SOLAR PV FED SEPIC CONVERTER FOR DRIVE APPLICATION

A PROJECT REPORT

Submitted by

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BONAFIDE CERTIFICATE

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ABSTRACT:

A solar PV fed SEPIC converter for motor drive has been discussed in our project. Solar PV array, SEPIC DC-DC Converter, a three phase voltage source inverter and a motor assembly are the main parts of the system. The first stage is to control the duty ratio of the dc-dc SEPIC converter to extract the maximum power from the Solar PV array. Under varying irradiance and temperature conditions, P&O control method is utilized for maximum power point tracking (MPPT) of PV systems to control the duty ratio. In the second stage, switching pulses of the VSI is controlled by v/f controller based on the sinusoidal pulse width modulation. The frequency of SPWM is controlled for controlling the stator frequency of the induction motor. The SEPIC converter offers advantages such as non-inverted output, continuous input current and inherit voltage regulation capabilities, making it well-suited for solar PV integration. The proposed solar PV fed SEPIC converter offers an efficient and reliable solution for integrating solar PV systems into drive applications. The converter’s unique characteristics make it suitable for maintaining a stable power supply while effectively utilizing solar energy. The results of this project contribute to the advantages of renewable energy integration into drive systems, paving the way for more sustainable and environmentally friendly transportation and industrial applications.

TITLE OF CONTENTS

LIST OF ABBREVATIONS

PV	Photovoltaic
MPPT	Maximum Power Point Tracker
PL	Programmable Logic Controller
MOM	Mean of Maximum
SEPIC	Single-ended primary-inductor converter
DC	Direct Current
AC	Alternative Current
Ah	Ampere Hours
SOC	State of Charge
MPP	Maximum Power Point
PWM	Pulse Width Modulation
P&O	Perturbation and Observation
MF	Membership Function
UOD	Universe Of Discourse.

LIST OF FIGURES

LIST OF SYMBOLS

T_c	The Absolute Temperature of The Cell Kelvin
V	The Voltage Imposed Across The Cell Volt
I_o	The Dark Saturation Current Ampere
R_{opt}	Optimal Load Resistance ohm
P_{max}	Maximum Power Watt
I_{max}	Maximum Current Ampere
V_{max}	Maximum Voltage Volt
Q_{max}	Nominal Capacity Coulomb
V_{PV}	PV Module Output Voltage Volt
V_{OC}	Open Circuit Voltage Volt
I_{SC}	Short Circuit Current Ampere
I_{PV}	PV Module Output Current Ampere
T_r	Reference Temperature Kelvin
I_{ph}	PV Module Light-Generated Current Ampere
I_s	PV Module Saturation Current Ampere
A, B	Ideality Factor = 1.6
K	Boltzman Constant = 1.38064852(79)×10−**23**J/K
R_S	PV Module Series Resistance Ohm
λ	PV Module Illumination
N_S	Number of Cells Connected in Series
N_p	Number of Cells Connected in Parallel
V_{mp}	Voltage at Maximum Power Volt
I_{mp}	Current at Maximum Power Ampere
G	Sun Light w/m2
V_{out}	Output Voltage Volt

P_{PV}	PV Power Watt
$v_{g(t)}$	Input Voltage of Dc-Dc Converter Volt
$v_{o(t)}$	Output Voltage of Dc-Dc Converter Volt
$\delta(t)$	Control Signal Volt
$d(t)$	Duty Cycle
T_s	Switching Period Second
t_{on}	Time When the Switch of Converter is On Second
t_{off}	Time When the Switch of Converter is Off Second
P_{mp}	Maximum Power Watt
I_g	Input Current Ampere
I_o	Output Current Ampere
D	Equilibrium Duty Cycle
R	Resistance of Load ohm
C	Capacitor farad
L	Inductor Henry
T	Diode
Q	Transistor

CHAPTER 1
INTRODUCTION

Integration of Renewable Energy to the power system has gained major interest in recent years due to the lack of carbon emission during their power generation cycles. Being non-polluting, renewable and available in most sites and requiring no fuel, PV and wind have been the most significant parts of Renewable Energy incorporated in the bulk power system. To improve the economic sustainability and technical characteristics, the hybrid energy plants including different types of Renewable Energy and energy storage systems are connected to the power system. The hybrid PV-wind power plant has been investigated as an economically and technically efficient scheme.

1.1 OBJECTIVES

One of the primary objectives of PV solar energy is to reduce greenhouse gas emissions and mitigate climate change. By generating electricity from the sun's abundant and clean energy source, PV systems help replace fossil fuel-based electricity generation, which is a significant contributor to global carbon dioxide emissions. PV solar energy promotes energy independence by reducing reliance on imported fossil fuels. It diversifies the energy mix and enhances energy security by utilizing a domestic and renewable energy resource, reducing vulnerability to price fluctuations and geopolitical tensions associated with fossil fuel supplies.

PV solar energy is environmentally friendly and has minimal environmental impacts compared to traditional energy sources. It does not emit harmful pollutants, such as sulfur dioxide, nitrogen oxides, or particulate matter, which contribute to air pollution, acid rain, and adverse health effects. PV systems also have a smaller ecological footprint compared to conventional power plants, which may require land disruption, habitat destruction, and water consumption.

