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ABSTRACT

For the first time in my entire life, I heard this statement from my father saying “Let me take my bike today instead of car to the office”. This can be expected from every middle-class family nowadays due to the increased fuel prices. Today petrol costs nearly 100Rs/liter and diesel costs around 90Rs/liter. Rapid hike in these prices affecting the daily commuting for many people as many of them simply can’t afford these high travelling expenses.

With this problem, everyone wants an alternative approach for their daily commuting which should be pocket friendly. That alternative is none other than electric vehicles, which are pocket friendly as well as environment friendly. Even though we know the problem and the solution things doesn’t end here.

Do you know that most of the electric bikes in the market which costs around 1.2L just gives a range of 60-70 KM for a full charge of 8hrs, this isn’t fair right? so to overcome this efficiency problem we have a solution, that is using solar panels to charge the vehicle on the go. By arranging solar panels in a way that doesn’t change the looks of the vehicle and using them to charge the batteries in the right way during sunny days will improve the efficiency of the vehicle by 25% which will make the worth we spend on these e-vehicles. Now we can charge the vehicle while it is resting and we can simultaneously charge and discharge while we are riding with the help of solar panels. Being said we use a DC motor to run the vehicle and probably Li-ion batteries for storing charge. A solar panel to charge the batteries. Several controllers and other miscellaneous hardware components make a perfect to use model.

INDEX

LIST OF FIGURES

ABBRIVATIONS

PV-Photo-Voltaic

MC4- Multi-Contact, 4 mm

USB- Universal Serial Bus

VRLA –Valve Regulated Lead Acid

DC-Direct Current

PWM-Pulse width Modulation

MPPT-Maximum Power Point Tracking

PMDC-Permanent magnet DC motor

nm-Nano Meter

Wb-Weber

CSP- Concentrating Solar Power

SHC-Solar -Heating and Cooling

c-Si-Crystalline Silicon

MJ-Multi-Junction

Ga-AS-Gallium Arsenide

CPV-Concentrator Photo-Voltaic

CIGS-Copper Indium Gallium Selenide

BIPV-Building-Integrated Photo-Voltaic

BAPV-Building-Applied Photo-Voltaic

RMI-Rocky Mountain Institute

BOS-Balance-of-System

UN-United Nations

U.S.-United States

CHAPTER 1: INTRODUCTION

Global warming is one of the major problems the world has been facing due to pollution and other factors that lead to the increase of carbon dioxide in the atmosphere. People have been looking for many solutions to help decrease this problem and to avoid causing more damage to the earth. A huge factor that has been playing a large role in causing pollution and therefore increasing the effect of global warming is car exhaust as recorded in 2004 (IPCC 2007, p 29). People have been looking for alternatives to this problem which lead them to focusing on studying and learning different ways to create environment friendly methods of transportation.

As people are becoming more aware of the negative effect climate change has towards our planet, electrical bikes have been increasing in popularity. Many people are using it as their main form of transport as it is very convenient and does not contribute to global warming. Specifically, in countries where one of their main source of transport is bikes, China for instance have been selling 9 out of every 10 electrical bikes are sold (Navigant Research, 2014).

Compared to other electrically dependent vehicles, the solar powered bike is considered low in cost and is very efficient as it relies on solar power. Solar energy is a very reliable energy source as it is available in every location in the world and is very dependent unlike other natural resources. Solar energy charges the vehicles motor which allows you to transport to your desired location without having to pedal, people always have the option to pedal the bike as well which makes it very reliable in case the battery is not charged.

Figure 0.1: Solar Bike

Solar Powered Bike is an alternative to many non-environment friendly form of transportation and its design is approached from the electrical bike. We will be mainly focusing on how to efficiently create a solar powered bike which allows you to travel the longest distance possible by properly utilizing energy generated from the sun. As well as improving and creating new technology designs for our bike. We will be also testing and implementing sun trackers on our bike to allow us to utilize the greatest amount of solar energy which will allow us to gain the maximum amount of sunlight wherever the sun is faced.

1.1 PROJECT MOTIVATION

Due to our geographical location in the Middle East, we have the advantage of having large amount of sunlight. During the day, we have extremely hot weather and long hours of sunshine and the summer seasons lasts for a very long time during the year. We realized we should take that to our advantage by thinking of a way to utilize the solar energy and create something to use that in our favour. With all that in mind, we thought of creating a solar powered car which uses the solar energy as an alternative to recharge and does not damage the earth.

Another factor we thought of was how inefficient biking was for people that travelled long distance, it causes them to arrive to their desired location extremely exhausted due to all the muscle work due to pedalling. This is another factor our bike will allow people to avoid, which is something many people would desire.

1.2 PROBLEM DEFINITION

As the sun moves its direction as the day goes by and people may be driving in different directions the solar panels may not be facing the sun. This would cause the bike not to obtain the greatest amount of sunlight possible, we decided to find a solution to this problem. We decided on implementing two solar panels on the front and back of the cycle. Energy generated from the solar power may by consumed rapidly due to constant movement and travelling long, we needed a way of storing the energy.

Figure 0.2: Our Solar bike with solar panels installed in the front and back

1.3 PROJECT OBJECTIVES

The main objective of our project is designing an solar vehicle that operates on solar energy gained from the solar panels attached without the need of human effort or using fuel to run it. Our project is to be able to manage power consumption using solar renewable energy and to store the power gained in a chargeable battery used to move the vehicle and to maximize the utilization of the sun.

1.4 NON-FUNCTIONAL REQUIREMENTS

Usability

Usability, simplicity and functionality of any system make it successful. Before starting the system, the user requirements will be specified in details. After that there will be research about the required hardware needed such as panels and electrical components will be specified. Each component will be tested independently to be sure that it fulfils the required operation Usability defines the ease of use and the acceptability of the system for the users.

There are many methods to measure usability such as analysis and study of the principles behind the efficiency. Below are some measurements included for assessing usability:

• Effectiveness. It shows how easy the users can successfully achieve their objectives.

• Efficiency. How much effort and resources the user provides to achieve those objectives successfully.

• Satisfaction. Reflect how much the stakeholder is satisfied with the delivered project.

Performance

The system performance should be optimized, and response time to the user request should be minimized to the lowest.

Scalability

The system should be highly scalable; since it is meant to be used by public people not only in India, but the ambition to reach the global as one of the renewable energy researches applications.

Extensibility

The system should be extensible to allow adding other services in the future, such as move into a longer distance and ability to receive bigger amount of power and energy.

Safety

System should implement safety that meets high standards to confirm that users will not be exposed to risk while riding the electronic bike or generating the power.

Maintainability

The system should be easily maintainable to allow for additional upgrades that can be implemented in the future.

CHAPTER 2: COMPONENTS

2.1 SOLAR PANELS

A solar panel, or photo-voltaic (PV) module, is an assembly of photo-voltaic cells mounted in a framework for installation. Solar panels use sunlight as a source of energy and generate direct current electricity. A collection of PV modules is called a PV Panel, and a system of Panels is an Array. Arrays of a photovoltaic system supply solar electricity to electrical equipment

Photovoltaic modules use light energy (photons) from the Sun to generate electricity through the photovoltaic effect. Most modules use wafer-based crystalline silicon cells or thin-film cells. The structural (load carrying) member of a module can be either the top layer or the back layer. Cells must be protected from mechanical damage and moisture. Most modules are rigid, but semi-flexible ones based on thin-film cells are also available. The cells are connected electrically in series, one to another to the desired voltage, and then in parallel to increase amperage. The wattage of the module is the mathematical product of the voltage and the amperage of the module. The manufacture specifications on solar panels are obtained under standard condition which is not the real operating condition the solar panels are exposed to on the installation site.

A PV junction box is attached to the back of the solar panel and functions as its output interface. External connections for most photovoltaic modules use MC4 connectors to facilitate easy weatherproof connections to the rest of the system. A USB power interface can also be used.

Figure 0.1:From a solar cell to a PV system

Figure 0.2:Solar PV modules mounted on a rooftop

Module electrical connections are made in series to achieve a desired output voltage or in parallel to provide a desired current capability (amperes) of the solar panel or the PV system. The conducting wires that take the current off the modules are sized according to the ampacity and may contain silver, copper or other non-magnetic conductive transition metals. Bypass diodes may be incorporated or used externally, in case of partial module shading, to maximize the output of module sections still illuminated.

Some special solar PV modules include concentrators in which light is focused by lenses or mirrors onto smaller cells. This enables the use of cells with a high cost per unit area (such as gallium arsenide) in a cost-effective way.

Solar panels also use metal frames consisting of racking components, brackets, reflector shapes, and troughs to better support the panel structure.

2.2 LEAD–ACID BATTERY

The lead–acid battery is a type of rechargeable battery first invented in 1859 by French physicist Gaston Planté. It is the first type of rechargeable battery ever created. Compared to later types of rechargeable batteries, Lead-Acid batteries have the lowest energy density. Despite this, its ability to supply high surge currents means that the cells have a relatively large power-to-weight ratio. These features, along with their low cost, make them attractive for use in motor vehicles to provide the high current required by starter motors.

As they are inexpensive compared to newer technologies, lead–acid batteries are widely used even when surge current is not important and other designs could provide higher energy densities. In 1999 lead–acid battery sales accounted for 40–45% of the value from batteries sold worldwide (excluding China and Russia), equivalent to a manufacturing market value of about $15 billion. Large-format lead–acid designs are widely used for storage in backup power supplies in cell phone towers, high-availability settings like hospitals, and stand-alone power systems. For these roles, modified versions of the standard cell may be used to improve storage times and reduce maintenance requirements. Gel-cells and absorbed glass-mat batteries are common in these roles, collectively known as VRLA (valve-regulated lead–acid) batteries.

In the charged state, the chemical energy of the battery is stored in the potential difference between the pure lead at the negative side and the PbO_2 on the positive side, plus the aqueous sulfuric acid. The electrical energy produced by a discharging lead–acid battery can be attributed to the energy released when the strong chemical bonds of water (H_2O) molecules are formed from H^+ ions of the acid and O^{2-} ions of PbO_2.Conversely, during charging, the battery acts as a water-splitting device.

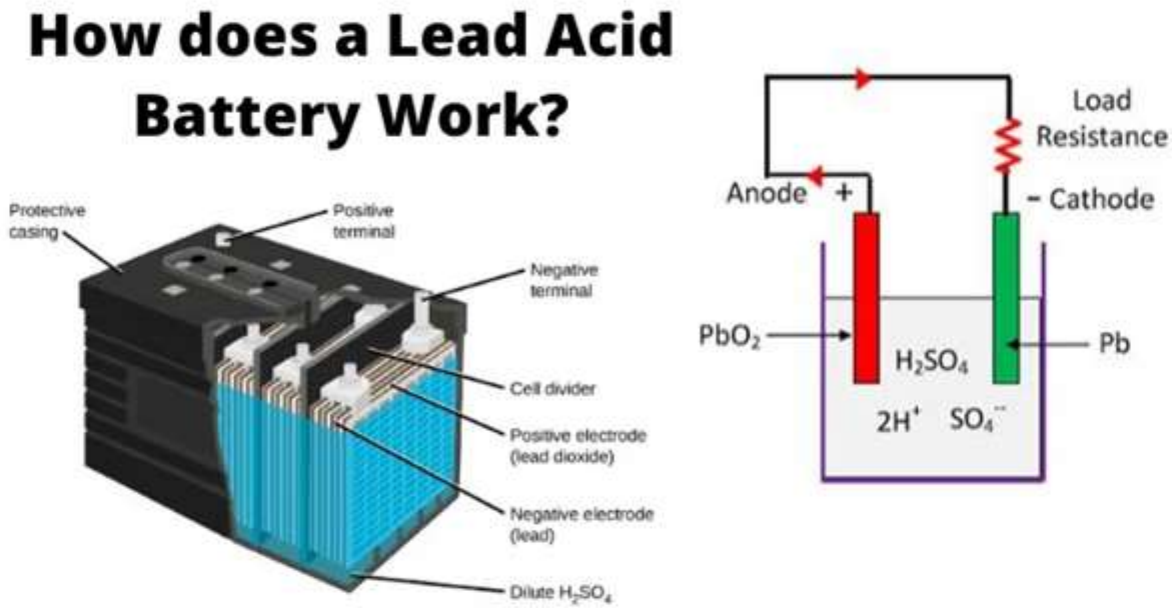

Figure 0.3: Working of lead-acid battery

Starting batteries for cycles

Lead–acid batteries designed for starting automotive engines are not designed for deep discharge. They have a large number of thin plates designed for maximum surface area, and therefore maximum current output, which can easily be damaged by deep discharge. Repeated deep discharges will result in capacity loss and ultimately in premature failure, as the electrodes disintegrate due to mechanical stresses that arise from cycling. Starting batteries kept on a continuous float charge will suffer corrosion of the electrodes which will also result in premature failure. Starting batteries should therefore be kept open circuit but charged regularly (at least once every two weeks) to prevent sulfation.

Starting batteries are of lighter weight than deep-cycle batteries of the same size, because the thinner and lighter cell plates do not extend all the way to the bottom of the battery case. This allows loose disintegrated material to fall off the plates and collect at the bottom of the cell, prolonging the service life of the battery. If this loose debris rises enough it may touch the bottom of the plates and cause failure of a cell, resulting in loss of battery voltage and capacity.

Deep-cycle batteries

Specially designed deep-cycle cells are much less susceptible to degradation due to cycling, and are required for applications where the batteries are regularly discharged, such as photovoltaic systems, electric vehicles (forklift, golf cart, electric cars, and others) and uninterruptible power supplies. These batteries have thicker plates that can deliver less peak current, but can withstand frequent discharging.

Some batteries are designed as a compromise between starter (high-current) and deep cycle. They are able to be discharged to a greater degree than automotive batteries, but less so than deep-cycle batteries. They may be referred to as "marine/motorhome" batteries, or "leisure batteries".

