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RESEARCH ARTICLE OPEN ACCESS

A Practical Approach to Design and Development of Solar Powered Low Cost, Efficient and Eco-Friendly Electric Vehicle

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Abstract:

Solar powered electric vehicle will utilise the renewable energy source like solar energy to run the automobiles with less cost and more reliability. Now- a-days we are in heavy need to use the solar power, as in the coming days everything we use might depend on this kind of systems. Therefore, it is deemed necessary to carry out research in order to design and develop a low cost, efficient and eco friendly electric vehicle.

Keywords: Solar Energy, Maximum Power Point Tracking, Electric Vehicle

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INTRODUCTION

"Solar energy refers to the utilisation of the radiant energy from the sun. Solar power is used interchangeably with solar energy, but refers more specifically to the conversion of sunlight into electricity by photovoltaic, concentrating solar thermal devices, or by an experimental technology such as solar chimney or solar pond. Solar panels are photovoltaic cells which gives voltage directly if you place them in sun light. Here if you change the position of panels the power output will vary. Means, direct sunrays on solar panel can give good output otherwise there might be decrease in the value of their outputs. So we have to track the path where the maximum power will attain.

From the beginning of the industrial revolution, the rate of energy consumption has increased at an alarming rate due to the synergistic effect of individual energy consumption and population. This situation can be overcome with mass production of the photovoltaic (PV) cell which uses solar energy with low fluctuation converted into electrical energy. The electrical energy is obtained by converting the Sun's energy by the photovoltaic (PV) cell. By using this method, solar vehicles can be run which reduce the pressure on the energy sector as well as help to make the environment green. Although it is not a popular vehicle, but for reducing CO_2 emission and to make the environment pollutant free, energy systems will require a large share of renewable energies, such as solar photovoltaic power, which is used in the tricycle.

The motive force to a shaft by an electric motor which is run by solar energy after some important conversion in electric vehicles instead of an internal combustion engine which is environmental pollution free is the basic working principle of a solar assisted tricycle. The electricity produced by photovoltaic (PV) cells using sunlight powers the electric motor directly for driving of solar-powered vehicles (SPVs). During sun shining the electricity is produced by PV cells otherwise, the vehicles use consuming energy in its batteries" (1)

OBJECTIVE

The main aim of our vehicle is to improve the efficiency and lower cost so that it can be affordable for all. The vehicle doesn't make use of fossil fuels like petrol and diesel. Hence our vehicle is eco-friendly with nature causing no pollution.

LITERATURE SURVEY

Electric solar vehicle –RayRacer a IEEE publication by **Akhilesh. K. Dewangan** and **Tathagata pachal** from KIIT University demonstrated a 750w solar powered electric vehicle which is high performance and cost efficiency. The vehicle carries single person .it makes use of 750w BLDC hub motor. Therefore a solar electric vehicle can carry a load ranging from 150kg to300 kg including the weight of the body.

An Efficient MPPT Solar Charge Controller is a IAJRE publication by **Dr.Anil S. Hiwale, Mugdha ,V.Patil ,Hemangi Vinchurkar** of MIT College of engineering, Pune, ,has developed a modular Simulink of Maximum Power point tracker solar charge controller .The publication introduced the basics of MPPT device ,its components and algorithm used for charge controlling.

Tutorial point charging ,discharging batteries a Web page elucidated the complete knowledge about the batteries .It also includes connecting batteries in either of the series and parallel connections depending upon the requirement , their construction ,reactions, charging and discharging rate.

What is solar vehicle?

A solar vehicle is an electric vehicle powered by a type of renewable energy, by solar energy obtained from solar panels on the surface (generally, the roof) of the vehicle.

Solar vehicle compared to internal combustion engine vehicles are simpler in that they have few major components. However, being an electrical system makes precise calculations of the ratings of these major components of the vehicle imperative at the design stage. The ratings of the 3 major components of the vehicle that will be determined are

1) The motor power rating required to achieve the necessary speed and acceleration.
2) The battery capacity which can support the distance required to be travelled.
3) The solar panel specifications needed to keep the battery sufficiently charged for the journey. The power rating of the motor will determine the battery capacity i.e. Ampere-hour charge and voltage needed to overcome the maximum distance that the solar vehicle will travel on solar power alone. Consequently this in turn will determine the panel wattage required to sustain the battery charge.

Principle and operation of solar powered Electrical vehicle:

The basic principle of the proposed vehicle is the energy drawn from the solar panel that is used to charge a battery which in turn runs the motor of the vehicle. A maximum power point tracker (MPPT) is used as an interface between the solar panel and the battery to obtain the required voltage and to extract maximum power from PV. The BLDC motor is preferred over DC motor because of high efficiency, low maintenance, long life, low weight and compact construction. The conventional DC motor is relatively more expensive and needs maintenance due to the brushes and commutator, whereas, BLDC motor has a rotor and a stator, which is connected to a power electronic switching circuit. This paper focuses on the modelling of solar cell, battery and implements a MPPT device for the solar vehicle driven by BLDC motor.

OPERATION OF POWER TRACKERS:

- Power trackers condition the electricity coming from the solar array to maximize the power and deliver it either to the batteries for storage or to the motor controller for propulsion.

- When the solar array is charging the batteries, the power trackers help to protect the batteries from being damaged by overcharging.

BLOCK DIAGRAM:

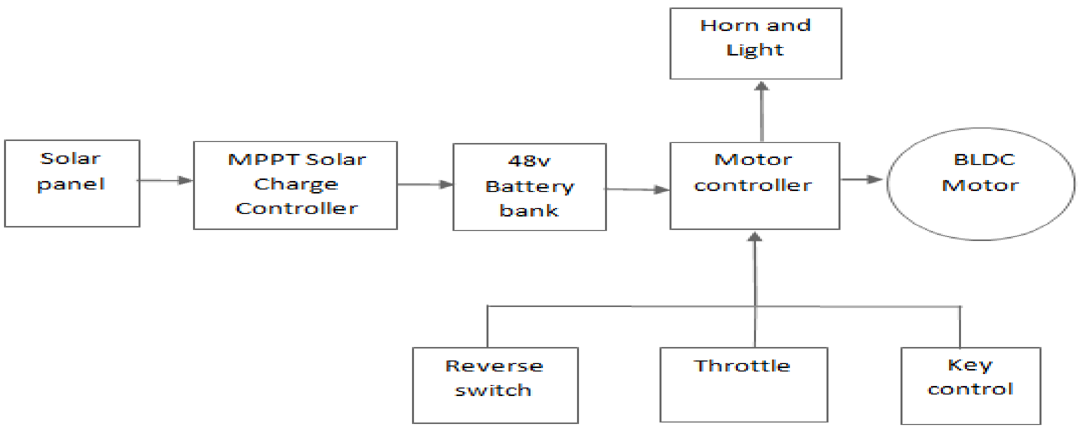


Fig:1 Block diagram

ADVANTAGES:

Eco-friendly and Quiet:

Solar-powered vehicles have zero emission level, as they don't utilize non-renewable resources and burn fuel. The electric motors generate electricity that doesn't emit any greenhouse gases or any other pollutants. These cars are quieter than the vehicles powered by conventional fuels, which don't cause noise pollution as well.

Energy Availability:

Solar cars derive their power from the sun, indirectly, that always shines and provides endless energy. The efficient solar panels can produce and store more horsepower for the vehicle.

No Fuel Costs:

Unlike the conventionally fuelled vehicles, solar vehicles have no fuel costs and a low cost of maintenance.

Driving Comfort:

Having metal and lightweight components, the solar-powered cars run faster and more smoothly than petrol and diesel engine vehicles.

DISADVANTAGES:

Design Challenge:

The solar vehicles require large surface area on roof for mounted solar panels, have low wind resistance and space only for two passengers.