PV solar energy supports sustainable development by providing a clean and renewable energy source that can be harnessed in a decentralized manner. It enables access to electricity in remote areas without a reliable grid infrastructure, contributing to poverty alleviation, education, healthcare, and economic opportunities. PV solar energy helps reduce energy costs over the long term. Once installed, solar PV systems can generate electricity at lower operational costs compared to conventional power plants. Additionally, as the technology advances and economies of scale are achieved, the cost of PV solar panels continues to decline, making solar energy increasingly competitive with traditional energy sources.

The widespread deployment of PV solar energy creates job opportunities across the value chain, including manufacturing, installation, operation, and maintenance. This stimulates local economies, attracts investments, and fosters innovation in the renewable energy sector, contributing to overall economic growth. PV solar energy plays a crucial role in providing access to electricity in regions with limited or no access to the grid. Off-grid and decentralized PV systems can power homes, schools, healthcare facilities, and businesses, improving living conditions, enabling educational opportunities, and enhancing socio-economic development.

Overall, the objectives of PV solar energy revolve around combating climate change, promoting sustainable development, reducing environmental impacts, ensuring energy security, and creating a cleaner and more resilient energy future for generations to come.

1.1.1 PHOTOVOLTAIC SYSTEM (PV)

Photovoltaic (PV) energy is the outcome of the direct conversion of light energy into electricity. The conversion is achieved via thin semiconductor devices called photovoltaic cells, which are also sometimes called solar cells or PV cells.

PV cells are basically flat light-sensitive diodes comprised of the same or similar materials as those used in transistors, PV The solar cell is the basic unit of a PV system. An individual solar cell produces direct current and power typically between 1 and 2 W, hardly enough to power most applications. Solar Cell or Photovoltaic (PV) cell is a device that is made up of semiconductor materials such as silicon, gallium arsenide and cadmium telluride, etc. that converts sunlight directly into electricity. The voltage of a solar cell does not depend strongly on the solar irradiance but depends primarily on the cell temperature. PV modules can be designed to operate at different voltages by connecting solar cells in series. When solar cells absorb sunlight, free electrons and holes are created at positive/negative junctions. If the positive and negative junctions of solar cell are connected to DC electrical equipment,current is delivered to computer chips, and related technology. A PV cell functions as follows : A semiconductor absorbs are there a using that of Enough energy from a light photon to transfer it to electrons. The high-energy electrons would then pass their energy to the semiconductor material, and in so doing create heat through recombining with the positively-charged “holes” formed by the light. An internal electrical field then emerges as a result of the PV cell’s junction that exists between the two forms of the semiconductor. When the electric field channels the charged electrons to one side of the cell (to prevent them from creating heat), a difference in voltage is thus formed between the opposite cell sides. An electric current is then able to be drawn from the cell through the contacts on the two sides. A PV cell creates electricity similar to how a chemical battery cell does (i.e., as a direct current[DC]). The electrical power created is limited by the amount of received light (irradiance), as well as the cell's temperature and the PV cell's connections.

1.1.2 DC-DC CONVERTER

Due to nonlinearity of PV system the output power is changeable according to the change of atmosphere conditions. Therefore, the best device can play the role of regulating the voltage and current output of PV source is called dc-dc converter. illustrates a schematic diagram for a DC-DC converter. The converter changes DC input voltage Vg(t) into DC output voltage Vo(t), but at a different voltage level than that of the input. Preferably, this change is done with low losses to the converter, so the transistor functions as a switch, applying the control signal d(t). As illustrated in Figure , the control remains at high for a designated period t on and at low for a designated period t off.When the transistor is 'ON', the voltage is low, indicating that the transistor's power loss is also low. However, when the transistor is 'OFF', both the current passing through it and the power loss are likewise low. To control the average output voltage, the width of the pulses must be altered when the switching period,3, is constant. In the interval 0 to 1, the duty cycle, d(t), is a real value equal to the ratio of the width of a pulse to the switching period, i.e., d(t) = t on/Ts

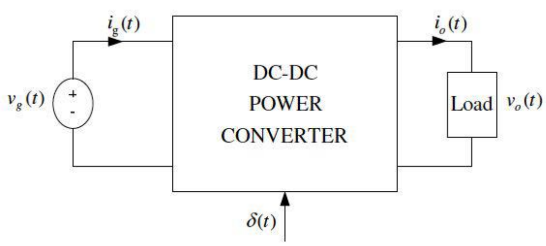


Figure 1.1 : Structure of a DC-DC converter .

1.1.3 MAXIMUM POWER POINT TRACKING

Due to nonlinear behavior of PV system the generated power varies according to the change of ambient temperature and solar irradiance. The highest produced power from PV system at different weather conditions is called a maximum power point (MPP). This happens at maximum voltage and maximum current. To achieve this, an electronic system called maximum power point tracking (MPPT) has been invented and developed . This implies that there is always one terminal voltage for the PV array to operate at each condition as illustrated in Figure , to obtain the maximum power output to enhance the array's efficiency .