Fast and slow charge and discharge

The capacity of a lead–acid battery is not a fixed quantity but varies according to how quickly it is discharged. The empirical relationship between discharge rate and capacity is known as “Peukert's law”.

When a battery is charged or discharged, only the reacting chemicals, which are at the interface between the electrodes and the electrolyte, are initially affected. With time, the charge stored in the chemicals at the interface, often called "interface charge" or "surface charge", spreads by diffusion of these chemicals throughout the volume of the active material.

Consider a battery that has been completely discharged (such as occurs when leaving the car lights on overnight, a current draw of about 6 amps). If it then is given a fast charge for only a few minutes, the battery plates charge only near the interface between the plates and the electrolyte. In this case the battery voltage might rise to a value near that of the charger voltage; this causes the charging current to decrease significantly. After a few hours this interface charge will spread to the volume of the electrode and electrolyte; this leads to an interface charge so low that it may be insufficient to start the car. As long as the charging voltage stays below the gassing voltage (about 14.4 volts in a normal lead–acid battery) battery damage is unlikely and in time the battery should return to a nominally charged state.

2.3 MOTOR CONTROLLER

A motor controller is a device or group of devices that can coordinate in a predetermined manner the performance of an electric motor. A motor controller might include a manual or automatic means for starting and stopping the motor, selecting forward or reverse rotation, selecting and regulating the speed, regulating or limiting the torque, and protecting against overloads and electrical faults. Motor controllers may use electromechanical switching, or may use power electronics devices to regulate the speed and direction of a motor.

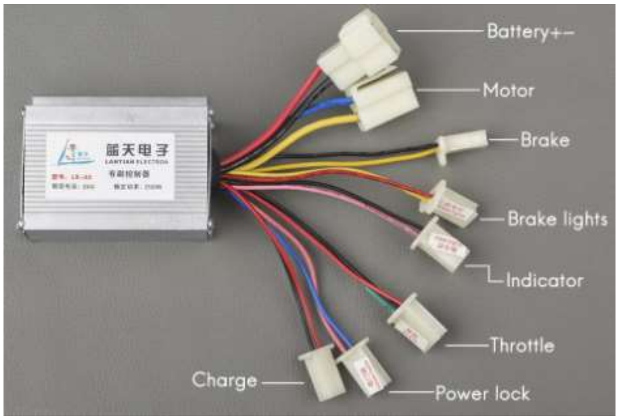

Figure 0.4: 250W,24VDC brushed Motor controller

Motor controllers are used with both direct current and alternating current motors. A controller includes means to connect the motor to the electrical power supply, and may also include overload protection for the motor, and over-current protection for the motor and wiring. A motor controller may also supervise the motor's field circuit, or detect conditions such as low supply voltage, incorrect polarity or incorrect phase sequence, or high motor temperature. Some motor controllers limit the inrush starting current, allowing the motor to accelerate itself and connected mechanical load more slowly than a direct connection. Motor controllers may be manual, requiring an operator to sequence a starting switch through steps to accelerate the load, or may be fully automatic, using internal timers or current sensors to accelerate the motor.

Some types of motor controllers also allow adjustment of the speed of the electric motor. For direct-current motors, the controller may adjust the voltage applied to the motor, or adjust the current flowing in the motor's field winding. Alternating current motors may have little or no speed response to adjusting terminal voltage, so controllers for alternating current instead adjust rotor circuit resistance (for wound rotor motors) or change the frequency of the AC applied to the motor for speed control using power electronic devices or electromechanical frequency changers.

TYPES OF DC MOTOR CONTROLLERS

Below are some common methods of DC motor control. Note that these methods are not exhaustive and that DC motors can be controlled in many ways, including servo motor controllers

Direction Controller: H Bridge

An H bridge circuit is one of the simplest methods to control a DC motor. Figure 2.5 below shows a simplified circuit diagram of the H Bridge:

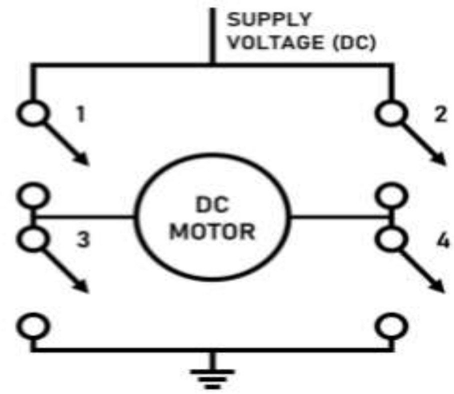

Figure 0.5: H bridge circuit for DC motor direction control.

There are four switches controlled in pairs (1 & 4, 2 & 3), and when either of these pairs are closed, they complete the circuit and power the motor. A 4 quadrant motor can, therefore, be made by pairing certain switches together, where the changing polarities will create different effects on the motor. In essence, this circuit is switching the leads of the DC motor, which will reverse its rotational direction on command. They are readily sold as chips and can be found in most microprocessor-based controllers, as the H Bridge can be scaled down with transistors to very small sizes.

Not only can H bridges reverse the motor direction, but they can also be used for speed control. If directional control is only desired, then the H bridge will be used as a so-called non-regenerative DC drive. However, more complexity can be added to create regenerative DC drives. Figure 2.6 shows a graph visualizing how regenerative drives work:

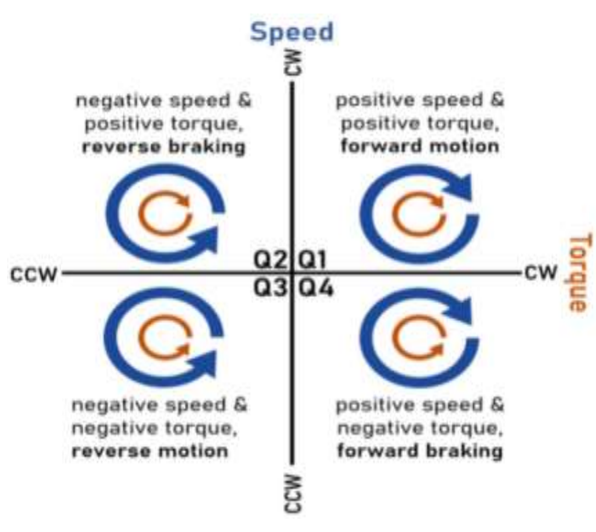

Figure 0.6: graphs representing the direction of both speed and torque when the polarity is changed on a DC motor. Notice how motion is created when they work in the same direction, and how breaking is achieved when they are in opposition.

Most DC motors are slowed down by just cutting their power to the motor; regenerative drives include braking capabilities, where switching the polarities as the motor is running will cause deceleration. Quadrants 1 and 3 are considered "motoring" quadrants where the motor is providing acceleration in either direction, and is what non-regenerative drives control. Quadrants 2 and 4 are considered "braking" quadrants where the motor is decelerating and is what regenerative drives benefit from. When the motor speed is opposing the motor torque, the motor becomes a generator where its mechanical energy will drive a current back to the power source (known as "regenerative braking"). This feature reduces energy losses and can recharge the power source, effectively increasing the motor efficiency. Figure 2.7 shows the simplified circuit diagram for each quadrant, and how quadrants 2 and 4 send current back to the supply to regenerate energy:

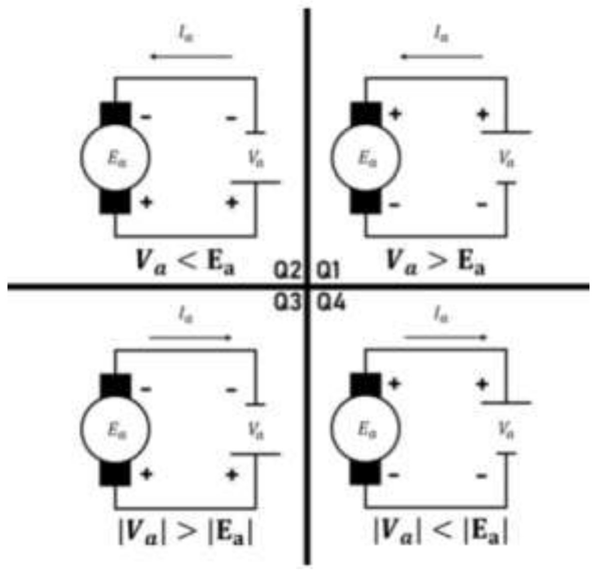

Figure 0.7: Circuit diagrams for each quadrant, showing the magnitudes of motor and supply voltages. Notice how the current direction (Ia) moves from the motor to the supply source in quadrants 2 & 4.

When the motor decelerates, Ea (the voltage produced/used by the motor) is greater than the supply voltage (Va), and current will flow back into the power source. Regenerative braking is currently being researched in electric vehicles and other applications which need to maximize efficiency. This method not only creates DC motor control, but it also provides a clever way to lower power consumption.

Speed Controller: Pulse Width Modulation (PWM)

PWM can be used in many kinds of motors, PWM circuits vary the motor speed by simulating a reduction/increase in supply voltage. Adjustable speed drive controllers send periodic pulses to the motor, which, when combined with the smoothing effect caused by coil inductance, makes the motor act as if it is being powered by a lower/higher voltage. For example, if a 12 V motor is given a PWM signal that is high (12 V) for two-thirds of each period and low (0 V) for the remainder, the motor will effectively operate at two-thirds the full voltage, or 8 V. The percentage of voltage reduction, or the PWM “duty cycle”, will therefore change the speed of the motor. PWM is both easy and inexpensive to implement, and virtually any duty cycle can be chosen, allowing for almost continuous control of motor speed. PWM is often paired with H bridges to allow for both speed, direction, and braking control.

Armature Controller: Variable resistance

Another way to affect DC motor speed is by varying the current fed through either the field coil or the armature. The speed of the output shaft will change when the current through these coils change, as its speed is proportional to the strength of the armature’s magnetic field (dictated by current). Variable resistors or rheostats in series with these coils can be used to alter the current, and therefore speed. Users can increase the resistance of the armature coil to decrease speed, or increase the stator resistance to increase it, all by regulating resistance. Note that this method introduces inefficiency into a motor, as increasing resistance means losing more energy to heat, and is why PWM is the preferred DC motor controller type.

2.4 SOLAR CHARGE CONTROLLER

A charge controller, charge regulator or battery regulator limits the rate at which electric current is added to or drawn from electric batteries. It prevents overcharging and may protect against overvoltage, which can reduce battery performance or lifespan and may pose a safety risk. It may also prevent completely draining ("deep discharging") a battery, or perform controlled discharges, depending on the battery technology, to protect battery life. The terms "charge controller" or "charge regulator" may refer to either a stand-alone device, or to control circuitry integrated within a battery pack, battery-powered device, or battery charger.

A solar charge controller manages the power going into the battery bank from the solar array. It ensures that the deep cycle batteries are not overcharged during the day, and that the power doesn’t run backwards to the solar panels overnight and drain the batteries. Some charge controllers are available with additional capabilities, like lighting and load control, but managing the power is its primary job.

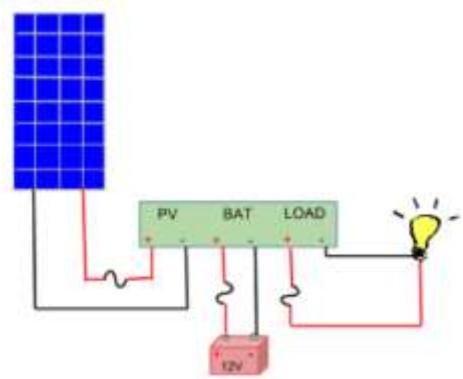

Figure 0.8: Solar charge controller

A solar charge controller is available in two different technologies, PWM and MPPT. How they perform in a system is very different from each other. An MPPT charge controller is more expensive than a PWM charge controller, and it is often worth it to pay the extra money.

PWM solar charge controller

A PWM solar charge controller stands for "Pulse Width Modulation". These operate by making a connection directly from the solar array to the battery bank. During bulk charging, when there is a continuous connection from the array to the battery bank, the array output voltage is 'pulled down' to the battery voltage. As the battery charges, the voltage of the battery rises, so the voltage output of the solar panel rises as well, using more of the solar power as it charges. As a result, you need to make sure you match the nominal voltage of the solar array with the voltage of the battery bank. *Note that when we refer to a 12V solar panel, that means a panel that is designed to work with a 12V battery. The actual voltage of a 12V solar panel, when connected to a load, is close to 18 Vmp (Volts at maximum power). This is because a higher voltage source is required to charge a battery. If the battery and solar panel both started at the same voltage, the battery would not charge.

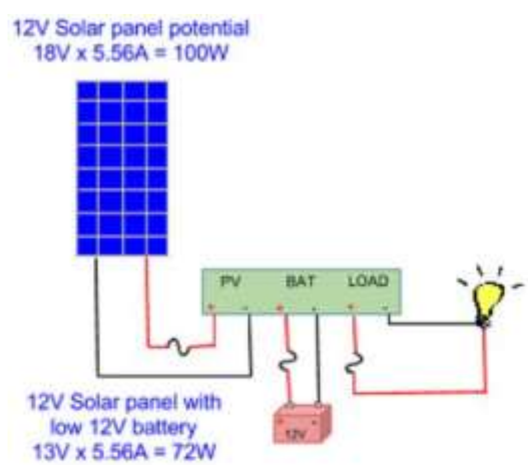

Figure 0.9: 12V solar panel with PWM charge controller charging a low 12V battery 28% loss

A 12V solar panel can charge a 12V battery. A 24V solar panel or solar array (two 12V panels wired in series) is needed for a 24V battery bank, and 48V array is needed for 48V bank. If you try to charge a 12V battery with a 24V solar panel, you will be throwing over half of the panel's power away. If you try to charge a 24V battery bank with a 12V solar panel, you will be throwing away 100% of the panel's potential, and may actually drain the battery as well.

