Visvesvaraya Technological University

Belgaum, Karnataka-590 018

A Project Report on

"Solar Powered Electric Vehicle"

Project Report submitted in partial fulfillment of the requirement for the award of the degree of

Bachelor of Engineering
In
Electrical & Electronics Engineering

Submitted by

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CMR INSTITUTE OF TECHNOLOGY
DEPARTMENT OF ELECTRICAL & ELECTRONICS ENGINEERING
AECS Layout, Bengaluru-560 037

Certificate

Certified that the project work entitled **"Solar Powered Electric Vehicle"** carried out by Mr. Satyam Kumar(1CR16EE070); Mr. Sudhir Kumar Raju(1CR16EE083); Mr. Utkarsh Anand(1Cr16EE089); Mr. Utkarsh Raj(1CR16EE090) are bona-fide students of CMR Institute of Technology, Bengaluru, in partial fulfillment for the award of Bachelor of Engineering in Electrical & Electronics Engineering of the Visvesvaraya Technological University, Belgaum, during the year 2019-2020. It is certified that all corrections/suggestions indicated for Internal Assessment have been incorporated in the Report deposited in the departmental library.

The project report has been approved as it satisfies the academic requirements in respect of Project work prescribed for the said Degree.

Signature of the Guide	*Signature of the HOD*	*Signature of the Principal*
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DECLARATION

We, [Mr. **Satyam Kumar (1CR16EE070),** Mr. **Sudhir Kumar Raju (1CR16EE083),** Mr. **Utkarsh Anand (1CR16EE089),** Mr. **Utkarsh Raj (1CR16EE090)],** hereby declare that the report entitled **"Solar Powered Electric Vehicle"** has been carried out by us under the guidance of **Dr. P. Ramesh,** Assistant Professor, Department of Electrical & Electronics Engineering, CMR Institute of Technology, Bengaluru, in partial fulfillment of the requirement for the degree of **BACHELOR OF ENGINEERING in ELECTRICAL & ELECTRONICS ENGINEERING**, of Visveswaraya Technological University, Belgaum during the academic year 2019-20. The work done in this report is original and it has not been submitted for any other degree in any university.

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Abstract

The Solar Powered Electric Vehicle is a single-seated vehicle powered by 1500W BLDC motor. The main aim is to design and fabricate a safe, high performance, cost-efficient electric solar vehicle. Now a days, dealers of natural resources like fuel, coal etc. are facing a hard time to keep pace with the increasing demand. Therefore, to carry out this demand it is quite necessary to make a new exploration of natural resource of energy and power and sunlight is now a days considered to be a source of energy which is implemented in various day to day applications. Solar energy is being used to produce electricity through sunlight. With the help of this technology we aim to make solar energy powered car in our project. The main component to build a solar car is the solar panel. The solar cells collect a portion of the sun's energy and store it into the batteries of the solar car. Before that happens, Boost Converter convert the energy collected from the solar array to the proper system voltage, so that the batteries can be charged safely. After the energy is stored in the batteries, it is available for use by the motor & motor controller (Kelly controller) to drive the car. We are going to use 48V lithium-ion battery which will get the electrical energy from the panel to drive the motor. MPPT incremental conductance method is used to extract maximum power from sun light in any condition. We used a complete circuitry to solve the problem of voltage fluctuation due to movement of the sun, earth, or cloud etc. The motor controller adjusts the amount of energy that flows to the motor to correspond to the throttle. The motor uses that energy to drive the wheels. Preliminarily our objective would be to implement our idea on a basic prototype and afterwards with help of this prototype we can extend our future work on building a real time electric solar powered vehicle.

Acknowledgement

The satisfaction and euphoria that accompany the successful completion of any task would be incomplete without the mention of people, who are responsible for the completion of the project and who made it possible, because success is outcome of hard work and perseverance, but steadfast of all is encouraging guidance. So with gratitude we acknowledge all those whose guidance and encouragement served us to motivate towards the success of the project work.

We take great pleasure in expressing our sincere thanks to ***Dr. Sanjay Jain****,* ***Principal, CMR Institute of Technology, Bengaluru*** *for providing an excellent academic environment in the college and for his continuous motivation towards a dynamic career.*

We would like to convey our sincere gratitude to ***Dr. K Chitra****,* ***Head of Electrical and Electronics Engineering Department, CMR Institute of Technology, Bengaluru*** *for her invaluable guidance and encouragement and for providing good facilities to carry out this project work.*

We would like to express our deep sense of gratitude to ***Dr. P. Ramesh, Assistant Professor, Electrical and Electronics Engineering, CMR Institute of Technology, Bengaluru*** *for his/her exemplary guidance, valuable suggestions, expert advice and encouragement to pursue this project work.*

We are thankful to all the faculties and laboratory staffs of ***Electrical and Electronics Engineering Department, CMR Institute of Technology, Bengaluru*** *for helping us in all possible manners during the entire period.*

Finally, we acknowledge the people who mean a lot to us, our parents, for their inspiration, unconditional love, support, and faith for carrying out this work to the finishing line. We want to give special thanks to all our friends who went through hard times together, cheered us on, helped us a lot, and celebrated each accomplishment.

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LIST OF ABBREVIATIONS AND SYMBOLS

EV : ELECTRCIC VEHICLE

PV : PHOTOVOLTEIC

PWM : PULSE WIDTH MODULATION

CHAPTER 1

INTRODUCTION

This chapter will explain the study that is related to the project task. 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 surplus usage of these fossil fuel-based vehicle has enhanced the excavating of these conventional resources in an untenable approach. The most important downside is global warming caused by the burning of fossil fuels, where large amount of greenhouse gases is emitted that causes pollution. In prospect, there will be no fuel left for usage because of the rise in demand for gasoline and diesel. So, it is wise to adapt to electric vehicles rather than traditional IC engine vehicles.

1.1 Brief Background of the Research

For the worldwide increasing energy demand, Energy saving is one cost effective solution but that does not help much. Renewable energy is a good option because it gives a clean and green energy, with no CO2 emission. Renewable energy is defined as energy that comes from resources which are naturally refilled on a human timescale such as sunlight, wind, rain, tides, waves, and geothermal heat.

1.1.1 Why Renewable Energy?

- Delhi, capital city of India is one of the most heavily polluted cities in India as per the Figure 1.1.1. Recent study shows that pollution due to road dust and vehicles account for about 50% of total pollution.

- Number of solutions was proposed which mainly includes afforestation and restriction on usage of the vehicles

- Fine particulate matter (PM2.5) is an air pollutant that is a concern for people's health when levels in air are high.

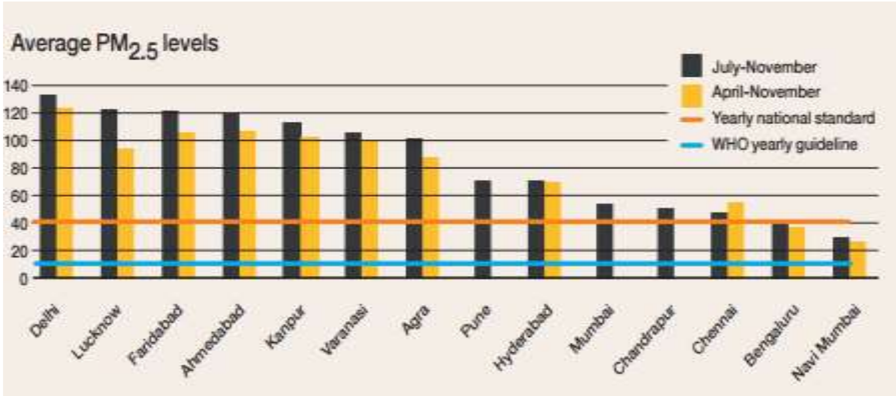


Fig. 1 Average PM 2.5 Levels

- Air pollution in Japan, China, and Germany forced government to adopt aggressive recycling and thus solar power in Japan has been on the rise since 1990s.

- Now Japan is the leading manufacturer of photovoltaic and it is also having the third largest solar PV installed capacity behind China and Germany.

Moreover, Japan opts for making solar power an important national project since the county's shift in policies towards renewable after Fukushima in 2011.

1.1.2 Why Solar Power?

Solar power is the conversion of energy from sunlight into electricity, either directly using photovoltaics (PV), or indirectly using concentrated solar power. Concentrated solar power systems use lenses or mirrors and tracking systems to focus a large area of sunlight into a small beam. Photovoltaic cells convert light into electric current using photovoltaic effect.

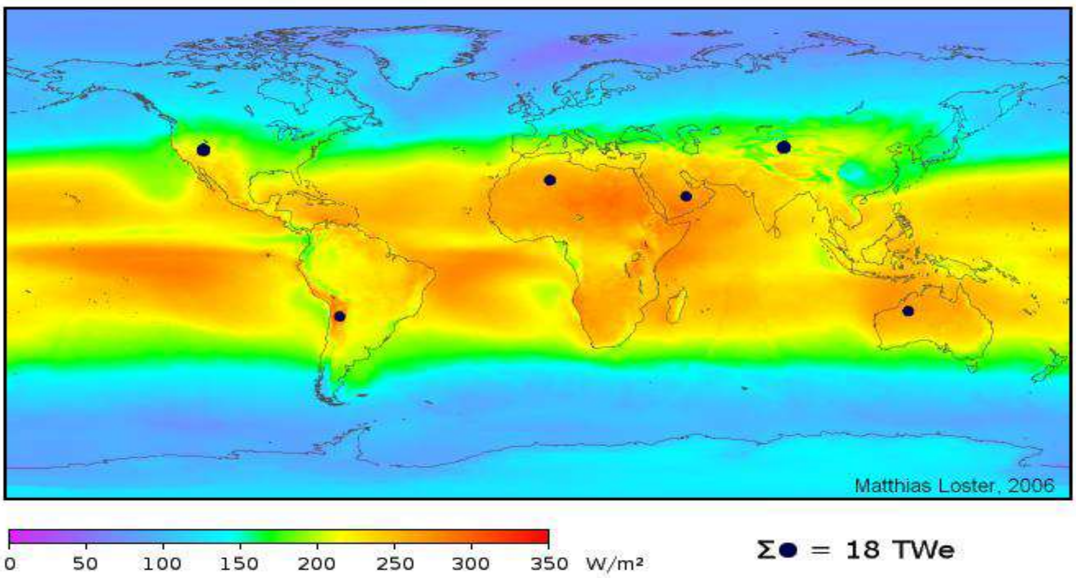


Fig. 2 Map showing Solar Energy distribution across the globe

The International Energy Agency projected in 2014 that under its "high renewables" scenario, by 2050, solar photovoltaics and concentrated solar power would contribute about 16 and 11 percent, respectively, of the worldwide electricity consumption, and solar would be the world's largest source of electricity. Most solar installations would be in China and India. The above Figure 2 represents the solar energy distribution across the globe.