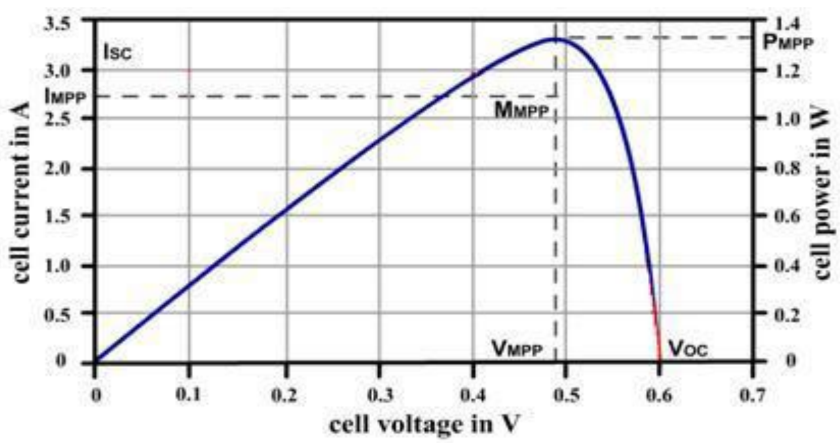


Figure 1.2 : PV curve showing Maximum Power Point .

In other words, an MPPT is a complete electronic system that varies the electrical operating point of the modules so that the modules can deliver maximum available power. Any increase in power that is reaped from the modules that increases battery charge current. The basic method of charge controller is called PWM (Pulse Width Modulation). Its operation based on simply connecting the modules directly to the battery. But this technique forces the PV modules to battery voltage, actually operating voltage at which the modules are able to produce their maximum available power (PPWM<PMPPT). Where PPWM is the extracted power by using PWM controller and PMPPT is the obtained power using MPPT controller.

For instance, as shown in Figure the MPPT vs PWM performance, the classical PWM controller frugally connects the module to the battery and hence forces the module to operate at 12V (Vpwm). By forcing a PV panel of 75W module to operate at 12V (Vpwm) the PWM reduces artificially power production to nearly 53W. This means the PWM decreases the efficiency of PV modules to about 29%. On the other hand, using MPPT system in a solar charge controller can calculate the voltage at which the module is able to produce maximum power (Vmp). Thus, the MPPT can extract the full 75W (+30% power), regardless of power presented.

1.1.4 PERTURB AND OBSERVE

Conventional Perturb & Observe algorithm has been extensively used due to ease of implementation. This is a continuous process of observation and perturbation till the operating point converges at the MPP. The algorithm compares the power and voltages of time (K) with the sample at a time (K-1) and predicts the time to approach to MPP. A small voltage perturbation changes the power of the solar panel if the power alteration is positive, voltage perturbation is continued in the same track. But if delta power is negative, it indicates that the MPP is far away and the perturbation is decreased to reach the MPP. Thus, in this way the whole PV curve is checked by small perturbations to find the MPP that increases the response time of the algorithm. Conversely, if the perturbation size is enlarged, it generates steady state oscillations about the MPP. Many researchers have proposed modifications in the P&O algorithm to overcome the response time problem and steady state oscillations.

P&O method is used for tracking the MPP. In this technique, a minor perturbation is introduced to, cause the power variation of the PV module. The PV output power is periodically measured and compared with the previous power. If the output power increases, the same process is continued otherwise perturbation is reversed. In this algorithm perturbation is provided to the PV module or the array voltage. The PV module voltage is increased or decreased to check whether the power is increased or decreased. When an increase in voltage leads to an increase in power, this means the operating point of the PV module is on the left of the MPP. Hence further perturbation is required towards the right to reach MPP. Conversely, if an increase in voltage leads to a decrease in power, this means the operating point of the PV module is on the right of the MPP and hence further perturbation towards the left is required to reach MPP. When the MPPT charge controller is connected between the PV module and battery, it measures the PV and battery voltages. After measuring the battery voltage, it determines whether the battery is fully charged or not. If the battery is fully charged (12.6 V at the battery terminal) it stops charging to prevent battery over charging. If the battery is not fully charged, it starts charging by activating the DC/DC converter. The microcontroller will then calculate the existing power Pnew at the output by measuring the voltage and current, and compare this calculated power to the previous measured power Pold. If Pnew is greater than Pold, the PWM duty cycle is increased to extract maximum power from the PV panel. If Pnew is less than Pold, the duty cycle is reduced to ensure the system to move back to the previous maximum power. This MPPT algorithm is simple, easy to implement, and low cost with high accuracy.

