A

Project Report

On

"Development of Solar Based Charging Station for E-Bicycle"

A Project Report

Submitted in the partial fulfilment of the requirements

For the Degree of

Bachelor of Engineering

In

Electrical (Electronics & Power)

Sant Gadge Baba Amravati University, Amravati

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DEPARTMENT OF ELECTRICAL ENGINEERING

SHRI SANT GAJANAN MAHARAJ COLLEGE OF ENGINEERING

SHEGAON 444203 M.S (INDIA)

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CERTIFICATE

Certified that the project report entitled, **"Development of Solar Based Charging Station For E-Bicycle"** is a bonafide work done under my guidance by

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In partial fulfilment of the requirements for the award of degree of Bachelor of Engineering in Electrical (Electronics & Power).

Date: 13/05/2023

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Abstract

A solar charging station is meant so ensure that vehicles is fully charged and are environmentally safe. This technique transforms solar power to electricity and stores it in a battery bank. Solar energy is a renewable energy source that is obtained from sunlight. It provides clean energy that comes from natural sources, which are free everywhere. Solar energy can be obtained through the use of solar panel. Solar photovoltaic energy is widely used for a variety of purposes, heating, cooking, and power generating. The utilisation of more amount of renewable energy will lower the prices of and demand for fossil fuels. The development of solar-powered vehicles has been boosted by recent invention. Electric vehicles are becoming more popular and must be truly imperishable, it's essential to charge them from sustainable sources of electricity, like solar or wind energy, geothermal etc. Electric Vehicles are becoming an attractive option for reducing global fossil fuel usage, as well as CO2 emission, from road transportation. So, for the purpose of eliminating fossil fuels and CO2 emission, this project focus on to promote renewable energy consumption, specific solar system based charging station. The report describes the development of a solar charging system for E-bicycle using a solar charge controller and also describes the components which are used in this project like solar panel, solar charge controller, battery, and BLDC motor. The proposed system's implementation will decrease the electricity costs as well as trying to reduce the charging time. In addition, the proposed solar charging system will be one of the steps taken to create an eco-friendly environment.

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CHAPTER-1

Introduction

At present, energy crisis is a vital unsolvable problem. The consumption and extraction cost of fossil fuels such as gasoline and diesel are very high. The major reason of the surplus usage of these fossils fuel-based vehicle is that have enhanced the excavating of these conventional resources in an untenable approach and population is also increasing day by day demand for vehicles hence is increasing. But fossil fuels have limitations such as pollution, economic problems due to their high cost, continuously growing environmental concerns as greenhouse gas emissions which causing global warming. Global warming is becoming major problems in the current scenario. Therefore, people try to move towards clean energy. And another important point is that it is a non-renewable energy. Transportation is one of the main sources of pollution or global warming because bike or any type of vehicle work on fuel e.g., petrol, diesel it burns and produce harmful gases in air due to which pollution is increasing. Considering these points and health benefits, cost reduction, environment friendliness and nearby travelling, demand of E-bicycles is increasing.

But as we know that current electricity grid is still primarily powered by fossil fuels. Which results in indirect emission at power plant. To solve this problem, we have used sun as source of energy. Which generates electricity from solar energy which is used to charge E-bicycle. Solar energy is a renewable source of energy. In terms of availability, it can be effective alternative because it is free from everywhere and also has advantages such as low cost, environment friendliness. This project is about the usage of solar energy to power up the vehicle. For use of photovoltaic power generation and storage system, in combination with conventional grid electricity and network force method, to establish a safe and reliable, no noise, no pollution of solar grid storage type electric vehicle status of the power system, in order to achieve stable for the electric vehicle charging and achieve energy-saving emission reduction.

Bicycling has enjoyed a renaissance as a form of urban transportation that is well suited for shorter rides. The emergence of bike share systems in cities around the world has further increased the popularity of bicycling as a “fun” form of transport. Bicycling provides many benefits, both to riders and to cities. From a rider’s standpoint, bicycling is seen as a form of transportation that is well suited for quick getaways and one that promotes an active lifestyle that provides health benefits. From the standpoint of cities, bicycling and bike share systems provide greening benefits. Bike rides can reduce reliance on cars, especially for very short rides (e.g. a few city blocks to a few kilometres), which reduces congestion on city roads. Bicycling is also a zero-carbon form of transportation which reduces pollution and carbon emissions.

CHAPTER-2

Literature Survey

To establish a charging station solar panel, solar charge controller, LiFePO4 battery is used. PV cells are mainly of three types monocrystalline silicon, polycrystalline silicon and amorphous silicon. In this literature Survey we have studied and compare all of these three types of PV cells and select polycrystalline silicon due to its high efficiency and low cost. In electric bicycles mostly lithium iron phosphate battery is used. Literature Survey help us in study of different components of this project and also in selection process.

2.1 A paper on "Greening Electric Bike Sharing Using Solar Charging Station" by John Wamburu, Christopher Raff, David Irwin and Prashant Shenoy.

This paper presented the design of a solar powered bike charging prototype. By combining measurements taken from the prototype with real world ridership data, it showed how the design can be scaled to an entire bike sharing program. They performed data-driven analysis to show feasibility of the design in net-zero and fully-zero carbon electric bike share systems. Its results indicated that a single solar panel installed at each station in the bike share system is sufficient to meet the annual demand of energy by the station, and that net-zero operation can be achieved using net-metering. It also showed that for an off-grid setup, a station needs twice the number of solar panels on average, along with a 1.8KWh battery, with the busiest bike station needing 6× more solar capacity than in the net-metering setup. Further, it showed that to achieve true-zero operation, a trade off between the size of solar array and battery size exists, with the number of solar panels ranging from 1 to 6, and battery size varying between 2.4kWh and 1.5kWh for a sample station. Finally, it showed that up to 1.1MT of CO2 emission can be reduced annually by substituting grid energy with solar in a bike sharing system.

2.2 A paper on "Solar charging station for electric vehicles" by Takadir S Pinjari, Sayali Shinde, Roshni Salunkhe, Shubham Gadhave, Shubham Bansode.

In this paper more electronic devices used to increase in energy consumption.Sun radiates, out close to 3.8*1026 joules of solar energy each second. Which we can used to generate electricity. It has Greater efficiency and reliability to access electric power for charging electric cars without environment pollution.

This paper presenting the solar charging station for sort of electric vehicles, which is generally used to avoid use of non-renewable source of energy to charge for all intents and purposes electric vehicles, which is fairly significant. This study develops a model that really combines the solar power station and

EVs to mostly reduce pollutants emission from the power generation and transportation sector in a suitable way.

2.3 A paper on "Solar PV based Electric Vehicle" by Nirmala. M, Malarvizhi. K, Thenemozhi. G

The projected paper describes solar PV powered Electric Vehicle , that solves the key downside of fuel and pollution. Electric vehicle uses a battery that is charged from an external power supply, but solar PV modules are used to charge a battery. This planned model has Buck-Boost convertor which is used to control the battery from the prime possible power generation using a solar PV system fixed on the vehicle. An effectiveness of the proposed system has been modelled and its results, verified in MATLAB/SIMULINK.The proposed solar powered electric vehicle has several merits such as fuel efficient, reduction in the pollution and provides noiseless operation. The paper deliberates about operation of the BLDC motor in closed loop control in accord with the change in solar irradiance condition and change in set speed of an electric vehicle. The advantages of BLDC motor are higher value of efficiency, power density and speed ranges, which makes selection of this motor, for various applications.

2.4 A paper on "Design of a New Type of Charging Station for Solar Electric Vehicle" by Huaizhong Chen.

This paper gives idea about,

1) MPPT Control Method.
2) CVT Control Method.
3) INC Control Method.

Comply with the rise of new energy vehicles, the solar energy grid storage energy type charging station system in full consideration of the light environment, such as a variety of environmental factors based on the advanced design concepts, a collection of new energy in the field of photovoltaic power generation, energy storage, grid, charging etc., many new technologies, fully embodies the its scientific rationality, economy, security and other characteristics, for the electric vehicle charging station construction provides an innovative integration solutions.

2.5 A paper on "Development of Solar Based E-Bicycle" by Prof. P. R. Bharambe, Dr. A. K. Damral, Ashwini Wagh, Mansi Rajput, Punam Makh, Rushikesh Bodade, Sachin Gaikwad, Shubham Shekokar

This paper describes development of solar based e-bicycle. In which 50W, 12V multi-crystalline solar powered PV module, MPPT, lithium iron phosphate battery, BLDC motor is used.

2.6 Prof. Vishal K. Vaidya and Onkar V. Bhole. "Solar Based Electric Vehicle Smart Charging Station" International research Journal of Engineering and Technology 2020.

Many EVs increase the load in power grids, which will have a negative impact on the safe and reliable operation of power system. EVS can bring considerable economic benefits by using vehicle-to-grid (V2G) technology. Recharging EVS is accomplished through connections to EVSE, which is protective, communicates with vehicle and monitors electrical activity to ensure safe charging

2.7 G.R. Chandra Mouli, P. Bauer "System design for a solar powered electric vehicle charging station" Elsevier Ltd. 2016.

electric vehicle charging station" Elsevier Ltd. 2016. In this paper, a 10 KW EV-PV charger will be considered that provides both charging and facility. A solar bicycle is a bicycle which runs using the electrical energy of battery to run the hub motor which ultimately runs the bicycle, Solar energy is used to charge the battery through the charge controller mounted under the seat of the bicycle. Battery gives the required voltage to the hub motor mounted on the back wheel Torun the bicycle.