1.2 Contribution

Solar energy is one source of power generation that independent away from petroleum and coal dependent energy resource. The major problem with solar energy is conversion efficiency poorer and high installation cost. Research going into this area to develop the efficient control mechanism and provide better control. So, the overall installation cost of the photovoltaic charging system reduces. The challenging research work going in this area is the motivation behind the project.

So, it is wise to adapt to electric vehicles rather than traditional IC engine vehicles. Solar power technology is an efficient and feasible alternative source of renewable energy. Solar energy from the sun is stored in a battery and is employed to run a vehicle. These vehicles result in pollution free atmosphere and quiet operation. In 2030, all IC engine vehicles might be replaced by electric vehicles. In recent times, DC solar power based various electric vehicle has been fabricated and tested.

1.3 Objective of the Thesis

Our objective is to hardware implement the solar powered electric vehicle using brushless DC motor, lithium ion battery, Kelly controller, solar panel, boost converter and apply MPPT incremental conductance technique to obtain maximum output power from solar module. We have to first simulate the same in MATLAB and obtain the desired results.

1.4 Layout of the Thesis

The main reason behind doing this project is already discussed above. Now, the question is its implementation. The operation will be like the motor in our projected will be coupled with Kelly controller, battery, and vehicle & the solar module will be coupled with boost converter circuit and battery. The output from solar panel will be stepped up using boost converter to charge the lithium-ion battery and then battery will supply power to motor to run the vehicle. MPPT conductance technique will be used to get maximum output through the solar panel throughout the day. Solar cars combine technology typical aerospace, bicycle, alternative energy and automotive industries. The design of a solar vehicle is severely limited by the amount of energy input into the car. Most solar cars have been built for the purpose of solar car races. Some solar cars are designed also for public use.

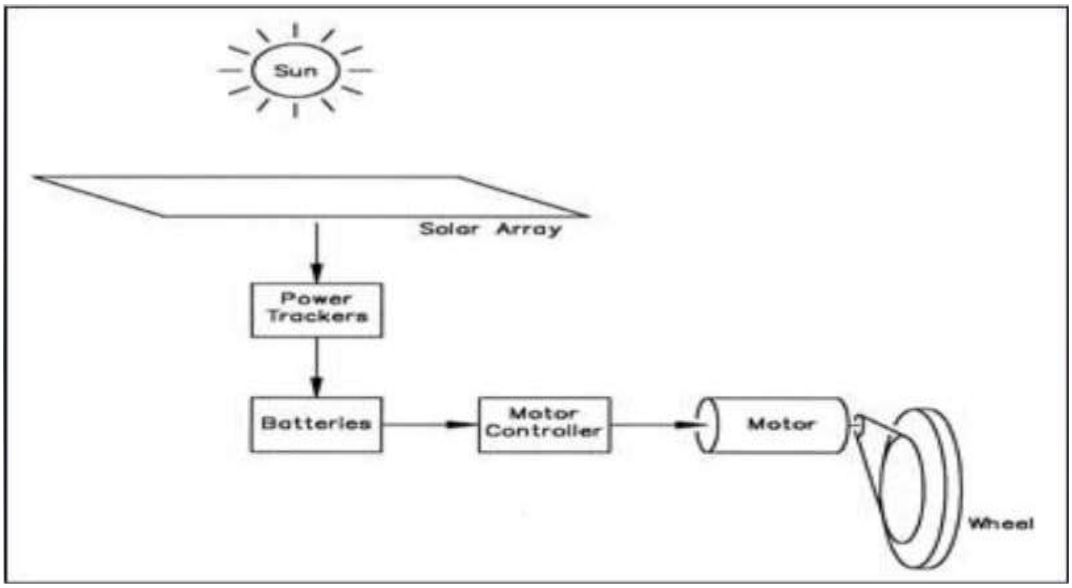


Fig. 3 Layout of the Solar Powered EV

This thesis enlists following topics:

- **Literature Review**
- **Proposed Model**
- **Design Process**
- **MATLAB Simulation**
- **Results and Discussions**
- **Conclusions**
- **Future Directions**
- **References**

CHAPTER 2

LITERATURE REVIEW

The review work is the study of all previous works related to the electric and solar cars have been done. Solar powered vehicle has been used for shorter distances. The main concentration was made on improving the design and making them cost effective. Energy from Sun is captured by the solar panels and is converted to electrical energy. The electrical energy thus obtained is being fed to the batteries that get charged and is used to run DC motor. The shaft of the motor is connected to the rear wheel of the vehicle through chain sprocket. The batteries are initially fully charged and thereafter they are charged by panels.

2.1 Different Models Being Proposed

2.1.1 Sun Mobile

In 1955, William G. Cobb of the General Motors Corp. (GM) demonstrates his 15-inch-long "Sun-mobile", world’s first ever solar-powered automobile at the General Motors Power and Auto show held in Chicago, Illinois. Cobb’s Sun mobile introduced the field of Photovoltaics - the process by which the sun’s rays are converted into electricity when exposed to certain surfaces. When sunlight hit 12 photoelectric cells made of selenium built into the Sun mobile, an electric current was produced which in turn powered an electric motor. The motor turned the vehicle's driveshaft which was connected to its rear axle by a pulley.

Fig. 4 Sun Mobile

2.1.2 Baker Electric car

In 1962, the first solar car that a person could drive was demonstrated to the public. The International Rectifier Company converted a vintage model 1912 Baker electric car to run on photovoltaic energy in 1958, but they did not show it until 4 years later. Around 10,640 individual solar cells were mounted to the
rooftop of the Baker to help propel it.

Fig. 5 Baker Car Model

2.1.3 GM Sunraycer

The GM Sunraycer in 1987 completed a 1,866 mile trip with an average speed of 42 mph. Since this time there have been many solar cars invented at universities for competitions such as the Shell Eco Marathon. GM Sunraycer
was 19.7 feet long, 6.6 feet wide and 3.3 feet high. It weighs 390 pounds and had gross weight of 573 pounds with driver. Average speed of 41.6 mph during 44.9 driving hours over 1950-miles race. It was made of aluminum tube space-frame chassis with body of composite sandwich material. It contains solar array of about 90 square-feet to power 3 KW, 4 HP brushless DC-Motor.

There is also a commercially available solar car called the Venturi Astrolab. Time will only tell how far the solar car makes it with today's and tomorrow's technology.

(a) Sunraycer

(b) Venturi Astrolab

Fig. 6 GM Designs

2.1.4 Citi Car

At Tel Aviv University in Israel, Arye Braunstein and his colleagues created a solar car in 1980. The solar car had a solar panel on the hood and on the roof. The Citicar comprised of 432 cells creating 400 watts of peak power. The solar car used 8 batteries of 6 volts each to store the photovoltaic energy. The 1320 pounds solar Citicar is said by the engineering department to have been able to reach up to 40 mph with a maximum range

Fig. 7 Citicar

of recently Abhinya Chaturvedi, Kirti Kushwaha, Parul Kashyap, Dr. J. P. Navani of Electrical & Electronics Department, Raj Kumar Goel Institute of Technology for Women, Ghaziabad, India presented a paper on April 2015 about solar powered vechicle.This survey aims at reducing fuel cost and to use hybrid technologies including the possibilities of hydrogen fuel. The paper also explains about the history of solar vehicles and development of a telemetry system where solar power cars can serve for better understanding of energy usage in vehicles and the aspects applicable to electric vehicle.

2.2 Different Methodology (MPPT CONTROL TECHNIQUES)

2.2.1. Fractional Open-Circuit Voltage (FOCV)

This algorithm is based on the relation between the maximum power point voltage $Vmpp$ and the open circuit voltage Voc. The maximum power point voltage $Vmpp$ is always a constant fraction of the open circuit voltage Voc as [4]
it is given by Eq. [$Vmpp = kv.Voc$]
The constant fraction kv is between 0.7 and 0.8. Voc is measured and used as in input to the controller. FOCV needs measurements of Voc. So, it is necessary to introduce a static switch into the PV array. The switch must be connected in series to open the circuit. In this method, Vpv is needed for the PI regulator.

2.2.2. Fractional Short-Circuit Current (FSCC)

The Fractional Short-Circuit Current (FSCC) [4] method is based on the proportionality between the optimum operating current $Impp$ and the short circuit current Isc. Eq. shows that $Impp$ can be determined instantaneously by detecting Isc. [$Impp = ki.Isc$] where k_i is the constant factor.
This technique requires measurements of the short circuit current Isc. It is essential to introduce a static switch in parallel with the PV array to get this measurement so that the short circuit's condition is generated. When $Vpv = 0$, there is no supplied power by the PV system. As a result, no energy is generated. As mentioned in the previous technique, the PV voltage measurement's is required for the PI regulator.

2.2.3. Perturb and Observe (P&O)

The application of Perturb and Observe (P&O) [5] algorithm has been widely used since it is an easy one to be implemented. This algorithm perturbs the operating voltage to ensure maximum power.

The P&O technique compares the power of the previous step and the new step so that it increases or decreases the voltage or current. Operating on the left of the MPP, it is noticeable that incrementing (decrementing) the voltage allows

to increase (decrease) the power and decrease (increase) the power when on the right of the MPP. The perturbation is kept the same to reach the MPP when there is an increase in power and vice-versa. P&O has a good behaviour when the irradiance does not change quickly with time. However, the power oscillates around the MPP in steady state operation and it fails with variations of temperature and irradiance.

2.2.4. Incremental Conductance method (IC)

The Incremental Conductance (IC) [5] algorithm, compares the incremental and instantaneous array conductance ($dI\ dV$ and $I\ V$ respectively) in a PV system. Depending on the result, it increases or decreases the voltage until MPP is reached.

Contrary to P&O, the PV voltage remains constant once the MPP is reached. This technique decreases the oscillations problem and it is easy to be implemented.

2.2.5. Robust Unified Control Algorithm (RUCA)

The Robust Unified Control Algorithm (RUCA) [6] exploits two control inputs $u1(k)$ and $u2(k)$ to reach the MPP. They are used either simultaneously or alternatively.

They are defined as

$$u1(k) = K1a1\,\Delta P(k)\,sign(\Delta V(k)) \quad (14)$$

$$u2(k) = K2a2\,\Delta P(k)\,sign(\Delta I(k))$$

2.3 Our Vehicle

After giving an overview about the cars which had already been used, here is a detailed description of our solar powered vehicle. It is a four-wheeler, two sitter vehicles. In this vehicle we have used a belt pulley mechanism. The solar energy is harnessed using solar panels which are used for charging the batteries. The batteries run the motor which drives the wheel of the vehicle. The vehicle which we have made as our project uses a belt pulley mechanism in which the shaft of the motor is connected through the belt pulley system. The power supplied to the batteries is from the solar panels which are giving a total output of 250-300 W and they are then used for charging the batteries. The batteries which we are using are lithium-ion batteries which are of 48V rating each of 12V connected in series. The motor's rating is of 50V which gets charged through the four 12V batteries. The belt used in our project is a timing belt which has teeth that fit into a matching toothed pulley. When correctly tensioned, they have no slippage, run at constant speed, and are often used to transfer direct motion for indexing or timing purposes. They are often used in lieu of chains or gears, so there is less noise and a lubrication bath is not necessary. Timing belts need the least tension of all belts and are among the most efficient. We have laid emphasis on the economical part so that it can be used to cover short distances without consuming energy from external sources and at the same time keep the environment pollution free.