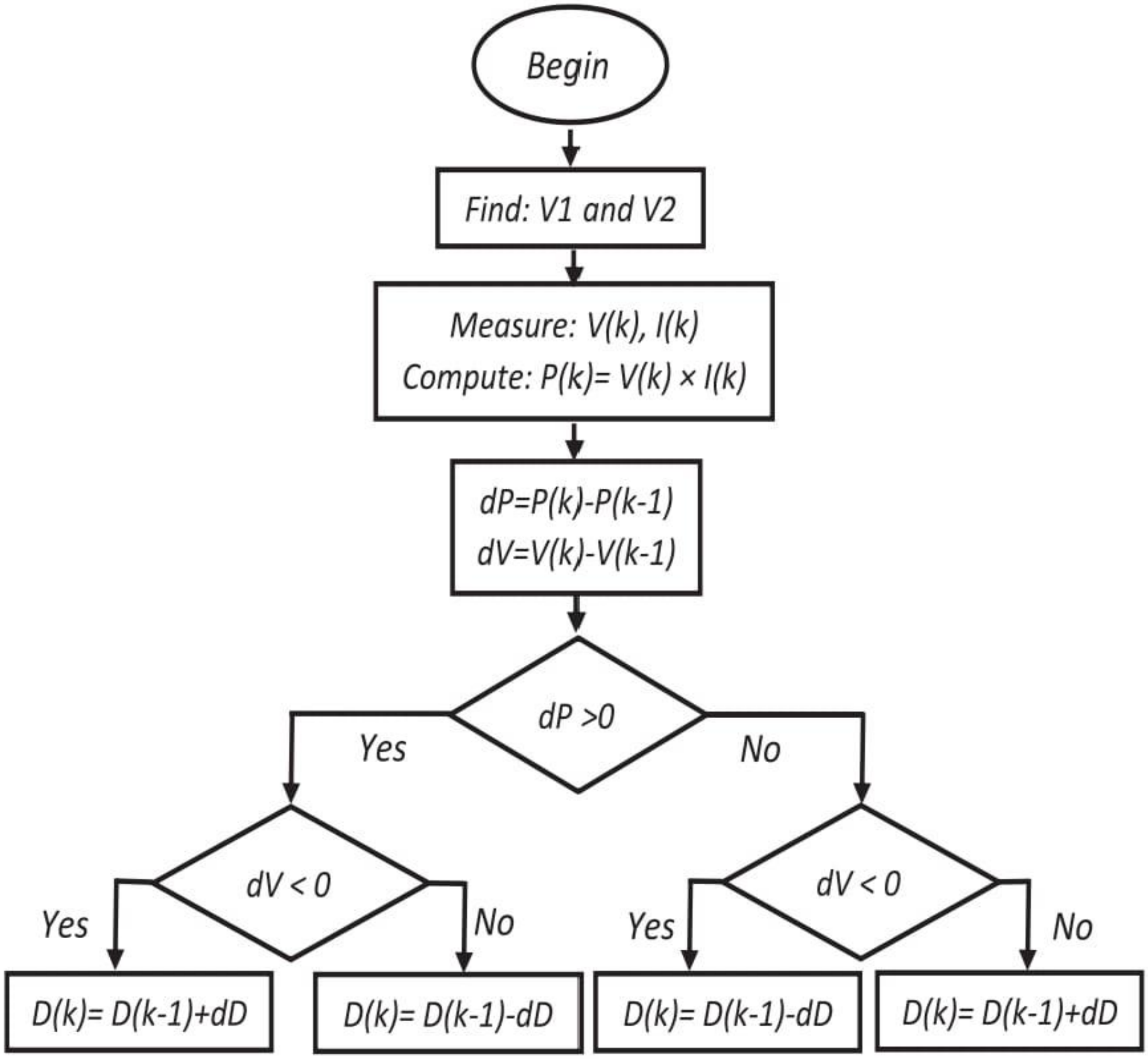


Figure 1.3 : Flow Chart Of P&O Algorithm

1.2 SINGLE-ENDED PRIMARY INDUCTOR CONVERTER (SEPIC)

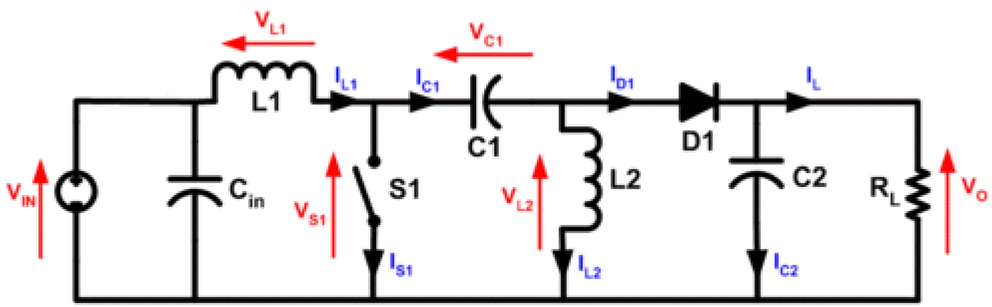


Figure 1.4 : Schematic Diagram of SEPIC Converter.

The important requirement of any DC–DC converter used in the MPPT scheme is that it should have a low input-current ripple. Buck converters will produce ripples on the PV module side currents and thus require a larger value of input capacitance on the module side. On the other hand, boost converters will present low ripple on the PV module side, but the load current exhibits more ripple and gives a voltage higher than the array voltage to the loads. The buck–boost converters can be used where the requirement of load voltage, either low or higher than the array voltage. However, with this converter the input and load currents are pulsating in nature. Furthermore, the load voltage will be inverted with buck–boost or CUK converters.

