Dedicated Solar Powered Charging Kit –A system alternative to the Solar Charging Station for single user

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

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Spring 2016
BRAC University, Dhaka

DECLARATION

We hereby declare that our research titled “Dedicated Solar Powered Charging Kit-A system alternative to the Solar Charging Station for single user” is a thesis submitted to the department of Electrical and Electronic Engineering of BRAC University in partial fulfillment of the Bachelor of Science in Electrical and Electronic Engineering. This paper, neither in whole nor in part, has ever been submitted previously for any assessment, degree or publication elsewhere. The materials collected from other sources have been acknowledged here.

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ACKNOWLEDGEMENT

We are thankful to our thesis supervisor Dr. A.K.M. Abdul Malek Azad, Professor, Dept. of Electrical and Electronic Engineering (EEE), BRAC University, for his guidance for completion of the thesis. Regards to our Project Engineer, Sheri Jahan Chowdhury and Research Engineers Ataur Rahman and Jaber Al Rashid for their support throughout the whole thesis time span. We are thankful to EEE department, BRAC University for providing us the necessary equipment for the completion of this project. We are also grateful to Control and Application Research Centre (CARC) for funding of our thesis project.

ABSTRACT

One of the best innovations of this century in the vehicle industry is the addition of battery powered motor in vehicle making it an electric vehicle. The ban on charging of batteries of electric vehicles using national grid by the government has narrowed the opportunities of those vehicles to continue its journey on the roads of Bangladesh. Our efforts allow these vehicles to continue its journey without using the national grid. It’s an off-grid solution for charging batteries of particular electric vehicles. We look to provide a dedicated solar powered charging kit dedicated to one particular vehicle that charges the batteries of only that vehicle. Our kit consists of a charge controller, a set of solar panel, a battery charge indicator and a set of battery. While one set of battery is charging the other already charged battery is on use in the vehicle. When discharged, the batteries are then easily swapped with the charged one. As this kit doesn’t require electricity from national grid it saves both electricity and electric bills. Unlike solar charging station our system provides the opportunity to charge the batteries at home without the hassle of waiting in the queue or going to the solar charging station for charging the batteries. A dedicated micro solar charging kit is best suited for the idea of our thesis as the user mounts this kit on his own rooftop making his own home a solar charging home.

LIST OF ABBREVIATIONS

CARC- Control and Application Research Centre

DSPCK – Dedicated Solar Powered Charging Kit

PV- Photovoltaic

SOC- State of Charge

SBCS- Solar Battery Charging Station

RND – Research and Development

DESCO – Dhaka Electricity Supply Company

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Chapter 1

INTRODUCTION

1.1 Introduction

Bangladesh is witnessing an increase in solar electricity generation as part of an ambitious plan to boost the provision of power from renewable energy sources. Solar energy is being harnessed and converted to electrical energy via solar panels and then stored in batteries which can then be used to power households and agricultural activities. The introduction of a prototype design for a dedicated solar powered charging kit can aid the process of solar electrification in rural areas and take the load off the grid in urban regions. The batteries charged by these kits can also be used to power modified rickshaws that are torque sensor based and electrically assisted. These sensor based hybrid rickshaws or vans have a longer battery life that requires infrequent charging, are faster than conventional rickshaws and need less human effort to be plied on the streets.

1.2 Background and Motivation

Electrical vehicles are widely used all over the world. The use of motorized vehicles on the roads of Bangladesh is also quite noticeable. These vehicle batteries are charged with the electricity coming from national grid. Most of these vehicle owners and users use this electricity unethically without paying electricity bills. Being an overpopulated country, Bangladesh is affected by frequent power cuts and load shedding due to an extensive demand of electricity. Electricity consumption for charging electric vehicle batteries will put extra pressure on the grid. This will lead us into massive trouble. We cannot think of a day without electricity and if frequent power cuts or long term load shedding takes place, nothing will be more miserable than this. So, if at least in the electric vehicle field, we take out the pressure of usage of electricity, this would be a great help. Keeping this on mind we come up with the idea of "Dedicated solar powered charging kit". This system will charge vehicle batteries without electricity. Electric vehicles are ecofriendly so to make the environment friendly vehicles go on the roads rechargeable batteries are required. To charge these batteries we want this system to the most desirable solution.

1.3 Purpose of Our Thesis

Purpose is the main criteria for any project. We have been attracted to this solar based project so that we can contribute to the society. The solar sector in Bangladesh is growing profoundly. Many solar electric vehicle have been put into work as both proto type and pilot project work, moreover companies are also investing in solar project to become more eco-friendly. Solar vehicle required batteries which has solar energy stored in them. Solar energy powers up these solar electric vehicles. Henceforth we have come up to these purposes for our thesis:

- To make an electric vehicle user independent of national grid
- To make a hassle free solution for battery charging with the help of solar
- To charge batteries without going to a charging station
- Easy battery swapping
- To know the exact battery charge level

1.4 Renewable Energy- Solar Energy

1.4.1 Solar Energy

Renewable energy is generally defined as energy that is collected from resources which are naturally replenished on a human timescale, such as sunlight, wind, rain, tides, waves, and geothermal heat. Among all these solar energy is being utilized immensely. This the most common, popular and demanding renewable energy. Researches and innovations on solar is constantly taking place. Every other day, something new, attractive and surprising inventions are created using solar energy. Radiant light and heat from the sun has been harnessed by humans since ancient times using a range of ever-evolving technologies. Solar radiation, along with secondary solar-powered resources such as wind and wave power, hydroelectricity and biomass, account for most of the available renewable energy on earth. Only a minuscule fraction of the available solar energy is used.

Solar energy's uses are limited only by human ingenuity. A partial list of solar applications includes space heating and cooling through solar architecture, potable water via distillation and disinfection, day lighting, solar hot water, solar cooking, and high temperature process heat for industrial purposes. To harvest the solar energy, the most common way is to use solar panels **[1].**

1.4.2 Solar Cell, module, panel and array

Solar (PV) Cell Module

The basic element of a PV System is the photovoltaic (PV) cell, also called a Solar Cell. An example of a PV / Solar Cell made of Mono-crystalline Silicon is shown in Fig below. This single PV / Solar Cell is like a square but with its four corners missing (it is made this way!).

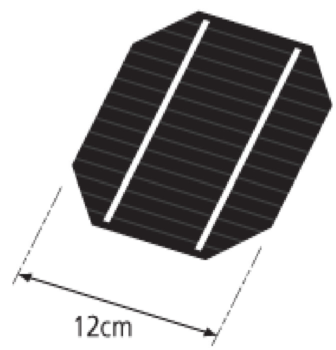


Figure 1.4.1: PV / Solar Cell

A PV / Solar Cell is a semiconductor device that can convert solar energy into DC electricity through the Photovoltaic Effect. When light shines on a PV / Solar Cell, it may be reflected, absorbed, or passes right through. But only the absorbed light generates electricity **[2]**

PV Module/ Panel and PV Array

To increase their utility, a number of individual PV cells are interconnected together in a sealed, weatherproof package called a Panel (Module).

To achieve the desired voltage and current, Modules are wired in series and parallel into what is called a PV Array. The flexibility of the modular PV system allows designers to create solar power systems that can meet a wide variety of electrical needs. Fig shows PV cell, Panel (Module) and Array.

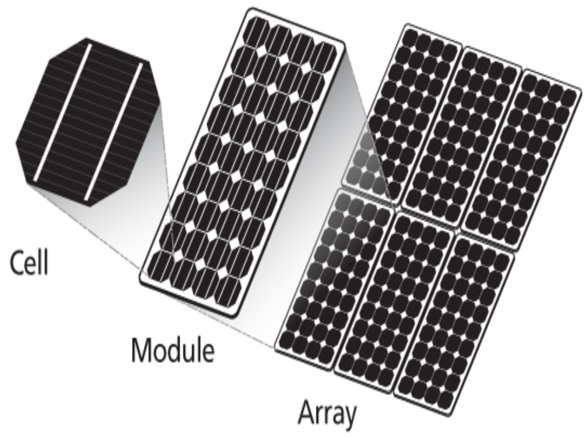


Figure 1.4.2: PV cell, Module and Array

The cells are very thin and fragile so they are sandwiched between a transparent front sheet, usually glass, and a backing sheet, usually glass or a type of tough plastic. This protects them from breakage and from the weather. An aluminum frame is fitted around the module to enable easy fixing to a support structure. The picture in Fig. 6 below shows a small part of a Module with cells in it. It has a glass front, a backing plate and a frame around it.