Expensive Batteries:

The efficient solar panels and batteries and their replacement are way too expensive that need to be changed so often. This is what makes the solar vehicles a costly affair.

Energy Storage Capacity:

The photovoltaic cells or solar panels can convert 15-30% of sunlight into electricity, depends on the material used, which is quite limited.

Electrical Construction of solar powered electric vehicle

List of electrical components

Various types of electrical components were used for making the solar powered vehicle. A list of these components used with their range and the specific quantities that were required for making the solar vehicle is given in the following table.

TABLE:1 List of various components used

Components used	Specifications	Quantity
Solar module(polycrystalline)	Power(Pmax)=320Wp Voltage at maximum power=37.44V Current at maximum power=8.55A	1
MPPT Solar charge controller (MPT-7210A)	Input voltage: DC 12-60V Output voltage: DC24V-72V Max output power=600W	1
Batteries(Lead Acid sealed maintenance free)	Battery rating:26AH Nominal voltage:12v	4
BLDC Motor	Rated Power:750W Rated voltage:48v DC Rated current:13.5A Rated speed :500 rpm	1
BLDC Motor controller	Rated voltage:48v Rated current:28A Rated power:750w	1
Connecting wires (Copper wires)	Motor connection:-25Sq.mm high voltage cables. Solar module to charge controller unit:-2Sq.mm Charge controller to battery unit:-2Sq.mm	3 meters 3 meters 2 meters

Apart from the above listed components the other electrical components used in solar powered electrical vehicle are:

1. Throttle.
2. Reverse switch
3. Horn.
4. Head lamp
5. Side indicators
6. Key switch

List of Mechanical Components

The mechanical components that forms the body of solar powered electrical vehicle

a)Chassis
b) Mechanical brakes
c) Shaft
d)Sprocket wheel

Design of Body of the Vehicle

"A **chassis** is the framework of an artificial object, which supports the object in its construction and use. An example of a chassis is a vehicle frame, the underpart of a motor vehicle, on which the body is mounted; if the running gear such as wheels and transmission, and sometimes even the driver's seat, are included, then the assembly is described as a rolling chassis.

- In the case of vehicles, the term rolling chassis means the frame plus the "running gear" like engine, transmission, drive shaft, differential, and suspension." (2)

Fig:2 Solar powered electric vehicle

Auto chassis design

1. Fire arms

"In firearms, the chassis is a bedding frame on long guns such as rifles to replace the traditionally wooden stock, for the purpose of better accurizing the gun. The chassis is usually made from metallic material such as aluminum alloy due to the more superior stiffness and compressive strength of metals compared with wood or synthetic polymer, which are commonly used in conventional rifle stocks. The chassis essentially functions as a more extensive pillar bedding, providing a metal-on-metal bearing surface for the reduced potential shifting under the stress of recoil. A barreled action bedded into a metal chassis would theoretically operate more consistently during repeated firing, resulting in better precision.

A vehicle frame, also known as its *chassis*, is the main supporting structure of a motor vehicle, to which all other components are attached, comparable to the skeleton of an organism. Nearly all trucks, buses, and most pickups continue to use a separate frame as their chassis."(3)

2.Functions:

"The main functions of a frame in motor vehicles are

1. To support the vehicle's mechanical components and body
2. To deal with static and dynamic loads, without undue deflection or distortion.
   These include:
   - Weight of the body, passengers, and cargo loads.
   - Vertical and torsional twisting transmitted by going over uneven surfaces.
   - Transverse lateral forces caused by road conditions, side wind, and steering the vehicle.
   - Torque from the engine and transmission.
   - Longitudinal tensile forces from starting and acceleration, as well as compression from braking.
   - Sudden impacts from collisions.

3.Frame rails

Typically the material used to construct vehicle chassis and frames is carbon steel; or aluminium alloys to achieve a more light-weight construction. In the case of a separate chassis, the frame is made up of structural elements called the rails or *beams*. These are ordinarily made of steel *channel* sections, made by folding, rolling or pressing steel plate.

There are three main designs for these. If the material is folded twice, an open-ended cross-section, either C-shaped or hat-shaped (U-shaped) results. "Boxed" frames contain chassis rails that are closed, either by somehow welding them up, or by using premanufactured metal tubing.

4.Design features

While appearing at first glance as a simple form made of metal, frames encounter great amounts of stress and are built accordingly. The first issue addressed is beam height, or the height of the vertical side of a frame. The taller the frame, the better it is able to resist vertical flex when force is applied to the top of the frame. This is the reason semi-trucks have taller frame rails than other vehicles instead of just being thicker.

As looks, ride quality, and handling became more important to consumers, new shapes were incorporated into frames. The most visible of these are arches and kick-ups. Instead of running straight over both axles, arched frames sit lower—roughly level with their axles—and curve up over the axles and then back down on the other side for bumper placement. Kick-ups do the same thing, but don't curve down on the other side, and are more common on front ends.

Another feature seen are tapered rails that narrow vertically and/or horizontally in front of a vehicle's cabin. This is done mainly on trucks to save weight and slightly increase room for the engine since the front of the vehicle does not bear as much of a load as the back. Design developments include frames that use more than one shape in the same frame rail. For example, some pickup trucks have a boxed frame in front of the cab, shorter, narrower rails underneath the cab, and regular C-rails under the bed.

On *perimeter* frames, the areas where the rails connect from front to center and center to rear are weak compared to regular frames, so that section is boxed in, creating what is known as *torque boxes*.

Platform frame

Fig: 3 Rikshwa body

Where the Volkswagen frame design relies heavily on a strong backbone, the Renault design is much closer to that of a typical perimeter frame.

This is a modification of the perimeter frame, or of the backbone frame, in which the passenger compartment floor, and sometimes also the luggage compartment floor, have been integrated into the frame as loadbearing parts, for extra strength and rigidity. Neither floor pieces are simply sheet metal straight off the roll, but have been stamped with ridges and hollows for extra strength.

Sub frame

A sub frame is a distinct structural frame component, to reinforce or complement a particular section of a vehicle's structure. Typically attached to a uni-body or a monocoque, the rigid sub frame can handle high chassis forces and can transfer them evenly to a wide area of relatively thin sheet metal of a unitized body shell. Sub frames are often found at the front or rear end of cars, and are used to attach the suspension to the vehicle. A sub frame may also contain the engine and transmission. It is normally of box steel construction, but may be tubular." (4)

BRAKING SYSTEM:

"Drum braking system was used for this project. A drum brake is a brake that uses friction caused by a set of shoes or pads that press against a rotating drum-shaped part called a brake drum.

The term drum brake usually means a brake in which shoes press on the inner surface of the drum. When shoes press on the outside of the drum, it is usually called a clasp brake. Where the drum is pinched between two shoes, similar to a conventional disc brake, it is sometimes called a pinch drum brake, though such brakes are relatively rare." (5)

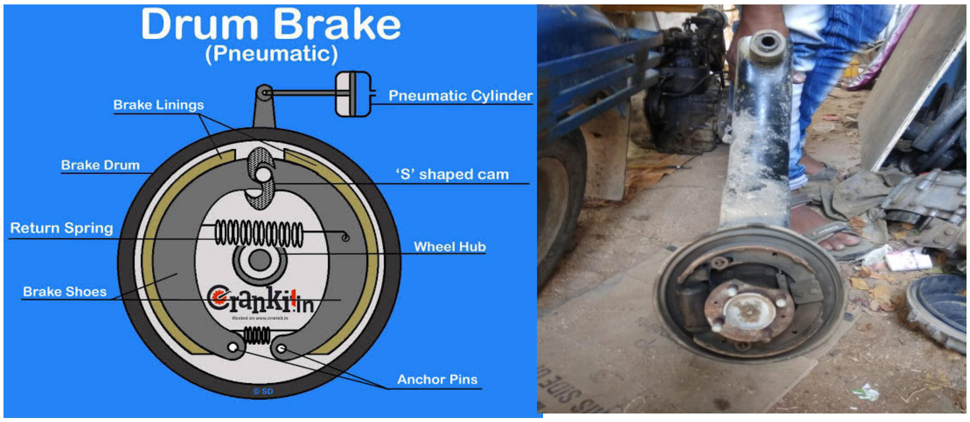


Fig: 4 Braking System

Wheel Arrangement:

Rare Wheel Arrangement:

Having one wheel in front and two in the rear for power reduces the cost of the steering mechanism but greatly decreases lateral stability when cornering while braking.