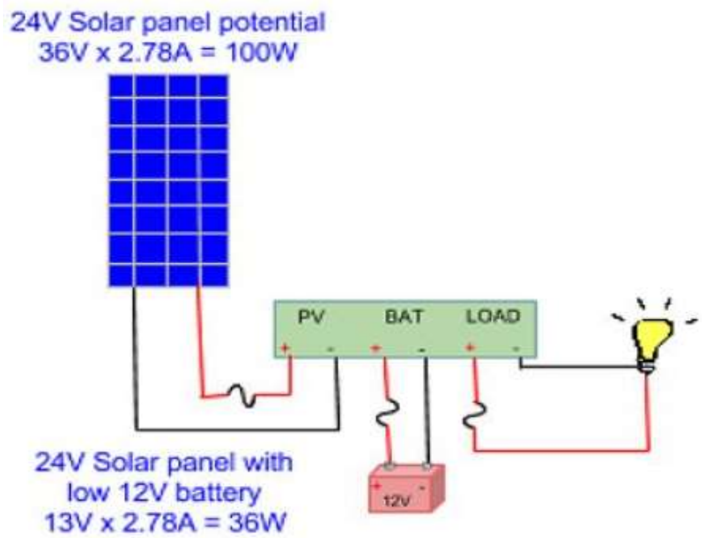

Figure 0.10: 24V solar panel with PWM charge controller charging a low 12V battery

64% loss

MPPT solar charge controller

An MPPT solar charge controller stands for "Maximum Power Point Tracking". It will measure the Vmp voltage of the panel, and down-converts the PV voltage to the battery voltage. Because power into the charge controller equals power out of the charge controller, when the voltage is dropped to match the battery bank, the current is raised, so you are using more of the available power from the panel. You can use a higher voltage solar array than battery, like the 60 cell nominal 20V grid-tie solar panels that are more readily available. With a 20V solar panel, you can charge a 12V battery bank, or two in series can charge up to a 24V battery bank, and three in series can charge up to a 48V battery bank. This opens up a whole wide range of solar panels that now can be used for your off-grid solar system.

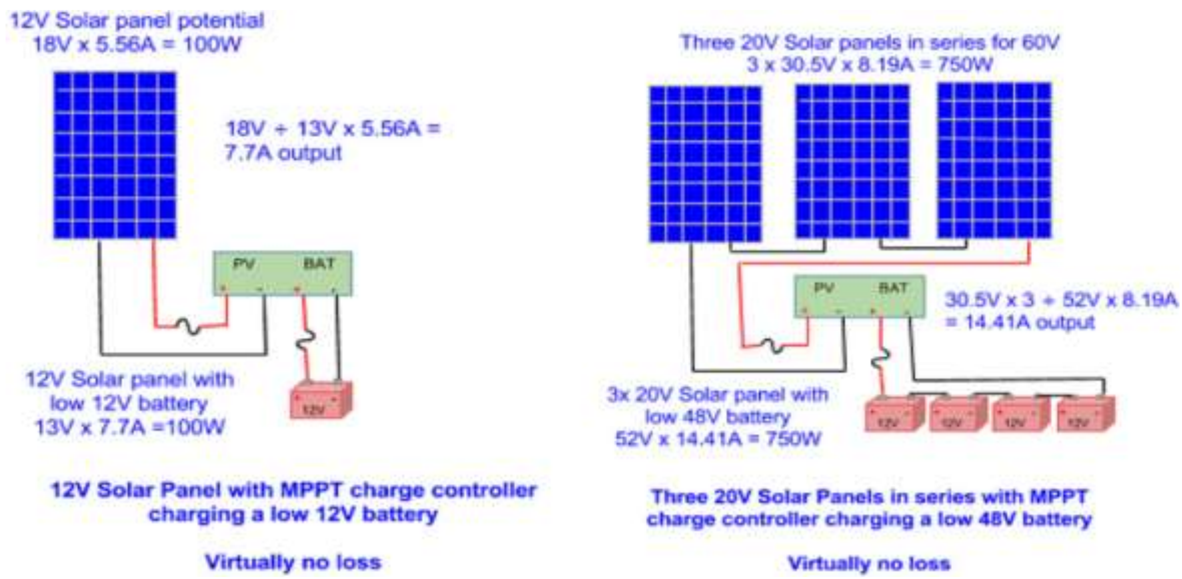

Figure 0.11:MPPT solar charge controller

The Key Features Of A Solar Charge Controller Are:

- Multistage charging of battery bank - changes the amount of power set to the batteries based on its charge level, for healthier batteries.
- Reverse current protection - stops the solar panels from draining the batteries at night when there is no power coming from the solar panels.
- Low voltage disconnect - turns off attached load when battery is low and turns it back on when the battery is charged back up.
- Lighting control - turns attached light on and off based on dusk and dawn. Many controllers are configurable, allowing settings for a few hours or all night, or somewhere in between.
- Display- may show voltage of battery bank, state of charge, amps coming in from solar panel.

2.5 BRUSHED SERIES WOUND DC MOTOR

Before knowing about brushed series wound DC motor lets know what a brushed DC motor is and it's types.

Brushed DC electric motor is a rotating DC electric machine that converts DC electric power into mechanical energy, in which at least one of the windings involved in the main process of energy conversion is connected to a commutator.

Construction of brushed DC electric motor

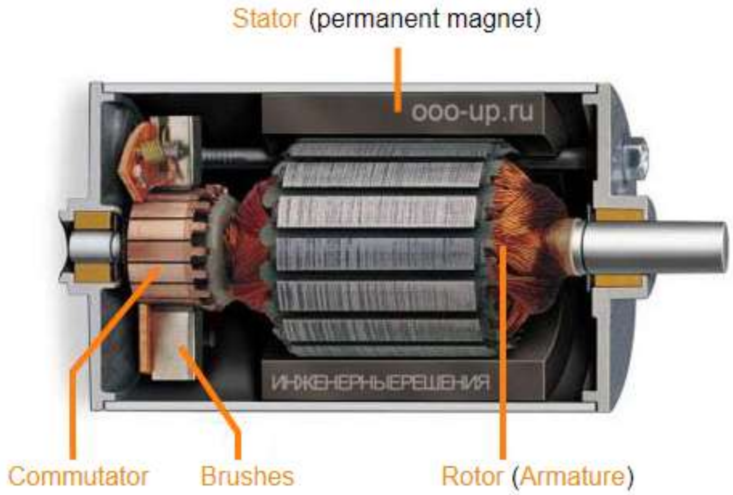

Figure 0.12: Permanent magnet DC motor

- Rotor is rotating part of the electric machine.
- Stator is a fixed part of the motor.
- Inductor (excitation system) is part of the DC commutator machine or synchronous machine, creating magnetic flux for the formation of the torque. The inductor includes either permanent magnets or a field winding. The inductor can be part of both the rotor and the stator. In the motor shown in fig. 2.11, the excitation system consists of two permanent magnets and is part of the stator.
- Armature is a part of a DC commutator machine or a synchronous machine in which an electromotive force is induced and a load current flows . As the armature can act as a rotor and stator. In the motor shown in fig. 11, the rotor is an armature.
- Brushes is a part of the electrical circuit through which the electric current is transmitted from the power source to the armature. Brushes are made from graphite or other materials. The DC motor contains one pair of brushes or more. One of the two brushes is connected to the positive and the other to the negative terminal of the power supply.
- Commutator is a part of the motor in contact with the brushes. With the help of brushes and a commutator, the electric current is distributed across the coils of the armature winding.

The working principle of the brushed DC motor

1. According to Ampere's law, a force F will act on a conductor with a current I in a magnetic field.

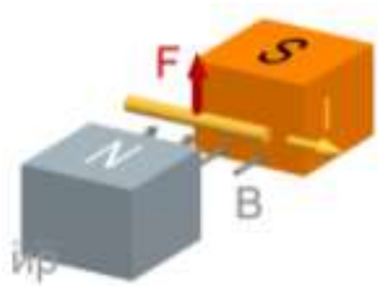

Figure 0.13: Direction of force according to Amperes law

2. If a conductor with current I is bent into a frame and placed in a magnetic field, then the two sides of the frame, which are at right angles to the magnetic field, will experience oppositely directed forces F.

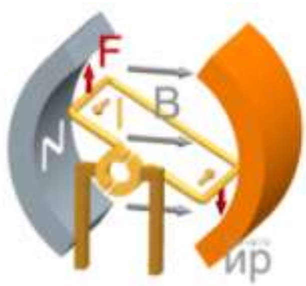

Figure 0.14: Conductor experiencing oppositely directed forces F.

3. The forces acting on the frame, create a torque or moment of force, rotating it.

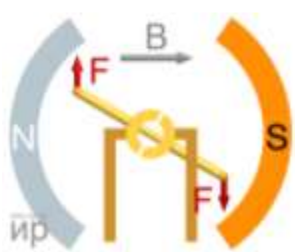

Figure 0.15: Torque produced, leading to rotation

4. The armature of the produced electric motors has several turns to provide greater constant torque.

Figure 0.16 : Several turns to provide greater constant torque.

5. The magnetic field can be created both by magnets and electromagnets. An electromagnet is usually a wire wound on a core. Thus, according to the Faraday's law of induction, the current flowing into the frames will induce a current in the windings of an electromagnet, which in turn will create a magnetic field.

2.5.1 Types of brushed DC motors

According to the stator construction, the brushed motor can be with permanent magnets and with wound stator.

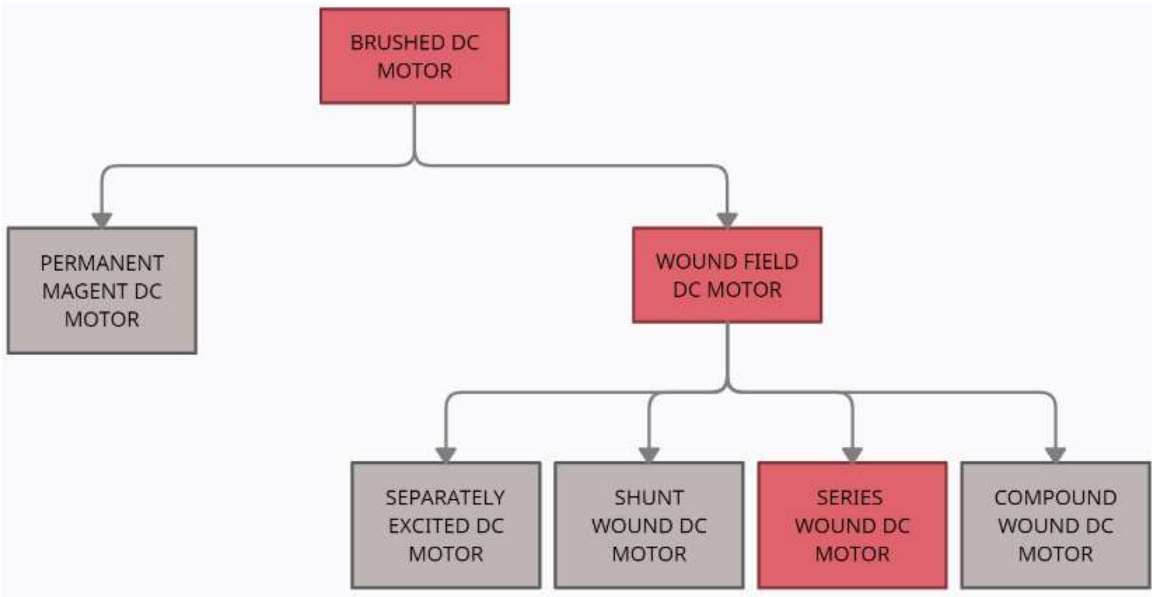

Figure 0.17: Types of Brushed DC motors

Permanent magnet DC motor

Figure 0.18: Permanent magnet DC motor scheme

Permanent magnet DC motor (PMDC motor) is the most common among the brushed DC motor. The inductor of this motor includes permanent magnets that create a magnetic field of the stator. Permanent magnet DC motors are usually used in tasks that do not require high power. PMDC motors are cheaper in production than wound field DC motors. At the same time, the torque of the PMDC motor is limited by the field of permanent magnets of the stator. The PMDC motor reacts very quickly to voltage changes. Thanks to the constant field of the stator, it is easy to control the speed of the motor. The disadvantage of a PM DC motor is that over time the magnets lose their magnetic properties, as a result of which the stator field decreases and the motor performance decreases.

Advantage:

- best price/quality ratio
- high torque at low speed
- fast voltage response

Disadvantage:

- permanent magnets over time, as well as under the influence of high temperatures lose their magnetic properties

Wound field DC motor

According to the wiring diagram of the stator winding, wound field DC motors are divided into:

- separately excited DC motor
- shunt wound DC motor
- series wound DC motor
- compound wound DC motor

Separately excited and shunt wound motors

In separately excited electric motors, the field winding is not electrically connected to the armature winding. Usually, the excitation voltage UFW differs from the voltage in the armature circuit U. If the voltages are equal, then the field winding is connected in parallel with the armature winding. The use in the electric drive separately excited or shunt wound motor is determined by the electric drive scheme. Properties (characteristics) of these motors are the same.

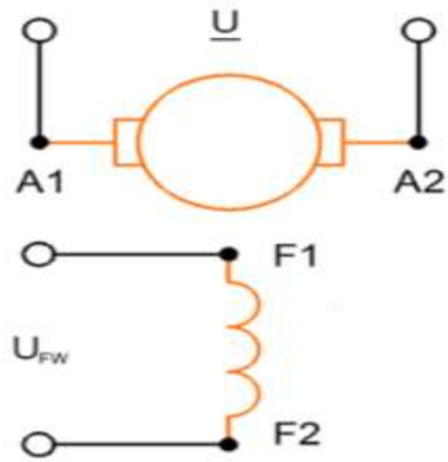

Figure 0.19 : Separately excited DC motor scheme

In shunt wound brushed DC motors, the currents of the field winding (inductor) and the armature are independent of each other, and the total motor current is equal to the sum of the field winding current and the armature current. During normal operation, increasing the supply voltage increases the total current of the motor, which leads to an increase in the stator and rotor fields. With an increase in the total motor current, the speed also increases, and the torque decreases. When the motor load increases, the armature current increases as a result the armature field increases. As the armature current increases, the inductor (field winding) current decreases, resulting in a decrease in the inductor field, which leads to a decrease in motor speed and an increase in torque.

