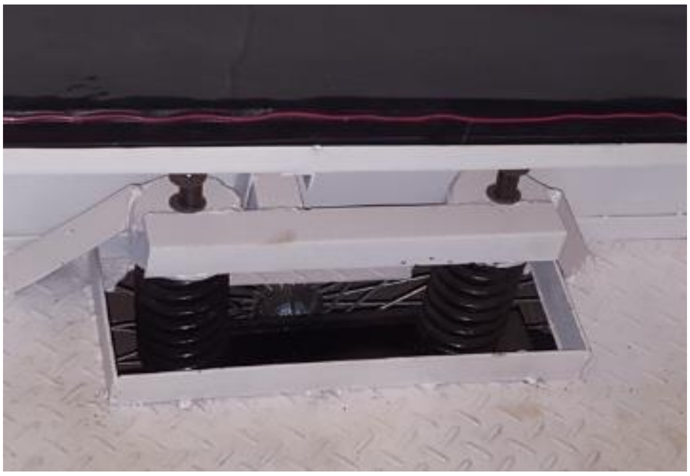
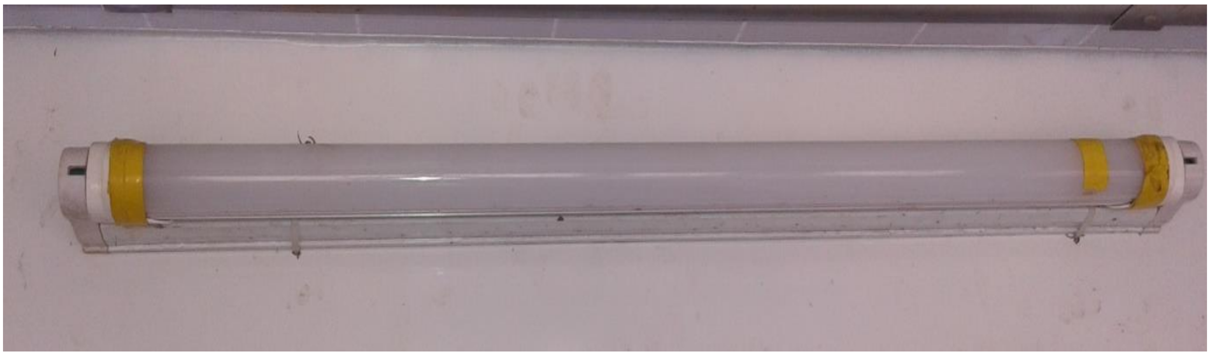


Fig: Helical Spring

The helical spring is installed in the vehicle as shown in the figure above. The helical spring is to control the spring and suspension movement. They reduce any jolts and make it more comfortable for the patient.

Accessories of the system



(a)

(b) **(c)**

(d) **(e)**

Fig: Tube Light (a), Head light (b), Fan (c), Warning Siren (d), First Aid Box(e)

A headlight is placed in front of the van which helps to see the obstacle at night while driving. Indicator lights are used while taking turns. There are 6 indicator lights in the van, two at the back, and two at the front. In side of the ambulance a LED strip light is also used which consume 31V and 9W. Siren is installed on top of the van. First aid box is placed inside the van as well. The accessories have been showed in the figure.

APPENDIX F

Table A: Test Data without any PV Array Assistance or Aid from Torque Sensor Pedal:

Battery set 1

Time (minutes)	Battery voltage (V)	Battery current (A)
0	50.9	1.1
2.5	50.9	30.1
5	50.8	3.4
7.5	50.7	6.2
10	50.6	4.2
12.5	50.5	9.1
15	50.4	15.5
17.5	50.4	1.8
20	50.3	15.2
22.5	50.2	2.1
25	50.1	8.6
27.5	49.9	2.9
30	49.8	8.3
32.5	49.7	4.5
35	49.6	4
37.5	49.4	3.9
40	49.3	29.4
42.5	49.2	3.5
45	49.1	2.9
47.5	49	1.3
50	48.9	12.3
52.5	48.7	25
55	48.5	5.3
57.5	48.4	4.13

Battery set 2

Time (minutes)	Battery voltage (V)	Battery current (A)
0	50.9	1.2
2.5	50.8	29.3
5	50.7	5.2
7.5	50.6	4.2
10	50.5	6.1
12.5	50.3	7.8
15	50.2	14.9
17.5	50.1	3.1
20	50	13.9
22.5	50	7.7
25	49.9	7.4
27.5	49.8	3.8
30	49.7	7.7
32.5	49.6	4.1
35	49.5	3.5
37.5	49.4	4.2
40	49.3	28.6
42.5	49.2	2.4
45	49.1	3.1
47.5	49.1	1.1
50	49	11.1
52.5	48.8	23.2
55	48.6	7.4
57.5	48.4	6.1