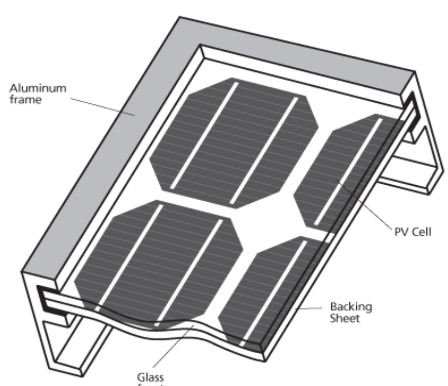


Figure 1.4.3: Construction of a typical Mono-crystalline PV / Solar Panel

1.4.3 PV System

A photovoltaic (PV), or solar electric system, is made up of several photovoltaic solar cells. An individual PV cell is usually small, typically producing about 1 or 2 watts of power. To boost the power output of PV cells, they are connected together to form larger units called modules. Modules, in turn, can be connected to form even larger units called arrays, which can be interconnected to produce more power, and so on. In this way, PV systems can be built to meet almost any electric power need, small or large.

By themselves, modules or arrays do not represent an entire PV system. Systems also include structures that point them toward the sun and components that take the direct-current electricity produced by modules and "condition" that electricity, usually by converting it to alternate-current electricity **[3].**

1.5 Overview of the contents

The following chapters portray the work that has been accomplished, the drawbacks and suggested future plans. The second chapter gives an overview of the whole system with components and attributes. The third chapter describes the solar battery charging station and the distinction between the existing charging station and ours dedicated charging kit. The fourth chapter is all about the electric vehicles we have used to accomplish our research works. The fifth chapter is about the battery voltage indicator, one of the attributes of our project work. The sixth chapter demonstrates the irradiance measurements we took and the motive of taking the measurements. The seventh chapter talks about the payback period calculation. The eighth one is the most important chapter as the field tests and analysis parts have been covered there. The ninth chapter is about the pitfalls, scope of improvements and future plans. The last one is the conclusion.

Chapter 2

Overview of the Thesis

2.1 Overall concept of our thesis

Our thesis illustrates the idea of implementing a dedicated solar powered charging kit, a system that is compiled with a monocrystalline series connected solar panel, a solar charge controller, four batteries connected in series making it a one unit battery and a battery voltage indicator. This system is solely made for charging up vehicle batteries staying at home with the help of solar energy instead of depending on the national grid. It's a complete off-grid solution which not only saves electricity coming from national grid but also reduces the hassle of charging batteries on a charging station. This kit is easy to use and requires not much skill to use it. Thus it suits best for the people of rural and developing areas.

Our thesis comprises only of hardware segment. Assembling all the hardware components with proper sequencing we get the dedicated solar powered charging kit.

2.2 Introduction to hardware Components

The whole project consists of hardware components only a tiny part is covered with the help of Arduino software (IDE). Undoubtedly solar panel is the main component as this is a solar based project but the regulatory component here is the charge controller and plays an important role in the overall set up. The components are as follows-

- Solar panel
- Charge controller
- Lead acid battery
- Arduino Uno
- 16x2 LCD Display
- Registers
- Meggar PVM210 Irradiance meter
- Stand
- Connectors
- Clamp on meter
- Multimeter

2.2.1 Solar photovoltaic panels

The most important component of our thesis is the PV panel. Photovoltaic cell or solar cell converts sunlight energy into DC current. The quality of the panel plays a very significant role. Cheap, Lower quality or duplicate panels come with very low efficiency. For this reason the overall efficiency of any system drops down. We are using four 100 watt 12 volt monocrystalline solar panels connected in series and framed as fig. The features of the panel is discussed below.

Figure 2.2.1: Monocrystalline Solar Panel

2.2.2 Features

GTS SOLAR

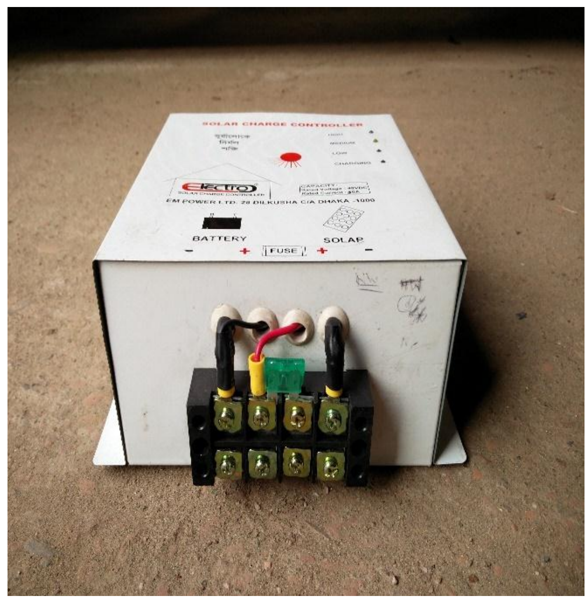
Peak power (pm)		100W	
Open circuit voltage (Voc)		22.35V	
Short circuit current (Isc)		5.72A	
Maximum Power Voltage (Vmp)		18.80V	
Maximum Power Current (Imp)		5.34A	
Power Output Tolerance		±3%	
Series Fuse Rating		10A	
Weight		7.5kg	
Module Size		1195*541*35	
Operating Temperature		-40°Cto+85°C	

Table 2.2.2: Specifications of a 100 W panel

2.2.3 The Charge Controller

The charge controller in Fig is used to ensure efficient charging of system battery and also supplying power to the load. While charging the battery the charge controller constantly check the current battery state and self-adjust accordingly to send only the right amount of charge to the battery. There are 4 terminals in the 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.

Top View



Side View

Figure 2.2.3: Solar Charge Controller

2.2.4 Features

1. Nominal output voltage is 48 volt

2. Solar charging current is 0 ~ 30 amps

3. Overvoltage and under voltage protection

4. LED indicates connected or disconnect and low, high and medium

2.2.5 Batteries

Four Batteries each of 12V are being charged by the solar charging kit. The batteries connected in series gives a total voltage of 48V. A total of three types of batteries were used in the DSPCK. The rating of the batteries is 25Ah, 35Ah and 50Ah. The 25Ah batteries are used to drive the Human Hauler and the Ambulance. The 35Ah is used in the Cargo hauler (C1 to C4). The 50 Ah is used in the Cargo Hauler C5.

12V 25Ah batteries connected in series

12V 50 Ah battery

Figure 2.3.5: The Batteries

2.2.6 Reasons to Use Lead Acid Battery

Lead Acid battery is the common solution for commercial application. Though it has some limitation like low energy density and unable to store at discharge condition sealed lead acid battery has some tremendous advantages that helps to what we have required for our work. We have worked with 12 V 20Ah batteries and for our requirements we have connected them in series to make it a set of 40V 20Ah. There are many types of batteries available in the market such as sealed lead acid, unsealed lead acid, deep cycle etc. However for our thesis we had to be very careful in case of choosing batteries. We are dealing with voltage of the batteries and providing methods of measuring them in real time in that case we chose sealed lead acid (SLA) batteries, hence as the voltage changes in real time from either charging or discharging our software will show that changes in real time accordingly. Here are the reasons for choosing our battery:

- Among all type of batteries, lead acid batteries have lowest self-discharge rate.
- Very less maintenance is required for this battery.
- Its capacity range is 0.2Ah to 30 Ah
- Inexpensive
- Mature technology
- Low cost
- Reliable
- Robust
- Tolerant to overcharging
- Can deliver very currents
- Many suppliers worldwide **[5]**

2.2.7 SOC (State Of Charge)

For charging a battery, we need to know the SOC of a battery. An SOC is the state of charge means that maximum charge a battery can contain within itself. It is measured in percentage (%) and plays an important part in case of charging batteries because we cannot exceed the maximum or the minimum SOC for a certain battery. There are two types of batteries; one is deep cycle and another one is lead acid battery. For a deep cycle battery SOC 20% is the lowest that means practically we can use the battery up to where its SOC is 20%; however for a lead acid battery that is up to 50%, which means we can discharge up to 50% SOC. Theoretically, 0% = empty/damaged battery and 100% = Fully charged.