2.8 C. Shivaprakash, C. Shankar, M. Nageena, B. Reetha Devi, K. Kiruthiga. "An innovative solar powered electric bicycle". Journal of Chemical and Pharmaceutical Sciences, July 2015.

This paper proposed E-Bicycle for police or law enforcement in cities where parking and traffic are a problem. The proposed E-Bicycle in an efficient manner with the speed of 20km and having the extra features like mobile charging capacity.

CHAPTER-3

Overview of project

The following figure represents the systematic block diagram of this project "Development of Solar Based Charging Station for E-Bicycle".

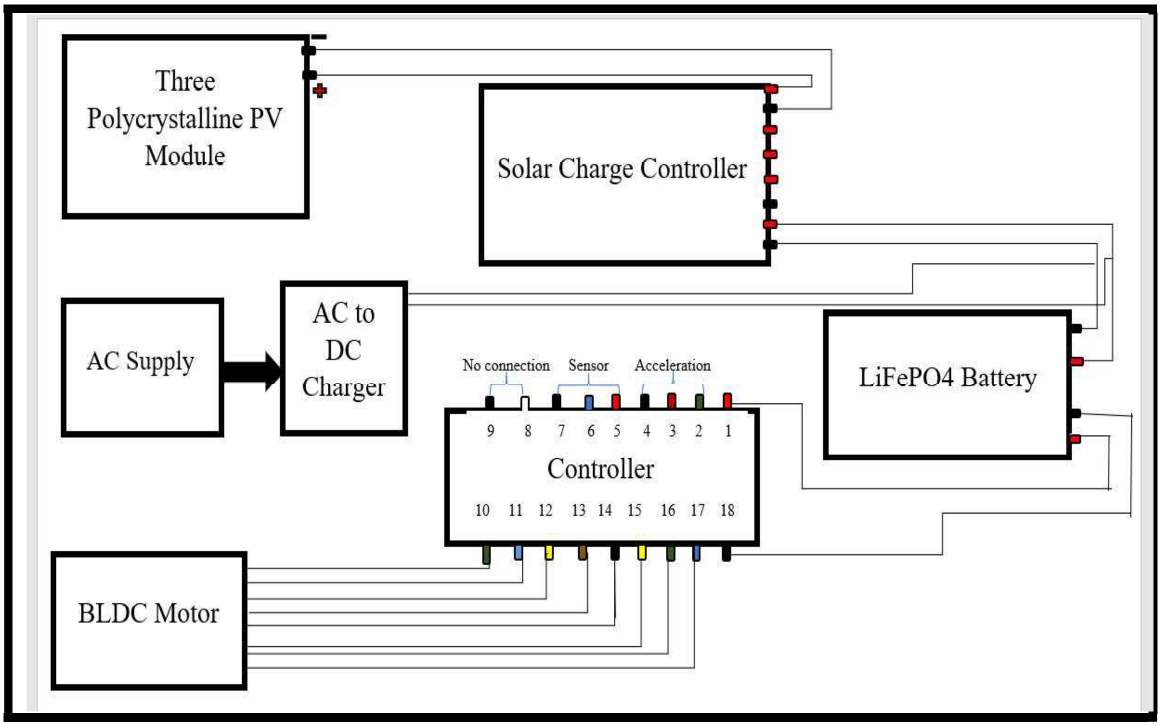


Fig.3.1 Block Diagram

The block diagram consists solar module, solar charge controller, Battery, ac to dc charger, controller, motor etc. The first block contains three polycrystalline pv module. Each module has the rating 12V, 50W. We connect them in series to get maximum output. Then output of solar module is given to the solar charge controller. Solar charge controller is a voltage and current controller that helps batteries from over charging. It is connected to LifePO4 battery of rating 36V, 10AH. For back up purpose we used ac to dc charger to charged battery.

Then the next block is controller which is responsible for taking control of motor and energy saving device. The core function of an electric bike controller is to take all the inputs from all the electric components (throttle, speed, sensor, battery, motor etc.) and then determine what should be signalled in return to them (motor, battery, display). Controller connected between battery and motor. It receives supply from battery and given to BLDC motor. BLDC motor has rating 36V, 250W.

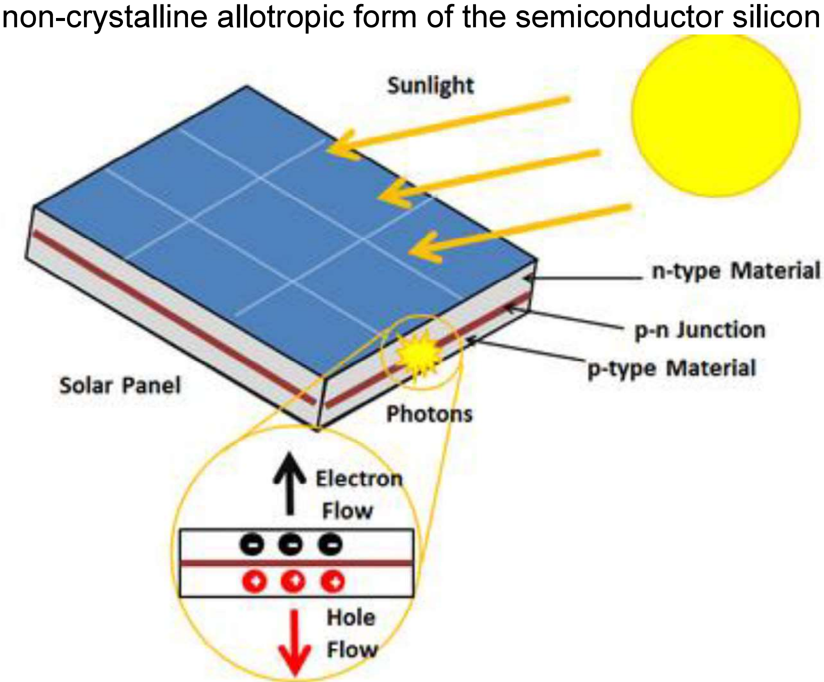
CHAPTER-4

PV Module

- **Solar Cell / PV Cell -** A solar cell, or photovoltaic cell, is an electronic device that converts the energy of light directly into electricity by the photovoltaic effect.
- **PV Module -** A single photovoltaic Module/Panel is an assembly of connected solar cells that will absorb sunlight as a source of energy to develop electricity.
- **PV Array -** A group of PV modules (also called PV panels) is wired into an extensive array called PV array to gain a required current and voltage.

4.1 Types of Solar Cell –

- **Monocrystalline solar cell -** This solar cell is also recognised as a single crystalline silicon & comes in a dark black shade. Monocrystalline solar cells are the most efficient & robust of the silicon pv family.
- **Polycrystalline solar cell –** Polycrystalline silicon solar cells consists of several crystals of silicon in a single pv cell & comes in blue colour.
- **Amorphous Silicon (a-si) solar cell –** Amorphous silicon is the non-crystalline allotropic form of the semiconductor silicon.



It is 50W, 12V polycrystalline solar PV module, also it is made by connecting photovoltaic (PV) cells. They are made up of semiconductor material such as crystalline silicon. Solar PV module convert light energy from sun into electrical energy. Typically, solar PV module rated at 50W to 350W. Solar PV module are used for boosting the power output of PV cells by connecting them. Solar PV module are used to increase power output of PV cells by connecting them. When PV cells (present in solar module) absorb sunlight, energy contained in light photons is transferred to semiconductor material. 50-Watt 12-volt polycrystalline solar panel is the perfect intro panel for solar beginners, or for seasoned users in need of a small solar setup. It has a key feature which is it is a reliable and it has advanced encapsulation material with multi-layered sheet laminations to enhanced cell performance and provide a long service life.

4.2 Features of PV Module -

Polycrystalline solar panel are more eco-friendly than monocrystalline solar panels as they do not require individual shaping and placement of each crystal and most of the silicon is utilized during production. So, very less waste is produced. The acceptable maximum temperature of polycrystalline solar panels is 85 °C while the acceptable minimum temperature is -40 °C. Polycrystalline solar panels have lower heat tolerance than monocrystalline panels. So, at higher temperatures, these solar panels have lower efficiency than others.