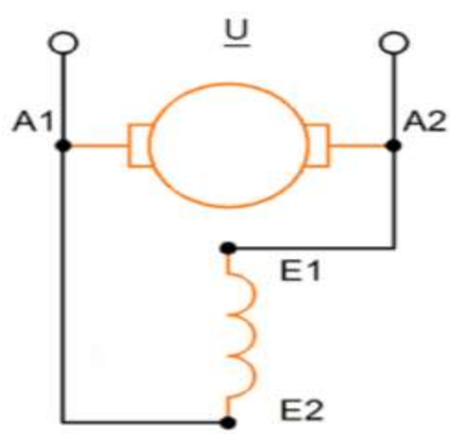

Figure 0.20: Shunt wound DC motor scheme

Advantage:

- almost constant torque at low speed
- good adjusting properties
- no loss of magnetism over time (since there are no permanent magnets)

Disadvantage:

- more expensive than PMDC motor
- the motor goes out of control if the inductor current drops to zero

Shunt-wound DC motor has the torque/speed characteristic with decreasing torque at high speeds and high, but more constant torque at low speeds. The current in the inductor winding and the armature does not depend on each other, thus, the total current of the electric motor is equal to the sum of the currents of the inductor and the armature. As a result, this type of motor has excellent speed control characteristics. Shunt-wound brushed DC motor is commonly used in applications that require a power of more than 3 kW, in particular in automotive applications and industry. In comparison with PMDC motor, the shunt wound DC motor does not lose its magnetic properties with time and is more reliable. The disadvantages of the shunt wound brushed DC motor is higher cost and the possibility of the motor runaway if the inductor current decreases to zero, which in turn can lead to motor failure.

Series wound DC motor

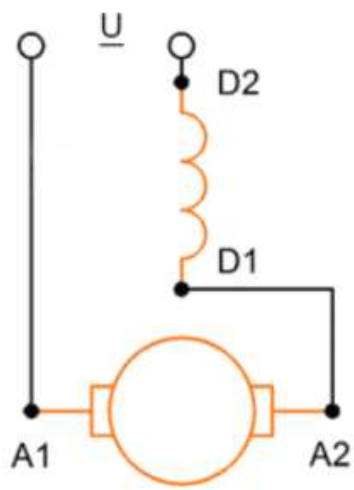

Figure 0.21: Series wound DC motor scheme

In series wound brushed DC motors, the field winding is connected in series with the armature winding, and the excitation current is equal to the armature current ($I_e = I_a$), which gives the motors special properties. Under small loads, when the armature current is less than the rated current ($I_a < I_{rat}$) and the magnetic system of the motor is not saturated ($\Phi \sim I_a$), the electromagnetic torque is proportional to the square of the current in the armature winding:

$$M = c_M \Phi I_a = c'_M I_a^2,$$

- where M is the motor torque, N·m,
- c_M is a constant coefficient determined by the design parameters of the motor,,
- Φ is main magnetic flux, Wb,
- I_a is armature current, A.

With load increasing, the magnetic system of the motor is saturated and the proportionality between the current I_a and the magnetic flux Φ is disturbed. With significant saturation, the magnetic flux Φ with increasing I_a practically does not increase. The graph of the dependence $M=f(I_a)$ in the initial part (when the magnetic system is not saturated) has the shape of a parabola, then, when saturated, deviates from the parabola and in the region of large loads turns into a straight line.

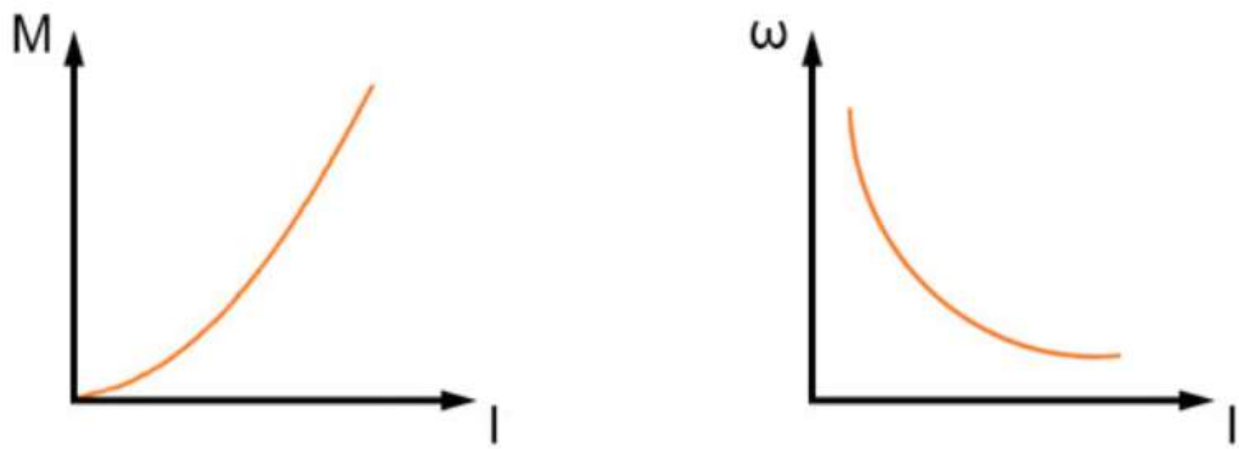

Figure 0.22: Performance characteristic vs Electromechanical characteristic of series wound DC motor

The ability of series wound DC motors to develop a large electromagnetic torque provides them with good starting properties.

Advantage:

- high torque at low speed
- no loss of magnetism over time.

Disadvantage:

- low torque at high speed
- more expensive than PMDC motor
- poor speed control due to the series connection of the armature and inductor windings
- the motor goes out of control if the inductor current drops to zero

Series wound brushed DC motor has a high torque at low speed and develops high speed with no load. This electric motor is ideal for devices that need to develop a high torque (cranes and winches), as the current of the stator and the rotor increases under load. Unlike PMDC motors and shunt wound brushed DC motors, the series wound DC motors does not have the exact characteristics of speed control, and in case of a short circuit of the field winding it can become uncontrollable.

Compound wound DC motor

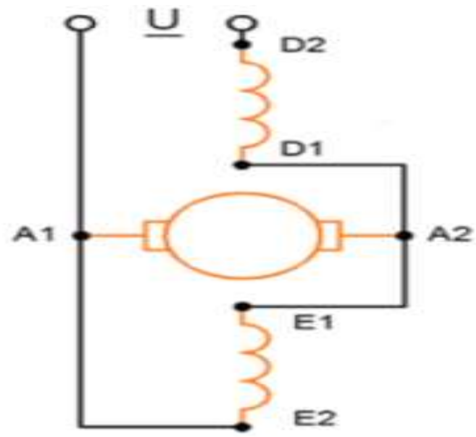

Figure 0.23: Compound wound DC motor scheme

Compound wound brushed DC motor has two field windings, one of them is connected in parallel with the armature winding, and the second is connected in series. The ratio between the magnetizing forces of the windings can be different, but usually one of the windings creates a large magnetizing force and this winding is called main, the second winding is called auxiliary. If the windings are connected such that the series field aids the shunt field, then the motor is called Cumulative compound brushed DC motor. On the other hand, if the windings are connected such that the two fields oppose each other, then the motor is called the Differential compound brushed DC motor. The speed characteristics of cumulative compound brushed DC motor are located between the speed characteristics of shunt wound and series wound DC motors. Opposite connection of the windings (differential compounding) is used when it is necessary to obtain a constant rotational speed or an increase in the rotational speed with increasing load. Thus, the performance characteristics of a compound wound DC motor is close to those of a shunt or series wound brushed DC motor, depending on which field winding plays the main role.

Advantage:

- good speed control
- high torque at low speed
- motor runaway less likely

Disadvantage:

- more expensive than other brushed DC motors

Compound brushed DC motors has the performance characteristics of shunt and series wound brushed DC motors. It has a high torque at low speed, as well as a series wound brushed DC motor and good speed control, like, a shunt wound brushed DC motor. Compound wound brushed DC motor runaway is less likely, because the shunt current should decrease to zero, and the serial field winding should be short-circuited.

Performance characteristics of brushed DC motors

The performance properties of brushed DC motors are determined by their operating, electromechanical and mechanical characteristics, as well as their adjustment properties.

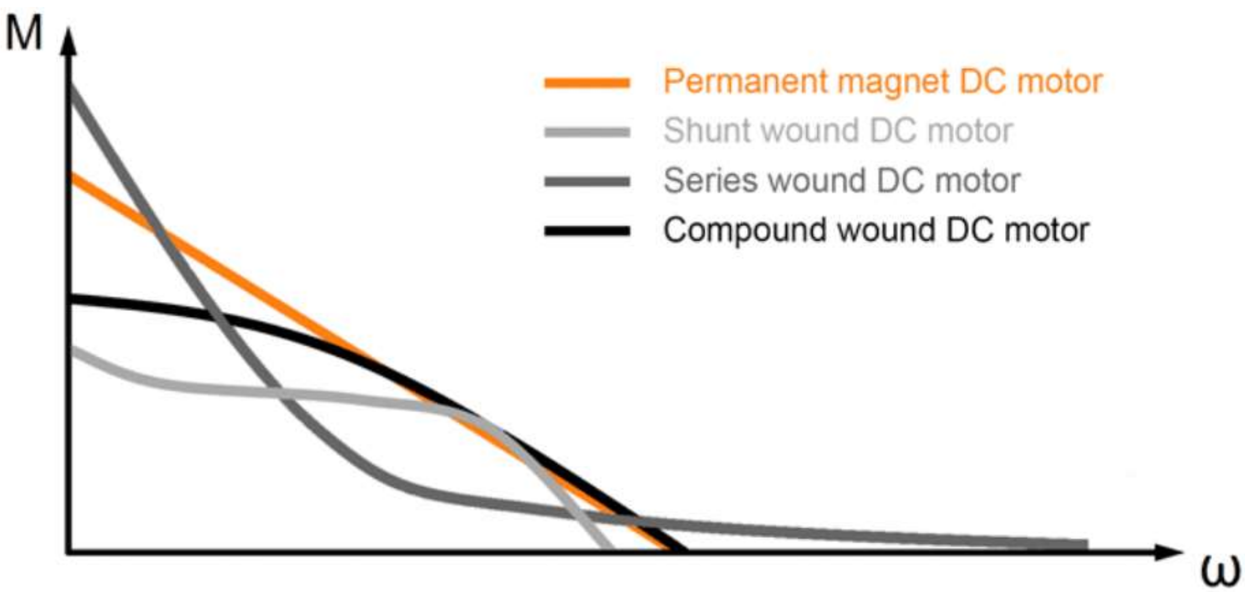

Figure 0.24: Torque-speed curves of brushed DC motors

The main parameters of the brushed DC motor

Torque constant

For a brushed DC motor, the torque constant is determined by the formula:

$$K_T = \left(\frac{Z}{2\pi}\right)\Phi ,$$

- where Z is total number of conductors,
- Φ is magnetic flux, Wb.

2.6 THROTTLE

Solar bike throttle operates in a very similar way many motorcycles (or scooters) operate. As soon as you engage the throttle button, the motor is powered on and it propels the Bike forward.

As the motor turns it takes it’s power from batteries which are in turn charged with the help of solar panels

Using a Throttle makes the ride go smoother and the speed will be under the control of the rider

Figure 0.25: Throttle

2.7 BICYCLE AND ACCESSORIES

The main idea of this project was to make it cost-efficient and environment friendly. Therefore, making a solar vehicle out of bicycle makes this project more affordable and ecofriendly.

To make a battery level indicator and to display the voltage value we have programmed Arduino to provide the battery level with help of LED’s and to voltage value given by the batteries on LCD screen.

2.7.1 Arduino Uno R3

The Arduino Uno is an open-source microcontroller board based on the Microchip ATmega328P microcontroller and developed by Arduino.cc. Its simplicity makes it ideal for hobbyists or novice to use as well as professionals. The Arduino Uno is equipped with sets of digital and analog input/output (I/O) pins that may be interfaced to various expansion boards (shields) and other circuits. The board has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It can be powered by the USB cable or by an external 9-volt battery, though it accepts voltages between 7 and 20 volts. It is similar to the Arduino Nano and Leonardo. The hardware reference design is distributed under a Creative Commons Attribution Share-Alike 2.5 license and is available on the Arduino website. Layout and production files for some versions of the hardware are also available. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with AC-to DC adapter or battery to get started. The Arduino Uno R3 uses an ATmega16U2 instead of the 8U2 found on the Uno (or the FTDI found on previous generations). This allows for faster transfer rates and more memory. No drivers needed for Linux or Mac (in file for Windows is needed and included in the Arduino IDE), and the ability to have the Uno show up as a keyboard, mouse, joystick, etc. The Arduino Uno differs from all preceding boards in that it does not use the FTDI USB-to-serial driver chip. Instead, it features the Atmega8U2 microcontroller chip programmed as a USB-to-serial converter. The Uno R3 also adds SDA and SCL pins next to the AREF. In addition, there are two new pins placed near the RESET pin. One is the IOREF that allow the shields to adapt to the voltage provided from the board. The other is a not connected and is reserved for future purposes. The Uno R3 works with all existing shields but can adapt to new shields which use these additional pins.