Charge (SOC)	12V Battery	48V Battery
100%	12.73	50.92
90%	12.62	50.48
80%	12.50	50.00
70%	12.37	49.48
60%	12.24	48.96
50%	12.10	48.40
40%	11.96	47.84
30%	11.81	47.24
20%	11.66	46.64
10%	11.50	46.04

Table 2.2.7: SOC chart of lead acid battery **[6]**

2.2.8 Methods of Measuring SOC

The two most common methods of measuring SOC:

1) Chemical method

2) Voltage method

The voltage method deals with voltage of the batteries, it converts the voltage of the battery to SOC percentage. According to this method the possible charge of the batter can be determined by only observing the battery voltage as in how long it takes to completely discharge from a successfully charged battery. We have used the voltage method to measure SOC because we are dealing with voltage and we need to measure battery voltage so that we can display them in our software. Another reason for using voltage method is our battery is sealed lead acid; therefore we cannot use the chemical method since that includes measuring pH or specific gravity of batteries' electrolyte. To get these SOC percentages we have charged these batteries for several days and took voltage readings and according to that made our SOC chart **[4].**

2.2.9 Efficiency of solar panel

Efficiency is the process of evaluating whether we get or desired output. It gives the comparison of how the output behaves compared to the input. The more the efficiency the better the result is. Efficiency is measured by dividing the output by the input. The results demonstrate how effectively the system is working and how much we can make out of the system in a given input. The efficiency of the solar panel is being measured by using the formula-

$$\eta = \frac{Po}{Pin} \times 100\ \%$$

To calculate the efficiency of the panels we needed to take the input of the panel and the output of the panel. The panels take input from the sun irradiance. The formula for measuring the input of the panel is –

Area of the panel (m^2) * Irradiance (W/m^2)

The irradiance is measured using irradiance meter. The irradiance measured at 12:00 pm on a sunny day was **998W/m^2**. The area of the panels is the product of the length and breadth of the panels. Each panel that we used had a length of 1195 mm that is 1.195m. The breadth of the panel was 541mm that is 0.541m. Therefore the area of one panel is 1.195m * 0.541m = 0.646 m^2. So the four panels together give us an area of **0.646×4 = 2.6 m^2**. Therefore the **input** that we get in the panel is

$$\mathbf{998W/m^2 \times 2.58m^2 = 2574.8\ W}$$

The output that we get from the panel is calculated using the formula

Solar output = V × I

At the time when the irradiance was 998W/m^2 the solar voltage was measured to be 58.5V and the solar current was measured at 4.4A. So the product of the solar voltage and solar current

$$\mathbf{58.5V \times 4.4A = 257.4W}$$

So the total efficiency of the panel is

$$\textbf{Efficiency} = \frac{\mathbf{257.4}}{\mathbf{2574.8}} \times \mathbf{100\% = 10\%}$$

The efficiency of the panel is calculated to be 10%.

2.2.10 Arduino

An Arduino board is used to read the battery voltage and show the corresponding percentage charge on a LCD display. The model used for the purpose is Arduino UNO R8. It has 12 Digital pins and 6 Analogue pins. The LCD display is connected to the digital pins and the voltage is read in the analogue pin. The code is loaded in the ATMEGA microcontroller loaded on the board. The code written in ARDUINO IDE language processes the input data and gives an output display data.

2.2.11 LCD Display 16x2

A 16x2 display is used to see the percentage of the battery charge. The output from the Arduino is shown in the display as percentage charge. The display has 16 pins of which 8 are data pins. Among the 8 data pins 4 data pins are interfaced with the Arduino. A 10K potentiometer is connected to the display to change the brightness level. The other pins are connected to VCC and ground.

2.3 Steps of our project

- Four 100 watt 12 volts monocrystalline solar panels are connected in series which makes it a 400 watt-power array providing a nominal 48 volts DC voltage.
- This 400 watt panels are connected to a solar charge controller that is capable of charging 48V batteries of rating 25Ah, 35Ah and 50Ah in one day.
- With constant supervision current coming from the panel and solar voltage is measured.
- The whole system consists of two sets of batteries. While one set of batteries are being used in the vehicle the other set is being charged in the solar charging garage.
- Battery swapping - one of the most important part of our thesis. Among the two sets of battery, one charged set is fitted in the vehicle to run on the roads. When this set is discharged to 50%, it is taken out from the vehicle and left for charging via the system. The other charged one is then used in place of the former one. This is battery swapping. A discharged set of batteries is being swapped with a fully charged one.
- This whole arrangement is done in a solar charging garage where the electric vehicle is to be parked. The panels are fitted on the roof of the garage and the solar charge controller is set inside the garage where the batteries are charged.
- The battery voltage indicator connected to the battery indicates the state of battery. At every different time it shows and informs us about the battery charge level.

2.5 Introduction to the proposed car port with the whole system

For establishing our idea of the charging kit to a slightly modified way we have introduced the solar car port. This is a concise version of a garage with the attributes of a solar charging station. This is more like a chamber which can accommodate only one vehicle. All the necessary setups are done there. On the rooftop of this car port solar panel is installed and inside the port the batteries, charge controller and battery voltage indicator are kept and connected. As we provide two sets of batteries in our system, the concept is that an electric vehicle will enter into the car port after the consumption of charge of the batteries and then swap with the other charged one and leave. The discharged set of batteries will then be kept for charging. The next day this one will be ready to use again. The vehicle can be kept here and the same time batteries can be charged. As the solar charging kit supports charging of batteries of one vehicle at one time on a single car port hence it’s named after “dedicated solar powered charging kit”.

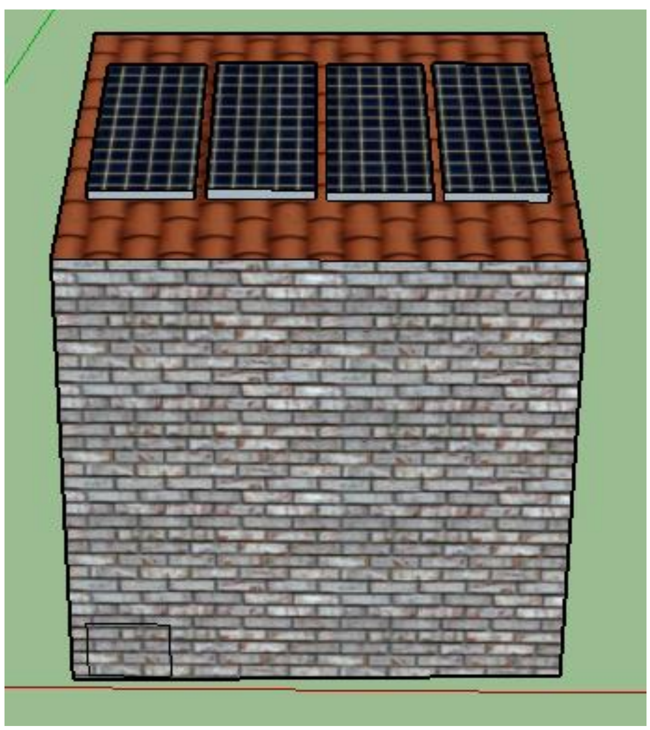


Figure 2.5.1: The solar car port

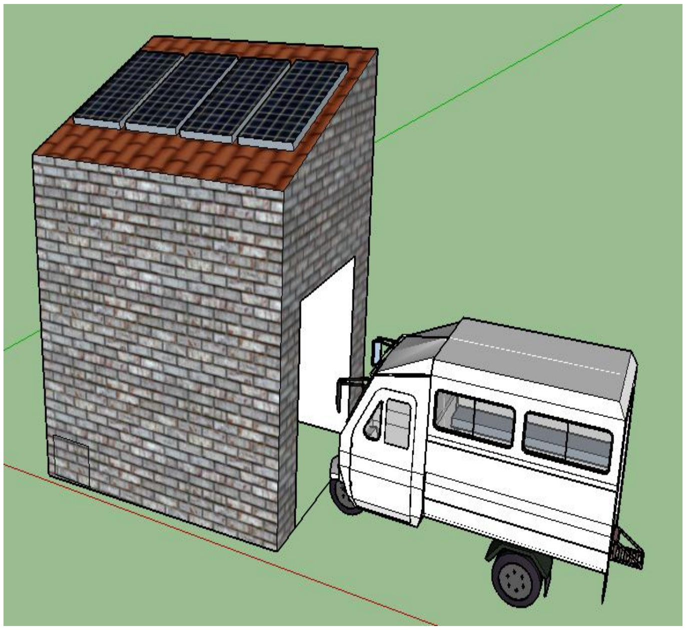


Figure 2.5.2: A vehicle entering into the solar car port

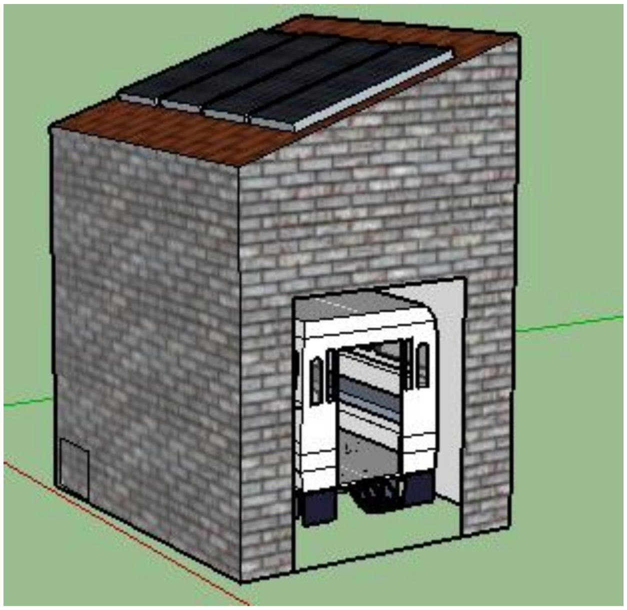


Figure 2.5.3: Side view of the solar car port accommodating only one vehicle

Chapter 3

Overview of Solar Battery Charging Station (SBCS)

3.1 Introduction to the Solar Battery Charging Station

A solar battery charging station is designed so that batteries can be charged in an environmentally friendly way. This system converts solar energy to electricity and stores it in a battery bank. Several batteries can be charged at a time in the battery charging station. A microcontroller based Data Acquisition Card provides a real time monitoring system that shows the current condition of the batteries and tells if there is any problem in any of the unit. It prevents the batteries from being overcharged and prevents the system from being used when the batteries need charging. When a unit is fully charged the user is being notified about the unit.