Under these conditions, the SEPIC converter, provide the buck–boost conversion function without polarity reversal, in addition to the low ripple current on the source and load sides. The SEPIC (Single Ended Primary Inductor converter) topology with PV module and MPPT controller and it is proposed the converter is operated in Continuous Current Mode (CCM).The inductance and capacitance values are designed. This converter has two inductors and two capacitors. The capacitor C1 provides the isolation between input and output. The

SEPIC converter exchanges energy between the capacitors and inductors in order to convert the voltage from one level to another. The amount of energy exchanged is controlled by switch, which is typically a transistor such as a MOSFET. L1 is the input inductance, L2 is the output inductance, C1 is the energy transfer capacitor, C2 is the output capacitor, Vin is the input voltage, Vo is the output voltage, VC1 is the voltage across capacitor C1, IL1 is the current though L1 and IL2 is the current through L2.

SEPIC is a type of DC-DC converter allowing the electrical potential (voltage) at its output to be greater than, less than, or equal to that at its input; the output of the SEPIC is controlled by the duty cycle of the control transistor.

A SEPIC is similar to a traditional buck-boost converter, but has advantages of having non-inverted output (the output voltage is of the same polarity as the input voltage), the primary means of coupling energy from the input to the output is via a series capacitor, and true shutdown mode: when the switch is turned off, its output drops to 0 V, following a fairly hefty transient dump of charge.

SEPICs are useful in applications in which a battery voltage can be above and below that of the regulator's intended output. For example, a single lithium ion battery typically discharges from 4.2 volts to 3 volts; if other components require 3.3 volts, then the SEPIC Circuit operation

The schematic diagram for a basic SEPIC is shown in Figure 1. As with other switched mode power supplies (specifically DC-to-DC converters), the SEPIC exchanges energy between the capacitors and inductors in order to convert from one voltage to another. The amount of energy exchanged is controlled by switch S1, which is typically a transistor such as a MOSFET; MOSFETs offer much higher input impedance and lower voltage drop than bipolar junction transistors (BJTs), and do not require biasing resistors (as MOSFET switching is controlled by differences in voltage rather than a current, as with BJTs).

1.2.1 CONTINUOUS MODE

A SEPIC is said to be in continuous-conduction mode ("continuous mode") if the current through the inductor L1 never falls to zero. During a SEPIC's steady-state operation, the average voltage across capacitor C1 (V_{C1}) is equal to the input voltage (V_{in}). Because capacitor C1 blocks direct current (DC), the average current across it (I_{C1}) is zero, making inductor L2 the only source of load current. Therefore, the average current through inductor L2 (I_{L2}) is the same as the average load current and hence independent of the input voltage.

Looking at average voltages, the following can be written:

$$V_{IN} = V_{L1} + V_{C2} + V_{L2} \quad \text{...(1)}$$

Because the average voltage of V_{C1} is equal to V_{IN}, $V_{L1} = -V_{L2}$. For this reason, the two inductors can be wound on the same core. Since the voltages are the same in magnitude, their effects of the mutual inductance will be zero, assuming the polarity of the windings is correct. Also, since the voltages are the same in magnitude, the ripple currents from the two inductors will be equal in magnitude.

The average currents can be summed as follows:

$$I_{D1} = I_{L1} - I_{L2} \quad \text{...(2)}$$

When switch S1 is turned on, current I_{L1} increases and the current I_{L2} increases in the negative direction. (Mathematically, it decreases due to arrow direction.) The energy to increase the current I_{L1} comes from the input source. Since S1 is a short while closed, and the instantaneous voltage V_{C1} is approximately V_{IN}, the voltage V_{L2} is approximately $-V_{IN}$. Therefore, the capacitor

C1 supplies the energy to increase the magnitude of the current in I_{L2} and thus increase the energy stored in L2. The easiest way to visualize this is to consider the bias voltages of the circuit in a d.c. state, then close S1.

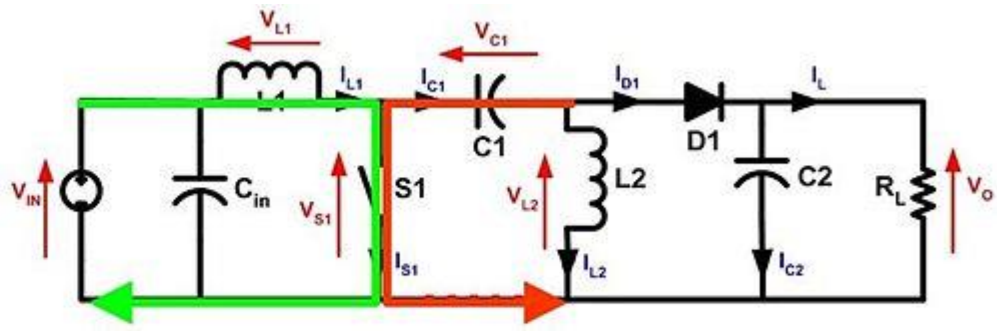


Figure 1.5 : Systematic Diagram Of Closed Current SEPIC Converter

Figure 1.5: With S1 closed current increases through L1 (green) and C1 discharges increasing current in L2 (red)

When switch S1 is turned off, the current I_{C1} becomes the same as the current I_{L1}, since inductors do not allow instantaneous changes in current. The current I_{L2} will continue in the negative direction, in fact it never reverses direction. It can be seen from the diagram that a negative I_{L2} will add to the current I_{L1} to increase the current delivered to the load. Using Kirchhoff's Current Law, it can be shown that $I_{D1} = I_{C1} - I_{L2}$. It can then be concluded, that while S1 is off, power is delivered to the load from both L2 and L1. C1, however is being charged by L1 during this off cycle, and will in turn recharge L2 during the on cycle.