Figure 0.26: Arduino 1.0

The word "Uno" means one in Italian and is named to mark the upcoming release of Arduino 1.0. Preferred quality and originals are made in Italy. The Uno board is the first in a series of USB-based Arduino boards ; it and version 1.0 of the Arduino IDE were the reference versions of Arduino, which have now evolved to newer releases. The ATmega328 on the board comes preprogrammed with a bootloader that allows uploading new code to it without the use of an external hardware programmer.

Technical specifications:

- Microcontroller: ATmega328
- Operating Voltage: 5V
- Input Voltage (recommended): 7-12V
- Input Voltage (limits): 6-18V
- Digital I/O Pins: 14 (of which 6 provide PWM output)
- Analog Input Pins: 6
- DC Current per I/O Pin: 40 mA

- DC Current for 3.3V Pin: 50 mA
- Flash Memory: 32 KB of which 0.5 KB used by bootloader
- SRAM: 2 KB (ATmega328)
- EEPROM: 1 KB (ATmega328)
- UART: 1
- 12C: 1
- SPPI: 1
- Clock Speed: 16 MHz 13
- Length: 68.6 mm
- Width: 53.4 mm
- Weight: 25 g

General pin specifications:

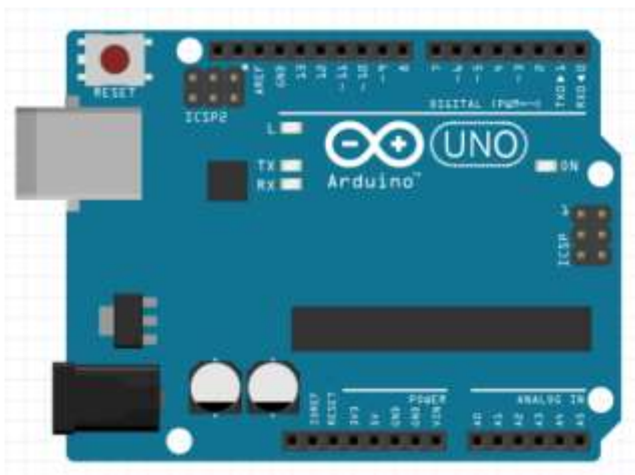

Figure 0.27:Arduino Pin Details

- LED: There is a built-in LED driven by digital pin 13. When the pin is high value, the LED is on, when the pin is low, it is off.
- VIN: The input voltage to the Arduino/Genuino board when it is using an external power source (as opposed to 5 volts from the USB connection or other regulated power source). You can supply voltage through this pin, or, if supplying voltage via the power jack, access it through this pin.
- 5V: This pin outputs a regulated 5V from the regulator on the board. The board can be supplied with power either from the DC power jack (7 - 20V), the USB connector (5V), or the VIN pin of the board (7-20V). Supplying voltage via the 5V or 3.3V pins bypasses the regulator, and can damage the board.
- 3.3V: A 3.3 volt supply generated by the on-board regulator. Maximum current draw is 50 mA.
- GND: Ground pins.
- IOREF: This pin on the Arduino/Genuino board provides the voltage reference with which the microcontroller operates. A properly configured shield can read the IOREF pin voltage and select the appropriate power source, or enable voltage translators on the outputs to work

with the 5V or 3.3V.

Reset: Typically used to add a reset button to shields that block the one on the board.

2.7.2 Light Emitting Diode

A light-emitting diode (LED) is a semiconductor light source that emits light when current flows through it. Electrons in the semiconductor recombine with electron holes, releasing energy in the form of photons. The color of the light (corresponding to the energy of the photons) is determined by the energy required for electrons to cross the band gap of the semiconductor. White light is obtained by using multiple semiconductors or a layer of light-emitting phosphor on the semiconductor device. Appearing as practical electronic components in 1962, the earliest LEDs emitted low-intensity infrared (IR) light. Infrared LEDs are used in remote-control circuits, such as those used with a wide variety of consumer electronics. The first visible-light LEDs were of low intensity and limited to red. Modern LEDs are available across the visible, ultraviolet (UV), and infrared wavelengths, with high light output.

Early LEDs were often used as indicator lamps, replacing small incandescent bulbs, and in seven-segment displays. Recent developments have produced high-output white light LEDs suitable for room and outdoor area lighting. LEDs have led to new displays and sensors, while their high switching rates are useful in advanced communications technology. LEDs have many advantages over incandescent light sources, including lower energy consumption, longer lifetime, improved physical robustness, smaller size, and faster switching. LEDs are used in applications as diverse as aviation lighting, automotive headlamps, advertising, general lighting, traffic signals, camera flashes, lighted wallpaper, horticultural grow lights, and medical devices.

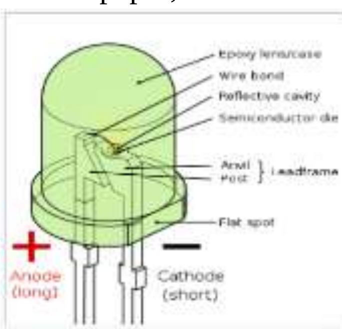

Figure 0.28: Parts of conventional LED

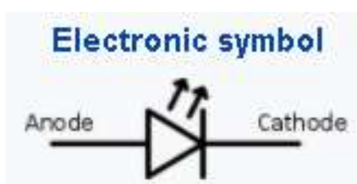

Figure 0.29:Electronic Symbol of LED

2.7.3 Liquid Crystal Display

Nowadays, we always use the devices which are made up of LCDs such as CD players, DVD players, digital watches, computers, etc. These are commonly used in the screen industries to replace the utilization of CRTs. Cathode Ray Tubes use huge power when compared with LCDs, and CRTs heavier as well as bigger. These devices are thinner as well power consumption is extremely less. The LCD 16×2 working principle is, it blocks the light rather than dissipate.

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Figure 0.30: 16x2 LCD

LCD 16×2 Pin Diagram

The 16×2 LCD pinout is shown below.

- Pin1 (Ground/Source Pin): This is a GND pin of display, used to connect the GND terminal of the microcontroller unit or power source.
- Pin2 (VCC/Source Pin): This is the voltage supply pin of the display, used to connect the supply pin of the power source.
- Pin3 (V0/VEE/Control Pin): This pin regulates the difference of the display, used to connect a changeable POT that can supply 0 to 5V.
- Pin4 (Register Select/Control Pin): This pin toggles among command or data register, used to connect a microcontroller unit pin and obtains either 0 or 1(0 = data mode, and 1 = command mode).
- Pin5 (Read/Write/Control Pin): This pin toggles the display among the read or writes operation, and it is connected to a microcontroller unit pin to get either 0 or 1 (0 = Write Operation, and 1 = Read Operation).
- Pin 6 (Enable/Control Pin): This pin should be held high to execute Read/Write process, and it is connected to the microcontroller unit & constantly held high.

- Pins 7-14 (Data Pins): These pins are used to send data to the display. These pins are connected in two-wire modes like 4-wire mode and 8-wire mode. In 4-wire mode, only four pins are connected to the microcontroller unit like 0 to 3, whereas in 8-wire mode, 8-pins are connected to microcontroller unit like 0 to 7.
- Pin15 (+ve pin of the LED): This pin is connected to +5V
- Pin 16 (-ve pin of the LED): This pin is connected to GND.

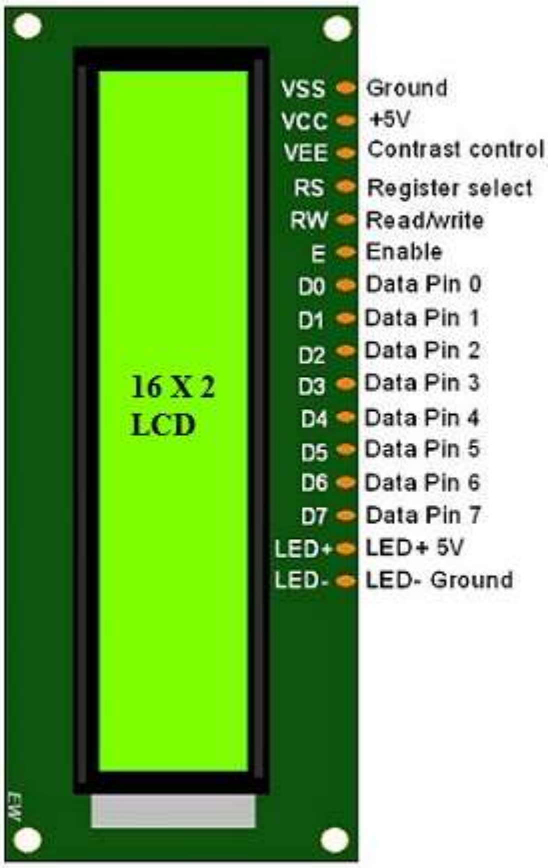

Figure 0.31:16x2 LCD pin-diagram

CHAPTER 3: SOLAR TECHNOLOGY

There are three primary technologies by which solar energy is harnessed: photovoltaics (PV), which directly convert light to electricity; concentrating solar power (CSP), which uses heat from the sun (thermal energy) to drive utility-scale, electric turbines; and solar heating and cooling (SHC) systems, which collect thermal energy to provide hot water and air heating or conditioning.

3.1 PHOTOVOLTAICS

Photovoltaic (PV) devices generate electricity directly from sunlight via an electronic process that occurs naturally in certain types of material, called semiconductors. Electrons in these materials are freed by solar energy and can be induced to travel through an electrical circuit, powering electrical devices or sending electricity to the grid.

PV devices can be used to power anything from small electronics such as calculators and road signs up to homes and large commercial businesses.

3.1.1 How does PV technology work?

Photons strike and ionize semiconductor material on the solar panel, causing outer electrons to break free of their atomic bonds. Due to the semiconductor structure, the electrons are forced in one direction creating a flow of electrical current. Solar cells are not 100% efficient in crystalline silicon solar cells, in part because only certain light within the spectrum can be absorbed. Some of the light spectrum is reflected, some is too weak to create electricity (infrared) and some (ultraviolet) creates heat energy instead of electricity.

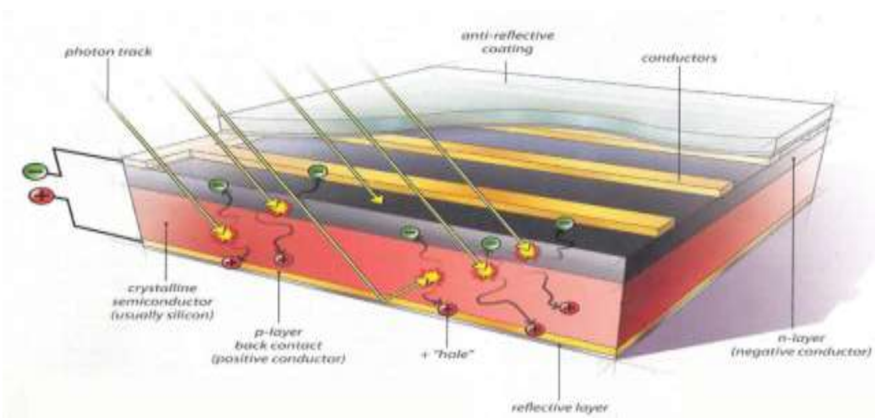

Figure 0.1: Diagram of a typical crystalline silicon solar cell. To make this type of cell, wafers of high-purity silicon are "doped" with various impurities and fused together. The resulting structure creates a pathway for electrical current within and between the solar cells

3.2 HISTORY OF PHOTOVOLTAIC TECHNOLOGY

In 1839, the ability of some materials to create an electrical charge from light exposure was first observed by Alexandre-Edmond Becquerel. Though the premiere solar panels were too inefficient for even simple electric devices they were used as an instrument to measure light. The observation by Becquerel was not replicated again until 1873, when Willoughby Smith discovered that the charge could be caused by light hitting selenium. After this discovery, William Grylls Adams and Richard Evans Day published "The action of light on selenium" in 1876, describing the experiment they used to replicate Smith's results.

Figure 0.2: Alexandre-Edmond Becquerel

Figure 0.3: Willoughby Smith

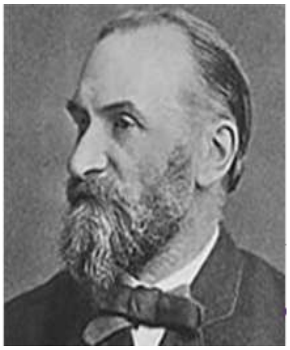

Figure 0.4: William Grylls Adams

Figure 0.5: Mohamed M. Atalla

In 1881, Charles Fritts created the first commercial solar panel, which was reported by Fritts as "continuous, constant and of considerable force not only by exposure to sunlight but also to dim, diffused daylight." However, these solar panels were very inefficient, especially compared to coal-fired power plants. In 1939, Russell Ohl created the solar cell design that is used in many modern solar panels. He patented his design in 1941. In 1954, this design was first used by Bell Labs to create the first commercially viable silicon solar cell. In 1957, Mohamed M. Atalla developed the process of silicon surface passivation by thermal oxidation at Bell Labs. The surface passivation process has since been critical to solar cell efficiency.

3.3 OTHER TYPES OF PHOTOVOLTAIC TECHNOLOGY

Most solar modules are currently produced from crystalline silicon (c-Si) solar cells made of multi-crystalline and monocrystalline silicon. In 2013, crystalline silicon accounted for more than 90 percent of worldwide PV production, while the rest of the overall market is made up of thin-film technologies using cadmium telluride, CIGS and amorphous silicon.

In addition to crystalline silicon (c-Si), there are three other main types of PV technology, Emerging, third generation solar technologies use advanced thin-film cells. They produce a relatively high-efficiency conversion for the low cost compared to other solar technologies. Also, high-cost, high-efficiency, and close-packed rectangular multi-junction (MJ) cells are preferably used in solar panels on spacecraft, as they offer the highest ratio of generated power per kilogram lifted into space. MJ-cells are compound semiconductors and made of gallium arsenide (GaAs) and other semiconductor materials. Another emerging PV technology using MJ-cells is concentrator photo-voltaic (CPV).