Fig 8. Our Vehicle

CHAPTER 3

PROPOSED MODEL WITH THEORETICAL BACKGROUND

3.1 Solar PV based Electric Vehicle

In general, the suggested solar PV established Electric vehicle block diagram is shown in Fig.3.1.

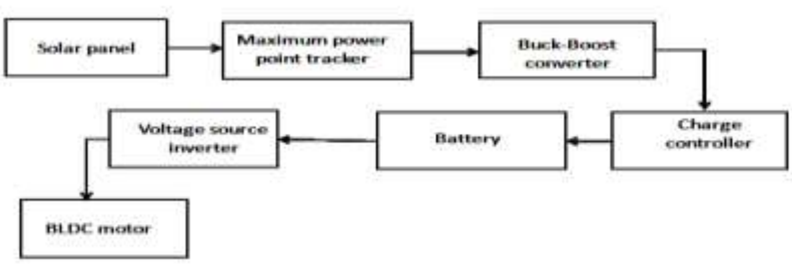
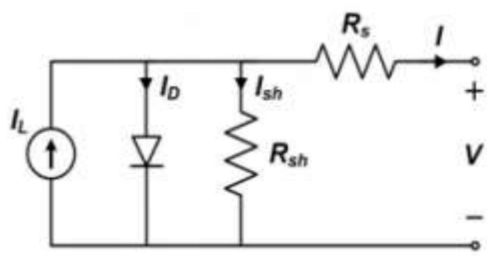


Fig 9. Block Diagram of Proposed Model

3.1.1 Solar PV system

A solar PV cell is a device that directly transforms solar energy to electrical energy by the photovoltaic effect, it defines an electrical characteristic such as current and voltage fluctuate when it exposed to light. The solar cell equivalent circuit is shown in fig 3.1.1 and Equation (1) describes the current drawn from the solar cell.



$$I = I_{sh} - I_d = I_{sh} - I_0(e^{\frac{Q(V+IR_S)}{akTc}} - 1)$$

[Equation 1]

a = Idealizing aspect

k= Boltzmann's constant
Tc= cell temperature in absolute
Q = charge of electron
V= voltage imposed across the cell
I0= dark saturation current

The essential parameters of a solar cell are following: Short circuit current (Isc) is the highest generated current under short circuit situations in which voltage across a cell is zero. Open circuit voltage is the voltage of cell at night, when generated current is zero and is given by the equation (2) mathematically

$$V_{open\ circuit} = V_t\, ln(\frac{I_{sh}}{I_0})$$

$$\text{Where, } V_t = \frac{\text{akTc}}{\text{Q}}.$$

[Equation 2]

$$\eta_{max} = \frac{P_{max}}{P_{min}}$$

[Equation 3]

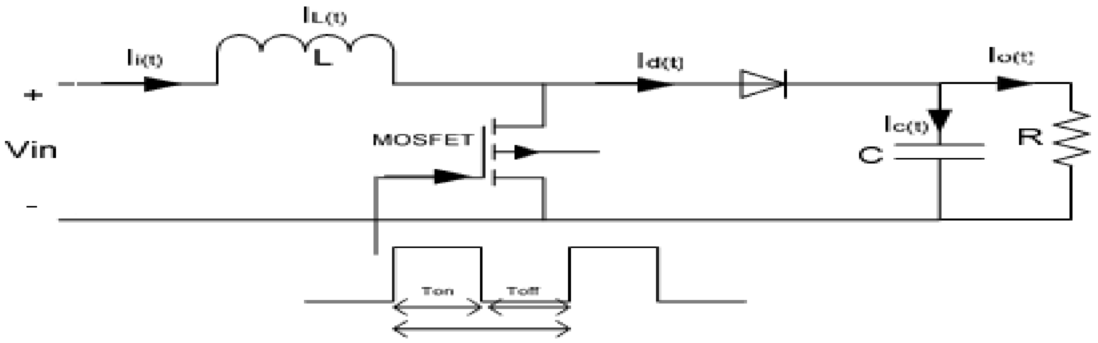
$$FF = \frac{P_{max}}{(V_{oc} I_{sc})}$$

[Equation 4]

MPP is the point of current-voltage curve, where dissipated power is maximum. Maximum efficiency is the ratio between power at maximum and power at incident light. Fill Factor is the ratio between power at maximum and the product of short circuit current and open circuit voltage.

3.1.2 Boost Converter

The converter is a switch mode DC to DC converter in which the DC output voltage can be altered to a lower or higher level than the DC input voltage. The magnitude of output voltage depends on the duty cycle of the switch in converter.



This DC-DC converter can be actuated in two ways of operation, continuous and discontinuous conduction way. In former mode, afore the beginning of the switching cycle, the current flows through inductor moderately discharges, but never goes to zero. In the second mode, the current through inductor goes to zero. In this DC-DC converter, the duty cycle adjustment of the power switch controls the output voltage. When the power switch is triggered ON, the input source makes current to the inductor (L) and load. When the power switch is triggered OFF, the stored energy from inductor freewheels current continuously to the load through the diode.

3.1.3 Solar PV Panel with MPPT Charge Controller

The greatest govern feature of the entire vehicle is designed based on the solar PV panel intention. The power rating of a motor is 1500W. So, the solar PV is designed with 250W with keeping 50W as tolerance. The total number of PV panel used in this vehicle is 1. The specification of solar PV is as follows: Maximum voltage from one cell is 0.6666V, the available size of the 24V solar panel for is 49 Square feet, the maximum voltage from 36 cells of the solar panel at open circuit is 24V and maximum voltage output at average condition of the sunlight is 21.5V. The maximum current from 36 cells of the solar panel at open circuit is 10A, the maximum current output at average condition of sunlight a short circuit is 8.15A, the maximum power output from a solar panel in average condition of sunlight is 220W and the maximum power output from 4 solar panel output is 1000W. The MPPT controller Simulink diagram is shown in the next chapter which is a controller with boost DC converter. It creates enhancement in the counterpart between the solar PV output panels and the battery voltage. It basically maintains DC output from the solar panels to the required voltage needed to charge the battery. The Boost Converter Simulink model is shown in **Fig (27).** To sustain the voltage in the battery, the main task of this converter is to excerpt the extreme power from the solar by regulating operating voltage and current of the converter in such a way that, it achieves the Maximum Power Point (MPP). The MPPT controller works as follows: the PV array current and voltage are intuited at a certain sampling cycle using a current and voltage sensor, respectively. These tracked values of voltage and current are fed into an MPPT block which computes MPP and provides the mention values for the current and voltage.

These are converted to a power value that must be same as requirement of the converter. If there is a difference between the two duty cycles of the boost converter is adjusted. The maximum power from the PV array is extracted when the measured power equals to the reference value. The converter is usually based on the typical non isolated, boost type. The most crucial feature of the MPPT is its ability to track the MPP as rapidly and powerfully as possible. There are many types of MPPT controller such as Perturb and observe, incremental conductance and hill climbing. These controllers are configured using static or adaptive step time. The “incremental conductance” method used provides improved tracking efficiency because it reduces steady state oscillation.

3.1.4 Battery

A lithium-ion (Li-ion) battery is an advanced battery technology that uses lithium ions as a key component of its electrochemistry. During a discharge cycle, lithium atoms in the anode are ionized and separated from their electrons. The lithium ions move from the anode and pass through the electrolyte until they reach the cathode, where they recombine with their electrons and electrically neutralize. The lithium ions are small enough to be able to move through a micro-permeable separator between the anode and cathode. In part because of lithium’s small size (third only to hydrogen and helium), Li-ion batteries are capable of having a very high voltage and charge storage per unit mass and unit volume.

Compared to the other high-quality rechargeable battery technologies (nickel-cadmium or nickel-metal-hydride), Li-ion batteries have a number of advantages. They have one of the highest energy densities of any battery technology today (100-265 W-h/kg or 250-670 W-h/L). In addition, Li-ion battery cells can deliver up to 3.6 Volts, 3 times higher than technologies such as Ni-Cd or Ni-MH. This means that they can deliver large amounts of current for high-power applications, which has Li-ion batteries are also comparatively low maintenance, and do not require scheduled cycling to maintain their battery life. Li-ion batteries have no memory effect, a detrimental process where repeated partial discharge/charge cycles can cause a battery to ‘remember’ a lower capacity.

Fig. 10 Li-Ion Battery

3.1.5. BLDC motor

1500W synchronous type BLDC motor controls the electric vehicle. BLDC motor generates both stator and rotor magnetic fields with related frequency. The BLDC motor has a higher efficiency and extensive life without brushes and mechanical commutator. Also, it has a lower loss owing to high starting torque and increased in efficiency. Out of many configurations, three phase motors are the most popular and are widely used in e-bikes. The vehicle is selected a hub motor because the motor replaces the hub of the wheel. Coupling loss is reduced and mounting can be made easy without the use of chains or belts, and that reduces size and weight of the vehicle. The data sheet or specifications of BLDC Motor is given as per the Indian Standards. The motor always comes with a controller which controls its output depending upon the requirements.