When the single wheel is in the front (the "delta" form, as in a child's pedal tricycle), the vehicle is inherently unstable in a braking turn, as the combined tipping forces at the center of mass from turning and braking can rapidly extend beyond the triangle formed by the contact patches of the wheels. This type, if not tipped, also has a greater tendency to spin out ("swap ends") when handled roughly.

Fig: 5 Rare wheel arrangement

Lateral stability

The disadvantage of a three-wheel configuration is lateral instability—the car will tip over in a turn before it will slide. This can be prevented in three ways:

- by placing the centre of mass closer to the ground
- by placing the centre of mass closer to the axle with two wheels
- by increasing the track width

In the case of a three-wheeled ATV, tipping may be avoided by the rider leaning into turns.

Motor and Wheel Coupling

In our auto chassis shaft is connected for the two rear wheels and the BLDC motor is coupled to the shaft with the help of chain and SP rocket wheel and the motor is bolted.

Fig: 6 Wheel Arrangement and motor coupling

Mechanical problems involved and rectified

Table:2 problem involved and rectified

Problem	Solution
1. Bending of shaft due to long length.	Bearing blocks are used on either side of chain sprocket
2.Loose chain when BLDC motor is in vertical position due to suspension	The position of the motor is changed to horizontal position
3. The movement of the motor is tight.	Grease is applied to the sprocket

Maximum Power Point Tracker and Battery Bank

This section covers the theory and operation of "Maximum Power Point Tracking" as used in solar electric charge controllers.

Since the output of the PV panel is not constant and it continuously varies with respective irradiance and temperature. It is required to maintain the PV output voltage at constant level in order to charge the battery bank .therefore we go for a device which keep the PV output voltage at constant level and always tracks thee maximum power point of the PV panel. This device is called as Maximum Power Point Tracker (MPPT).

DEFINITION:

"An MPPT, or maximum power point tracker is a Power electronic DC to DC converter that optimizes the match between the solar array (PV panels), and the battery bank or utility grid. To put it simply, they convert a higher voltage DC output from solar panels (and a few wind generators) down to the lower voltage needed to charge batteries. It also convert the lower panel voltage to the required level needed to charge the batteries. Hence an MPPT is basically a BUCK-BOOST DC to DC converter.

The controller uses advanced software algorithms quickly and accurately tracking the maximum power point of photovoltaic panel voltage and current, actively tracking at the maximum power point of the solar cell module in order to get more solar energy. Enhance the charging current and power generation.

PRICIPLE OF OPERATON:

Maximum power point tracking (MPPT) is the process for tracking the voltage and current from a solar module to determine when the maximum power occurs in order to extract the maximum power. The **MPPT** then adjusts the voltage to the battery to optimize the charging. This results in a maximum power transfer from the solar module to the battery. **MPPT charge controllers** normally use PWM in their operation

A simplified block diagram of the functional concept is shown in Figure 6.1.1. The Maximum power point tracking (MPPT) can be implemented in several ways, so the figure illustrates only the basic functions.

The purpose of the DC to DC converter is to isolate the DC input from the DC output so the output can be adjusted for maximum power. The MPPT control typically employs a microprocessor.

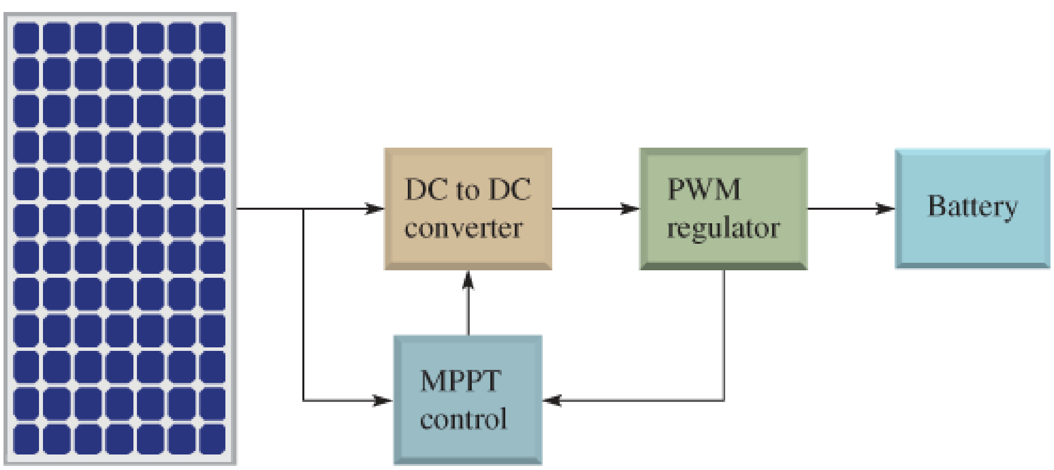


Fig: 7 Maximum power point tracking (MPPT) Charge Controller Circuit Diagram

First, the MPPT microprocessor tracks and sets the solar module output at the maximum power point. The DC to DC converter consists of the DC to AC converter, the transformer, and the AC to DC converter.The purpose of these blocks is to convert the V_{MPP} to AC voltage and transformer-couple the AC voltage to the AC to DC converter, where the AC is converted back to a DC voltage.

As you know, a **transformer** is an electromagnetic device that works only with AC and isolates its input electrically from its output. The reason for the isolation is to allow the output DC voltage to be controlled independently of the voltage from the solar module.The transformer can also step the AC voltage up or down, depending on what is required by the system. The Maximum power point tracking (MPPT) microprocessor then adjusts the PWM switching regulator to produce the proper voltage required by the battery.) (6)

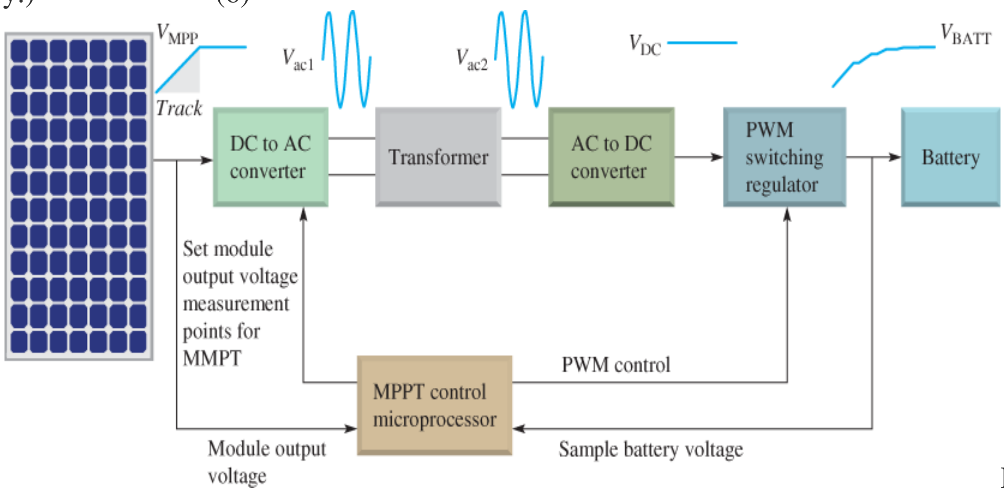


Fig: 8

Operation of an MPPT Charge Controller

DC TO DC CONVERTER

There are several topologies available for DC-DC converter. Among them buck converter is in an increasingly popular topology, particularly in battery powered applications, as level of the output voltage can be changed with respect to input voltage

The commonly used a converter in PV systems is a DC/DC power converter. It ensures, through a control action, the transfer of the maximum of electrical power to the load. The structure of the converter is determined according to the load to be supplied. In this article we focus on the step-down DC/DC converter (Buck converter). MPPT uses the same converter for a different purpose, such as regulating the input voltage at the Maximum power point and providing load matching for the maximum power transfer

Algorithms:

There are many MPPT algorithm which can be used for implementation viz. Incremental conductance method, constant voltage method, Fuzzy logic based method etc. Different MPPT algorithms are briefed about their features and limitations as follows

1) Incremental conductance (INC) method of tracking the MPP does not depend upon PV array, tracking efficiency is good, and implementation is medium. Sensing parameters are voltage and current, convergence speed is medium and of analog type.