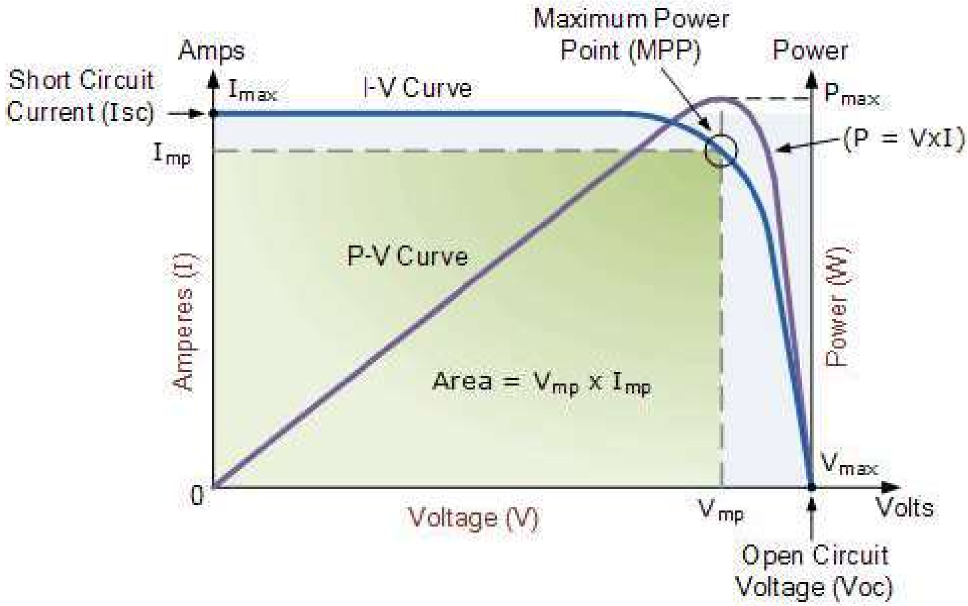
Polycrystalline solar panels have a higher temperature coefficient than monocrystalline panels. These panels have a high-power density. They come with a structural frame of their own which makes mounting cheaper and simpler.

STC (Standard Test Condition) is an industry-wide standard to indicate the performance of PV modules and specifies a cell temperature of 25°C and an irradiance of 1000 W/m^2 with an air mass 1.5 (AM1. 5) spectrum.

4.3 Solar Cell I-V Characteristic and the Solar Cell I-V Curve –

The Solar Cell I-V Characteristic Curves shows the current and voltage (I-V) characteristics of a particular photovoltaic (PV) cell, module or array. It gives a detailed description of its solar energy conversion ability and efficiency. Knowing the electrical I-V characteristics (more importantly P_{max}) of a solar cell, or panel is critical in determining the device’s output performance and solar efficiency.

Solar Cell I-V Characteristic Curve



The above graph shows the current-voltage (I-V) characteristics of a typical silicon PV cell operating under normal conditions. The power delivered by a single solar cell or panel is the product of its output current and voltage (I x V). If the multiplication is done, point for point, for all voltages from short-circuit to open-circuit conditions, the power curve above is obtained for a given radiation level.

4.4 Solar Cell Parameter –

The various parameters of a solar pv module includes open-circuit voltage (Voc), short-circuit current (Isc), maximum power (Pm), fill factor (FF), efficiency (η), series resistance (Rs) and shunt resistance (Rsh).

- **Voc = open-circuit voltage –** This is the maximum voltage that the array provides when the terminals are not connected to any load (an open circuit condition). This value is much higher than Vmp which relates to the operation of the PV array which is fixed by the load. This value depends upon the number of PV panels connected together in series.

- **Isc = short-circuit current –** The maximum current provided by the PV array when the output connectors are shorted together (a short circuit condition). This value is much higher than Imp which relates to the normal operating circuit current.

- **MPP = maximum power point –** This relates to the point where the power supplied by the array that is connected to the load (batteries, inverters) is at its maximum value, where MPP = Imp x Vmp. The maximum power point of a photovoltaic array is measured in Watts (W) or peak Watts (Wp).

- **FF = fill factor** – The fill factor is the relationship between the maximum power that the array can actually provide under normal operating conditions and the product of the open-circuit voltage multiplied by the short-circuit current, (Voc x Isc) This fill factor value gives an idea of the quality of the array and the closer the fill factor is to 1 (unity), the more power the array can provide. Typical values are between 0.7 and 0.8.

FF= Voc - ln(Voc+o.72)/Voc +1

Or

FF= Vmp*Imp/Voc*Isc

- **η = efficiency** – The efficiency of a photovoltaic array is the ratio between the maximum electrical power that the array can produce compared to the amount of solar irradiance hitting the array. The efficiency of a typical solar array is normally low at around 10-12%, depending on the photovoltaic type (monocrystalline, polycrystalline, amorphous or thin film) of cell being used.

η = MPP/Pin = Vmp*Imp/Pin = Voc*Isc*ff/Pin %

- **Rs =** Series Resistance **–** This resistance is the sum of resistance of all the components that come in the path current. It is desirable to have the value of series resistance as low as possible.

- **Rsh =** Shunt Resistance **–** The Shunt Resistance is due to the leakage across the P-N junction. It could be due to the crystal detect or precipitates of impurities in the junction region. It is desirable to have the value of shunt resistance as high as possible.

CHAPTER-5

Charging Methods

Most of the "12 volt" solar panels put out about 16 to 20 volts, so if there is no regulation the batteries will be damaged from overcharging. Most batteries need around 14 to 14.5 volts to get fully charged. Therefore, it is necessary to observe the suitable charging of the battery. A charge controller or charge regulator is basically a voltage and current regulator to help batteries from overcharging. It regulates the voltage and current from the solar panels going to the battery. It prevents overcharging, avoid overvoltage, which can reduce battery performance or lifespan, and may pose a safety risk. It prevents completely draining ("deep discharging") a battery, or perform controlled discharges, depending on the battery technology, to protect battery life.

Brighter the sun light, more voltage solar cells can produce the excessive voltage, which could damage the batteries. A charge controller is used to maintain the proper charging voltage on the batteries. As the input voltage from the solar array rises, the charge controller regulates the charging process of the batteries preventing any overcharging.

Following are the charging methods to charge the battery from solar panels using charge controllers -

1. Linear charge controller
2. Pulse width modulator (PWM)
3. Maximum Power Point Tracking (MPPT)
4. Proposed PWM MPPT

5.1 Linear Charge Controller-

A linear charge controller is a charge controller that just senses the voltage from the solar panel and gives it to the battery. A linear charge controller does not regulate the voltage or current. It does not perform buck and boost operation. Whatever the voltage obtained from the panel is directly given to the dc load. In Linear charge controller, the solar panel receives irradiation from sun and converts this solar radiation into an electrical energy through 'Photo Voltaic effect'. The power coming from the solar panel is fed to the battery through solar charge controller. The charge controller helps to keep the battery safe from over voltage coming from the panel and also it cuts off the charging when the battery is full in order to prevent the sulphation due to overcharging and to protect the battery life. The major drawback of this linear controller is that, it will not do any conversion operation (buck or boost the voltage) due to this there will be losses around and the efficiency drops, also battery life gets reduced, so in order to minimize the losses from solar panel to battery, MPPT charge controller should be used which minimize the losses and increases the efficiency of battery about 95%.

5.2 PWM Charge Controller Pulse Width Modulation (PWM)-

It is the most effective means to achieve constant voltage battery charging by switching the solar system controller's power device. Where in PWM regulation, the current from the solar array tapers according to the battery's condition and charging needs.

The solar charge controller (frequently referred to as the regulator) is identical to the standard battery charger, i.e., it controls the current flowing from the solar panel to the battery bank to prevent overcharging the batteries. As in a standard battery charger, it can accommodate different types of batteries.

The absorption voltage can select the float voltage, and it can often also set the time and tail current. They are best suitable for lithium-iron-phosphate batteries since when the controller is in full charge, it remains at the fixed float or maintains a voltage of about 13.6V (3.4V per cell) for the rest of the day.