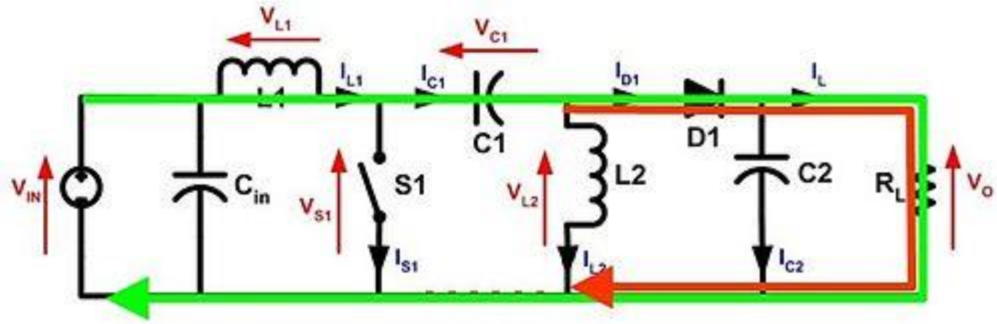


Figure 1.6 : Systematic Diagram Of Open Current SEPIC Converter.

Figure 1.6 : With S1 open current through L1 (green) and current through L2 (red) produce current through the load

Because the potential (voltage) across capacitor C1 may reverse direction every cycle, a non-polarized capacitor should be used. However, a polarized tantalum or electrolytic capacitor may be used in some cases[1], because the potential (voltage) half cycle of resonance with inductor L2, and by this time the current in inductor L1 could be quite large.

The capacitor C_{IN} is required to reduce the effects of the parasitic inductance and internal resistance of the power supply. The boost/buck capabilities of the SEPIC are possible because of capacitor C1 and inductor L2. Inductor L1 and switch S1 create a standard boost converter, which generates a voltage (V_{S1}) that is higher than V_{IN}, whose magnitude is determined by the duty cycle of the switch S1. Since the average voltage across C1 is V_{IN}, the output voltage (V_O) is V_{S1} - V_{IN}. If V_{S1} is less than double V_{IN}, then the output voltage will be less than the input voltage. IfV_{S1} is greater than double V_{IN}, then the output voltage will be greater than the input voltage.

The evolution of switched-power supplies can be seen by coupling the two inductors in a SEPIC converter together, which begins to resemble a Flyback converter, the most basic of the transformer-isolated SMPS topologies.

1.2.2 DISCONTINUOUS MODE

A SEPIC is said to be in discontinuous-conduction mode (or, discontinuous mode) if the current through the inductor L1 is allowed to fall to zero.

1.2.3 RELIABILITY AND EFFICIENCY

The voltage drop and switching time of diode D1 is critical to a SEPIC's reliability and efficiency. The diode's switching time needs to be extremely fast in order to not generate high voltage spikes across the inductors, which could cause damage to components. Fast conventional diodes or Schottky diodes may be used.

The resistances in the inductors and the capacitors can also have large effects on the converter efficiency and ripple. Inductors with lower series resistance allow less energy to be dissipated as heat, resulting in greater efficiency (a larger portion of the input power being transferred to the load). Capacitors with low equivalent series resistance (ESR) should also be used for C1 and C2 to minimize ripple and prevent heat build-up, especially in C1 where the current is changing direction frequently.

1.2.4 DESIGN OF SEPIC CONVERTER

The amount that the SEPIC converters step up or down the voltage depends primarily on the Duty Cycle and the parasitic elements in the circuit. The output of an ideal SEPIC converter is

$$V_O = \frac{D*V_i}{1-D} \quad \text{(3)}$$

However, this does not account for losses due to parasitic elements such as the diode drop VD. These make the equation:

$$V_O + V_D = \frac{D*V_i}{1-D} \quad \text{(4)}$$

$$D = \frac{V_O+V_D}{V_i+V_O+V_D} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (5)$$

The maximum Duty Cycle will occur when the input voltage is at the minimum. If VD=.5V, the Duty Cycle is

$$D_{min} = \frac{10V+.5V}{6V+10V+.5V} \approx .64 \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (6)$$

The minimum Duty cycle will occur when the input voltage is at the maximum.

$$D_{min} = \frac{10V+.5V}{6V+10V+.5V} \approx .37 \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (7)$$

In theory, the larger the inductors are the better the circuit will operate and reduce the ripple. However, larger inductors are more expensive and have a larger internal resistance. This greater internal resistance will make the converter less efficient. Creating the best converter requires choosing inductors that are just large enough to keep the voltage and current ripple at an acceptable amount.

$$L = \frac{V_{imin}(D_{max})}{\Delta i_{omax} f_{sw}} = \frac{(6V).(63)}{(.5A)(50kHz)} = 151.2\mu H \dots\dots\dots\dots\dots (8)$$

Inductors with low internal resistance and around 150uH will be ideal for both of the inductors in the circuit.