The components used in the SBCS project done in BRAC University are

- 760 Watt solar panels
- 2 sets of charge controller
- 2 sets of batteries, each 48V 20Ah
- DAQ card

3.2 Features of Solar Battery Charging Station

- All status & measuring can be monitored in real time.
- Any problem can be detected quickly without any difficulties.
- Can easily determine when manual backup is needed.
- Status of multiple battery sets can be shown through one channel at a time.
- Along with the battery, solar status can be acknowledged.
- Helpful for off grid areas.

Chapter 4

Introduction to the Motorized Electric Vehicles

4.1 Introduction

Beevatech Limited is the first electric auto rickshaw manufacturer in Bangladesh, established in 2001 as a group of company of Prime Logistics Limited **[7].** The full throttle controlled motorized rickshaw vans are manufactured by Beevatech. The motorized van is made with light weighed steel body and a different architecture from the rickshaws or vans. A massive modernization of such electric tri-wheeler will improve the lifestyle of a huge number of people including rickshaw pulling profession. As government has disapproved commercialization of such motorized vehicles due to consumption of already overloaded grid, CARC, BRAC University conducted a research on torque sensor paddle used usually in some bicycles. Encouraged by the results obtained from the research with torque sensor paddle along with the PV array support, CARC has developed three battery operated rickshaw vans with PV support and torque sensor paddle. Solar battery charging station was implemented to charge the batteries to make the whole system independent of national grid. These three vehicles are-

- Human Hauler
- Cargo Hauler &
- Ambulance

Figure 4.1.1: The three vehicles

4.2 The Human Hauler

This is the first electric rickshaw-van invented by a group of students which was a resultant of a research conducted by CARC, BRAC University in 2015. Two main attributes make it one exceptional vehicle, a unique vehicle which is a combination of rickshaw and van and those are – torque sensor paddle and PV support. Usually traditional rickshaw is capable of carrying 2 or 3 passengers and rickshaw-van is capable of carrying 4 or 5 passengers, whereas the motorized rickshaw-van is capable of carrying 6 to 8 passengers. The distance travelled by the vehicle with both PV support and torque sensor is 2.8 times greater than normal battery operated rickshaw-van and thus this system lengthens the battery lifetime. This vehicle is driven by 48V (four 12V batteries connected in series) 25Ah lead acid batteries.

Front View Side View Rear View

Figure 4.2.1: Human Hauler

4.3 The Cargo Hauler

The human hauler is followed by a slightly modified vehicle with almost the same features and functionality which is actually cargo and so name after cargo hauler. This electric vehicle has three hub motors fitted in three wheels. Each hub motor has a rating of 48V 500W. Four 12V, 35Ah lead acid batteries connected in series which gives a total output of 48V is used to power the three 500W motors. A torque sensor circuit fitted with the vehicle ensures optimum energy consumption saving around 40% of energy increasing the battery life. This vehicle is also fitted with four 100W 12V solar panels on the rooftop. This four panels connected in series gives an output of 48V and 400W. This panel slows the discharge of the batteries as it keeps on charging the battery while the vehicle is driven. It saves around 20% of the battery charge while driving.

The cargo hauler has a compartment and a trailer to load goods to be carried from one place to another

Rear View Side View Front View

Figure 4.3.1: Cargo Hauler

4.4 The Ambulance

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. CARC came up with the human hauler which was modified to solar electric ambulance van. 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 6 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 **[10]**. The solar powered ambulance can 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.

Front view of ambulance Side View of Ambulance Inside view of Ambulance

Figure 4.4.1: Ambulance

4.5 Reasons behind using these vehicles

The design of the DSPCK was done keeping the three vehicles in mind. The three electric vehicles built by the students of BRAC University needed a charging solution apart from the national grid. It is where part of idea came from. Like most of the electric vehicles all three of this vehicles use 48V batteries to power their motor. This vehicles are fitted with four 12V batteries that can be easily unloaded to load a new set of batteries. So this vehicles were ideal to be used for our DSPCK. These vehicles are in use in CARC, Savar under a project of IDCOL. All the tests were undertaken in Savar using this three vehicles. Though primarily the DSPCK was designed with the concept of the three vehicles and all the tests were also done using the three vehicles the use of this is not limited only to these vehicles. The DSPCK is universal for all electric vehicles using 48V batteries. Any electric vehicle using 48V batteries can be taken in the solar charging port where the batteries can be easily swapped.

Chapter 5

Battery Voltage indicator

5.1 Introduction

The battery voltage indicator is a meter that shows the current state of charge of a set of batteries. When connected to a battery set, the indicator shows the percentage of the exact state of charge of the battery set. It shows the percentage range of charge of 10%-100%. Whenever we need to measure the voltage we just need to connect it with the battery and it shows the percentage.

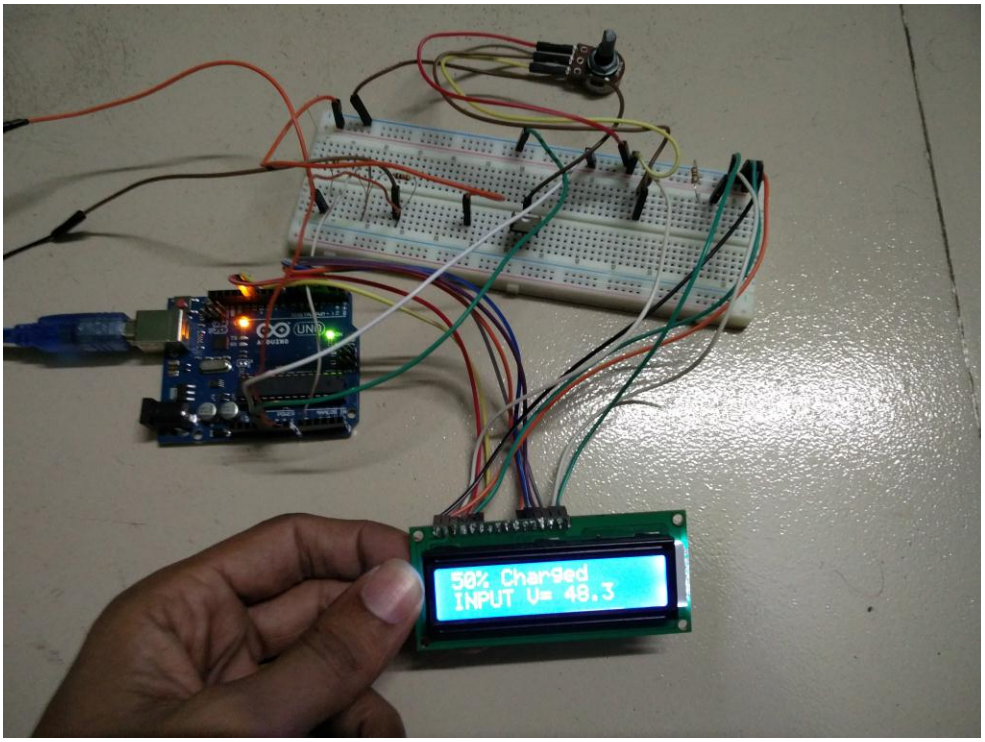


Fig 5.1.1: The Battery Voltage Indicator

5.2 Components

The heart of the voltage indicator circuit is Arduino. A voltage divider circuit is constructed to send a voltage in range of 5V to the Arduino to avoid it from burning.