3.3.1 Thin film

In rigid thin-film modules, the cell and the module are manufactured in the same production line. The cell is created on a glass substrate or superstrate, and the electrical connections are created in situ, a so-called "monolithic integration." The substrate or superstrate is laminated with an encapsulant to a front or back sheet, usually another sheet of glass. The main cell technologies in this category are CdTe, or a-Si, or a-Si+uc-Si tandem, or CIGS (or variant). Amorphous silicon has a sunlight conversion rate of 6–12%.

Figure 0.6: thin-film silicon laminates being installed onto a roof.

Flexible thin film cells and modules are created on the same production line by depositing the photoactive layer and other necessary layers on a flexible substrate. If the substrate is an insulator (e.g. polyester or polyimide film) then monolithic integration can be used. If it is a conductor then another technique for electrical connection must be used. The cells are assembled into modules by laminating them to a transparent color-less fluoropolymer on the front side and a polymer suitable for bonding to the final substrate on the other side

3.3.2 Concentrator photovoltaics

Concentrator photovoltaics is a photovoltaic technology that generates electricity from sunlight. Unlike conventional photovoltaic systems, it uses lenses or curved mirrors to focus sunlight onto small, highly efficient, multi-junction (MJ) solar cells. In addition, CPV systems often use solar trackers and sometimes a cooling system to further increase their efficiency.

Figure 0.7: Thousands of small Fresnel lenses, each focusing sunlight to ~500X higher intensity onto a tiny, high-efficiency multi-junction solar cell.

All CPV systems have a solar cell and a concentrating optic. Optical sunlight concentrators for CPV introduce a very specific design problem, with features that make them different from most other optical designs. They have to be efficient, suitable for mass production, capable of high concentration, insensitive to manufacturing and mounting inaccuracies, and capable of providing uniform illumination of the cell. All these reasons make non-imaging optics the most suitable for CPV.

For very low concentrations, the wide acceptance angles of non-imaging optics avoid the need for active solar tracking. For medium and high concentrations, a wide acceptance angle can be seen as a measure of how tolerant the optic is to imperfections in the whole system. It is vital to start with a wide acceptance angle since it must be able to accommodate tracking errors, movements of the system due to wind, imperfectly manufactured optics, imperfectly assembled components, finite stiffness of the supporting structure or its deformation due to aging, among other factors. All of these reduce the initial acceptance angle and, after they are all factored in, the system must still be able to capture the finite angular aperture of sunlight.

3.3.3 Building-integrated photovoltaics (BIPV)

Building-integrated photovoltaics (BIPV) are photovoltaic materials that are used to replace conventional building materials in parts of the building envelope such as the roof, skylights, or facades. They are increasingly being incorporated into the construction of new buildings as a principal or ancillary source of electrical power, although existing buildings may be retrofitted with similar technology. The advantage of integrated photovoltaics over more common non-integrated systems is that the initial cost can be offset by reducing the amount spent on building materials and labor that would normally be used to construct the part of the building that the BIPV modules replace. These advantages make BIPV one of the fastest growing segments of the photovoltaic industry

Figure 0.8: The CIS Tower in Manchester, England was clad in PV panels at a cost of £5.5 million

The term building-applied photovoltaics (BAPV) is sometimes used to refer to photovoltaics that are a retrofit – integrated into the building after construction is complete. Most building-integrated installations are actually BAPV. Some manufacturers and builders differentiate new construction BIPV from BAPV.

3.4 COSTS OF SOLAR PHOTOVOLTAICS

The price of solar electrical power has continued to fall so that in many countries it has become cheaper than ordinary fossil fuel electricity from the electricity grid since 2012, a phenomenon known as grid parity.

Average pricing information divides in three pricing categories: those buying small quantities (modules of all sizes in the kilowatt range annually), mid-range buyers (typically up to 10 MWp annually), and large quantity buyers (self-explanatory—and with access to the lowest prices). Over the long term there is clearly a systematic reduction in the price of cells and modules. For example, in 2012 it was estimated that the quantity cost per watt was about US$0.60, which was 250 times lower than the cost in 1970 of US$150. A 2015 study shows price/kWh dropping by 10% per year since 1980, and predicts that solar could contribute 20% of total electricity consumption by 2030, whereas the International Energy Agency predicts 16% by 2050.

Real-world energy production costs depend a great deal on local weather conditions. In a cloudy country such as the United Kingdom, the cost per produced kWh is higher than in sunnier countries like Spain.

According to U.S. Energy Information Administration, prices per megawatt-hour are expected to converge and reach parity with conventional energy production sources during the period 2020–2030. According to EIA, the parity can be achieved without the need for subsidy support and can be accomplished through organic market mechanisms, namely production price reduction and technological advancement.

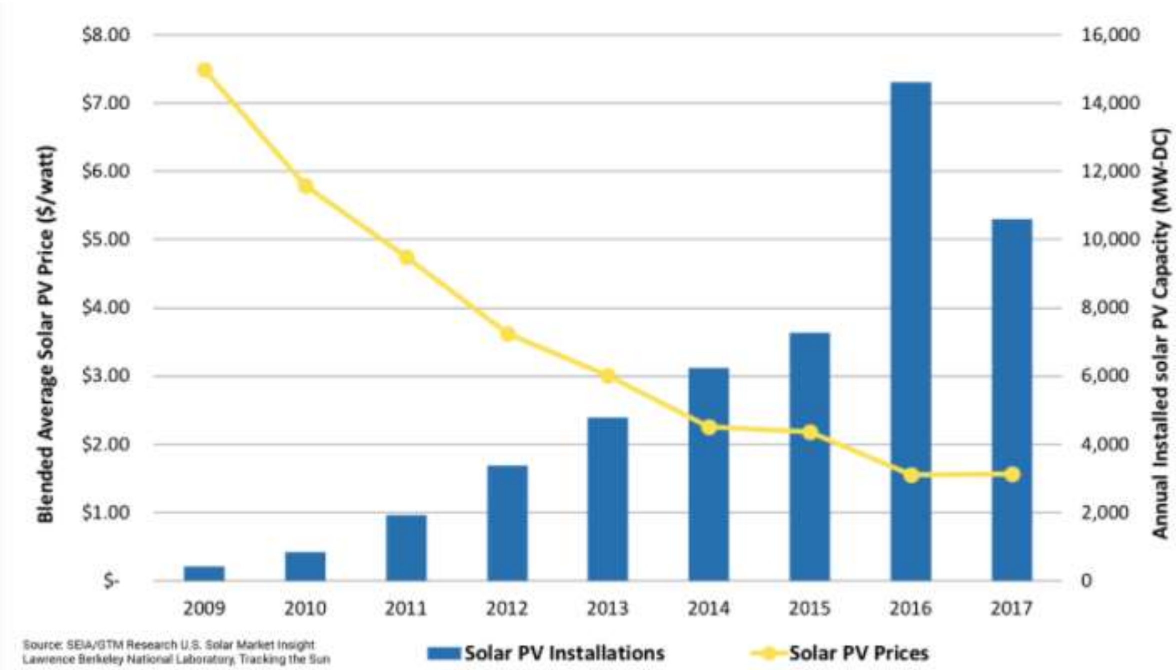

Figure 0.9 :graph of falling solar PV cells and rising solar PV installations

Following to RMI, Balance-of-System (BoS) elements, this is, non-module cost of non-microinverter solar modules (as wiring, converters, racking systems and various components) make up about half of the total costs of installations.

For merchant solar power stations, where the electricity is being sold into the electricity transmission network, the cost of solar energy will need to match the wholesale electricity price. This point is sometimes called 'wholesale grid parity' or 'busbar parity'.

Some photovoltaic systems, such as rooftop installations, can supply power directly to an electricity user. In these cases, the installation can be competitive when the output cost matches the price at which the user pays for his electricity consumption. This situation is sometimes called 'retail grid parity', 'socket parity' or 'dynamic grid parity'. Research carried out by UN Energy in 2012 suggests areas of sunny countries with high electricity prices, such as Italy, Spain and Australia, and areas using diesel generators, have reached retail grid parity.

3.5 MODERN PHOTOVOLTAICS

The cost of PV has dropped dramatically as the industry has scaled up manufacturing and incrementally improved the technology with new materials. Installation costs have come down too with more experienced and trained installers. Globally, the U.S. has the third largest market for PV installations, and is continuing to rapidly grow.

Most modern solar cells are made from either crystalline silicon or thin-film semiconductor material. Silicon cells are more efficient at converting sunlight to electricity, but generally have higher manufacturing costs. Thin-film materials typically have lower efficiencies, but can be simpler and less costly to manufacture. A specialized category of solar cells - called multi-junction or tandem cells - are used in applications requiring very low weight and very high efficiencies, such as satellites and military applications. All types of PV systems are widely used today in a variety of applications.

There are thousands of individual photovoltaic panel models available today from hundreds of companies. Compare solar panels by their efficiency, power output, warranties, and more on Energy-Save.

CHAPTER 4: PROJECT

4.1 AIM

Since the fuel prices not only in India but throughout the world is increasing day by day thus there is a tremendous need to search for an alternative to conserve these natural resources. Thus a solar vehicle is an electric vehicle that provides that alternative by harnessing solar energy to charge the battery and thus provide required voltage to run the motor. Since India is blessed with nine months of sunny climate thus concept of solar vehicle is very friendly in India. Thus solar vehicle can become a very vital alternative to the fuel using automobile thus its manufacturing is essential as:

- Using solar energy to enhance the efficiency of the vehicle so that we can drive it for a longer time.
- Shifting towards Sustainable movement by saving fossil fuels and using sunlight, a renewable resource.
- To reduce pollution in the environment, as solar vehicles do not emit toxic gases.

4.2 BLOCK DIAGRAM

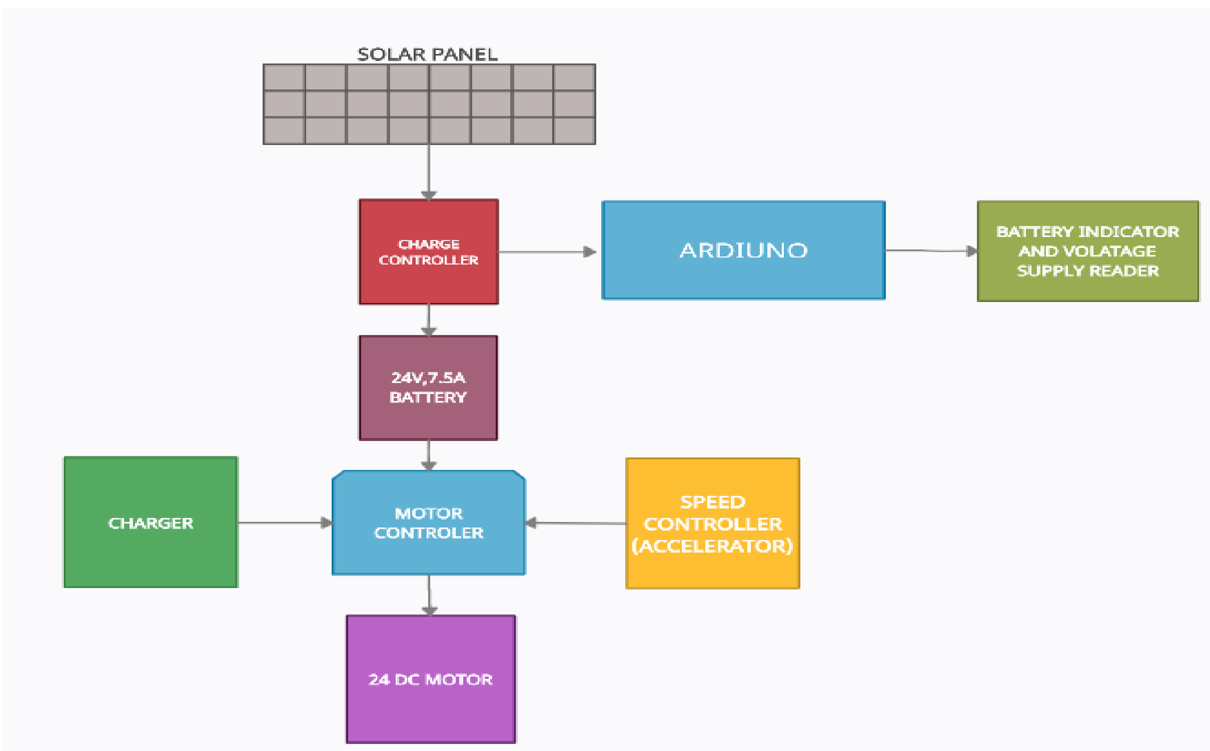

Figure 0.1 Basic block diagram of working of Solar Bike

4.3 WORKING MODEL

4.3.1 Modifications:

Here we used a cycle to implement our project. To make sure that everything works well we have to make some modifications which include

- Arranging frames on the front and back to the cycle to place solar panels
- Making a box to hold batteries and other used equipment.
- Adjusting DC motor using brackets and nut bolts to rotate the wheel.
- Installing brakes and accelerator to control the motor.

Let us discuss every modification step by step below.

- Arranging frames: Since the stock cycle comes with minimal metal we can’t simply install solar panels. So to overcome this problem we designed a pair of iron frames that can be fitted to cycle by holding solar panels on top of it.
  Here we have to think about the efficient usage of solar panels that give 100% of it. So to experience that we have to arrange solar panels in such a way that they are always exposed to the sun during our ride and during rest as well. So considering all these we placed the front solar panel above the front tire with a little angle and arranged the back panel on the back tire which is straight. We used welding throughout this process. After checking the reading’s we succeeded in doing what we thought.