2) Fuzzy logic control based MPPT is PV array dependent, Tracking efficiency is good, implementation is very complex, convergence speed is fast and of digital type.

3) Neural network based MPPT is also PV array dependent, tracking efficiency is good, implementation is very complex, convergence speed is fast and of digital type.

4) Linear current control based MPPT is PV array dependent, tracking efficiency is not so good, Implementation complexity is medium, convergence speed is fast, sensing parameter is irradiance and of digital type.
5) Temperature based MPPT depends upon PV array, tracking efficiency is excellent, implementation is simple and MPPT is comparatively accurate and sensing parameters are voltage and temperature.
6) Array reconfiguration based MPPT is PV array dependent, tracking efficiency is poor, convergence speed is slow, implementation complexity is high, sensing parameters are voltage and current and of digital type.
7) Perturb and observe based MPPT is not PV array dependent, tracking efficiency is good but with unstable operating points, implementation is simple, sensing parameters are voltage and current.
8) Advanced Perturb and Observe based MPPT is not PV array dependent, tracking efficiency is very good with stable MPPs, implementation is medium, sensing parameters are voltage and current.
Out of many MPPT algorithms, Perturb and observe (P&O) algorithm is mostly used for increasing the efficiency of PV system due to its simpler implementation, high reliability and better efficiency" (6)

Selection of MPPT:

MPPT is selected depending upon the various factors .the factors are as follows
1) Response towards the small change in input voltage and current.
2) Response towards the small change in irradiance and temperature.
3) Based upon the type of the algorithm used.
4) Reliability and efficiency of the device.
5) Cost of the device.
An MPPT device should be highly sensitive towards the changes in the input voltage from the PV panel, it should continuously observe and record the changes in temperature and irradiance. The algorithm used in them MPPT device determines the efficiency and reliability hence it is important to select a high efficient algorithm for the smooth working of the MPPT.

Device manual:

"1. MPT-7210A MPPT DC-DC Step-Up Power Solar Regulator Charge Controller for 24V 36V 48V 72V Battery Solar Panel 50% off is used in this project.

Fig: 9 Front panel view

2. The product parameters

1. Input voltage: DC12-60V
2. Output voltage: DC24V-72V can be the key to set voltage is continuously adjustable to accommodate 24V / 36V / 48V / 72V battery pack
3. Output Current: 0-10A key settings can be continuously adjustable Output Power: 600W maximum output power of best-fit 100W-600W solar panels, the greater the power, MPPT effect is more obvious.
4. Scope: 20W-600W, applicable 12-60V solar panels to the battery group, lithium battery packs, distributed household photovoltaic power generation systems, solar car wind turbines, and solar street lamps.
5. Module properties: Controller MPPT tracking accuracy and industry-leading conversion efficiency, automatic charge only of management, high efficiency step-MPPT solar panel controller, dedicated to batteries and lithium battery charge management.
6. Display interface: Color LCD voltage / current / power / charge status. 7. Mode: MPPT / DC-DC two options. MPPT of photovoltaic panels' application, DC-DC step-up power applications. 8. Charging options: charging mode can be freely set, built and set their own 20 sets of data storage, support of a machine.

3. Wiring

Fig: 10 connection diagram

Please note that in strict accordance with the wiring diagram in the instructions, make sure the input and output do not pick the wrong line positive and negative do not quit rice. All electrical equipment must eliminate the live wiring, ranging from live action or line equipment will burn, weight will lead to personal injury and property damage

(1) The first pick of the solar cell, the positive and negative attention, do not reverse and reverse, the controller does not show that the controller will not damage internal components.

(2) then connect the battery wires, the positive and negative attention, do not reverse; if there is sunshine, the solar charge current display, otherwise check the connections on the right. Note: The solar panels should be placed outdoors, all illuminated in the sun!

4. Dimensions Mounting

Fig: 11 Device installation

Install the controller at -10 degrees to 60 degrees, a relatively dry environment. Display devices are easy to pollution easily broken, the installation process and avoid touching the collision force, use screws to secure the controller firmly, avoid installation in order to avoid irreparable damage to the internal circuitry in severe vibration device. Avoid long-term exposure to the sun, to guard against rain." (7)

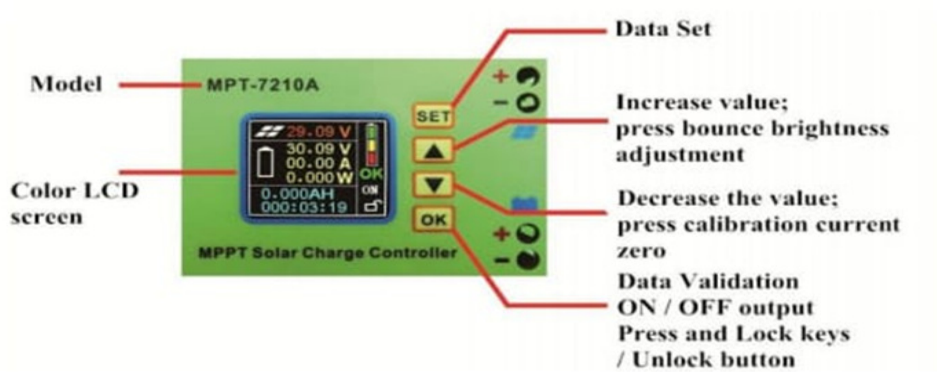
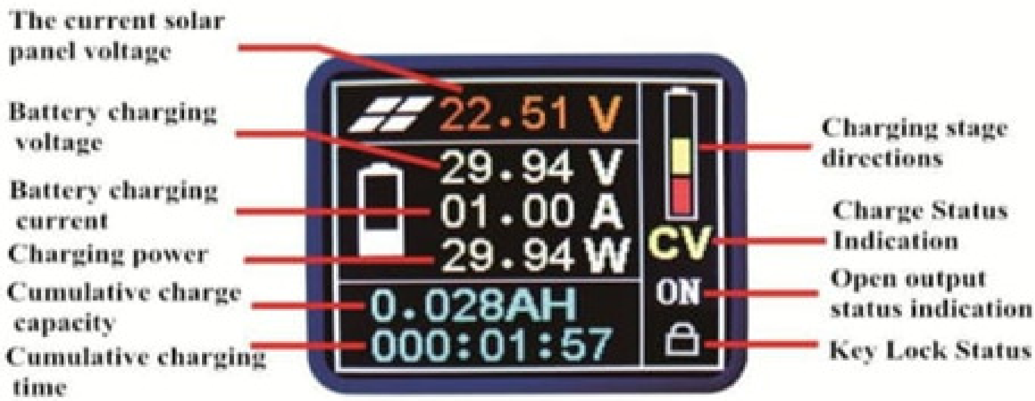
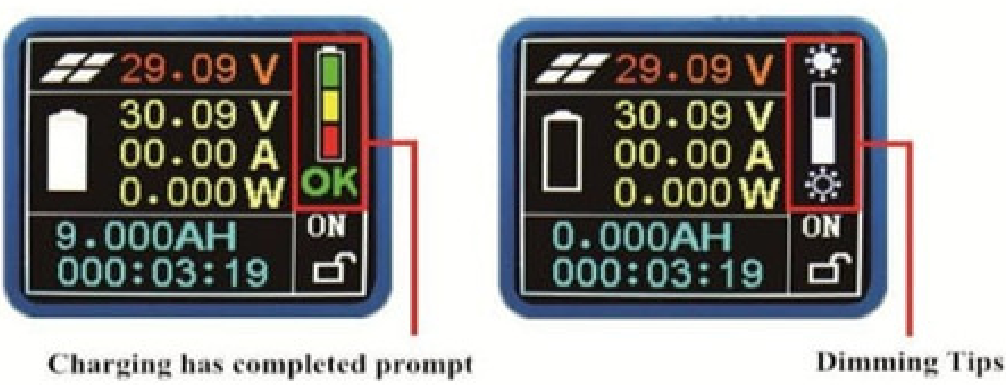