- Arduino
- 16*2 LCD display
- Resistors: 100K
  10K

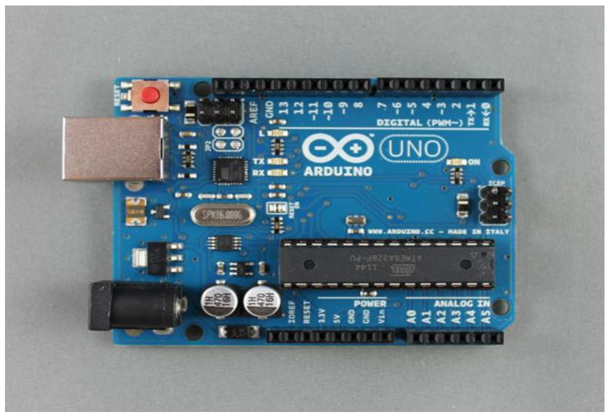


Fig 5.2.1 Arduino UNO

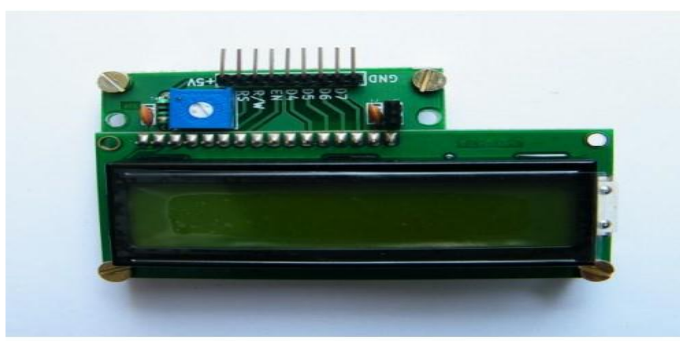


Fig 5.2.2: 16x2 LCD display

5.3 Work procedure

The Arduino board can receive a maximum voltage of 5V. Any voltage higher than that will burn the Arduino. A voltage divider circuit is constructed using 10K and 100K resistor. Any voltage below 55V gives a voltage drop below 5V in the 10K resistor. The input in the Arduino is taken across the 10K resistor. This voltage across the 10K resistor is feed to an analogue pin of the Arduino. The analogue voltage is then converted to digital voltage. This voltage is then converted to the original input voltage taken from the battery. The SOC values are uploaded to the Arduino. The corresponding SOC percentage for the voltage is then shown in the 16*2 LCD display connected to the Arduino.

This voltage indicator can very easily be connected to the battery set to get the exact percentage according to the SOC of the battery. This helps the driver to know the percentage of battery charge and keeping it from getting over discharged. Same way it tells if the battery gets fully charged and the battery can be removed from charge to connect another set of battery to be charged.

Chapter 6

Irradiance Measurements

6.1 Introduction to solar irradiance

Solar irradiance is the measure of how much power we are getting at our location. It varies throughout the day, depending on the position of the sun in the sky, the weather and also throughout the year depending on the season **[8].** It differs with time as well. It is intense when sun is directly facing to the point or area where we are measuring irradiance from. The standard solar panels has input rate 1000 W/m2. Our ones have the same input rate.

6.2 Megger PVM210 Irradiance meter

Irradiance of sun on a particular point of earth is measured using irradiance meter. Irradiance meter is placed perpendicular with the panel on its edge facing in the same direction as the panel so that same amount of light is incident on both panel and the meter. This gives the exact reading of light incident on both the panel and the meter.

The meter that we use for our measurement is MEGGER PVM210 irradiance meter. This small handheld meter has a range from 0 to 1999 W/m^2 for measuring irradiance. It has an accuracy rate of 15%. The sampling time for the meter is 0.25 sec which gives quite accurate reading for every second.

Figure 6.2.1: Megger PVM210 Irradiance meter

6.3 Features of Megger PVM210 Irradiance meter

- Optimal incident angle and positioning of solar panels
- Measurement of solar power for panel short circuit calculation
- 3¾ digit LCD display with 1999 W/m² range
- Single handed use
- Mini pocket size
- Standard camera mount fixing for accurate placement

6.4 Why we used irradiance meter

Irradiance meter is used to measure the input in the solar panel. Using the measurements we can find out the efficiency of the panels. Irradiance is the power of sun in W/m^2. When this is multiplied by the area of the panel, we get the total wattage in that area. The resultant one is the input in watt on the panel. The output on it is then measured.

$$\textbf{Efficiency} = \frac{\textit{Solar Output}}{\textbf{Solar Input}} * 100\%$$

Using irradiance we can also find out the difference between the rated and calculated current. Calculated current is the current that is supplied on a particular irradiance in a time of a day. The formula of the calculated current is –

$$I_{sc\ calc} = \frac{1000}{Irradiance\ (g)} * I_{sc}\ \textbf{measured}$$

6.5 Measured irradiance values

One a sunny day we did the measurements with the help of Meggar PVM 210 and got some values. All the measured and calculated values are given in the following table

Measured Irradiance W/m^2	Measured I_{sc} A	Calculated I_{sc} A	Rated I_{sc} A	Difference with rated I_{sc} A	Average difference	% difference	Average %
998	4.8	4.81	5.72	0.91	1.168	16%	20.2%
984	4.6	4.67	5.72	1.05		18%	
976	4.5	4.61	5.72	1.11		19%	
970	4.5	4.63	5.72	1.09		19%	
966	4.4	4.56	5.72	1.16		20%	
958	4.3	4.5	5.72	1.22		21%	
946	4.2	4.44	5.72	1.28		22%	
935	4.2	4.49	5.72	1.23		21%	
926	4.1	4.42	5.72	1.30		23%	
911	4.0	4.39	5.72	1.33		23%	

Table 6.5.1: Verification of the rated short circuit current specification of the 400W PV array using the PVM 210 and error calculation

Chapter 7

Payback Period Calculation

7.1 Introduction

Our dedicated solar powered charging kit offers battery charging completely free of cost. As mentioned earlier, it has no affiliation with the national grid, this system doesn't consume power from the grid to charge the batteries. This means the system charges up the batteries absolutely free of cost using solar energy. This statement is indeed true but to make the whole system, initially we had to pay an amount. In this chapter we are going to discuss about the payback period calculation. Payback period is the time in which the initial cash outflow of an investment is expected to be recovered from the cash saved due to the investment. It is one of the simplest investment appraisal techniques **[9].**

The formula is -

Payback Period =Initial Investment/Cash saved per Period

Through this calculation we are able to know how much money it costs us initially to make the dedicated solar powered charging kit, how much money is saved as part of electricity bills and after what period our expenses will be totally utilized and the charging will be full free after installation.

7.2 Price of components

Price of panels used- 55 taka per watt

Each 100 W panel costs 5,500 taka

4 panels cost = 5500*4 = 22,000 taka

Price of battery-

25Ah battery- 3,500 taka each

Price of 2 sets of batteries = 3500*8 = 28,000 taka

Price of solar charge controller - 4000 taka

Total cost of the full set is – 22,000 + 28,000 + 4,000 = 54,000 taka

7.3 Total electricity expense for charging the batteries

Each 25Ah battery is of 12V

The total set is of 48V, 25Ah

The watt consumption of the battery set is – 48*25 = 1,200Wh

With 5A current supplied to the battery it takes 5 hours to charge 25Ah battery. It can be charged a total of 3 times to drive the vehicles ceaselessly for 1 full day. Therefore the power consumption by the battery set for 1 day is – 1200*3 = 3,600Wh.

3600Wh in KWh = 3600/1000 = 3.6KWh

The standard average rate for 1 KWh electric consumption as per the DESCO rate charts around 6.5 taka

So, for one day the cost is - 3.16*6.5 = 20.54 taka

The total cost of the solar charging kit is = 54,000 taka

With 20.54 taka per day it takes- 54,000/20.54 = 2629 days = 7.3 years = 7 years 4 months

To conclude, it takes 7 years 4 months after which every charge is totally free.

Chapter 8

Field Tests and Analysis

8.1 Introduction

Several tests were done with the system to find the outputs to analyze the results. All the tests to analyze the behavior of the system were done in CARC, Savar. The tests included

- Finding the charging data of the 25Ah, 35Ah and 50Ah batteries.
- Finding the discharging data of the 25Ah, 35Ah and 50Ah batteries.
- Calculating the efficiency of the panels using Megger Irradiance meter.
- Calculating the short circuit current output with the measurements taken from the Megger irradiance meter.
- Analyze the data measured using the irradiance meter.

8.2 Equipment used for the field test

A set of equipment were needed to do the field test in CARC, Savar. The equipment used to do the field tests are

- **Multimeter** used as Voltmeter. Different voltages were taken to analyze the output of the whole system. The voltages were measured using the multimeter. Open circuit voltage was measured across the output of the solar panels. Solar voltage during charging was measured across the solar charge controller input. Battery voltage was measured to check the state of charge of the batteries across the battery terminals.