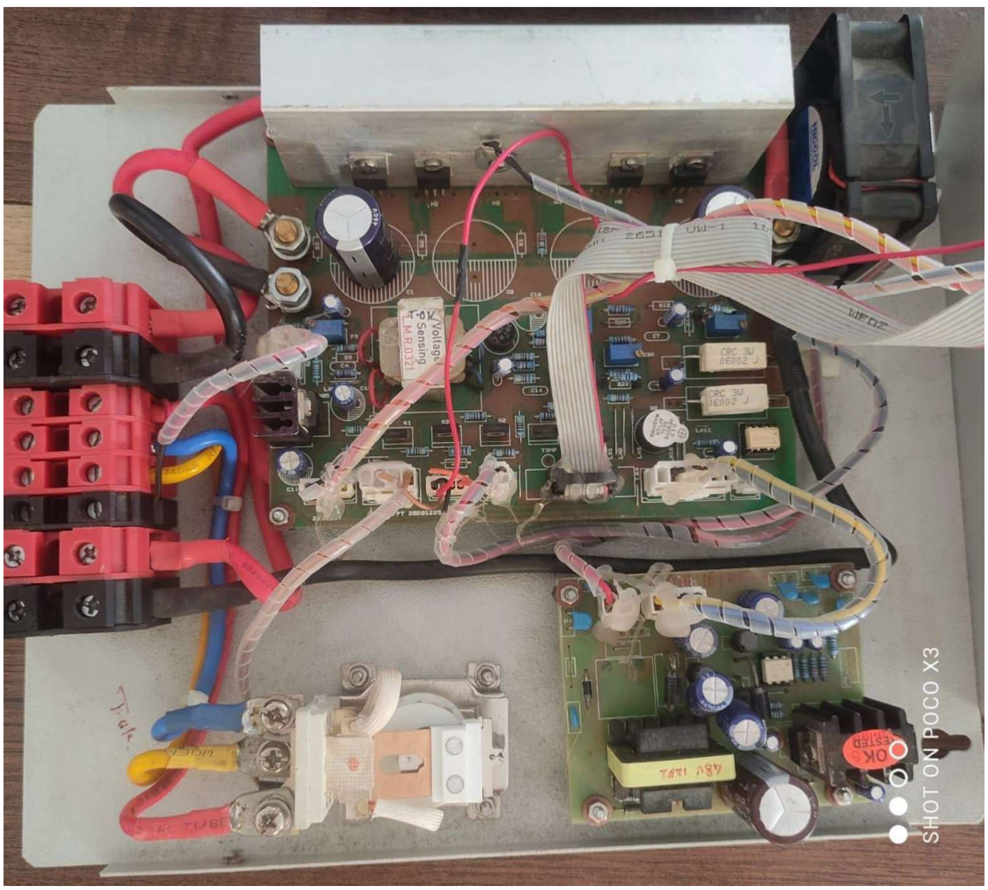


Fig.5.1 PWM Solar Charge Controller

The most popular charging profile is the same simple sequence found on a quality mains adapter, i.e., bulk mode – absorption mode – float mode. Entry to bulk charging mode happens at:

Sunrise in the morning

If the battery voltage drops down the specified voltage for longer than a specified period, e.g., 5 seconds (re-entry)

This re-entry into bulk mode works better for lead-acid batteries since the voltage drop and drop are more significant than lithium-based batteries, which retain a higher, more stable voltage for the rest of the discharge period.

In the solar charge controller:

The switch is ON while the charger mode is in bulk charging mode.

The switch is ON and off when required (pulse width modulated) to keep the absorption's battery voltage.

It is OFF at the end of the absorption when the battery voltage decreases to the float voltage.

The switch is ON and OFF again as required (pulse width modulated) to keep the battery voltage at the float voltage.

Notice that when the switch is off, the panel voltage will be at the open-circuit voltage (Voc). When the button is on the panel, the voltage will be at the battery voltage + the voltage decreases between the board and the controller.

PMW 3 Stage Charging

Bulk Charge: The bulk charging level is where the PV device continues much of the battery's charge. The device will charge the battery with a high current and voltage when the voltage is down. When the voltage at the end of the battery is more significant than this maintenance value while setting, direct charging should stop.

Absorb Charge: Usually, after the first step of charging, the battery will wait for a period to allow the voltage to decrease naturally and then reach the balanced charging stage. The stage is also called constant voltage charging.

Float Charge: It is the last stage of 3-stage charging, known as Trickle charging. The trickle is a slight charging current to the battery at a low rate and steady. Most rechargeable batteries lose power when entirely powered due to self-discharge. If the charging stays at the same low current as the self-discharge rate, it can sustain the charge capacity.

PWM Solar Controller Pros:

The PWM Regulator has matured and established techniques.

Simple structure and cost-effective

Easy deployment of the PWM regulator

The lower budget on a small initiative

PWM Solar Charge Controller Cons:

- Low conversion rate
- Input voltage must balance the bank voltage of the battery.
- Less scalability for device development
- Less Loading Mode
- Less protection

The Function of the Solar Charge Controller:

The central charge controller essentially regulates the unit's voltage and opens the circuit, stopping the charge as the battery voltage rises to a certain amount. More charge controls used a mechanical relay to open or shut off the course, stop or start power from the electrical storage unit.

Generally, 12V batteries are for solar power applications. Solar panels can convey much more voltage than the battery needs to charge. The charge voltage will be maintained at the highest possible level while the time taken to set the electrical storage equipment entirely is minimal. It helps the solar systems to run continuously optimally. The wires ' power dissipation is significantly low by running a higher voltage in the solar panels' cables to the charge controller.

Solar charge controllers can also control the flow of reverse electricity. The charge controllers will discern whether there is no power coming from the solar panels and open the circuit separating the solar panels from the battery devices and stopping the reverse current flow.

5.3 Advantages of PWM Charger :

Charging a solar-powered battery is a unique and challenging challenge. In the old days, essential on-off regulators were used to reduce the battery from gas when the solar panel provided excess electricity. However, as the solar systems evolved, it became apparent how much these simplistic instruments had messed with the charging process.

On-off regulators' experience has been early battery errors, rising load disconnects, and increasing consumer frustration. PWM has recently emerged as the first breakthrough in the charging of solar batteries. PWM solar chargers use hardware similar to most modern, high-quality battery chargers.

As the battery voltage exceeds the control limit, the PWM algorithm slowly decreases the charging current to prevent the battery from being heated and gaseous, while charging begins to return the total amount of energy to the battery in the shortest time possible. It results in better charging efficiency, fast recharging, and a long-lasting battery at maximum power.

Also, this new way of charging solar batteries offers some very fascinating and unusual PWM pulsation advantages.

These include:

Ability to restore reduced battery power and dissipate the battery

Dramatically boost the approval of the battery charge.

Retain high overall battery capacity (90 percent to 95 percent) relative to on-off controlled state-of-charge ranges usually between 55 percent and 60 percent.

Equalize the drift cells of the battery.

Limit the heating and gasification of the battery.

Automatically compensate for the age of the battery.

Self-regulation of voltage rises and temperature effects in solar systems

For smaller devices

Where the reliability of the device is not essential (the charging process)

For solar panels with a nominal voltage (Vmp) of up to 18V for charging a 12V battery (36V for 24V battery, etc.)

The MPPT controller is ideally suited for:

For more extensive networks where an additional 20%* or more energy harvesting is worthwhile;

Where the solar array voltage is considerably more significant than the battery voltage, e.g., using house panels, for charging 12V batteries;

Applications

In recent days, the method of producing electricity from sunlight has become more common than other alternative sources, and photovoltaic panels are free of emissions and do not require high maintenance. Here are few examples where we are using solar energy.

Street lamps use photovoltaic cells to transform sunlight to DC electrical charge. This machine uses a solar charge device to store DC in the batteries and uses it in several locations.

Home systems use the PV module for house-holding purposes.

The hybrid solar panel uses various energy sources to provide full-time backup supplies to other sources.

5.4 MPPT Charge Controller-

Maximum Power tracking is the algorithm that used in Charge controller to extract Maximum Available Power from PV module under certain condition. The voltage at which PV module can produce maximum power called maximum power point. Maximum power varies with solar radiation, ambient temperature. Generally, PV module produce power at voltage around 17 v measured at a 25-degree Celsius temperature. To improve the efficiency of a solar panel, use of MPPT, which is a power electronic device, comes into picture. By using MPPT, the system will start operating at Maximum Power Point (MPP) and produces its maximum power output by detecting the maximum radiation from the sun that falls on the PV module. Under certain conditions, MPPT charge controllers are used for extracting maximum available power from PV module so that the voltage at PV module can produce maximum power that is called 'maximum power point'. Maximum power changes with solar radiation, ambient temperature and solar cell temperature. Maximum power point tracking (MPPT) technique is used to improve efficiency of solar panel. Fig. shows I-V characteristics of a non-linear output efficiency of a solar cells. Thus, the purpose of MPPT system is to sample the output PV cell and apply proper resistance to obtain maximum power for any environmental conditions. It is the product of MPP voltage (Vmpp) and MPP current (Impp).

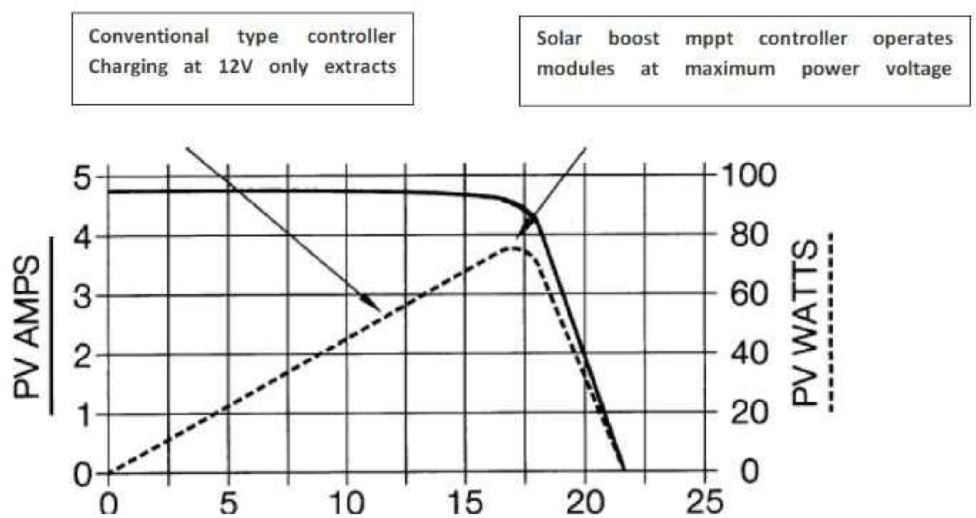


Fig.5.1 I-V characteristics of solar cell

5.5 Methods for MPPT

There are many methods used for maximum power point tracking a few are listed below:

- Perturb and Observe method
- Incremental Conductance method
- Parasitic Capacitance method
- Constant Voltage method
- Constant Current method

5.5.1 Perturb and Observe method

This method is the most common. In this method very less number of sensors are utilized. The operating voltage is sampled and the algorithm changes the operating voltage in the required direction and samples /*dV*. If / _ is positive, then the algorithm increases the voltage value towards the MPP until / _is negative. This iteration is continued until the algorithm finally reaches the MPP. This algorithm is not suitable when the variation in the solar irradiation is high. The voltage never actually reaches an exact value but perturbs around the maximum power point (MPP).