Fig:12 Panel Description

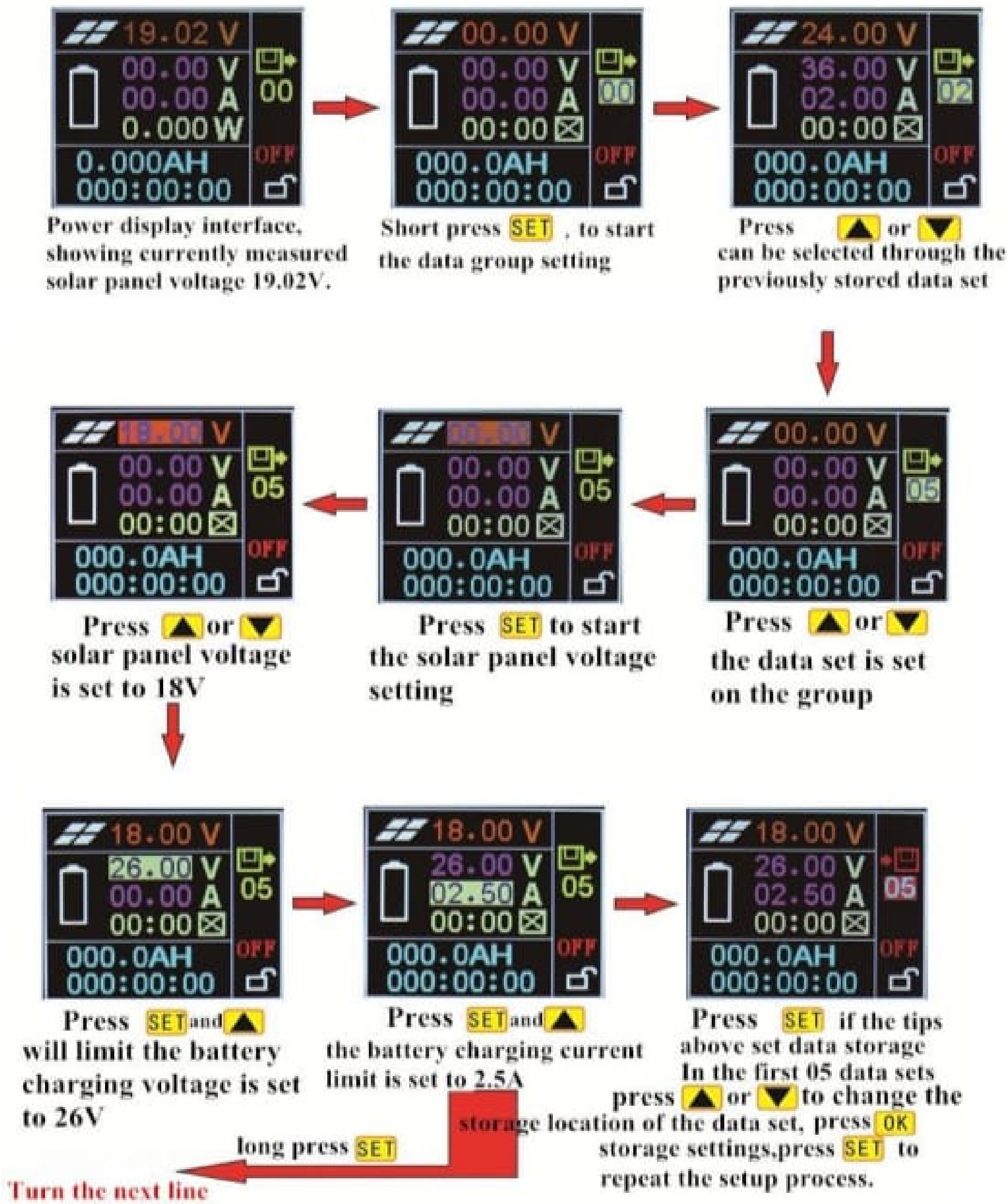
Fig:13 MPPT Installed in SPEV

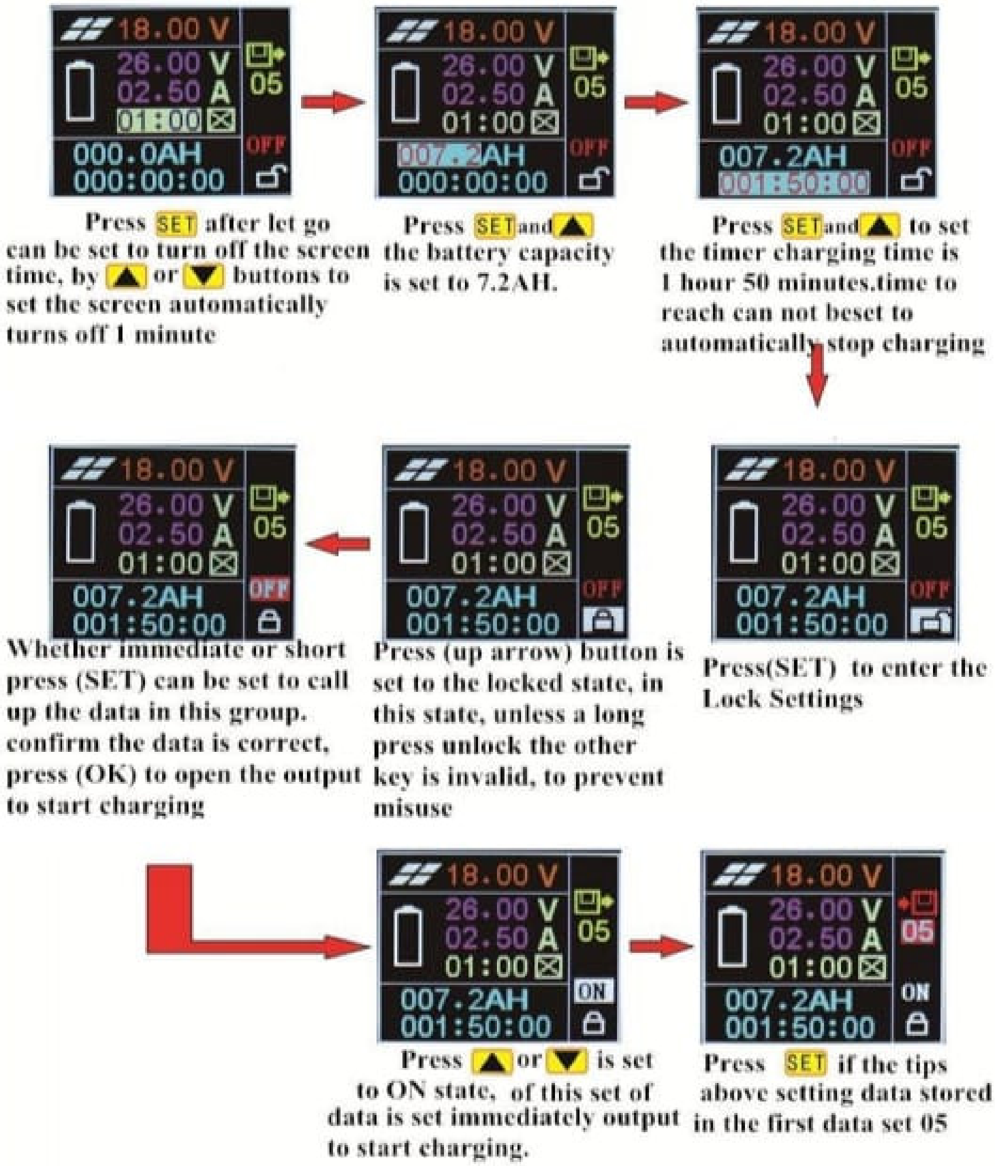

Solar panel voltage setting value
Maximum battery charge voltage
Battery charge level display
Close screen time setting
Battery capacity setting
Charging time setting
22.59 V
30.00 V
05.00 A
01:30
0.032AH
000:02:12
00
OFF
Call up the data identification
Call up the data sets indicate
Maximum battery charging current
Output off tips
Key unlocked state