- **Ammeter** and **clamp on meter** was used to measure the current flow. Solar current was measured in the input of the charge controller. Short circuit current was measured in the output of the solar panels with no load connected.
- **Megger Irradiance meter** was used to measure the irradiance of the sun on a particular time. The instrument was aligned with the solar panel at the same angle to get the perfect reading the solar irradiance in unit of W/m^2.
- **Speedometer**, an android application that measures the distance travelled using GPS. This was used to measure the distance travelled by vehicles till the battery reached to 50% charge.

8.3 The Field test results

- **25 Ah Charging and Discharging curve**

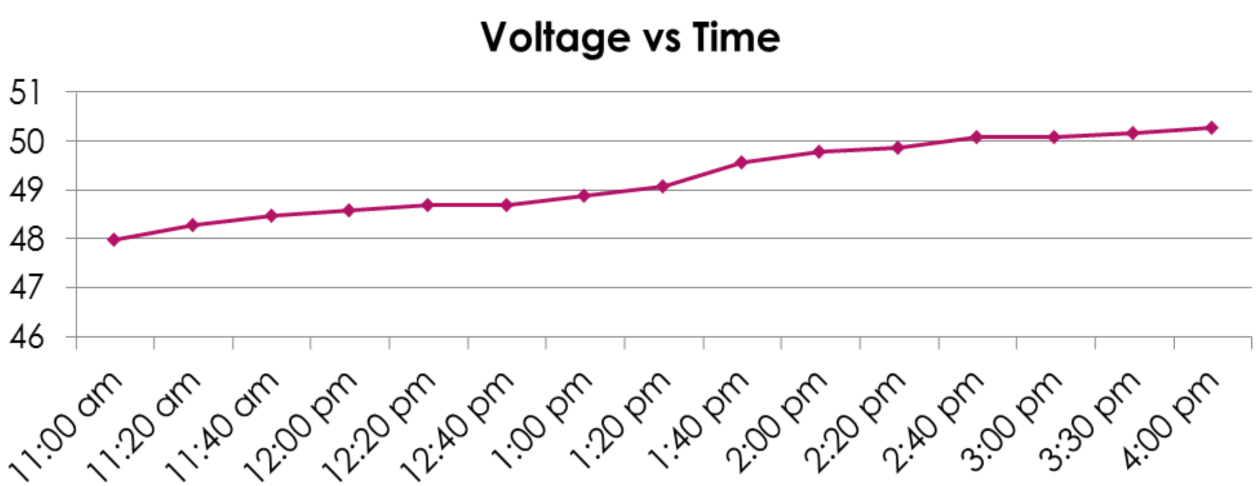


Figure 8.3.1: 25Ah Charging curve

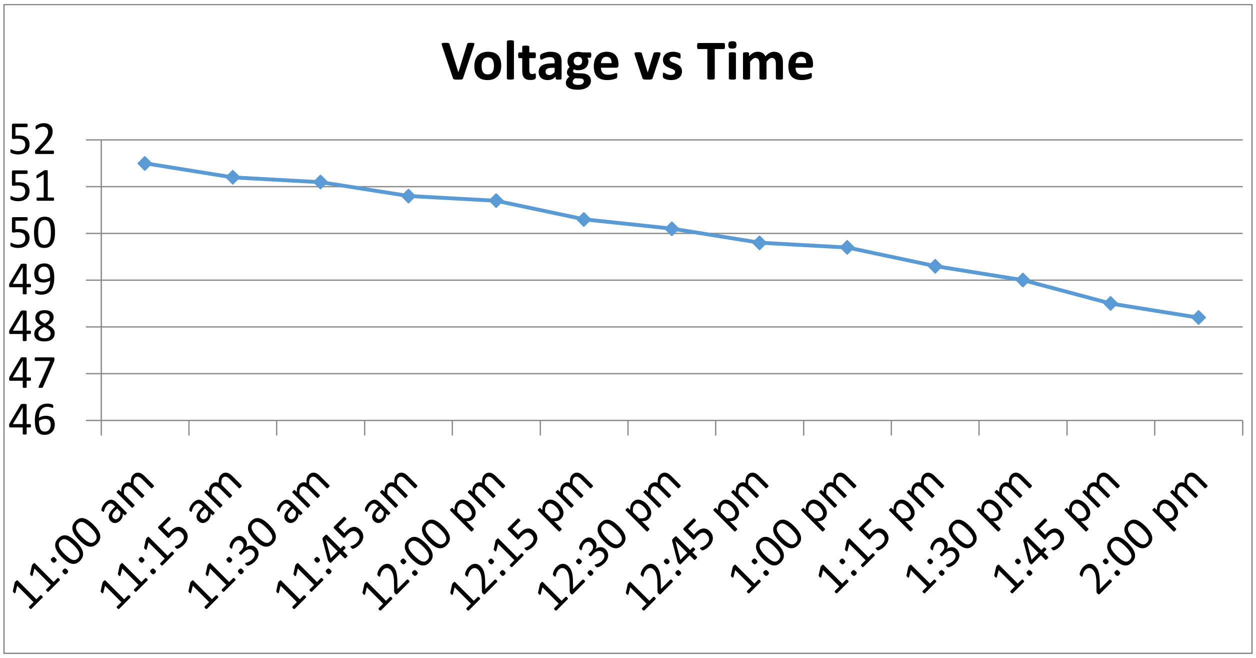


Figure 8.3.2: 25Ah Discharging curve

- **35Ah Charging and Discharging Curve**

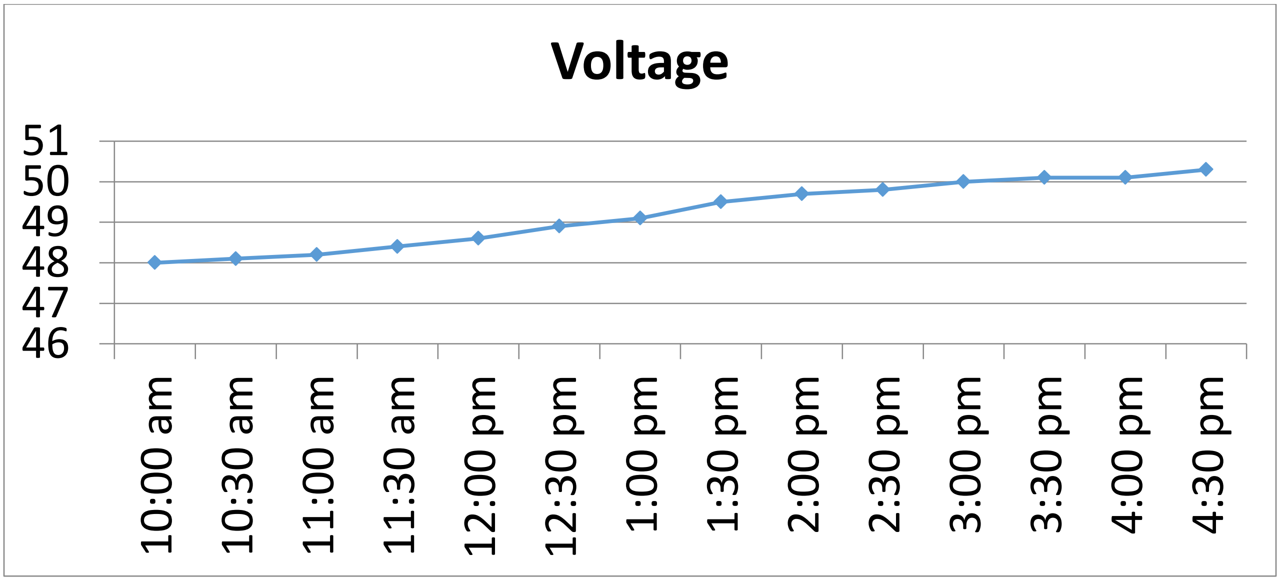


Figure 8.3.3: 35Ah Charging curve

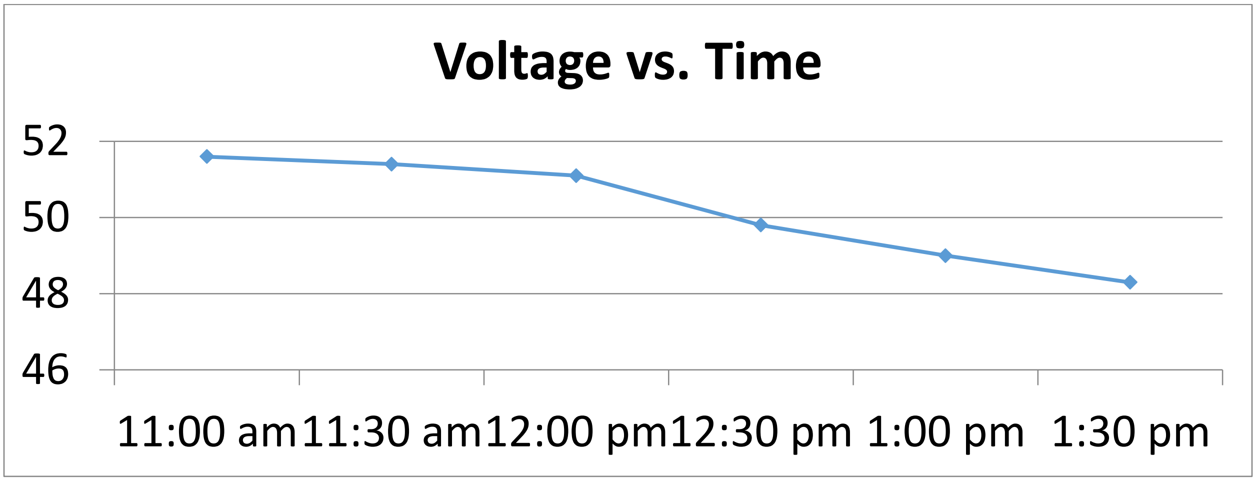


Fig 8.3.4: 35Ah Discharging curve

- **50Ah Charging and Discharging curve**

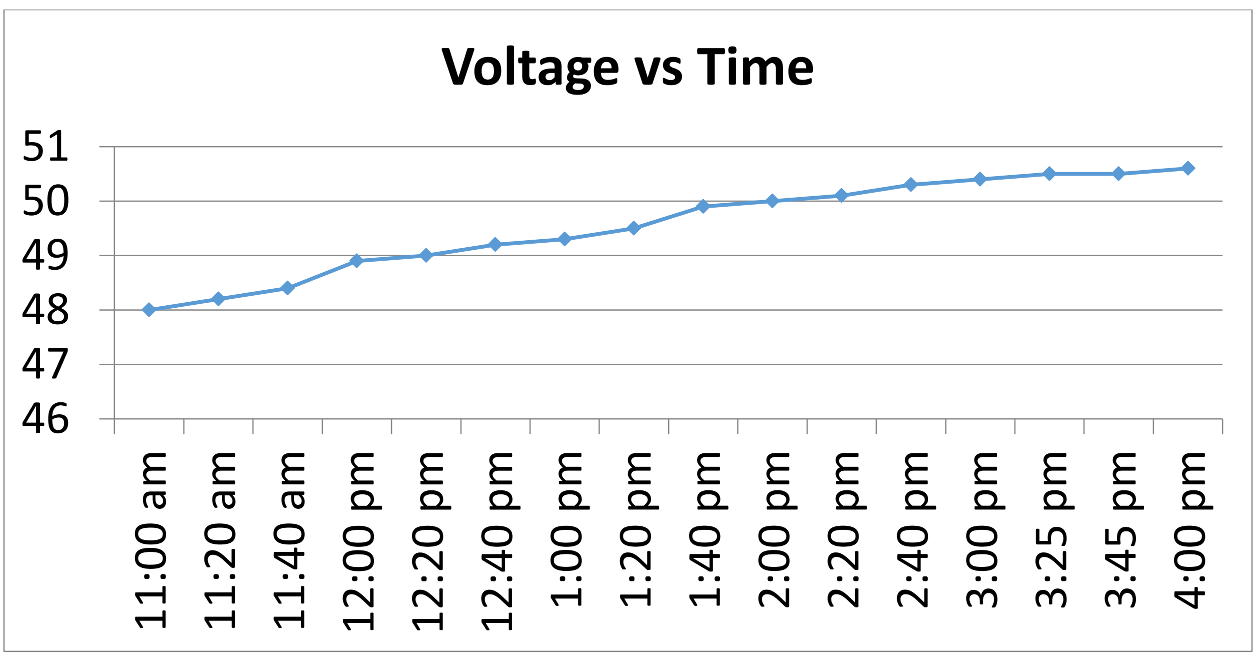


Fig 8.3.5: 50Ah Charging Curve

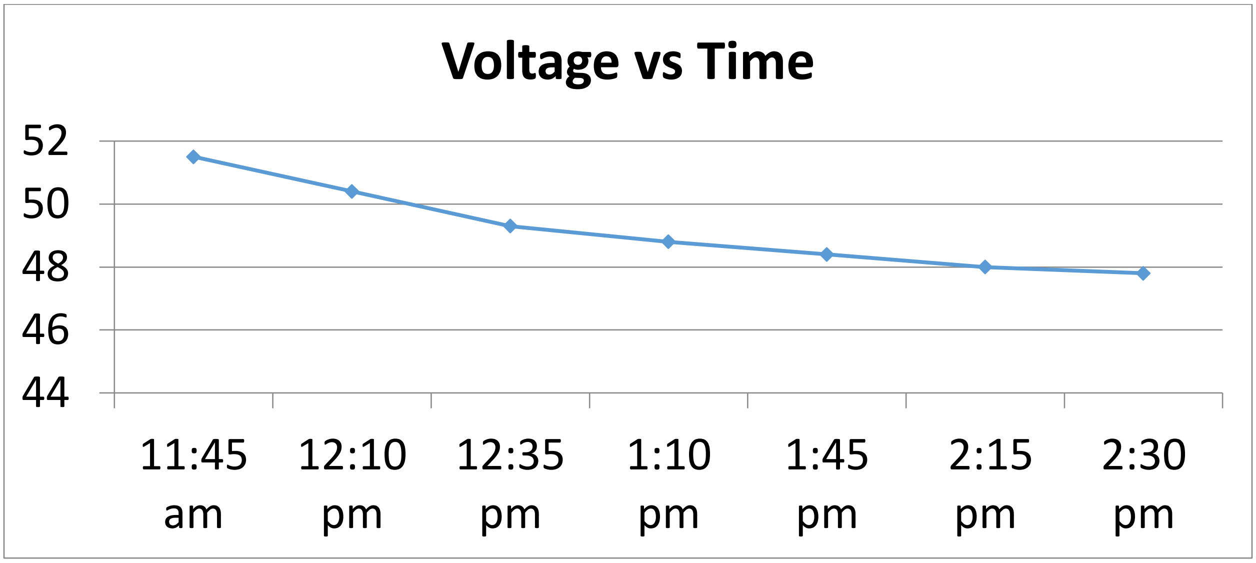


Fig 8.3.6: 50Ah Discharging Curve

The data measured from the field test are given above in graphical model. The tests were done on three types of batteries 25Ah, 35Ah and 50 Ah. This batteries were charged using our solar charging kit and then discharged in electric vehicles. All the measurements were recorded. The electric vehicles used for this purpose are Human Hauler and Cargo hauler. The 25Ah batteries were discharged using the Human hauler vehicle (H4). The 35 Ah batteries were discharged using the Cargo hauler vehicle (C4). The 50 Ah batteries were discharged using the cargo hauler vehicle (C5). All the discharge data were recorded. The charging and discharging curve were plotted using those data.