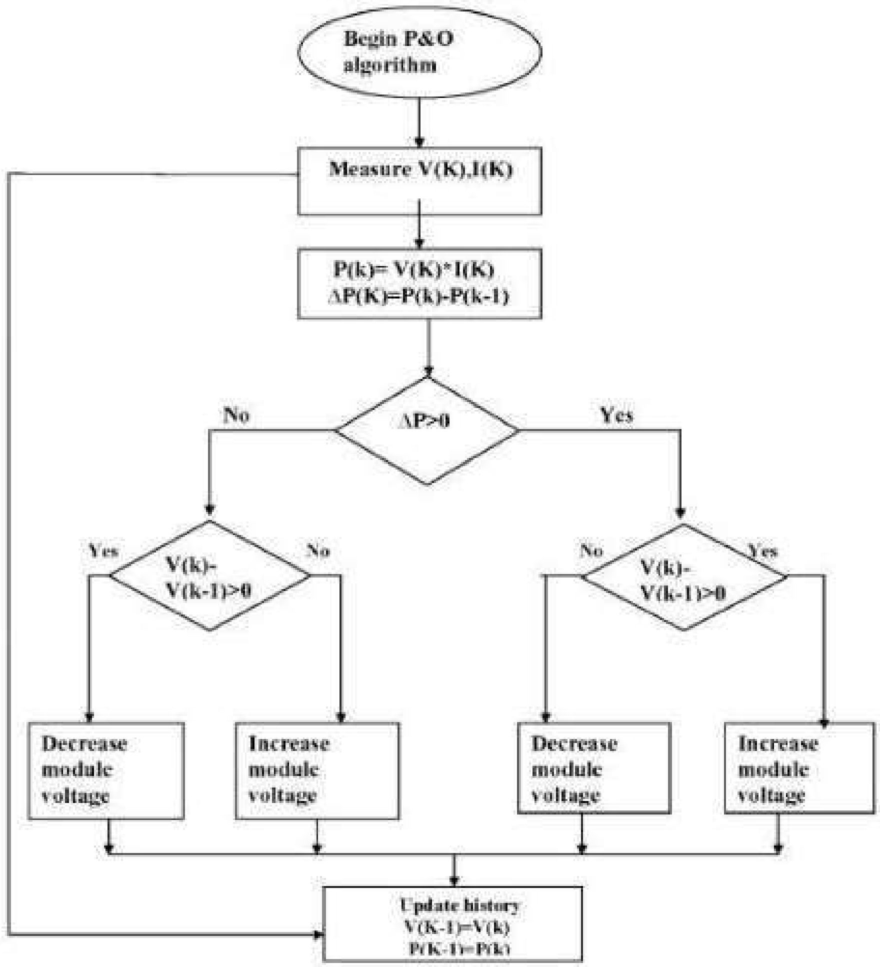


Fig.5.2 Perturb and Observe algorithm flow chart.

Benefits:

P&O is very popular and most commonly used in practice because of

1. Its simplicity in algorithm.
2. Ease of implementation.
3. Low cost
4. It is a comparatively an accurate method

Drawbacks:

There are some limitations that reduce its MPPT efficiency. That are, it cannot determine when it has actually reached the MPP. Under steady state operation the output power oscillates around the MPP.

5.5.2 Incremental Conductance method

This method uses the PV array's incremental conductance to compute the sign of / _. When _/ _is equal and opposite to the value of I/V (where _=0) the algorithm knows that the maximum power point is reached and thus it terminates and returns the corresponding value of operating voltage for MPP. This method tracks rapidly changing irradiation conditions more accurately than P&O method. It starts with measuring the present values of PV module voltage and current. Then, it calculates the incremental changes, dI and dV, using the present values and previous values of voltage and current. The main check is carried out using the relationships in the equations. If the condition satisfies the inequality equation $\Delta I/\Delta V=-I/V$, it is assumed that the operating point is at the left side of the MPP thus must be moved to the right by increasing the module voltage. Similarly, if the condition satisfies the inequality equation $\Delta I/\Delta V<-I/V$, it is assumed that the operating point is at the right side of the MPP, thus must be moved to the left by decreasing the module voltage.

When the operating point reaches at the MPP, the condition satisfies the equation $\Delta I/\Delta V=-I/V$, and the algorithm bypasses the voltage adjustment. At the end of cycle, it updates the history by storing the voltage and current data that will be used as previous values in the next cycle.

Benefits:

It can determine the maximum power point without oscillating around this value.

Drawbacks:

1. The incremental conductance method can produce oscillations and can perform erratically under rapidly changing atmospheric conditions.

2. The computational time is increased due to slowing down of the sampling frequency resulting from the higher complexity of the algorithm compared to the P&O method.

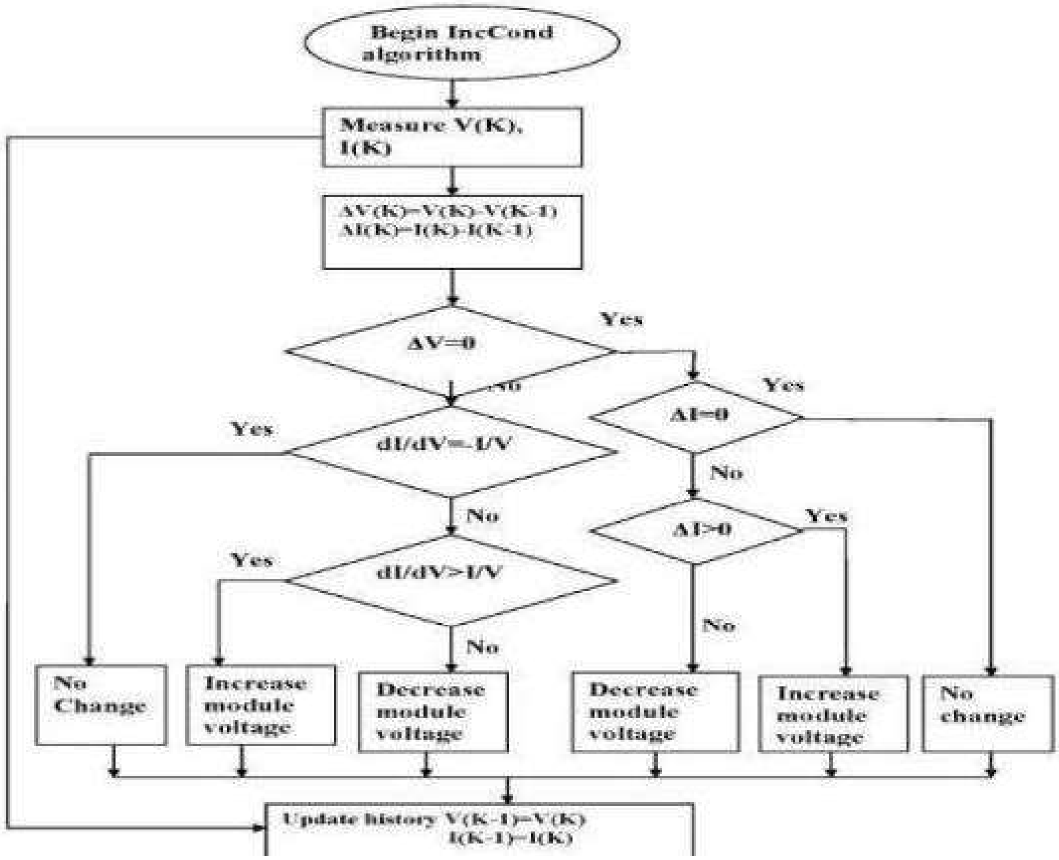


Fig.5.3 The Flowchart of Incremental Conductance Method

5.5.3 Parasitic Capacitance method

This method is an improved version of the incremental conductance method, with the improvement being that the effect of the PV cell's parasitic union capacitance is included into the voltage calculation.

5.5.4Constant voltage method

This method which is a not so widely used method because of the losses during operation is dependent on the relation between the open circuit voltage and the maximum power point voltage. The ratio of these two voltages is generally constant for a solar cell, roughly around 0.76. Thus, the open circuit voltage is obtained experimentally and the operating voltage is adjusted to 76% of this value.