Figure 0.2: Solar panel fitted on the front

Figure 0.3: Solar panel fitted on the back

- Since we dealt with the solar panel arrangement it's now time to see our possible chances to arrange batteries and controllers along with wires so that the overall model looks good to our eyes instead of having hanging wires and exposed hardware which not only looks bad but also harmful when exposed.
  We decided to go with a box made with steel that is welded to the right side of the cycle. We punctured two one-inch holes, one of them is used to take wires from outside and the other to install a security lock to increase the safety of the vehicle. To avoid the incidents like thefts we made an inbuilt hinge lock to the box.
  The box capacity is designed in such a way that it can accommodate up to four lead-acid batteries and controllers. Right now we installed only two batteries keeping expenses in our mind, but since there's a way to arrange two more batteries it will always be a handy option for us to add them if the present output feels underpowered.

Figure 0.4: Battery arrangement and connections fitted in a steel box

- Arranging the accessories, just out with the old and in with the new. With a decent quality accelerator and brake, it will be easy to control the motor working without any hurdles. To display the battery percentage we installed Arduino controlled battery level indication with the help of LED's and, we also programmed the Arduino to display the voltage supply given out by the lead-acid batteries

- Finally the motor. We have to be accurate and precise while arranging the motor to the cycle. There is no margin for error here. Even a little imbalance between cycle wheel and motor gear will lead do chain damage that helps to rotate the cycle wheel from motor. We spent enough time and tried all possible combinations to set the motor in such a way that it is stable even with heavier loads.

Figure 0.5: Motor Fixed to the back wheel.

Figure 0.6:Chain arrangement to make the wheel turn with help of Motor

This is all about the modifications we made to the stock cycle to use it as a solar electric vehicle. Now we look forward to the working part of the vehicle.

4.3.2 Working

Now every component is arranged at their respective place, the only thing left is to turn on the power to the vehicle and go for a ride. But to do that we have to know how this entire system works.

From the above block diagram, we'll get a basic idea of what's going on. Let us divide this block diagram into two parts 1. Below Part and 2. Above part.

The below part tells us how the connections are made between motor and controller and the above part explains us additionally how solar panels are arranged and used along with the main system.

In this entire arrangement, the motor controller is the heart of the system. It is used to control the motor by taking the input from the accelerator and brakes. The accelerator is used to control the speed of the motor and brakes are used to cut the power supply to the motor so that there will be no rotation exist. The internal structure and working phenomenon of every individual part have been explained in the components section. The motor controller is also used to power the headlamps, brake lights. It also comes with an inbuilt charging port which allows us to charge the batteries using an adaptor. The working of this model is as simple as this: The motor controller takes the input from the accelerator and controls the rotation of the motor and it takes input from brakes to cut off the rotation of the motor. But without an external energy source, it is not possible to use the motor. So we have to connect the batteries to the power port on the motor controller to supply adequate power to drive the motor. There are some other minor components such as headlamps, charge indicators which are used according to our comfort.

To this system, we additionally need to connect the solar panels to make this an efficient model to use. After arranging the panels, we have to connect the two 12v solar panels in series making in 24v. these wires from solar panels are connected to the charge controller. The use of a charge controller is to avoid any fluctuations and to avoid overcharging of the batteries. To charge the batteries with solar energy we have to connect the battery terminals at their respective terminals on the charge controller. Since we have 2 options to charge the bike now out of which one is a continuous source, we have succeeded in making an efficient and low-cost electric vehicle to use.

4.3.3 : Ardiuno programming for battery level indication and voltage supply display

The indicator shows the status of the battery by lighting LEDs on a LED Bar Graph depending on the battery voltage reading.

We all know that batteries come with a certain voltage limit. Exceeding or completely losing the battery’s voltage can lead to a lot of frustration, component damage, or data loss. to be able to monitor the battery’s to decide whether it needs to be charged or replaced, adding of this feature makes it more convenient and reliable to use.

It is good to understand that batteries have what we call a level of charge. It can be understood as the amount of voltage contained in your battery.The Arduino's analog pin acts as a simple voltmeter where the voltage value is retrieved. Then, we can convert the analog value into a digital voltage value by using the ADC conversion formula.

The values we convert will display on the LED bar graph where it can project the strength. So, if all six LEDs are lit, the battery is at full strength. If only three LEDs are on, the battery is at half strength. The Arduino Uno ADC is of 10-bit resolution. The ADC converter will map input voltages between 0 and 5 volts into integer values between 0 and 1023. So if we multiply input analogValue to (5/1023), then we get the digital value of input voltage.

```
analogvalue = analogRead(A0);

voltage = value * (5.0/1023);
```

But the problem arises when the voltage to be measured exceeds 5 volts. This can be solved using a voltage divider circuit which consists of 2 resistors connected in series as shown. One end of this series connection is connected to the voltage to be measured (Vm) and the other end to the ground. A voltage (V1) proportional to the measured voltage will appear at the junction of two resistors. This junction can then be connected to the analog pin of the Arduino. The voltage can be found out using this formula.

V1 = Vm * (R2/(R1+R2))

The voltage V1 is then measured by the Arduino.

Now to build this voltage divider, we first need to find out the values of resistors. Follow these steps to calculate the value of resistors.

- Determine the maximum voltage which is to be measured.
- Decide a suitable and standard value for R1 in kilo-ohm range.
- Using formula, calculate R2.
- If the value of R2 is not (or close to) a standard value, change R1 and repeat the above steps.
- Since Arduino can handle a maximum of 5V, V1 = 5V.

For example, Let the maximum voltage (Vm) to be measured be 24V and R1 = 19 kilo-ohms. Then using the formula R2 comes out to be equal to 5kilo-ohms.

Now, Build a voltage divider circuit using these resistors.

With this setup, we now have an upper and lower limit. For Vm = 24V we get V1 = 5V and for Vm = 0V we get V1 = 0V. That is, for 0 to 24V at Vm, there will be a proportional voltage from 0 to 5V at V1 which can then be fed into the Arduino as before.

With a slight modification in the code, we can now measure 0 to 24V.

Analog value is read as before. Then, using the same formula mentioned previously, the voltage between 0 and 12V is measured.

```
analogvalue = analogRead(A0);

voltage = analogvalue * (5.0/1023) * ((R1 + R2)/R2);
```

Circuit diagram

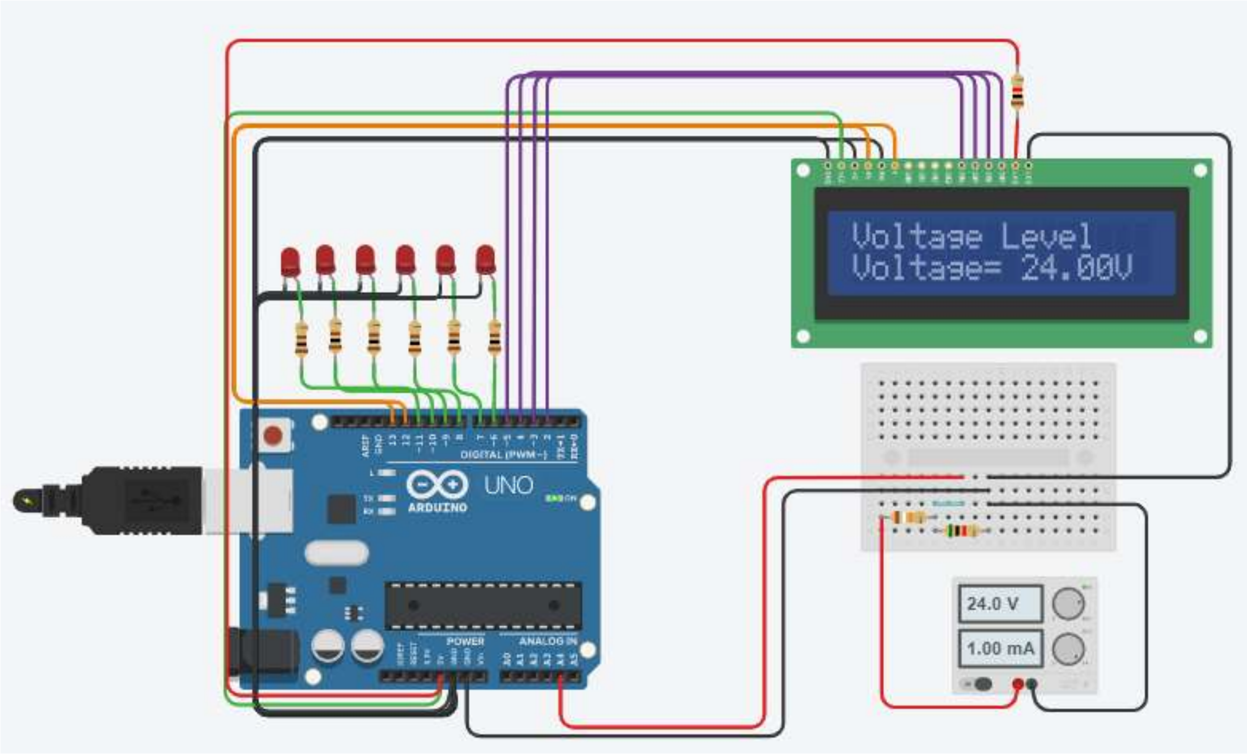

Figure 0.7: Circuit diagram of battery level indicator and voltage supply at full charge

CODE

```
#include <LiquidCrystal.h>

const int rs = 12, en = 13,d4 = 5, d5 = 4, d6 = 3, d7 = 2;

const int analogPin = A4;

LiquidCrystal lcd(rs, en, d4, d5, d6, d7);

float analogValue;

float input_voltage;

int ledPins[] = { 6, 7, 8, 9, 10, 11 }; // an array of pin numbers to which LEDs are attached

int pinCount = 6;           // the number of pins (i.e. the length of the array)

void setup()

{

  Serial.begin(9600);     //  opens serial port, sets data rate to 9600 bps

  lcd.begin(16, 2);       //// set up the LCD's number of columns and rows:

  pinMode(A4,INPUT);

  lcd.print("Voltage Level");

}

void LED_function(int stage)

{

   for (int j=6; j<=11; j++)

   {

   digitalWrite(j,LOW);

   }

   for (int i=1, l=1; i<=stage; i++,l++)

   {

   digitalWrite(l,HIGH);
```

```
    }
}
void loop()
{
//  Conversion formula for voltage
  analogValue = analogRead (A4);
  Serial.println(analogValue);
  delay (1000);
  input_voltage = (analogValue * (5.0/1023) * 4.8);
  lcd.setCursor(0, 1);
  lcd.print("Voltage= ");
  lcd.print(input_voltage);
  lcd.print("V");
  Serial.println(input_voltage);
  delay(100);

  if (input_voltage < 0.50 && input_voltage >= 0.00 )
    {
    digitalWrite(1, HIGH);
    delay (30);
    digitalWrite(1, LOW);
    delay (30);
    }
   else if (input_voltage < 4 && input_voltage >= 0.50)
    {
```

```
  LED_function(6);
  }
 else if (input_voltage <8 && input_voltage >= 4)
  {
  LED_function(7);
  }
 else if (input_voltage < 12 && input_voltage >= 8)
  {
  LED_function(8);
  }
 else if (input_voltage < 16 && input_voltage >= 12)
  {
  LED_function(9);
  }
 else if (input_voltage < 20 && input_voltage >= 16)
  {
  LED_function(10);
  }
 else if (input_voltage <= 24 && input_voltage >= 20)
  {
  LED_function(11);
  }
}
```

4.4 OBSERVATIONS

For observing the battery voltage, and the power given out from the solar panels and different situation we have used the multimeter and have noted down the readings as shown below:

4.4.1 Battery voltage

As mentioned in the components section we have use two 12V,7.5Ah lead-acid batteries and connected them in series, hence the expected output in multimeter was to get 24V, and the observation was met as shown in the below figure and have observed 24V.

Figure 0.8: Battery voltage showing a reading of 24V

4.4.2 Voltage from solar panel under shade

The reading of the voltage produced by the two 12 V solar panels which were connected in series and observed under shade was expected to be lower than the half of the fully effective solar panels and hence the reading we got was 10V.

Figure 0.9: Voltage from solar panel under shade reading as 10V

4.4.3 Voltage from solar panel under indirect sunlight

The reading of the voltage produced by the two 12 V solar panels which were connected in series and observed under indirect sunlight was expected to be greater than the half of the fully effective solar panels reading and lower than fully effective solar panels reading and hence the reading we got was 24V.

Figure 0.10:Voltage from solar panel under indirect sunlight reading as 24V

4.4.4 Voltage from solar panel under direct sunlight

The reading of the voltage produced by the two 12 V solar panels which were connected in series and observed under direct sunlight was expected to be equal or greater than fully effective solar panels reading and hence the reading we got was greater than 25V.

Figure 0.11: voltage from solar panel under direct sunlight reading as greater than 25V

4.4.5 Simulation of Motor:

To get the characteristics of a permanent magnet DC motor we used MATLAB and Simulink to design a mathematical model of motor and display Speed and Torque characteristics.

The equations involved in building a mathematical model are:

Va=iaRa+La(dia/dt)+Eb

Eb=(KePhi)Wm

Tm=(KePhi)Ia=TL+J(dWm/dt)+BWm

Applying Laplace transform for further analysis we get

Va(S)-Eb(S)=Ia(S)[Ra+SLa]

Ia(S)=(Va(S)-Eb(S))/(Ra+SLa) that leads to Ia(S)=(Va(S)-Eb(S))/Ra(1+STau_a) where Tau_a=La/Ra.

Motor Speed (Wm(S))= (Tm(S)-TL(S))/(B(1+STau_m))

Finally Armature Current is given as Ia(S)=(Va(S)-(KePhi)Wm(s))/Ra(1+STau_a)

Where

Va= Applied Voltage

Ra= Armature Resistance

La= Armature Inductance

B= Viscous fiction Co-efficient

J= Moment of Inertia

TL= Load Torque

Tau_a= Armature time constant

Tau_m= Mechanical time constant

KePhi= Constant

Eb= Back EMF.