8.4 Graphical analysis of charging and discharging data

From the charging data of the field test we found out it took 4 hours and 30 minutes to fully charge a 25Ah battery starting from 50% SOC. The 35Ah batteries took around 6 hours to get fully charged. And on a bright sunny day it took only 5 hours to fully charge the 50Ah batteries. The batteries took an average of 5 hours to get fully charged. It concludes us to a result that the batteries can be fully charged within one day. And on bright sunny days it takes even lesser time to charge the batteries.

From the discharging data of the field test we found out that it took an average of 2 hours and 45 minutes for the vehicles to discharge the batteries to 50% SOC at semi load condition.

These results show us that if a vehicle battery drains to 50% SOC on a day, this vehicle can easily return to the charging port and swap a fully charged battery on the same day. The vehicles doesn’t need to wait for another day for the batteries to get charged as the batteries takes around 5 hours to get fully charged.

8.5 Megger Irradiance Chart and data analysis

Time	Irradiance	Solar Voltage	Solar Current	Short Circuit Current
12:15 pm	998	58	4.4	4.8
1:00 pm	984	57	4.4	4.6
1:30 pm	958	57	4.2	4.3
2:00 pm	946	56.5	4.0	4.2

Table 8.5 Irradiance chart

Figure 8.5.1: Irradiance measurement

Measurements of irradiance were taken at different times of day. The readings are recorded in the table above. The reading shows that at 12:15 on a particular day the solar irradiance was 998. This irradiance gave us a short circuit current of 4.8. With the batteries connected to charge the panel gave a current of 4.4 at the same irradiance. The reading are very close to the rated current of the battery that is 5A.