5.5.5 Constant Current method

Similar to the constant voltage method, this method is dependent on the relation between the open circuit current and the maximum power point current. The ratio of these two currents is generally constant for a solar cell, roughly around 0.95. Thus, the short circuit current is obtained experimentally and the operating current is adjusted to 95% of this value.

5.6 Features of MPPT

- MPPT Increases charge current by up to 30% compared to a PWM controller.
- Remote temperature sensor.
- Protected against over current.
- Protected against short circuit.
- Protected against reverse polarity connection of the solar panels and/or battery

.

MPPT is more effective

- Cold weather, cloudy or hazy days: Normally, PV module works better at cold temperatures and MPPT is utilized to extract maximum power available from them.
- When battery is deeply discharged: MPPT can extract more current and charge the battery if the state of charge in the battery is lowers.

5.6 Charging methods and power ratings

5.6.1Charging methods

EV charging involves supply of DC to the battery pack. AC power is provided by electricity distribution systems converter is required to provide DC power to battery. Conductive charging can be AC or DC. In case of AC EVSE, AC power is delivered to the onboard charger of EV which converts it to DC.DC EVSE converts power externally and supplies DC power directly to the battery by passing through the onboard charger. There are four modes of charging. Mode 1,2and3 charge an EV by AC current where mode 4 uses DC current for charging. Mode1 and 2 are applicable for connecting an EV to a standard socket outlet utilizing a cable and plug Mode 1 is also known as “dumb charging” as it does not permit any communication between EV and EVSE and its use is not recommended. Mode2 uses portable cable with inbuilt protection and control and it is used for home charging. Mode 3 and 4 provides separate charger device to supply power to the EV . It has improved control system and they used for commercial or public charging.

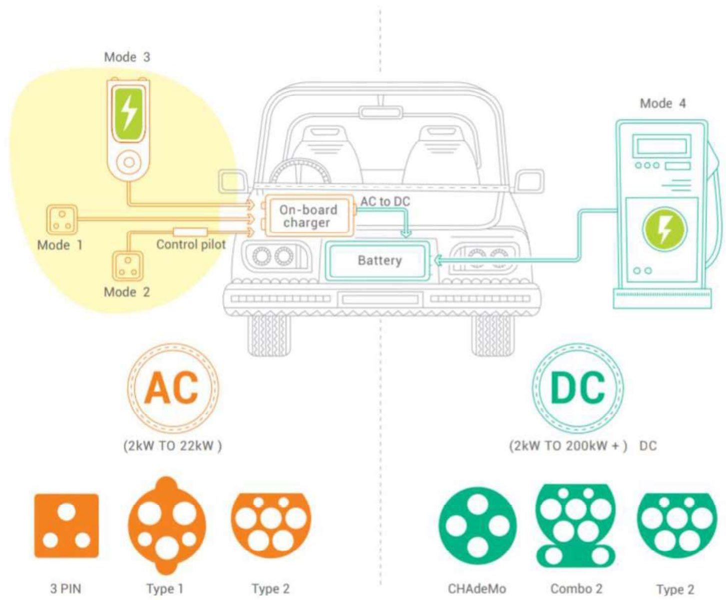


Fig: Modes of charging

5.6.2 Power Ratings

On the basis of power level EV charging categories into two types Normal Power Charging High Power Charging. Normal power charging has Power level unto 22kw and high power charging up to 200kw. EVSE with power rating up to 500kw are also globally available which is largely applicable for heavy vehicles like buses and truck. Normal power AC charging is adequate for E-2Ws ,E-3Ws and e- cars Normal power charging is less expensive and it required less electricity and less space. For high voltage e- cars with battery capacity between 30-80 kWh high power DC charging of 50 kw is used. High power DC charging takes less time for e-cars it requires higher electricity supply with additional infrastructure. Normal power charging points are therefore adequate for most charging of e-cars.

	Power level	Current type	Compatible EV segments
Normal power charging	P ≤ 7kW	AC & DC	E-2Ws, e-3Ws, e-cars, other LCVs (up to 1 ton)
	7kW < P ≤ 22kW	AC & DC	
High power charging	22kW < P ≤ 50kW	DC	E-cars, LCVs and MCVs (1-6 tons)
	50kW < P < 200kW	DC	

Fig: EVSE Power Ratings

CHAPTER-6

Battery

A battery is electrochemical device that stores electrical energy in the form of chemical by means of electrochemical reaction it converts the stored chemical energy into direct current (dc) electric energy. The electrochemical rection in battery involves transfer of electrons from one material to another through an electric current. A battery can be charged electrically and released electric charge when needed. The battery consists of anode, cathode and electrolyte. In our project Lithium iron phosphate battery 36V-10AH is used.

There are different types of batteries as follows: -

6.1 Lead acid batteries

- Lead acid batteries are cheap, rechargeable and easily available but its performance is poor.
- It used in machinery, robotics, and other systems where a lot of power is needed and weight is not as important.

6.2 Nickel Cadmium Batteries

- A Nickel Cadmium Battery is a rechargeable battery that commonly finds use in portable computers, drills, and other small battery-operated devices.
- A Nickel Cadmium Batteries suffer from the memory effect and negative environmental impact.

6.3 Nickel Metal Hydride Batteries

- A Nickel Metal Hydride Batteries are non-toxic. Hence, environmentally friendly.
- The limitation of those batteries is high self-discharge time.

6.4 Lithium-Ion Batteries

- Lithium ion is an advanced type of battery which uses Lithium ions as a fundamental component for its electrochemistry.
- Lithium-ion battery has high energy density and less self-discharge time.

Some different types of Lithium-Ion batteries are: -

Lithium-ion Batteries	Benefits	Drawbacks	Application
Lithium Cobalt Oxide	LCO batteries deliver power over a long period of time due to high specific energy.	Costly, shorter lifespan, cannot be used for high load applications.	Small portable electronic items such as- mobile phones, laptops, cameras etc.
Lithium manganese Oxide	Quick charging, high current delivery, better thermal stability, safety.	Short lifespan is the biggest drawback of the LMO.	Portable power tools, electric and hybrid vehicles, medical instruments.
Lithium Nickel Manganese Cobalt Oxide	High energy density, longer lifecycle and lower cost.	Lower voltage output than Cobalt based batteries.	Power tools, electric powertrains for e-bikes and some electric vehicles.
Lithium Iron Phosphate	Safety, durability and long-life cycle.	Performance suffers in low temperatures and they also have a low specific energy.	LFPs are the most common Lithium-ion batteries used to replace the conventional lead acid batteries.
Lithium Nickel Cobalt Aluminium Oxide	High energy with a decent lifespan and can perform in high load applications.	NCA batteries are expensive and comparatively less safe.	Most popular in Electric Vehicle market, e.g., Tesla Cars.
Lithium Titanate	Fast charging, wide operating temperatures, long lifespan, very safe.	Low energy density, very expensive.	Electric vehicles, wind and solar energy storage, street lights, aerospace, telecommunication systems.

LiFePO4 Battery

Lithium iron phosphate is a rechargeable battery and it is a type of lithium-ion battery that is capable of charging and discharging at high speeds compared to other types of batteries. In LFP battery, iron phosphate is used as active material in cathode and graphite is used as anode material. During charging process, the lithium ions travel from cathode to anode electrolyte. These lithium ions combined with external electrons are deposited between the carbon layers as lithium atoms. During discharging process, the lithium ions move from the anode through as electrolyte to cathode electrode. The chemical makeup of LFP batteries gives them a high current rating, good thermal stability, & a long lifecycle. The nominal voltage of LFP battery cell is 3.2V. Connecting four LFP battery cells in series results in a 12-volt battery that is an excellent replacement option for many 12-volt lead-acid batteries. 12V LFP batteries have four cells connecting in series, thus for a 36V LFP battery, 12 cell are connecting in series. Energy has more competing technology, high-quality cell technology, and stability. The voltage of the Lithium-phosphate battery, means that it has less energy than other lithium batteries. As a result, these batteries are frequently used in electric vehicle and other application requiring a long lifecycle and high level of safety. Advantages of LFP batteries are Eco-friendly, lightweight, no maintenance, more reliable longer lifespan & extremely safe. The typical estimated life of a Lithium-iron phosphate battery is about 8 years or 2000 cycle or more. LiFePO4 batteries can be continually discharged to 100% DOD and there is no long-term effect. However, recommend only discharge down to 80% to maintain battery life. These types of batteries are also referred to as lithium-metal batteries. They stand apart from other batteries in their high charge density and high cost per unit.