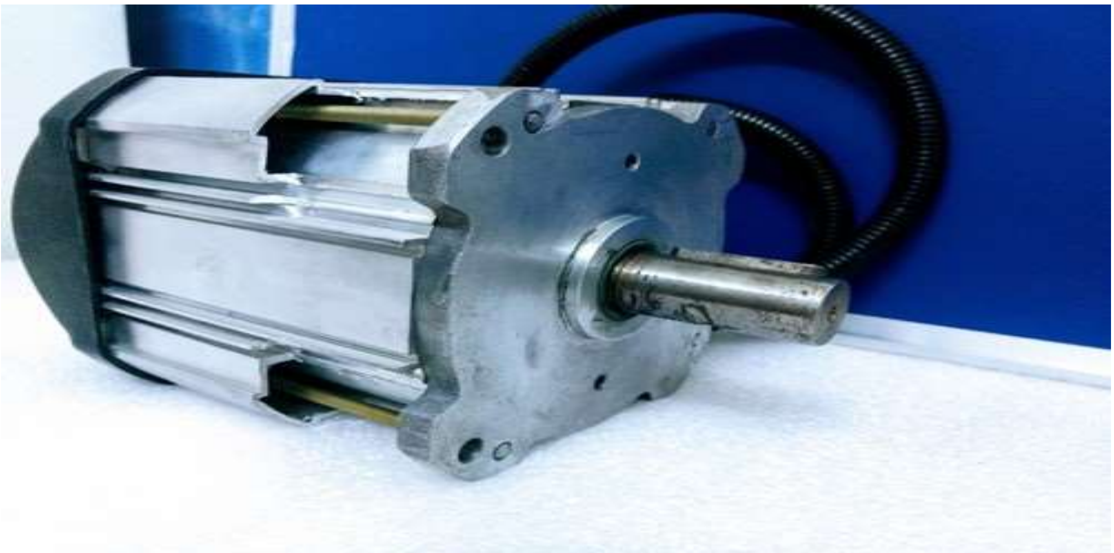
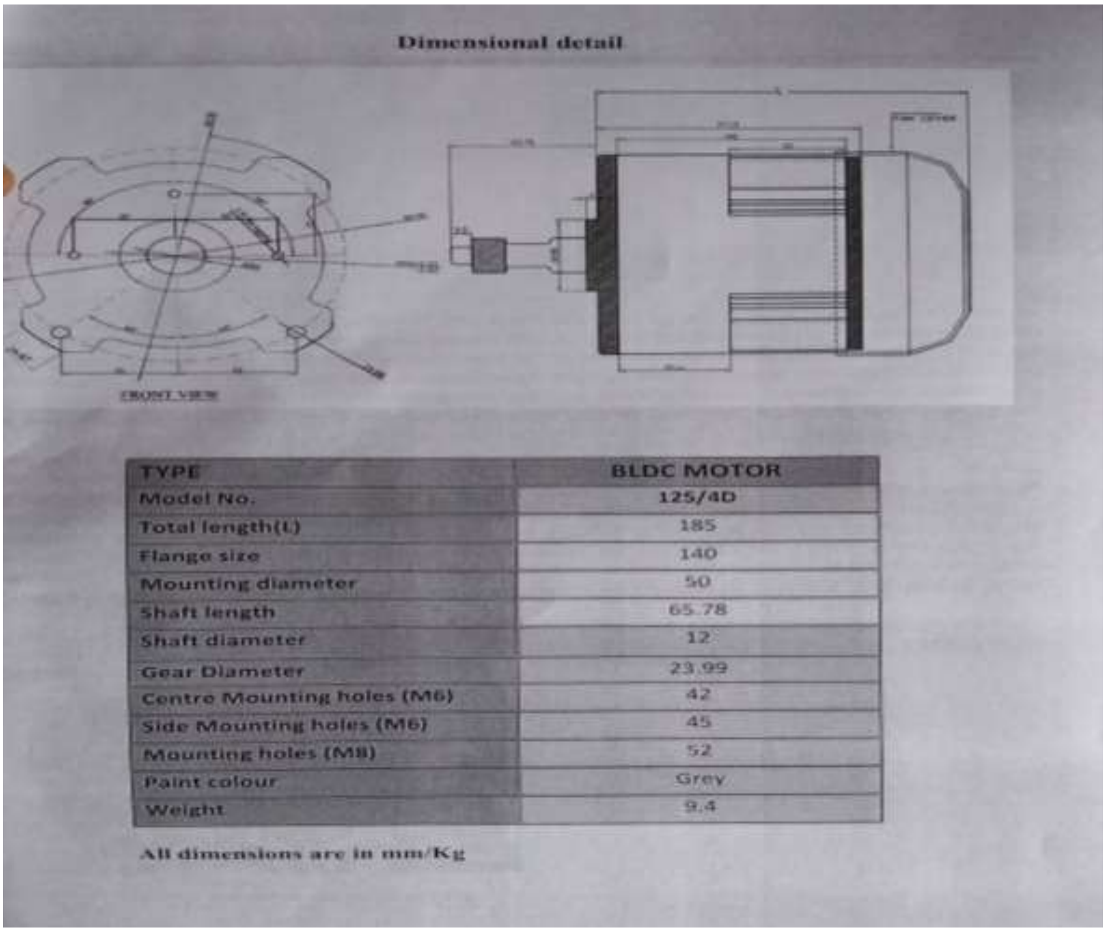


Fig. 11 BLDC Motor

Specifications of BLDC Motor:



Dimensional detail

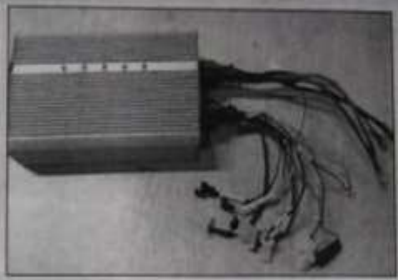
FRONT VIEW

TYPE	BLDC MOTOR
Model No.	125/4D
Total length(L)	185
Flange size	140
Mounting diameter	50
Shaft length	65.78
Shaft diameter	12
Gear Diameter	23.99
Centre Mounting holes (M6)	42
Side Mounting holes (M6)	45
Mounting holes (M8)	52
Paint colour	Grey
Weight	9.4

All dimensions are in mm/Kg

Fig. 12 Specification of BLDC Motor

SPECIFICATIONS OF BLDC 125/4D:



Motors type	BLDC
Frame size:	BLDC 125/4D,
Power (watt)	1500
Current (Amp)	32.0
Voltage range ±Variation	48 /60 V DC, (± 10%)
Speed (RPM)	3000
Motor poles	8
Hall Sensor	5 Volts
Mounting	Flange
Degree of protection	IP 55
Class of insulation	F
Ambient Temp. / Max Temp.	50° C / 70° C
Duty / Rating	S1/ continuous
Direction of rotation	Bi-directional
Cooling	Shaft mounted fan
Seal	Front and back seals are provided

Fig. 13 Specification of BLDC Motor

3.1.6 Kelly Controller

It is a motor controller which has various connections which are used to establish connection between Motor – Controller, Controller – Throttle, Battery – Controller. It uses MosFets inside and PWM for efficiency. BLDC motors are not self-commutating hence they are complicated to control. It has a 5-pin hall sensor which connects motor to controller and is used to measure the position of shaft of motor so that controller could decide how to deliver power. Hall sensor is used because it has low resolution and low cost as well as accurate about the position of shaft. Sensors are very important because if we don't get the shaft position information correctly then passing current to adjacent pole could not be on time and too early or too late switching of current can affect the performance (Torque)

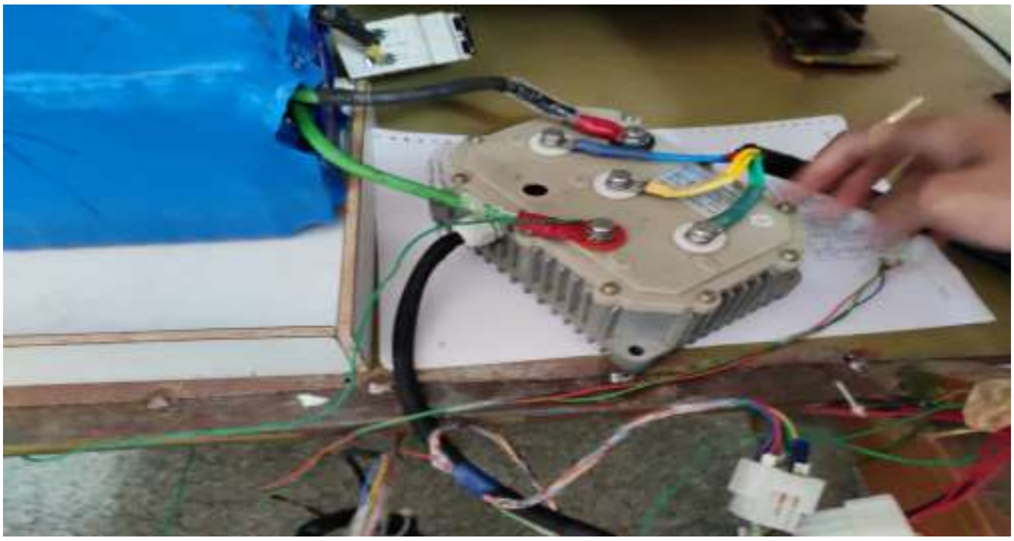


Fig. 14 Kelly Controller

3.2 Hardware components involved within MPPT Controller

To maximize a photovoltaic (PV) system's output power, continuously tracking the maximum power point (MPP) of the system is necessary. The MPP depends on irradiance conditions, the panel's temperature, and the load connected. Maximum power point tracking algorithms provide the theoretical means to achieve the MPP of solar panels;

these algorithms can be realized in many different forms of hardware and software. PV systems that lack MPPT rarely operate at the most efficient, MPP. Therefore, the rated power of the solar panel is almost never realized when connecting a load.

The team first look through existing analysis and possible solutions to the MPP problem. It became clear that the perturb and observe (P&O) technique was widely used for its ease of implementation. It is based on the following criterion: if the operating voltage of the PV array is perturbed in a given direction and if the power drawn from the PV array increases, this means that the operating point has moved toward the MPP and, therefore, the operating voltage must be further perturbed in the same direction. Otherwise, if the power drawn from the PV array decreases, the operating point has moved away from the MPP and, therefore, the direction of the operating voltage perturbation must be reversed.

Figure 3.2 Solar MPPT model]

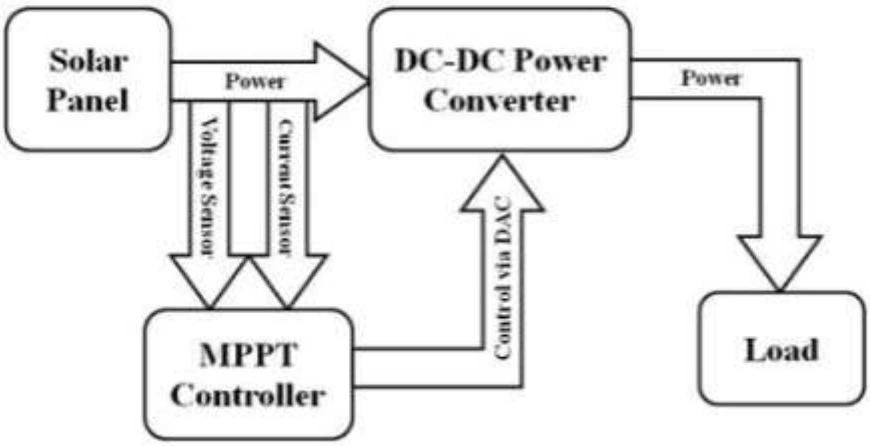


Fig. 15 Block Diagram of EV

3.2.1 Digital controller

The microcontroller provides the control in our system. The choice of microcontroller for the system dictates much of the cost, performance, and flexibility of the entire system. Taking into consideration the projects constraints, the Texas Instruments TMS320F28335 model digital signal controller (DSC) was chosen. The single-chip C2000 family of microcontrollers is targeted toward real-time control applications thanks to powerful, high performance integrated peripherals.

The core gives designers the means to improve system efficiency, reliability, and flexibility when the application requires complex algorithms.