The current solar panel voltage
Battery charging voltage
Battery charging current
Charging power
Cumulative charge capacity
Cumulative charging time
22.51 V
29.94 V
01.00 A
29.94 W
0.028AH
000:01:57
CV
ON
Charging stage directions
Charge Status Indication
Open output status indication
Key Lock Status

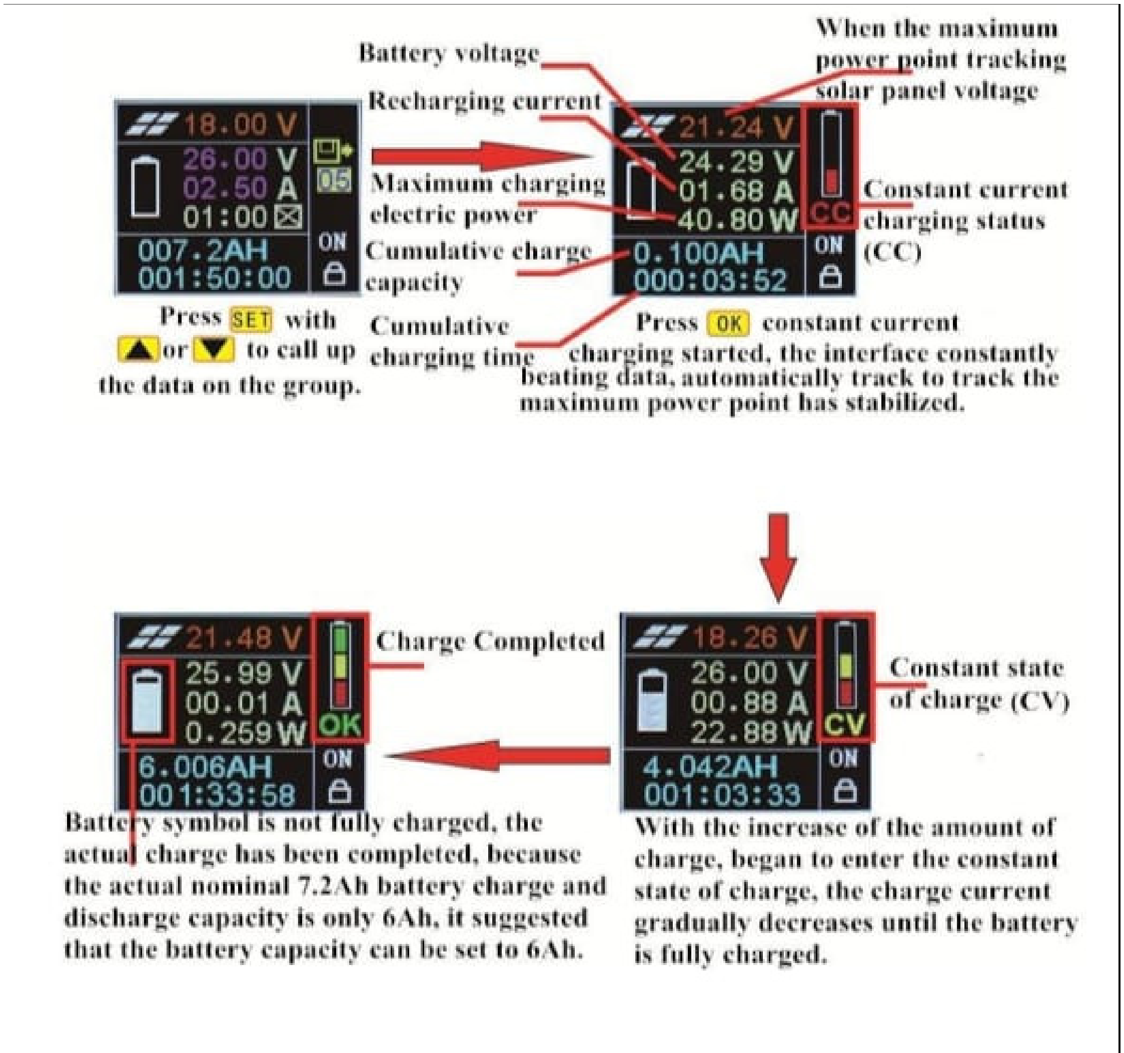

29.09 V
30.09 V
00.00 A
0.000 W
9.000AH
000:03:19
OK
ON
29.09 V
30.09 V
00.00 A
0.000 W
0.000AH
000:03:19
ON
Charging has completed prompt
Dimming Tips

The instrument uses 160 * 128 high-resolution color LCD display, with interactive menus and flexible buttons, allowing you to operate special square wave. Below 18V 100W solar panels 24V 7.2AH battery charging example to explain the procedure.



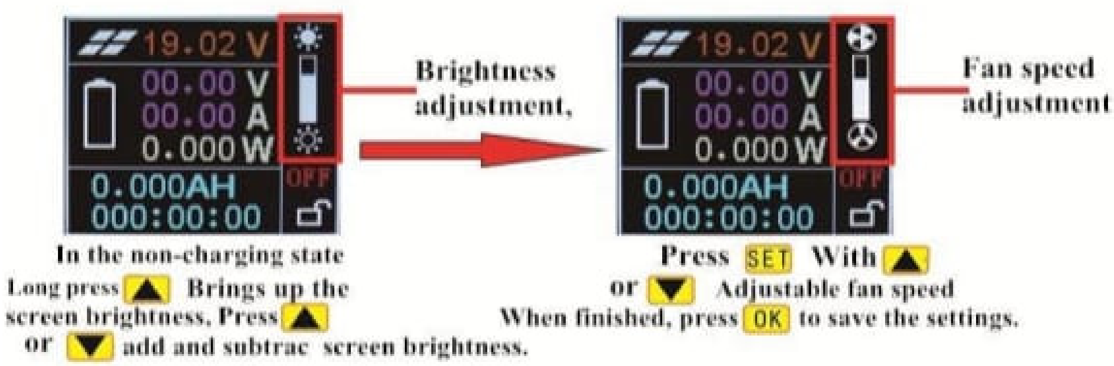


Above to call up the process and save the settings set and data set of the data controller. Solar panel voltage recommends setting its nominal value, such as do not know, you can set Found 19.02V on power-up. Battery charging set voltage and current values must not exceed the limits of the battery, otherwise there is the risk of burn out of the battery, a fully charged battery is generally set to the state of the output voltage and the maximum permissible charging current value. Here's how to call up the data set above the battery charging process.



In any process, press OK to lock or unlock the keys.key lock recommend long-term use.it is recommended to set a good time to turn off the screen, lower power consumption, such as engineering, long-term use, do not set the timer charging time, prevent the arrival time after the controller has stopped working.