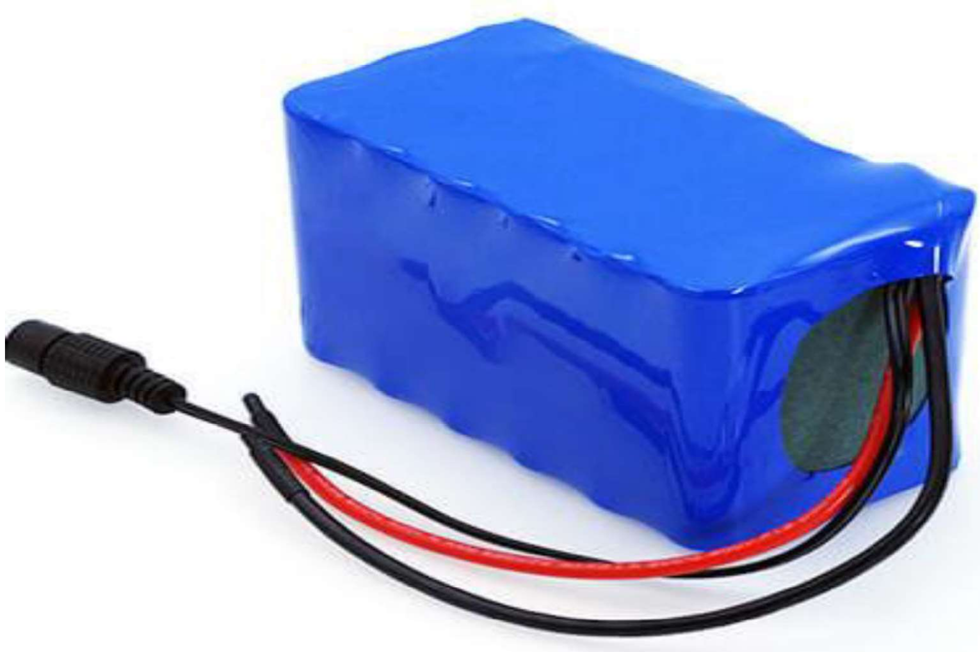


Fig.6.1 36V, 10 Ah LFP Battery

Reasons for selecting LiFePo4 energy storage device: -

The major distinction that lithium iron phosphate batteries have from other li-ion batteries is that LFP is capable of delivering a constant voltage and also has a comparatively higher charge cycle, in the range of 2000-3000. LFP batteries are environmentally safe and structurally stable. They have a lower energy density and low discharge. They do not heat up easily and relative cooler than other batteries. The chemistry of the battery saves it from thermal runaway, and hence it is considered to be safe for home use. Due to their constant voltage and safe discharge, LFPs have found applications in cars, bicycles and solar devices. They are also used as replacements for costly lead-acid starter batteries. They are well suited for applications that require high-load currents and endurance. They are easy to store and carry due to their light weight and ability to provide huge amounts of energy. They are widely used in portable electronic devices like laptops and mobile phones. A recent improvement over the original lithium iron phosphate cathode material by MIT has allowed these batteries to be charged up to 100 times faster than the previous speed. An improvised coating of an ion conductor onto the LFP has enabled the acceleration of ions, and thus the charging time has been greatly reduced.

CHAPTER-7

E-Bicycle

7.1 BLDC Motor

Electric motors of various types are used in electric vehicles, including DC Series Motors, Brushless DC Motors, Permanent Magnet Synchronous Motors (PMSM), Three Phase AC Induction Motors, and Switched Reluctance Motors (SRM). Among these motors, you've probably heard of the BLDC motor, which is very popular in EVs.

BLDC motor is electronically commutated motor, which is also called synchronous motor. The specification of the BLDC motor is given the reason for opting for the BLDC motor is because of its efficiency, noiseless operation, dynamic response and high torque to weight ratio. BLDC motors have a higher torque-to-weight ratio, which is important for electric vehicles because it allows us to make the vehicle lighter while still achieving adequate torque.

As the name implies, BLDC motors do not use brushes for commutation; instead, they are electronically commutated. BLDC motors have many advantages over brushed DC motors and induction motors. A few of these are:

- Better speed versus torque characteristics
- High efficiency
- Long operating life
- Noiseless operation
- Higher speed ranges

BLDC motors are a type of synchronous motor. This means the magnetic field generated by the stator and the magnetic field generated by the rotor rotate at the same frequency. BLDC motors do not experience the "slip" that is normally seen in induction motors. BLDC motors come in single-phase, 2-phase and 3-phase configurations. Corresponding to its type, the stator has the same number of windings. Out of these, 3-phase motors are the most popular and widely used.

Hall Sensors:

Unlike a brushed DC motor, the commutation of a BLDC motor is controlled electronically. To rotate the BLDC motor, the stator windings should be energized in a sequence. It is important to know the rotor position in order to understand which winding will be energized following the energizing sequence. Rotor position is sensed using Hall effect sensors embedded into the stator. Most BLDC motors have three Hall sensors embedded into the stator on the non-driving end of the motor. Whenever the rotor magnetic poles pass near the Hall sensors, they give a high or low signal, indicating the N or S pole is passing near the sensors. Based on the combination of these three Hall sensor signals, the exact sequence of commutation can be determined.

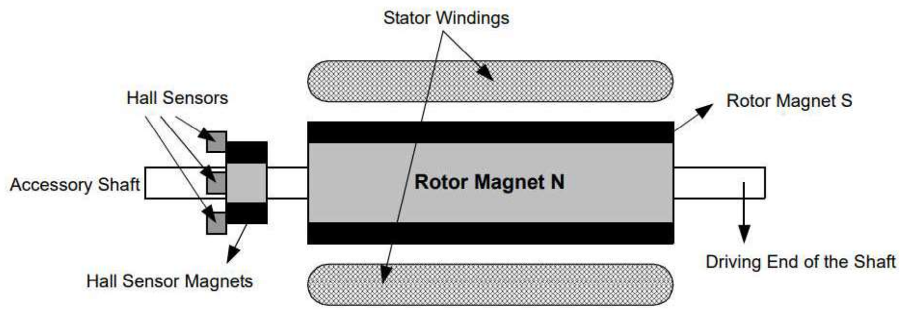


Fig.7.1 BLDC Motor transverse section

Specification of Motor

Operating voltage: 36 v

Operating power: 250 w

Rated speed: 1500

Fig.7.2 BLDC Motor

7.2 BLDC Motor Controller

A BLDC motor controller detects the position of the rotor either by using sensors (for example, a Hall-effect sensor) or senselessly. The sensors measure the rotor's position and send out this data. The controller receives the information and enables the transistors to switch the current and energize the required winding of the stator at the right time.

BLDC motor controller provides efficient, smooth and quiet controls for electric motorcycles, golf carts, go-carts, as well as industry motors speed or torque control. Motor speed controller uses high power MOSFET.

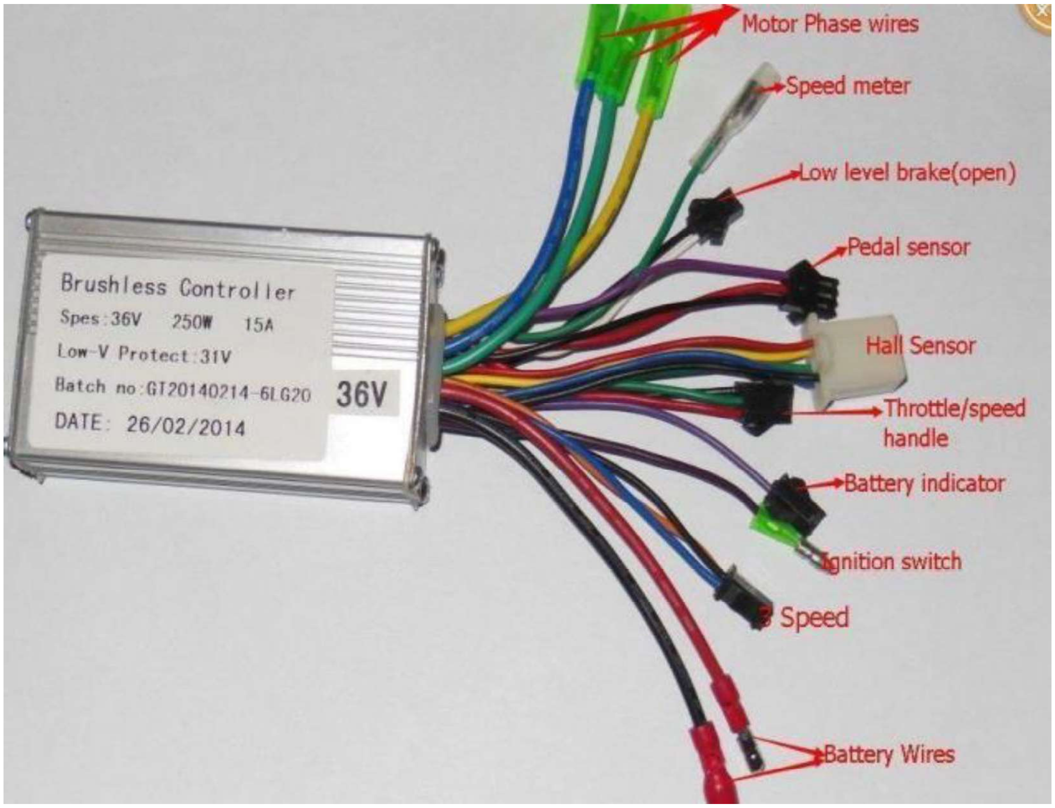


Fig.7.3. Brushless Controller

7.3 Accelerator / Throttle

This solar electric bicycle thumb throttle is easy to use and great for those that want to keep their original handlebar grip. Typically, the thumb throttle is used on bikes that have a twist gear changing system. Thumb throttle that said it comes down to personal choice as the thumb throttle can also be used on a bike that has a thumb gear changing system. A “Thumb Throttle “refers to a method of controlling the speed of an engine or motor.