It features:

- 32-BIT FLOATING POINT CPU
- MEMORY: 68K SARAM, 512K FLASH
- MAC OPERATIONS
- 16 12-BIT ADC CHANNELS
- 18 PWM OUTPUTS
- LOW POWER DISSIPATION
- 32-BIT CPU TIMERS
- 1 WATCHDOG TIMER
- 88 GPIO
- 6 CHANNEL DMA

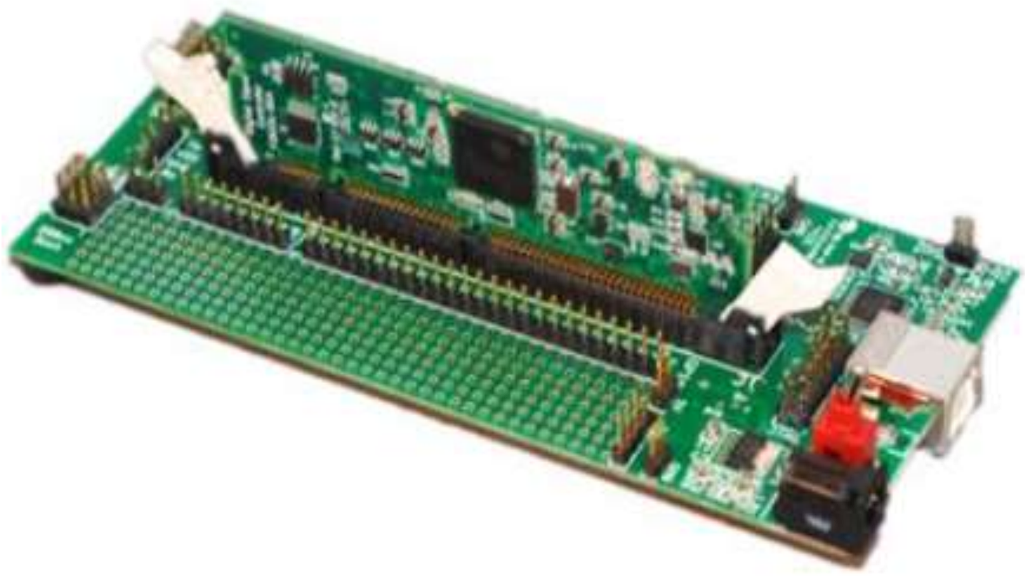


Fig. 16 Digital Converter

3.2.2 DC-DC Converter

A DC-to-DC converter is an electronic circuit which converts a source of direct current from one voltage level to another. It is a class of power converter. Electronic switch-mode DC to DC converters operate by storing the input energy temporarily and then releasing that energy to the output at a different voltage and current. Just like a transformer, they essentially just change the input energy into a different impedance level. So whatever the output voltage level, the output power all comes from the input; there is no energy manufactured inside the converter. In fact some energy is used by the converter circuitry and components while doing their job. It is this principle that makes a DC-DC Converter essential for MPPT.

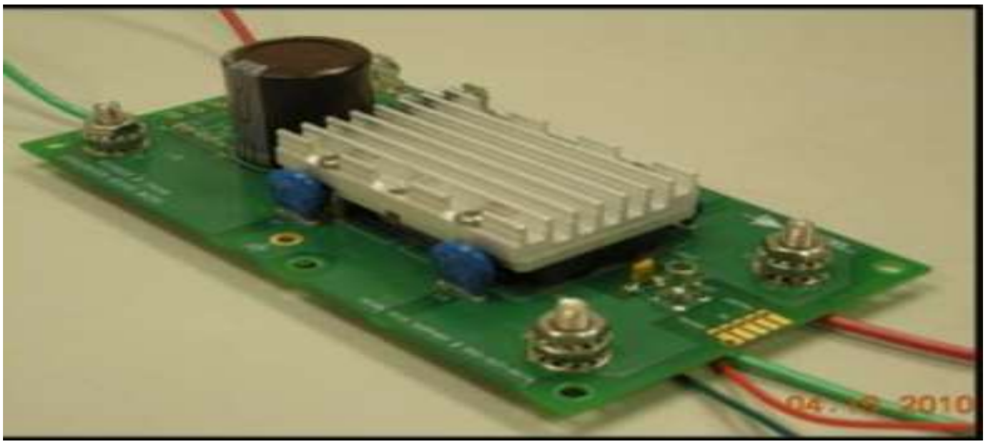


Fig. 17 DC-DC Converter

The DC-DC power converter used in our system is a 48-60 V_{out}, 250 W V28C24C100BL model manufactured by Victor. The input voltage range of the converter is 9-36 Vdc. Because the voltage provided by the solar panel (which serves as the input voltage to the converter) can drop below the converter's 9 Vdc minimum and thus cause the converter to shut down, our MPPT system is only operational when the voltage provided by the solar panel is greater than or equal to 9 Vdc. The output voltage of the converter can be varied between 10% and 110% of its nominal 50 Vdc output (i.e. 5-55 Vdc) via a reference input voltage at the SC pin with respect to the -OUT pin between 0.123-1.353 Vdc. The converter has the capability of functioning in isolated or non-isolated mode depending on whether the grounds of the converter (-IN and -OUT) are separate or connected respectively.

3.2.3 Sensing circuits

Voltage Sensing Circuit

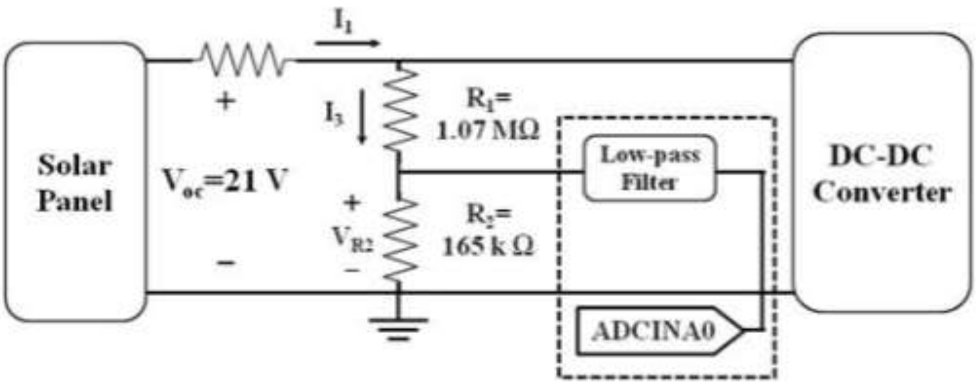


Fig. 18 Voltage Sensor

In order for the MPPT controller to measure the voltage provided by the solar panel, two resistors, R1 and R2, are employed in parallel with the solar panel to act as a voltage divider. The voltage across R2 in the voltage divider is fed into an analog-to-digital converter (ADC) driver circuit (op-amp in a voltage follower configuration that feeds into a low-pass filter) before being delivered to the ADCINA0 channel of the MPPT controller. By choosing the values of R1 and R2 as 1.07 MΩ and 165 kΩ respectively, the maximum amount of current diverted from the load, I2, is small enough, even in a worst-case scenario, to be considered negligible. The allowable voltage range for each ADC channel of the MPPT controller is 0-3 Vdc. Therefore, the voltage across R2 (which serves as a scaled-down representation of the solar panel's voltage) should not exceed 3 Vdc. Based on the chosen value of R2 as 165 kΩ, the maximum voltage, V(R2,max), sent to the ADC driver circuit (and thus ADC channel ADCINA0) is ~2.81 Vdc.

Current Sensor

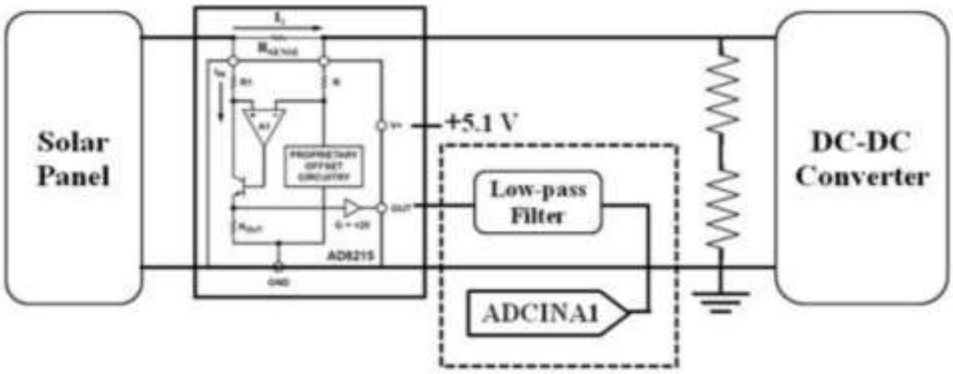


Fig. 19 Current Sensor

In order for the MPPT controller to measure the current provided by the solar panel, a single resistor (Rsense) is placed in series between the solar panel and the DC-DC converter. The voltage across Rsense is fed into an AD8215 current sensor manufactured by Analog Devices whose output voltage is then fed into an ADC driver circuit (op-amp in a voltage follower configuration that feeds into a low-pass filter) before being delivered to the ADCINA1 channel of the MPPT controller. By choosing the value of Rsense as 51 mΩ, the maximum voltage drop across Rsense, VRsense, is small enough, even in a worst-case scenario, to be considered negligible. As stated previously, the allowable voltage range for each ADC channel of the MPPT controller is 0-3 Vdc. Therefore, the output voltage of the AD8215 current sensor (which serves as an equivalent voltage representation of the solar panel's current) should not exceed 3 Vdc. Based on the chosen value of Rsense as 51 mΩ, the maximum voltage, Vout, sent to the ADC driver circuit (and thus ADC channel ADCINA1) is ~2.73 Vdc.

Sensing circuit with ADC Driver

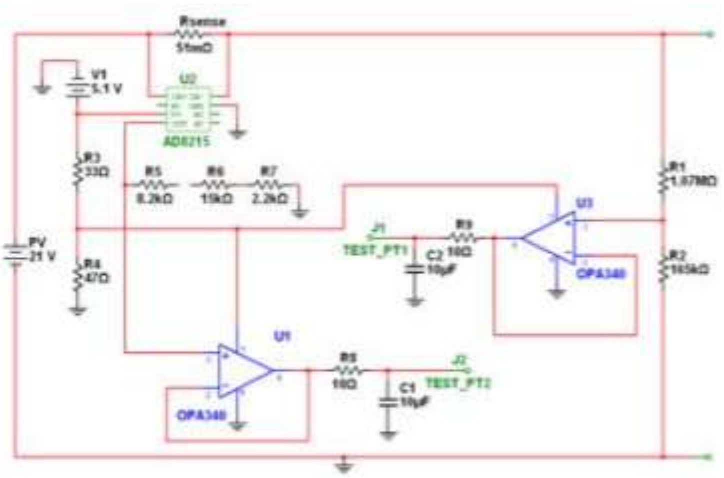


Fig. 20 Sensing circuit with ADC driver

In order to condition each of the voltage signals sent to the ADC channels of the MPPT controller, Texas Instruments OPA340 model op-amps are used in voltage follower configurations with each of their outputs fed into a low-pass filter. The OPA340s provide low output impedance to each of the ADC channels without modifying each of the output voltages being sent from the voltage and current sensor circuits. Of added benefit is the op-amps' ability to protect each of the ADC channels from being permanently damaged by an input voltage that exceeds its maximum operating threshold. This is accomplished by powering each of the op-amps with the maximum allowed voltage of the ADC channels: 3 Vdc. This effectively clips any potentially damaging voltage that would otherwise be fed into the ADC channel at a safe value of 3 Vdc. The voltage and sensor circuits along with their corresponding ADC driver circuits are all combined to form the sensing circuit for the MPPT

3.2.4 Digital to Analog converter

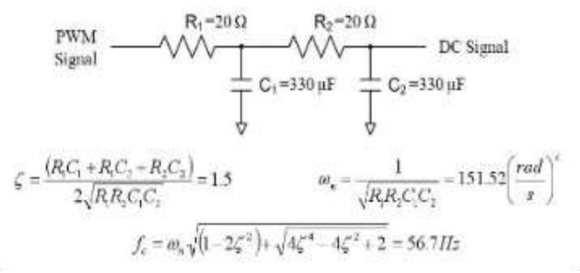


Fig. 21 DAC

The DC-DC converter is controlled via a reference input voltage at the SC pin with respect to the -OUT pin between 0.123-1.353 Vdc. The digital signal controller utilizes on-chip pulse width modulated (PWM) signal generators to create an output signal meant to control the DC-DC converter. An analog low-pass filter can remove the high frequency components of the PWM signal, leaving only the low-frequency content. In this MPPT application, a second-order passive filter was used to provide adequate filtering and resolution. The PWM duty cycle is controlled via software; the duty cycle values for which the reference input voltage of the converter is 0.123-1.353 Vdc were obtained experimentally and the software ensures that the signal is never out-of-range. This (PWM as DAC) solution is a legitimate lower cost alternative to dedicated off-chip DACs.