Here's how to adjust the screen brightness and fan speed operation.



Theatrical and practical evaluations:

The rolling resistance force is the frictional force is the frictional force resisting the rolling motion of the tires s they roll over the road surface.

- The **rolling resistance force** can be expressed as

$F_{rolling} = \mu_{r*W}$ ------------------ (1)

W= weight of the vehicle =mg

μ_r = coefficient of rolling resistance (0.003 to 0.0004)

$F_{rolling}$ = 375*9.81*0.01

=36.78 N

- **Aerodynamic drag force:**

The aerodynamic force or resistive force is simply force entered by the ait to prevent the vehicle from moving through it.

F_{drag} =[1/2*C_d*A_{cross}*p*$(V)^2$]--------------(2)

C_d = Coefficient of aerodynamic drag

A_{cross} = frontal area in square feet

P= air mass density=1.2 Kgm^3 as per ISA

V = is the vehicle speed

$F_{drag} = [(1/2)*0.32*1*1.2*(8.33)^2]$

= 13.32 N

The drag is noticeable at speed of 40 Km/h

- **Force of acceleration:**

According to newton's second law of motion

$F_{acceleration}$=M*a --------------- (3)

$$a = \frac{(v-u)}{t}$$

$$= \frac{8.33}{1.5*60} = 0.0925\ m/s^2$$

F=375*0.0925 = 34.6 N

The total driving force thus required to overcome the sum of these opposing forces to move the vehicles.

- **$F_{total} = F_{rolling} + F_{drag} + F_{accelarated}$ (adding 1+2+3)**

F_{total}= 34.6+13.2+36.78

F = 84.78 N

Total power required is

P= 84.78*8.33

=706 Watts

Hence, 750 watts motor is chosen

Practical values:

Table:3 Below table shows the values of MPPT readings and Set values in MPPT

Time	PV output Voltage (VOLTS)	MPPT voltage set value(V)	MPPT Voltage reading(V)	Current set value (AMP)	Current reading (AMP)	POWER (Watts)
09:45 AM	37.77	54	50.39	2.6	2.53	127.4
10:58 AM	39.80	54	51.8	2.6	2.6	133
11:25 AM	40.28	54	52.36	2.6	2.52	125.25
12.54 PM	41.20	54	53.03	2.6	2.6	138
02:00 PM	41.09	54	54.01	2.6	2.01	113.7
03:30 PM	40.99	54	50.39	2.6	1.48	72.53

Graphical Analysis

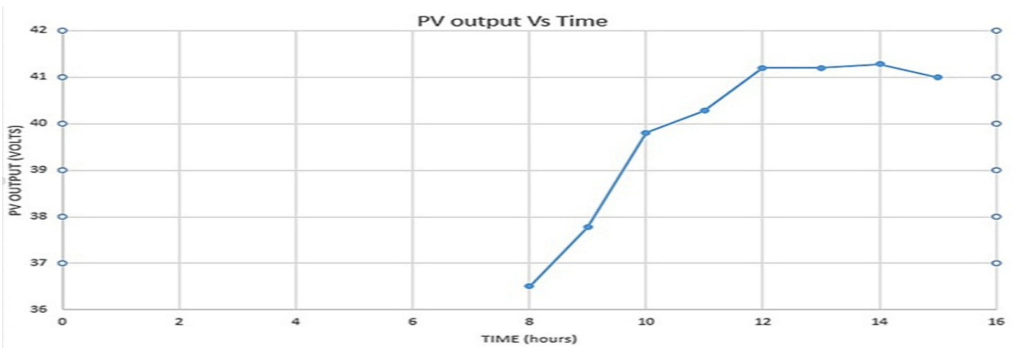


Fig:14 Graph-1: PV output vs Time

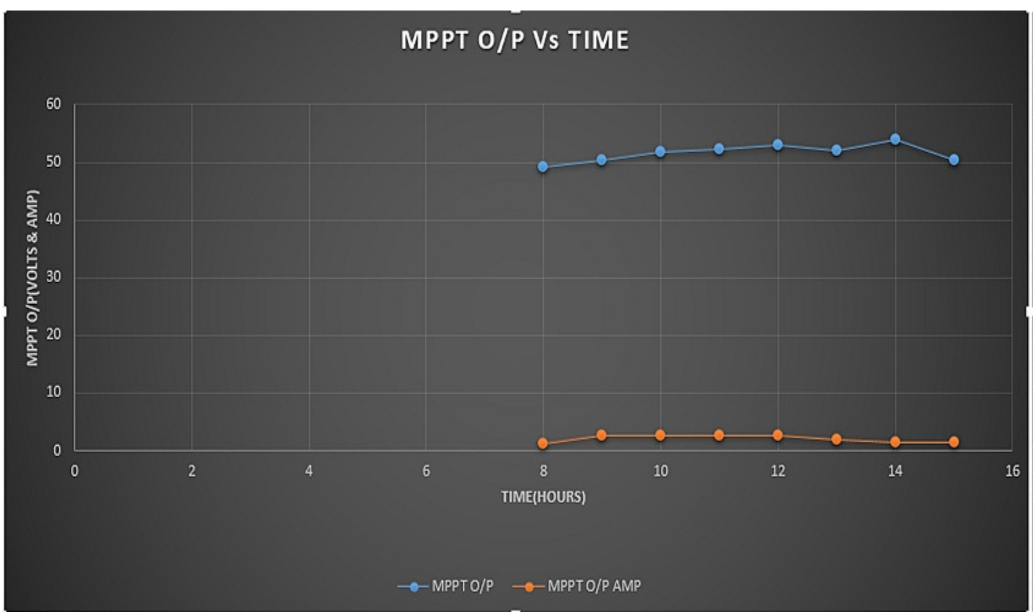


Fig:15 Graph-2: MPPT output vs Time

Table:4 speed vs time characteristics at different modes and on different surface

Time (Sec)	High Plane surface Speed (kmph)	Medium Plane surface Speed(kmph)	low Plane surface Speed(kmph)	Back wards Speed on Plane surface	Speed on mud surface	Speed on rough surface
0	0	0	0	0	0	0
4	12	10	9	_	_	12
6	15.5	15.4	11	7.7	5.5	14.9
8	17	15.4	11	7.4	8.4	16.3
12	19.5	15.6	11.2	7.5	11.5	17.4
14	18.4	_	_	_	_	_
16	22	_	_	_	_	_