7.4 Design Calculation

Diameter of the E-bicycle wheel, D = 0.66 m Radius, r = 0.33 m

Speed Required, N = 30 Km/hr

Weight of bicycle, Wb = 20 Kg Weight of rider, Wr = 50 Kg(approx.)

Total weight, Wt = 70 Kg

Normal reaction on each tyre, Wn = Wt/2 = 35 Kg

Force on each tyre, F = 35 * 9.81 = 343.35 N

Considering static friction:

Fs = u * F = 0.03 * 343.35 = 10.30 N

Torque, Ts = Fs * r = 10.30 * 0.33 = 3.399 Nm

Considering dynamic friction :

Fd = u * F = 0.004 * 343.35 = 1.373 N

Torque, Td = Fd * r = 1.373 * 0.33 = 0.453 Nm

Angular speed :

w = N/r = 30000/(0.33*3600) = 25.25 rad/sec

Power Requirements :

On plane surface,

Ps = Ts * w = 3.399 * 25.25 = 85.82W

Pd = Td * w = 0.453 * 25.25 = 11.43 W

Power requirement = 85.82 * 2 = 171.64 W

On inclined surface, Let angle of inclination a= 2 degree

1.Considering static friction,

F = u*m*g*cos(a)+m*g*sin(a)

F = 0.03*70*9.81*cos(2)+70*9.81*sin(2) = 44.55 N

Power required = F*v = 44.55*8.33 =371.1 W

Extra power required = 371.1 - 171.64 = 199.46 W

2.Considering dynamic friction,

F = 0.004*70*9.81*cos(2)+70*9.81*sin(2) = 26.71 N

Power required = F*v = 26.71*8.33 = 222.49 W

By considering the above calculations we require 250W hub motor.

Charging adapter selection

Charging current should be 10% of the Ah rating of the battery.

Therefore,

Charging current of adapter = battery Ah * (10/100) = 1 A

Due to some losses, we may take 1- 3 Amperes for battery charging purpose instead of 1 Amp.

We select 36V 2.2A charging adapter.

Calculation of charging time of battery:

Charging time of battery by adapter = BatteryAh / charging current.

Charging time for 10Ah battery = 10 Ah/ 2.2 A = 4.5 Hrs.

It is for ideal cases.

CHAPTER-8

Experimental Setup

In this project, we are developing the renewable energy powered charging station for E- bicycle in which the source of energy is sun from which the radiations are captured by the Solar PV Module installed in our charging station and then it will convert the solar energy into electricity which will be given for charging of our E-Bicycle.

Fig.8.1 Experimental Setup

The main components of this model comprise Solar PV Module, Charging Adapter, LiFePo4 Energy Storage Device, Charge Controller, BLDC hub motor and ratings of this components are selected according to the application. The main component of this E-Bicycle is the charge controller that performs the whole controlling action from taking supply from the source and then charge the energy storage device in the healthy condition. There is a switch connected near the pedal of the bicycle that turn ON the E-Bicycle and the battery is then connected to the motor through controller which supplies the right amount of current to be delivered during the different condition of operation.

In this setup we implemented an idea that make use of solar energy with the help of three solar panels having rating of 50w and 12v each connected in series to fulfil the requirement of our load, so as per the BLDC hub motor rating 250W 36v, the rating of battery is selected LiFePo4 10Ah 36v, charge controller having the same rating as motor and battery which is 36v.

In this project PWM solar charge controller is used to charge the LiFePO4 battery from the solar panels. Solar charge controller is the main part of the charging system.

Fig.8.2 PWM Solar Charge Controller

In above shown PWM charge controller many components are used, some of them are - Operational amplifier, Aluminium Electrolytic Capacitor, Relay, CDILBD139 MBT Transistor, IC MCT2E, IC L7805CV, IC TLP250L.

Fig.8.3 shows the internal structure of PWM solar charge controller-

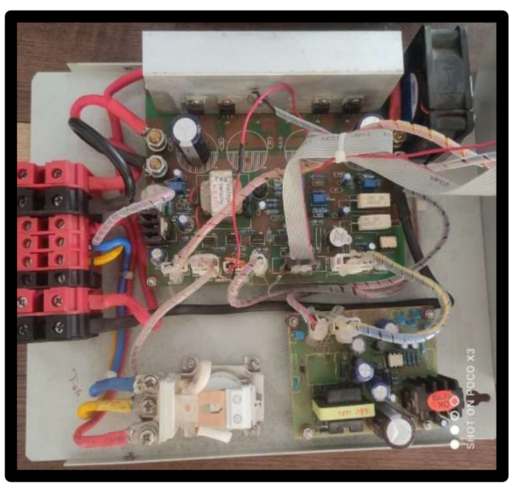


Fig. 8.3 PWM

Features

1)Live usage when battery is fully charged from sunlight.

2) Smart backup of 3-5 hours from battery, when power is not available

3) Fully automatic operations.

4) Long life (Life of solar panels are more than 25 years)

5) Display as well as LED to indicators to observe the working status, Solar Power generation (in watts), operations modes etc.

6) Maximum usage of solar power.

7) Effective Power Management.

8) Two Ways of Power Selection

a) Automatic Power Selection (Mains or Solar)

b) Manual Power Selection (For Mains Power)

CHAPTER-9

Result and Discussion

Outcomes after comparison of PWM and MPPT based charge controller:

PWM helps to get batteries charged up, extends the life of the battery, and more of the power generated by the solar panels is stored. Since the batteries store more energy on average, a smaller battery can be used reducing overall system cost. While MPPT solar charge controllers allow users to use PV module with a higher voltage output than operating voltage battery system. Since MPPT units are generally larger in physical size so they are more costly as compared to PWM controllers.

· PWM charge controllers work is to match the voltage of the panel to battery voltage and pulls output voltage in doing so. Whereas MPPT is the latest technology meant to extract maximum from soar panel. They operate according to the panel voltage and converts extra voltage of panel into current which increases the output from the solar system.

· MPPT controller is at least 30% more efficient than PWM controller i.e., wimpy we get 30% more output of the solar power system

Outcomes getting from E-Bicycle:

After doing all the calculation work it is found that once the battery is fully charged and a person approximately having a weight of 50 kgs riding it can run the bicycle up to 45 km with the maximum speed of 30km/hr. The advantage that the rider is getter here is once he found the battery gets discharge, then he can also take it by simply switch OFF the supply and ride it by pedalling.

Performance characteristics for energy storage device:

Lifepo4 battery has constant battery capacity at various rates discharge as compare to other batteries. The most notable difference between lithium iron phosphate and lead acid is the fact that the lithium battery capacity independent of the discharge rate. The figure below compares the actual capacity as a percentage of the rated capacity of the battery versus the discharge rate as expressed by C (C equals the discharge current divided by the capacity rating). With very high discharge rates, for instance 8C, the capacity of the lead acid battery is only 60% of the rated capacity. Find out more about C rates of batteries.

Solar Charging Result:

Date	Time	Solar Voltage	Solar Current	Battery Voltage	Power
10/02/23	1:28 pm	40.1 V	3.2 A	38.4 V	137 W
10/02/23	2:28 pm	41.4 V	3.2 A	39.5 V	128 W
10/02/23	2:58 pm	41.4 V	3.0 A	39.5 V	123 W
11/02/23	9:23 am	41.0 V	1.2 A	39.5 V	49 W
11/02/23	9:53 am	41.4 V	2 A	39.5 V	83 W
11/02/23	10:23 am	41.9 V	2.4 A	39.9 V	100 W
11/02/23	10:53 am	41.9 V	2.8 A	39.9 V	117 W
11/02/23	11:23 am	42.3 V	3.0 A	40.6 V	126 W

Experimental Readings:

Solar Charging Time: 4 hrs

AC Charging Time: 4:30 hrs

Distance covered after full charged: 40-45 km

Experimental Speed: 21.6 kmph

Time required to charge E-bicycle from solar charging is less than time required by AC charging.

CHAPTER-10

Conclusion

It is observed that demand of E-vehicle is increasing day by day and E-bicycle is becoming more popular among them. E-bicycle can replace the both normal operated bike and a simple bicycle. While driving E-bicycle if we lost electric supply to motor then it can be driven by using pedals as a normal bicycle. In this project as we are proposing to charge E-bicycle with the energy generated from non-renewable source of energy, this project minimizes the dependence on fossil fuels like petrol and diesel. If number of such type of charging station get increased in our country then there will be decrease in energy demand from the Grid. Ultimately the carbon emission will reduce and pollution will be less the energy gap between demand and supply of electricity will be reduce and daily consumption of electricity will be provided everyone. As India is a developing country so it will help in growing the economy also, as number of charging station will increase, the demand for EV will also increase and more manufacturing units will open. It will create a greater number of job opportunities and strengthen the economy. Apart from charging the E-bicycle with renewable energy-based charging station we can also move towards self generating E-bicycle, means charging the battery while riding the bicycle by pedal.

CHAPTER-11

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