The difference between the rated battery current and the maximum short circuit current is 0.2A. This does not make much difference to charge the battery. This shows that at higher irradiance charging using the panel and charging using the grid gives us the same output.

Chapter 9
Future Works

❖ Areas need to be improved

After the completion of the whole research we found out some flaws. We felt that there are some areas which need to be modified. Monocrystalline panels usually have an efficiency range 15-20% but we got only 10%. We didn't get the actual rated current rather got a 20.22% deviation from the rated one. If we give a benefit of doubt to the field test data still we would not have got the desired efficiency which lies in that standard range. This means the panels weren't of good quality. To satisfy the needs considering the money factor we had to go for the available comparatively cheap ones. This costs us the lower efficiency. So, to increase the efficiency we need more efficient PV panels. This would be our first area for improvement. Our series connected panels were framed and for that it was rigid and heavy. If the framing is done in such a way that this can be folded while carrying it will be another advantage. As sealed lead acid batteries are too heavy to carry a roller based adjustable trolley can be used for lifting of batteries. This can be kept in the car port and used when needed. This is the best help one can get for battery swapping and for the earlier mentioned three vehicles with this trolley can act together as bread and butter. So there are scopes for customization in this system.

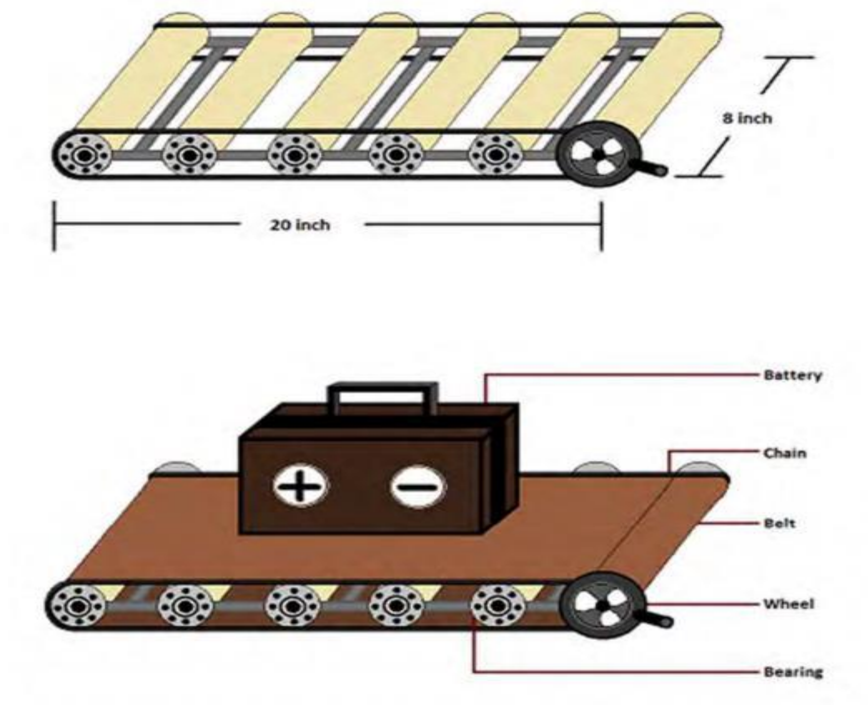


Figure 9.1: Overall roller system design

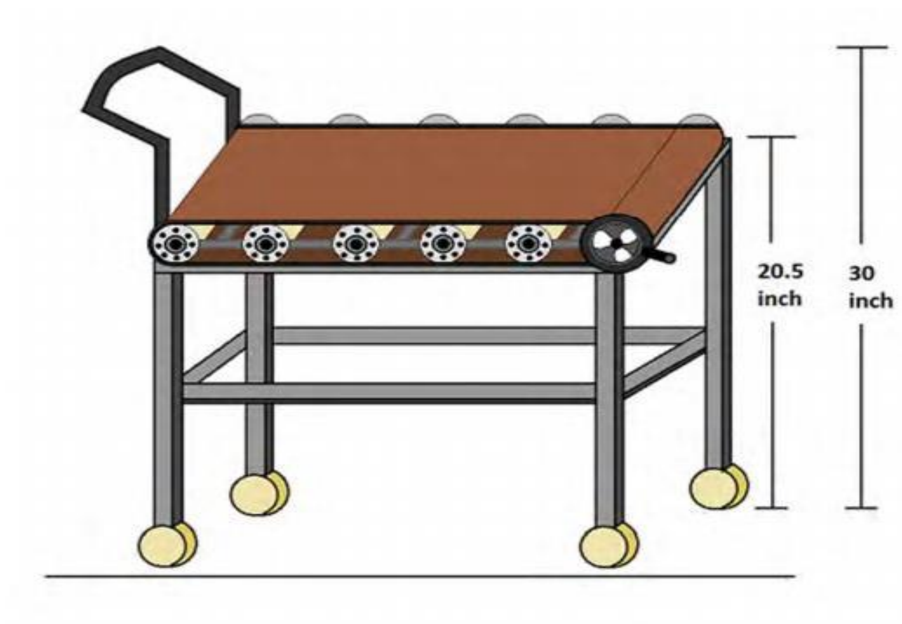


Figure 9.2: The Roller System Based Adjustable Trolley

❖ Our contribution to the thesis

The main contribution to the thesis is the idea itself that has been implemented as part of the research. Moreover, the field test results are also our contribution. These data justify the overall efficiency, success and the pitfalls of the system also the areas that need to be improved to make this system more accomplished. An awareness of not to put loads of pressure on national grid is a message that we want to convey by the thesis. Solar energy is being used in various sectors. A dedicated solar powered charging kit is also an application of solar energy. Advantages of using electric vehicles are huge. This kit works as a cheery on the top. Our target is to make it accepted by people especially rural people. Undoubtedly this is one of the best way to save electricity. Our thesis is on a simple system which can be easily implemented and used widely.

Chapter 10

Conclusion

After implementing our idea of the dedicated solar powered charging kit and obtaining all the field test analysis we come up with an affirmative result that this system is a success to a great extent. This charging system is one of the simplest inventions conducted using solar energy for charging purpose. It can minimize consumption of national grid power in rural areas to some extent. Though at first the sum of money required for buying the equipment can be a pressure for the village people but if they dare to invest money in this kit they will not only prove themselves responsible citizens but also receive the benefits of using the kit. Starting from one it can create a chain by influencing more and more people for buying this kit. The dedicated solar powered charging kit is an alternative to solar charging station. No need for any charging station if this kit is used. The benefits would be even better if all the modifications as part of our future work is being done.

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Appendix

Code for Battery voltage indicator

```
#include <LiquidCrystal.h>
LiquidCrystal lcd(12, 11, 5, 4, 3, 2);
int analogInput = 0;
float vout = 0.0;
float vin = 0.0;
float R1 = 100000.0; // resistance of R1 (100K) -see text!
float R2 = 10000.0; // resistance of R2 (10K) - see text!
int value = 0;
void setup(){
   pinMode(analogInput, INPUT);
   lcd.begin(16, 2);

}
void loop(){
   // read the value at analog input
   value = analogRead(analogInput);
   vout = (value * 5.0) / 1024.0; // see text
   vin = vout / (R2/(R1+R2));
   //if (vin<0.09) {
   //vin=0.0;//statement to quash undesired reading !
   if(vin>50.92)
   {
    lcd.clear();
    lcd.setCursor(0,0);
    lcd.print("100% charged");
    }
    if(vin>50.48)
    {
      lcd.clear();
      lcd.setCursor(0,0);
      lcd.print("90% charged");
    }
    if(vin>50)
    {
      lcd.clear();
      lcd.setCursor(0,0);
      lcd.print("80% charged");
    }
    if(vin>49.48)
```

```
    {
      lcd.clear();
      lcd.setCursor(0,0);
      lcd.print("70% charged");
    }
    if(vin>48.96)
    {
      lcd.clear();
      lcd.setCursor(0,0);
      lcd.print("60% charged");
    }
    if(vin>48.40)
    {
      lcd.clear();
      lcd.setCursor(0,0);
      lcd.print("50% charged");
    }
    if(vin>47.84)
    {
      lcd.clear();
      lcd.setCursor(0,0);
      lcd.print("40% charged");
    }
    if(vin>47.24)
    {
      lcd.clear();
      lcd.setCursor(0,0);
      lcd.print("30% charged");
    }
    if(46.64)
    {
      lcd.clear();
      lcd.setCursor(0,0);
      lcd.print("20% charged");
    }
    else
   {
    lcd.clear();
    lcd.setCursor(0,0);
    lcd.print("10% Charged");
   }

lcd.setCursor(0, 1);
lcd.print("INPUT V= ");
lcd.print(vin);
delay(500);
}
```