1.3 INDUCTION MOTOR

An induction motor or asynchronous motor is an AC electric motor in which the electric current in the rotor needed to produce torque is obtained by electromagnetic induction from the magnetic field of the stator winding.An induction motor can therefore be made without electrical connections to the rotor. An induction motor's rotor can be either wound type or squirrel-cage type.Three-phase squirrel-cage induction motors are widely used as industrial drives because they are self-starting, reliable, and economical.

1.3.1 WORKING PRINCIPLE

Single-phase induction motors are used extensively for smaller loads, such as garbage disposals and stationary power tools. Although traditionally only used for one-speed service, single- and three-phase induction motors are increasingly being installed in variable-speed applications using variable-frequency drives (VFD). VFDs offer especially important energy savings opportunities for existing and prospective induction motors in applications like fans, pumps and compressors that have a variable load.

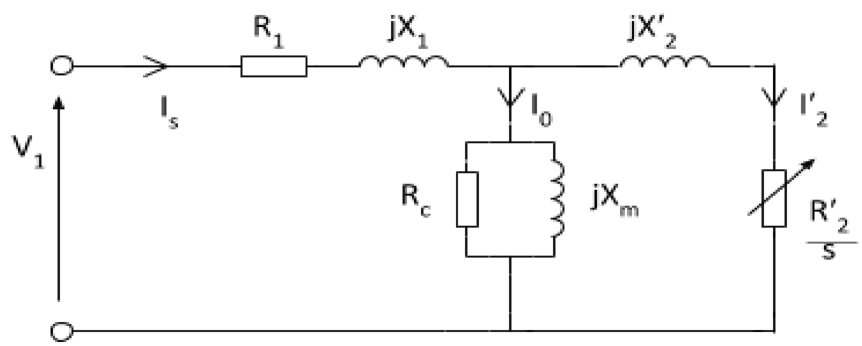


Figure 1.7: induction motor circuit diagram

1.3.2 INDUCTION MOTOR OPERATION

In an induction motor only the stator winding is fed with an AC supply.Alternating flux is produced around the stator winding due to AC supply. This alternating flux revolves with synchronous speed. The revolving flux is called as "Rotating Magnetic Field" (RMF).The relative speed between stator RMF and rotor conductors causes an induced emf in the rotor conductors, according to the Faraday's law of electromagnetic induction. The rotor conductors are short circuited, and hence rotor current is produced due to induced emf. That is why such motors are called as induction motors.

This action is same as that occurs in transformers, hence induction motors can be called as rotating transformers.Now, induced current in rotor will also produce alternating flux around it. This rotor flux lags behind the stator flux. The direction of induced rotor current, according to Lenz's law, is such that it will tend to oppose the cause of its production. As the cause of production of rotor current is the relative velocity between rotating stator flux and the rotor, the rotor will try to catch up with the stator RMF.

Thus the rotor rotates in the same direction as that of stator flux to minimize the relative velocity. However, the rotor never succeeds in catching up the synchronous speed. This is the basic working principle of induction motor of either type, single phase of 3 phase.Induction motors are simple and rugged in construction.

Advantage of induction motors are that they are robust and can operate in any environmental condition.Induction motors are cheaper in cost due to the absence of brushes, commutators, and slip rings.They are maintenance free motors unlike dc motors and synchronous motors due to the absence of brushes, commutators and slip rings. Induction motors can be operated in polluted and explosive environments as they do not have brushes which can cause sparks 3 phase induction motors will have self starting torque unlike synchronous motors, hence no starting methods are employed unlike synchronous motor. However, single-phase induction motors does not have self starting torque, and are made to rotate using some auxiliaries.

Slip

Induction motors are asynchronous. The stator magnetic field rotates at the motors synchronous speed (n_s). The rotor can never rotate at synchronous speed, otherwise there would be no induced current. Typically the rotor full speed will between 2 and 6% that of the synchronous speed. The difference between the motors synchronous and actual asynchronous speed is known as the slip

The difference between the motors synchronous speed (n_s) and actual rotor speed (n_r) is known as the slip (s). Slip can be expressed as either a fraction or percentage:

$$S = \frac{n_s - n_r}{n_s} \qquad (1)$$

Frequency

From magnetic winding theory, the relationship between frequency in the stator (f), number of pole pairs (p) and the synchronous speed is given by:

$$f = n_s p \qquad (2)$$

Within the rotor, the frequency (f_r) is given by the speed difference between that of the rotor and stator:

$$f_r = (n_s - n_r)p \qquad (3)$$

which when combined with the above equation for slip, gives:

$$f_r = s n_s p = sf \qquad (4)$$

the synchronous speed in revolutions per second is:

$$n_s = \frac{f}{p} \qquad (5)$$

and in revolutions per minute (rpm)