The Mathematical representation of a Permanent Magnet DC motor using above equations looks like:

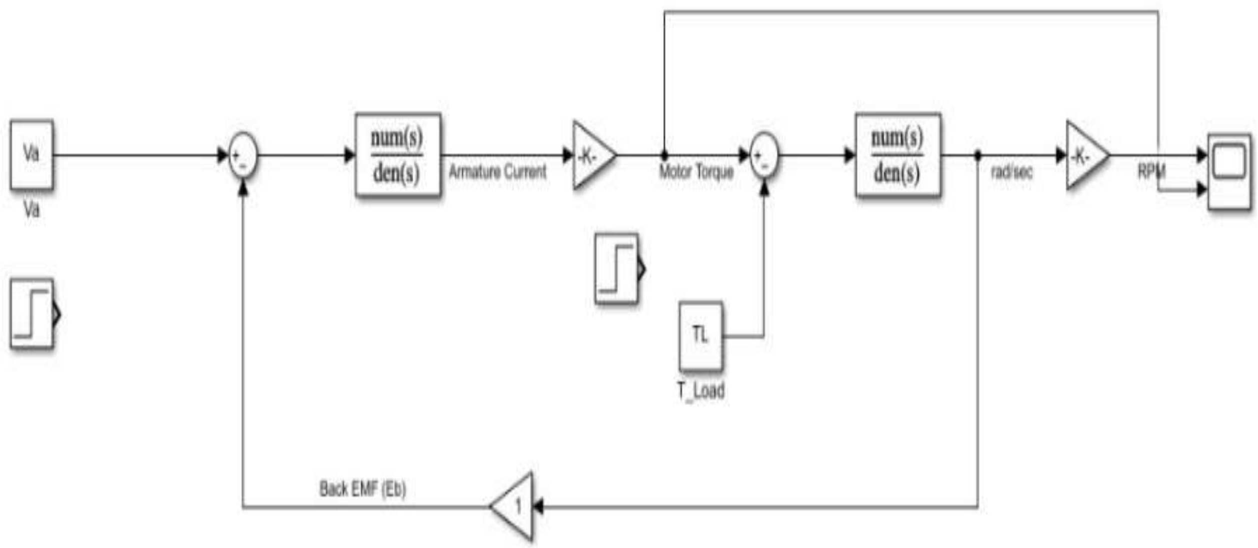

Figure 0.12: Mathematical representation of Permanent Magnet DC motor

The Default Values for Motor are:

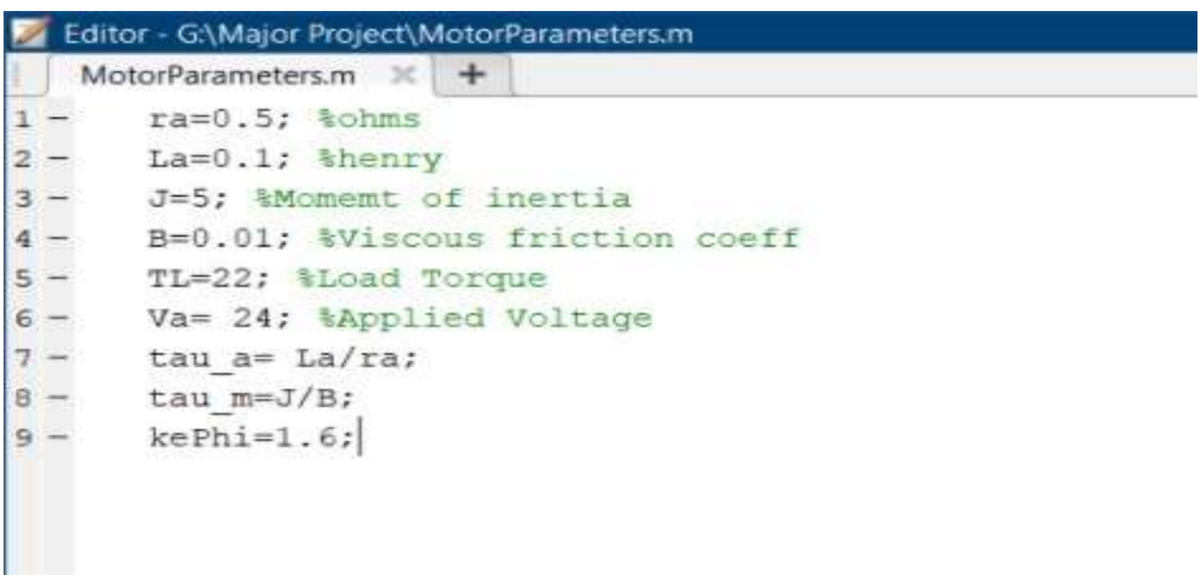

Figure 0.13: Default values for motor

The Speed and Load characteristics of motor looks like:

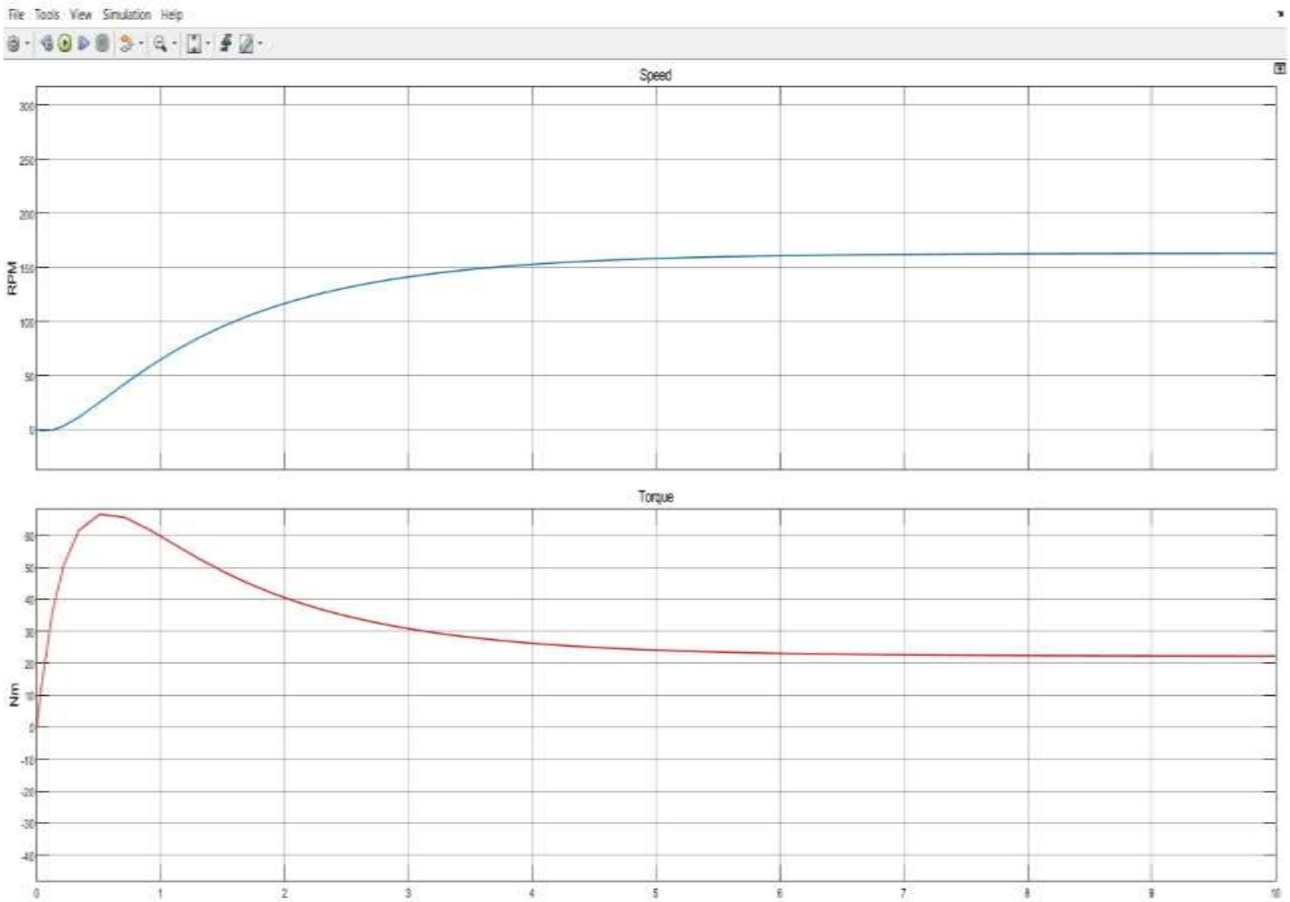

Figure 0.14 : Speed and Torque Characteristics.

4.5 RESULTS

After the completion of the project the expected result was to check if all the advantages are met and to check the successful running of the vehicle. the vehicle is working and running successfully and also has the met the descent speed condition.

The solar vehicle runs at a maximum speed of 15kmph without pedaling and working completely dependent on the solar power charge, and 25kmph with pedaling.

We took the speed reading with the help of google maps which shows the speed of the vehicle when on the go, as shown below.

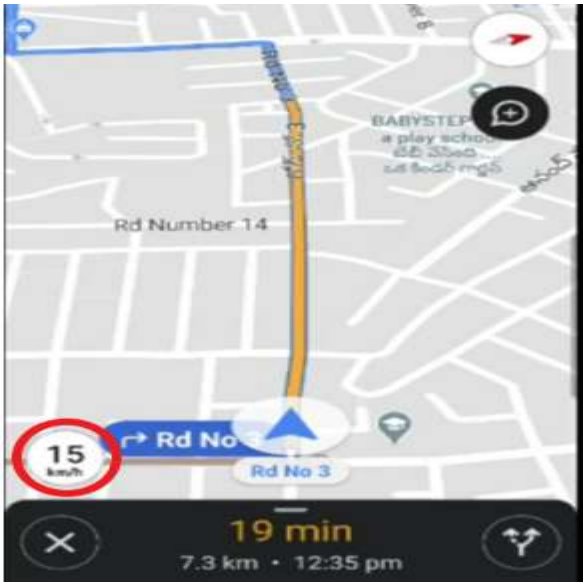

Figure 0.15: Red circle showing the max. speed of solar vehicle without pedaling

Figure 0.16: Red circle showing the max. speed of solar vehicle with pedaling

CHAPTER 5: ADVANTAGES AND DISADVANTAGES

5.1 ADVANTAGES

TIME SAVER

They get you to places faster than the average speed of traffic, Urban congestion has led to a state of affairs where traffic moves much slowly at peak hours. In such a scenario, a solar vehicle will get you to your destination faster than a normal car. The solar powered vehicle tops at 25 kmph, which means given a free road it can travel 4 km in approximately 10 minutes. If there is a roadblock approaching, you can easily man-oeuvre it within the traffic.

HEALTHY LIFESTYLE

Introducing a solar vehicle into your daily life means that you are blocking out certain times of the day for physical activity by default. High levels of Pedal Boost can help you travel to your destination with lesser effort. A solar vehicle has a Throttle mechanism which you can rely on the to take the exhaustion out of your pedaling.

COST-EFFICIENT

your daily fitness routine now comes free of cost, as you don't have to buy a gym membership. Since your solar vehicle actually saves you the cost of petrol, your savings are twofold.

ECOFRIENDLY

Once you adopt a solar vehicle as a means to commute and travel, you effectively remove one petrol guzzler from the roads. That's a very significant change.

5.2 DISADVANTAGES

- The solar panels or the photovoltaic cell can only convert 20-30% of the sunlight into electricity depending upon the material that has been used.
- The solar vehicle does not have driver safety features
- Lower solar production in the winter months.
- Cloudy days do not produce as much energy.
- Solar powered vehicles do not have the same speeds and power as typical gas powered vehicles.
- Looks unattractive to public
- Does not work effectively during nights
- Solar panels are not being massed produced due to lack of material and technology to lower the cost enough to be more affordable.

5.3 FUTURE SCOPE

Solar cars are quickly becoming a reality that many are very excited about. In fact, the first solar vehicle may hit the road in 2019. The technology is still somewhat in its infancy and needs to have some time to work out unexpected issues. However, solar cars could be on their way to regular people's driveways in the near future.

One Dutch company has already put a vehicle to the test. It averaged a speed of 69 kilometers per hour and was able to travel across Australia from Darwin to Adelaide. While doing so, it was even able to resupply the grid and power some of the areas that it passed through.

This information indicates that a future solar car may be able to not only supply itself for either short trips to and from work or long trips across the country, but may also be able to play a role in contributing to the world power supply. This is big news considering some of the major issues associated with the world's growing power needs. Modern technologies are coming a long way.

There are a number of significant health and environmental problems associated with the current status quo in transportation. Although still in early stages of their development, solar cars offer real promise and a way forward in combating these issues. Early models are promising, and it may not be long before the solar car becomes a regular sight on a road near you.

CONCLUSION

Solar power is an immense source of directly useable energy and ultimately creates other energy resources: biomass, wind, hydropower and wave energy. Most of the Earth's surface receives sufficient solar energy to permit low-grade heating of water and buildings, although there are large variations with latitude and season. At low latitudes, simple mirror devices can concentrate solar energy sufficiently for cooking and even for driving steam turbines.

The energy of light shifts electrons in some semiconducting materials. This photovoltaic effect is capable of large-scale electricity generation. However, the present low efficiency of solar PV cells demands very large areas to supply electricity demands. Direct use of solar energy is the only renewable means capable of ultimately supplanting current global energy supply from non-renewable sources, but at the expense of a land area of at least half a million km

The solar vehicle solves many problems related to the environment and is the best pollution free method. We need to make use of them so that we can reduce our dependence on fossil fuels. Solar vehicles do have some disadvantages like small speed range, initial cost is high. Also, the rate of conversion of energy is not satisfactory (only 17%). But these disadvantages can be easily overcome by conducting further research in this area; like the problem of solar cells can be solved by using the ultraefficient. solar cells that give about 30-35% efficiency. As this field of automobiles will be explored the problems will get solved. The solar automobiles have a huge prospective market and we should start using them in our day to day life.

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