3.3MPPT (P & O and Incremental Conductance)

Various algorithms may perform MPPT. Important factors to consider when choosing a technique to perform MPPT are the ability of an algorithm to detect multiple maxima, costs, and convergence speed. The irradiance levels at different points on a solar panel's surface tend to vary. This variation leads to multiple local maxima power points in one system. The efficiency and complexity of an algorithm determine if the true maximum power point or a local maximum power point is calculated. In the latter case, the maximum electrical power is not extracted from the solar panel.

The type of hardware used to monitor and control the MPPT system affect the cost of implementing it. The type of algorithm used largely determines the resources required to build an MPPT system. For a high-performance MPPT system, the time taken to converge to the require operating voltage or current should be low. Depending on how fast this convergence needs to occur and your tracking system requirements, the system requires an algorithm (and hardware) of suitable capability.

- PERTURB AND OBSERVE
- P & O INCREMENTAL CONDUCTANCE

3.3.1 Perturb and Observe

The concept behind the perturb and observe (P&O) method is to modify the operating voltage or current of the photovoltaic panel until you obtain maximum power from it. For example, if increasing the voltage to a panel increases the power output of the panel, the system continues increasing the operating voltage until the power output begins to decrease. Once this happens, the voltage is decreased to get back towards the maximum power point. This perturbance continues indefinitely. Thus, the power output value oscillates around a maximum power point and never stabilizes.

P&O is simple to implement and thus can be implemented quickly. The major drawbacks of the P&O method are that the power obtained oscillates around the maximum power point in steady state operation, it can track in the wrong direction under rapidly varying irradiance levels and load levels, and the step size (the magnitude of the change in the operating voltage) determines both the speed of convergence to the MPP and the range of oscillation around the MPP at steady state operation.

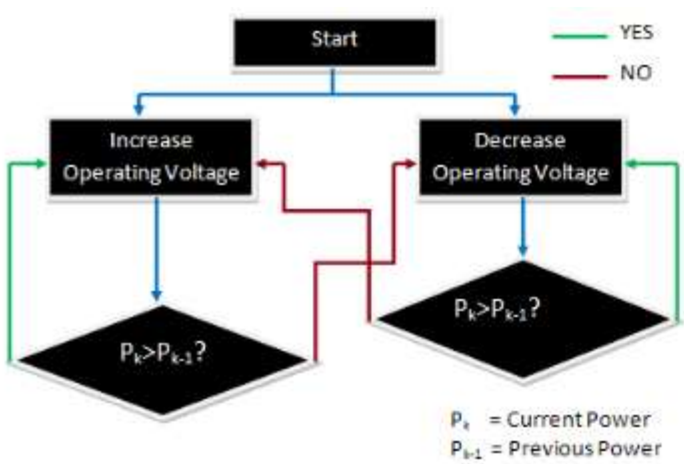


Fig. 22 P & O Algorithm

3.3.2 Incremental Conductance Method

Incremental conductance considers the fact that the slope of the power-voltage curve is zero at the maximum power point, positive at the left of the MPP, and negative at the right of the MPP. The MPP is found by comparing the instantaneous conductance (I/V) to the incremental conductance (ΔI/ΔV). Once you have the MPP, the system maintains this power point unless a change in V or I occur (caused by an external event). If this happens, the algorithm will find the new MPP.

This technique has an advantage in that it can reach and maintain the MPP without losing some efficiency by having to oscillate around this point. Under rapidly changing conditions this algorithm tracks more accurately than the P&O method. The disadvantage of this method is that it can take longer to reach the MPP because the increased computation required decreases the number of perturbations to the operating voltage and current possible in a set amount of time.

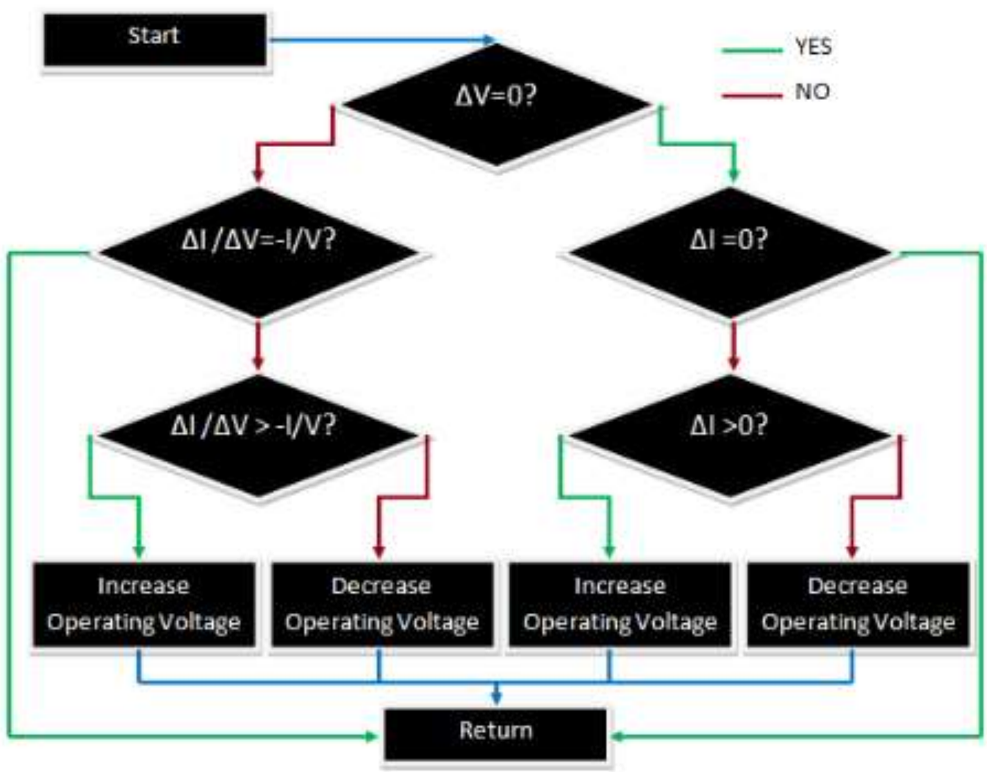


Fig. 23 Incremental Conductance Algorithm

CHAPTER 4

DESIGN PROCESS

4.1 Design of DC-DC Boost Converter

The DC-DC converter has mainly two modes, both are being used as their own purpose. CCM is being used for efficient power conversion and discontinuous conduction mode is mainly used for low power or stand by operation.

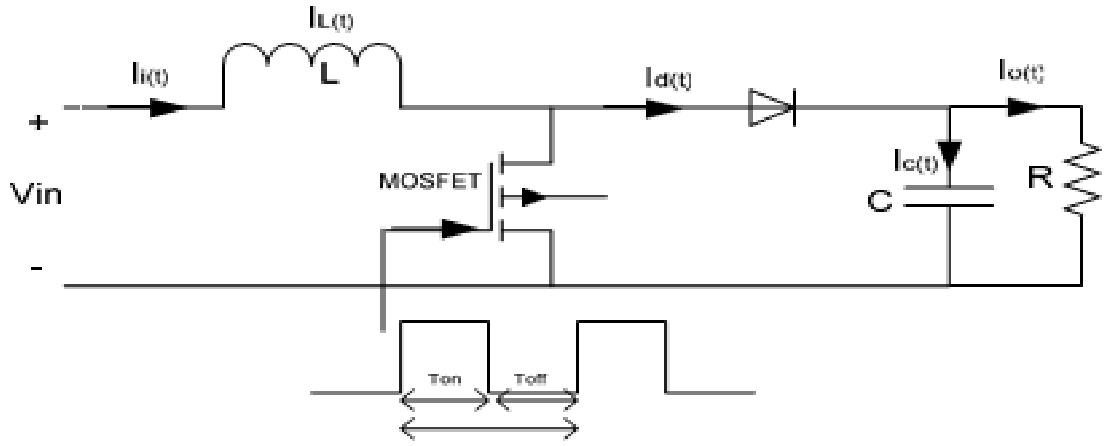


Fig 24 Electrical equivalent circuit of DC-DC Converter

4.1.1 Continuous Conduction Mode

(a) Mode1 ($0 \leq t \leq t_{on}$)

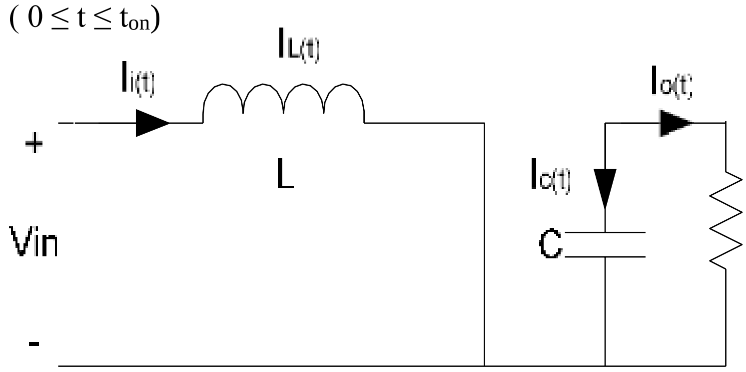


Fig. 25 Electrical equivalent of Boost Converter for CCM

Mode 1 begins when MOSFET is switched on at t =0.The equivalent circuit is shown in figure. When it is on the inductor current is greater than zero and it will ramp up linearly. The equivalent circuit for mode 1 has been shown in figure given below.