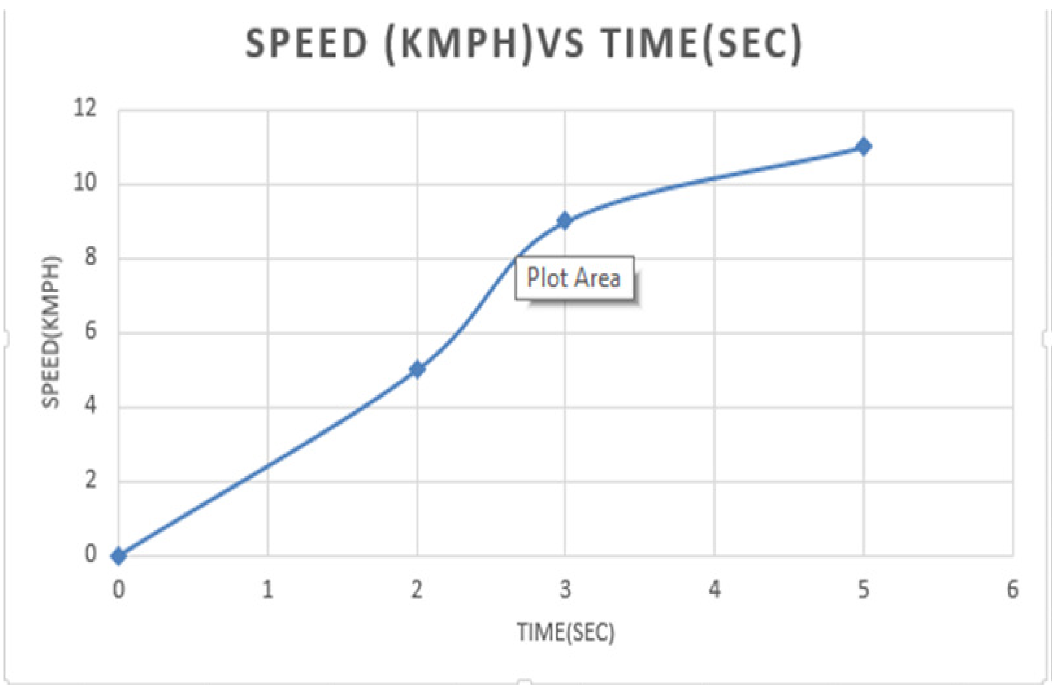


Fig:16 **Graph 6.3: At low speeds**

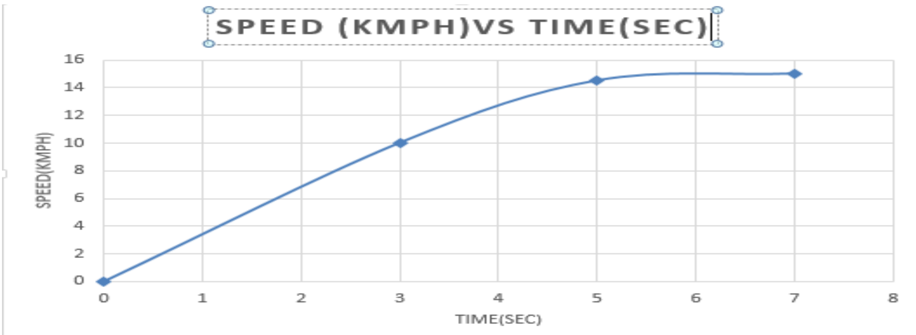


Fig:17 Graph 6.4: At medium speeds

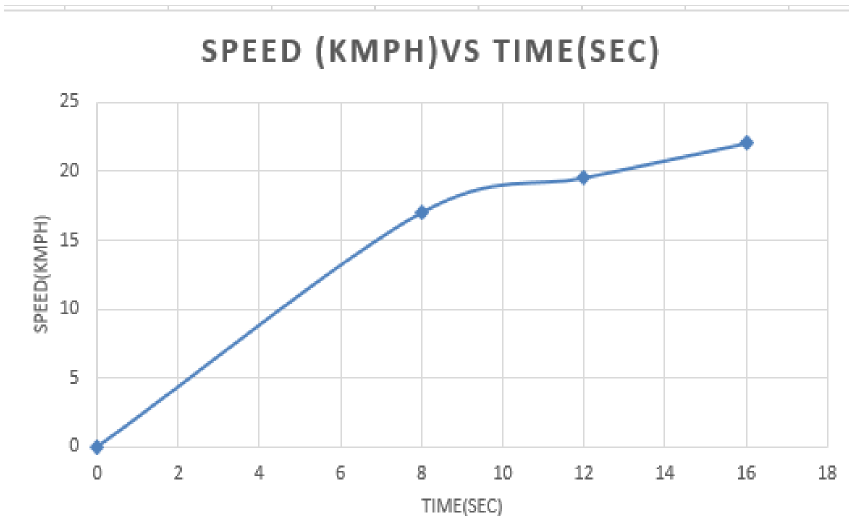


Fig:18 Graph 6.5: At high speeds

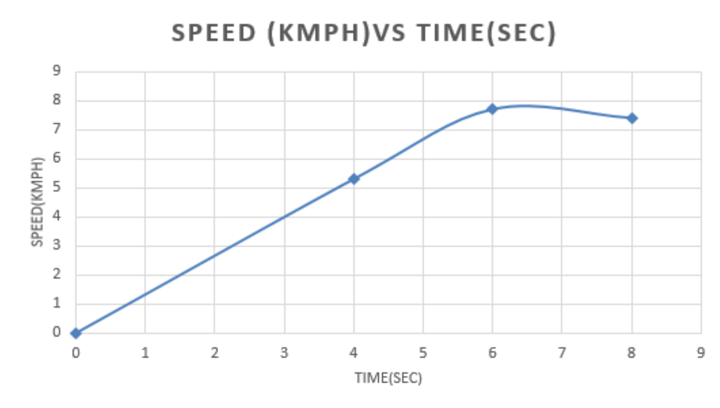


Fig:19 Graph 6.6: Reverse high speed mode

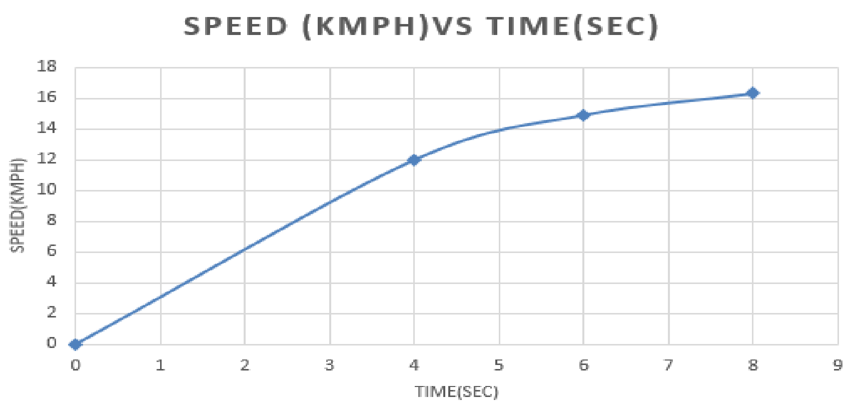


Fig: 20 Graph 6.7: speed on rough surface

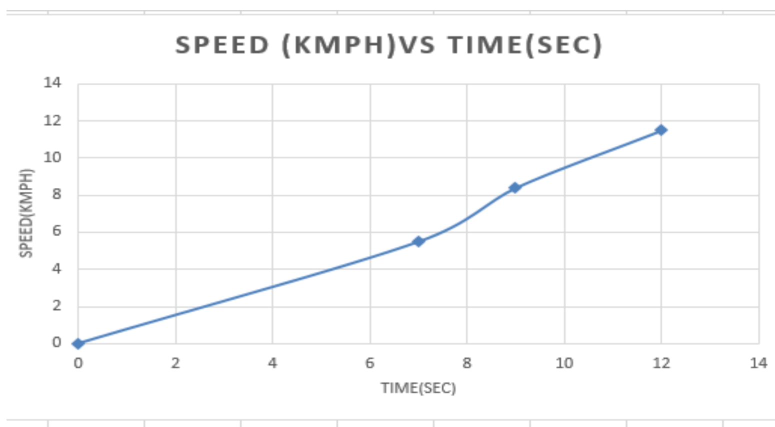


Fig: 21 Graph 6.8: Speed on mud surface

CONCLUSION

The designed and developed 3 wheeler solar powered electric auto is completely independent of fossil fuel. It has zero tailpipe emissions unlike conventional IC engines. The design of the vehicle consists of polycrystalline 320Wp solar module, 600W maximum power output MPPT Solar charge controller, 26AH lead acid battery, 750W BLDC motor and controller for both cost effectiveness and environmental friendly nature which in turn will optimize the energy efficiency.

Lower cost was our aim so that it can be affordable for all. A total of 42,000 Indian Rupees was the spent amount to develop the auto. Hence our vehicle is eco-friendly with nature causing no pollution.

FURTHER WORK:

Ultra-efficient solar cells can be used in the place of poly crystalline solar cells so that efficiency increases to about 30-35%**.** Advanced batteries like graphene batteries can be used instead of Lead Acid Battery bank. Graphene batteries have low discharging period and high charging rate. Auto gear mechanism can be installed for frictionless movement of wheels.

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