(b) Mode-2 ($t_{on} \leq t \leq t_{off}$)

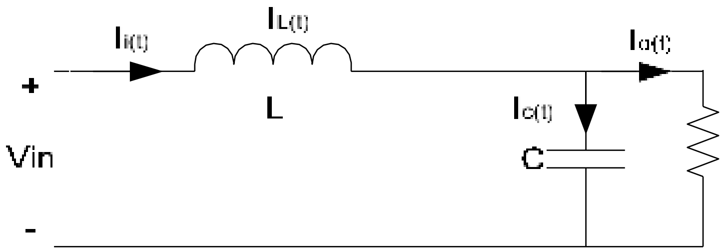


Fig. 26 Electrical equivalent of Boost Converter for CCM

Mode 2 starts when MOSFET is switched off at t=t_{on} and terminates at t=t_{off}. Equivalent circuit for Mode 2 has been shown in the above figure. The inductor current decreases in this mode until the MOSFET is turn on for the next cycle.

$$V_{in}t_{on} + (V_{in} - V_{out})t_{off} = 0$$

The equation for Duty cycle of the converter is given below

$$D = 1 - \frac{v_{in} \times \eta}{v_{out}}$$

4.1.2 Selection of Semiconductor Devices

The selection of semiconductor should be done in such a way so that it can withstand the worst case voltage and current the maximum voltage of solar PV will be the maximum voltage stress for the switch.

$$V_{\max, stress} = V_{pv,\max}$$

Maximum current stress will take place only when system power is predominately provided by PV system.

$$I_{PEAK} = I_{OUTPUT} + I_{RIPPLE}$$

$$I_{PEAK} = \underline{P_{in}}$$

Selection of Inductor

It should be ensured that coil should have low dc resistance. Selection of inductor should be done on the basis so that it allows the maximum ripple current at minimum duty cycle D. Boost inductor value can determined by the following equation.

$$L = \frac{v_{in} \times (v_{out} - v_{in})}{\Delta I_L \times F_S \times V_{out}}$$

Selection of Capacitor

The value of capacitor should be chosen in such a way so that its ESR should be minimum. Lower ESR will also minimize the ripple in output voltage.

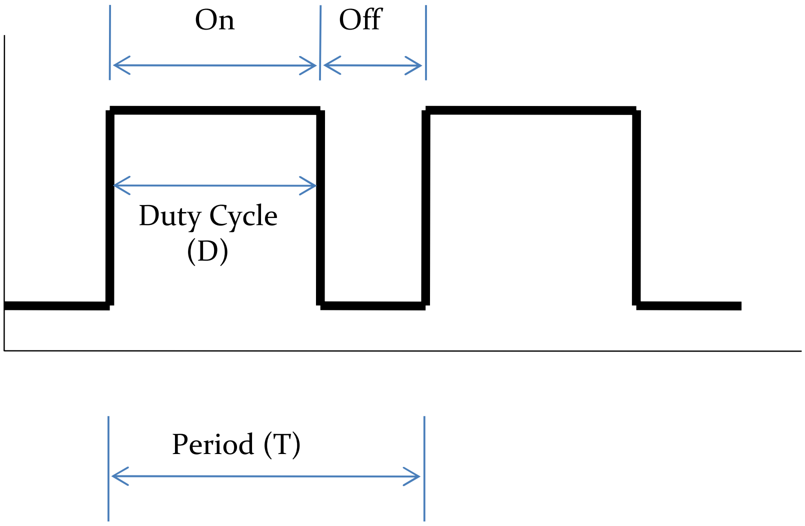
An approximate equation for determining the value of capacitance is given below

$$C_{out} = \frac{I_{out\ (max)} \times D}{F_S \times \Delta V_{out}}$$

4.1.3 PWM – Used to manipulate MOSFET

PWM is one of the two principal algorithms used in photovoltaic solar battery charger the other being MPPT. The average value of voltage (and current) fed to the load is controlled by turning the switch between supply and load on and off at a fast pace. The longer the switch is on compared to the off periods, the higher the power supplied to the load is.

Duty Cycle:



$$Duty\ Cycle = \frac{On\ Time}{Period} \times 100\%$$

Average signal can be found as

$$V_{avg} = D \cdot V_H + (1 - D) \cdot V_L$$

4.1.4 Specification of DC-DC Boost Converter

Parameter	Value	Unit
Input voltage	24	Volt
Output voltage	48	Volt
Switching frequency	100000	Hz
Duty cycle	50	%
Inductor value	161.9	μH
Capacitor value	220	μF
Ripple	.025	
Load resistance	10	ohm

Simulation of DC-DC converter

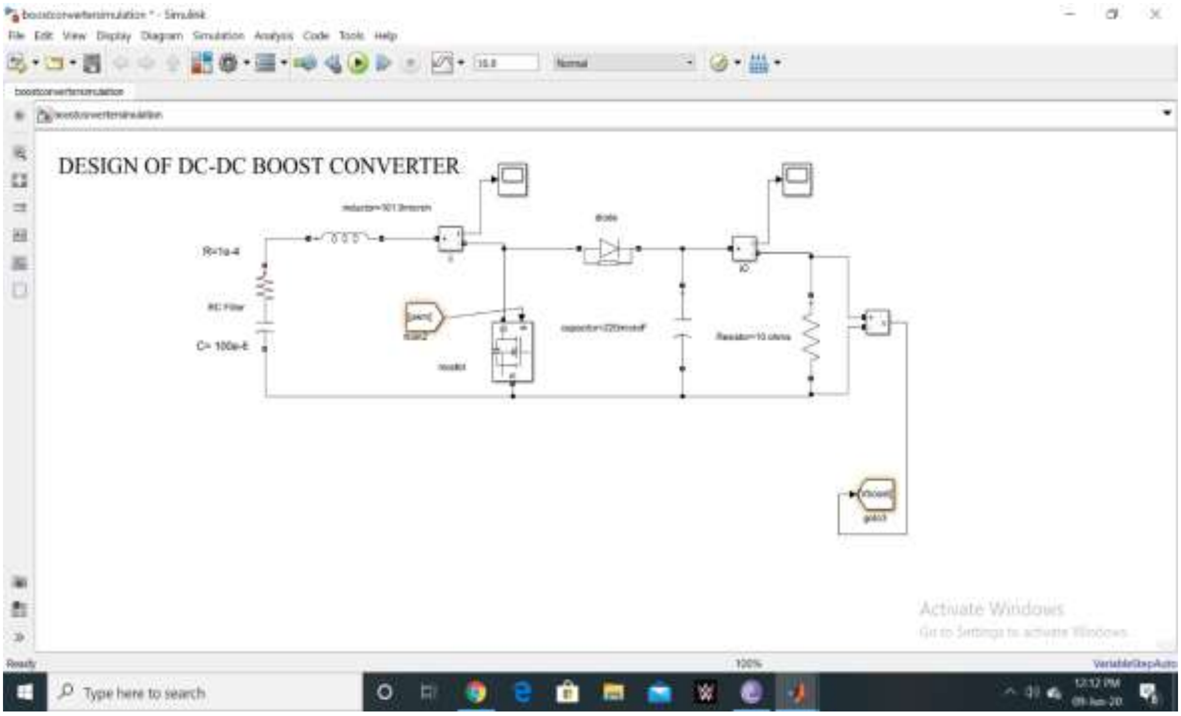


Fig 27. Simulation of DC-DC Converter

4.2 MPPT Algorithm and Related Program

In this methodology, we are more intended to use Incremental Conductance algorithm which helps to endeavor the maximum power from the solar array and deliver the same to the Li-ion battery.

Key features of MPPT block simulation:

- MPPT MATLAB FUNCTION BLOCK is used in which the program has been directly fed and the same is used to provide the duty cycle as output.
- Goto and From blocks are used to jump the command or values within the path directed in order to reduce the complexity.
- Voltage and current from solar array is fed as the inputs to the function.
- Delta which is a constant is nothing but an incremental step value of duty cycle, which is here kept at 0.0000125 for getting precise results at output.

4.2.1 MPPT Block Programing

```
function dutynew = MPPT_algorithm(Vpv,Ipv,delta)
%here dutynew is output and name of the function is MPPT_algorithm
duty_init=0.1;
duty_min=0;
duty_max=0.85;

persistent Vold Iold Pold duty_old;
dutynew=0;

if isempty(Vold)
   Vold=0;
   Iold=0;
   Pold=0;
   duty_old=duty_init;
end
P=Vpv*Ipv;
dV=Vpv-Vold;
dI=Ipv-Iold;

if dV~=0
   if dI/dV == -Ipv/Vpv
      dutynew=duty_old;
   elseif dI/dV >= -Ipv/Vpv
      dutynew=duty_old+delta;
   else
      dutynew=duty_old-delta;
   end
else
   if dI~=0
      if dI>0
         dutynew=duty_old+delta;
```

```
else
        dutynew=duty_old-delta;
      end
      dutynew=duty_old;
   end
end

if dutynew>=duty_max
   dutynew=duty_max;
elseif dutynew<duty_min
   dutynew=duty_min;
end
duty_old=dutynew;
Vold=Vpv;
Iold=Ipv;
```

4.2.2 Simulation of MPPT Block

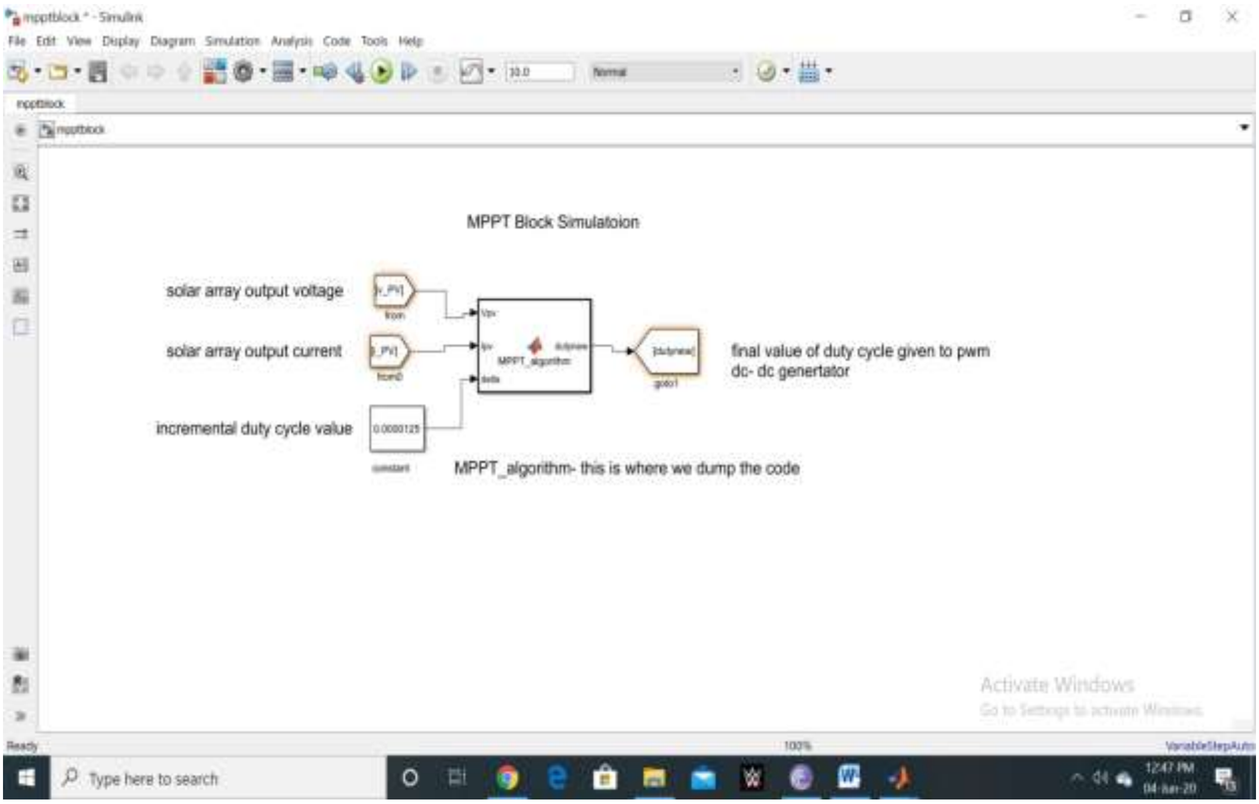


Fig 28. Simulation of MPPT Block

4.3 Solar PV Array Block Simulation

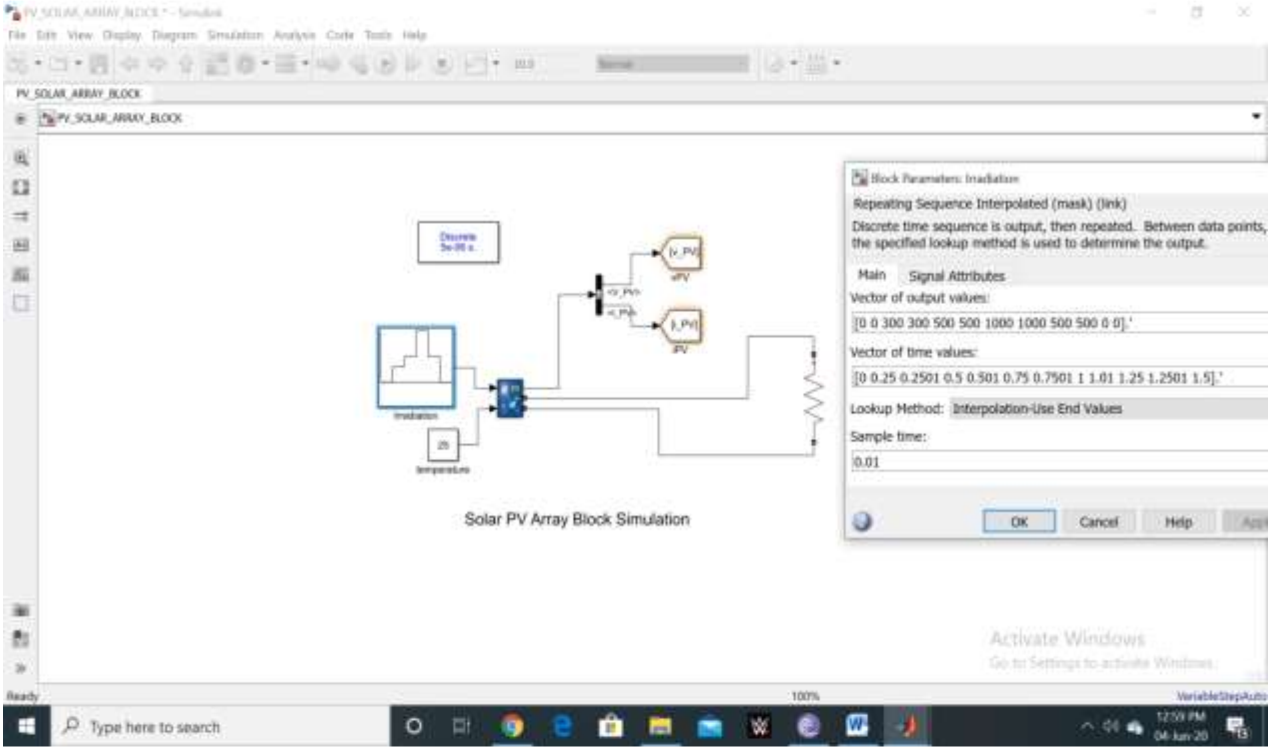


Fig. 29 Simulation of Solar PV Array

Solar PV Array block is a readymade block which can easily be used in order to achieve the desired output in terms of voltage and current. The two important factors which influence the performance of PV Array are irradiation and temperature. The output pins are directly connected with the RC filter of the DC-DC converter. The measurement pin is connected with the two Go-to blocks named V_{pv} and I_{pv} respectively.

In our project, we desire the output of solar panel to be around 24-30V and the wattage of panel is approx. 300. Using MPPT technique, the output of panel is taken and boosted. The result of converter is given to Li-ion battery and the output flutters around 51 V which is perfect for charging 48 V Battery.

4.4 Complete MATLAB Simulation of Solar Powered Electric Vehicle

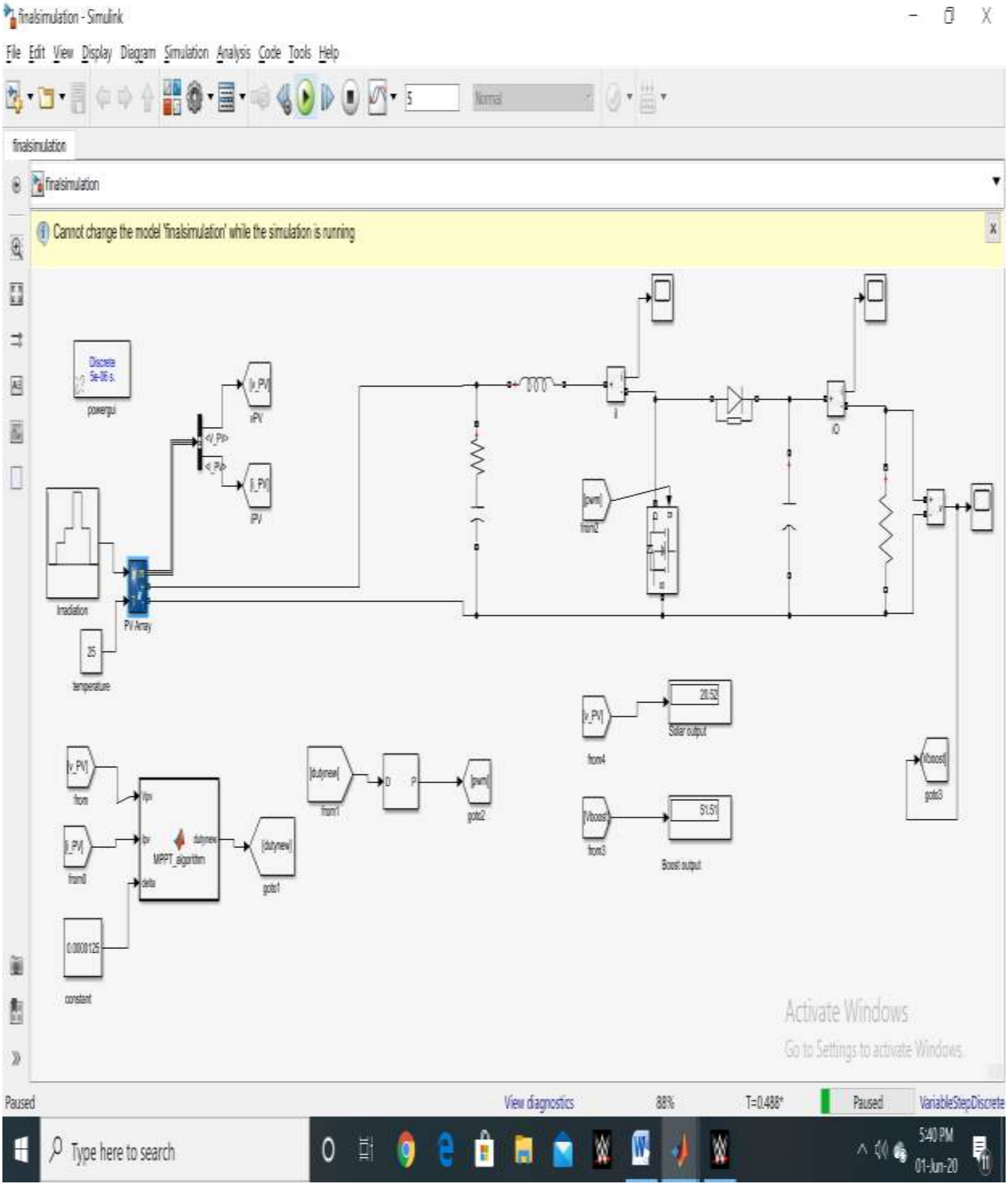


Fig. 30 Complete MATLAB Simulation for Solar EV

CHAPTER 5

RESULTS AND DISCUSSIONS

5.1 Results

This project explains the mechanism and advantages of Solar Powered Electric Vehicle. The outcome of our project can be viewed in the form of output which drives this vehicle with the help of Incremental Conductance method used within MPPT technique. The Li-ion battery gets charged and deliver the power to the BLDC Motor, which on the other side is controlled by a Kelly Controller. The controller converts the dc which it gets as an input from the battery into ac and the sane is used to drive the motor.

Solar Output: 24-30 V
Li-ion Battery: 48 V, 50 Ah
Boost Converter Output: 50-55 V

The desired simulation is obtained using MATLAB 2018 version and is further proceeded to be implemented in hardware. Advantages of using the MPPT technique is that the output can easily be managed according to the load characteristics.

The output of the simulation is recorded and its screenshot is presented in the design process section. The solar panel used here is monocrystalline, 24 volt, 10 amps, 36 solar cells. MPPT technique with all integrated hardware components are used to charge the battery. The program for the method is self-written and fed into MATLAB function for the working of simulation.

CHAPTER 6

CONCLUSION AND FUTURE DIRECTIONS

6.1 Conclusion

This method presented here control lead acid battery charging faster and efficiently. The control algorithm executes Incremental Conductance method which allow module to operate at maximum power point according to solar irradiation, and match load with the source impedance to provide maximum power. This MPPT model is more suitable because of less cost, easier circuit design. And efficiency of the circuit is increased by 20-25% in case of MPPT solar charge controller compare to a circuit without MPPT. And also saved the extra energy required in mechanical tracking. As Microcontroller based controlling is used, it maintained constant 50V at the output terminal i.e. at the battery terminal.

6.2 Future Directions

1) Hybrid of MPPT with mechanical tracking will give more efficiency, project can be extended in this direction.

2) Battery output is directly utilized to feed power in the dc grid which can be used for charging electronic devices like laptop, mobile directly.

3) By adding Wi-Fi Module we can record our data in the system and optimize the data for better use.

4) Solar panel installed on urban and sub-urban areas with modified technology will lead in saving of our bill.

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