$$n_s = \frac{60f}{p} \qquad (6)$$

The quantity n_s is the speed at which the flux rotates relative to the stator and sn_s the speed of the rotor flux relative to the rotor. However, the rotor itself is rotating at n_r, giving a total rotor flux speed of:

$$sn_s + n_r = (n_s - n_r) + n_r = n_s \qquad (7)$$

Motor Current

Once the equivalent circuit parameters are known, it is easy to calculate the motor current, by reducing the circuit to an equivalent impedance Z_{eq}, giving:

$$I_s = \frac{V_1}{Z_{eq}} \qquad (8)$$

By inspecting the equivalent circuit, we can see that Z_{eq} is of the form:

$$Z_{eq} = R_{eq} + \frac{R_2'}{s} + jX_{eq} \qquad (9)$$

Motor Power

As a simplification, if we neglect the core losses (R_c and giving $I_s = I'_2$) the power (P_{in}) delivered to the motor per phase is given by:

$$P_{in} = I_s^2(R_1 + \frac{R_2'}{s}) \qquad (10)$$

The power loss dissipated by the windings is given by:

$$P_{\omega} = I_s^2(R_1 + R_2') \qquad (11)$$

The difference between the power supplied to the motor and losses in the windings is the power (P_m) delivered to the connected load. This (per phase) is given by:

$$P_m = P_{in} - P_\omega = I_s^2\left(\frac{1-s}{s}\right)R_2' \qquad (12)$$

and for all three phases

$$P_{m3\phi} = 3 * I_s^2\left(\frac{1-s}{s}\right)R_2' \qquad (13)$$

Motor Torque

Knowing that power can be the motor torque (M) multiplied by the angular velocity (ω), this can be rearranged and a formulae for torque (T) derived:

$$T = \frac{P_{m3\phi}}{\omega} \qquad (14)$$

and

$$\omega = \frac{2\pi n_r}{60} = \frac{2\pi}{60}(1-s)n_s \qquad (15)$$

which combined with the power equation gives

$$T = \frac{3 * I_s^2\left(\frac{1-s}{s}\right)R_2'}{\frac{2\pi}{60}(1-s)n_s} = I_s^2\,\frac{90R_2'}{\pi n_s s} \qquad (16)$$

CHAPTER 2
LITERATURE REVIEW

2.1 INTRODUCTION

Many MPPT algorithms have been proposed and are generally categorized into the following groups as examples: 1) Perturbation and Observation(P&O) methods; 2) Incremental Conductance (IC) methods; 3) Fuzzy logic and neural network-based methods and much more. In (P&O) and (IC) methods of MPPT controllers were simulated and analyzed with photovoltaic panels and a SEPIC DC-DC converter. The results show that the P&O gave a stable output, but the Inc controller could achieve the maximum power output at 23.66 V, which means it was better than the P&O performance. A Sliding Mode Control method of MPPT controller was used with the photovoltaic system, DC-DC converter, DC-AC inverter and load. The system was implemented in MATLAB/Simulink and was evaluated as an adequate performance of designed control.The incremental conductance method is one of many MPPT techniques that have been implemented for small and medium power applications. A complete linearized small signal model for the incremental conductance MPPT algorithm has been proposed and integrated with a boost DC-DC converter topology. Due to the redundancy of state variables within the control system, the classical linearization mechanisms initially have led to an unsolvable system. To deal with this challenge, another styling process using Taylor Series expansions was adopted. There is very good agreement between the output of the model and the simulation results of a PV system in PSCAD/EMTDC. The system's state-space representation allows for stability and control design as well as analysis of robustness. It is well known that the incremental conductance MPPT algorithm is extremely robust even under changing conditions in solar irradiance. Therefore, according to the above modeling approach, PV solar arrays based on incremental conductance based MPPT are able to be completely integrated into software for eigen value analysis, along with conventional generators. The model presented above is easily adaptable to PV system configurations that include different converter.

1) Trishan Esram and Patrick L Chapman (2019) "Comparison of photovoltaic array maximum power point tracking techniques" provides an overview of the various techniques used to track the maximum power point (MPP) of photovoltaic (PV) arrays. The authors review both traditional and advanced MPP tracking algorithms, and evaluate their effectiveness in different conditions. Esram and Chapman then compare the performance of these algorithms under different conditions, including uniform irradiance, partial shading, and rapid variations in irradiance. They evaluate the algorithms in terms of their efficiency, accuracy, and robustness, and provide recommendations for selecting the most appropriate algorithm for a given application.

2) Subudhi and R Pradhan (2018) "Comparative study of Maximum Power Point Tracking techniques for photovoltaic power systems" presents a comparative study of various Maximum Power Point Tracking (MPPT) techniques for photovoltaic (PV) power systems. Subudhi and Pradhan evaluate the performance of these MPPT techniques in terms of their efficiency, accuracy, and response time, using simulation and experimental results. They compare the algorithms under different operating conditions, such as varying irradiance levels and load conditions. The authors also present a detailed analysis of the advantages and disadvantages of each technique.

The paper concludes with a discussion on the implementation of MPPT algorithms in PV systems and the challenges associated with real-time implementation. The authors emphasize the importance of selecting the appropriate MPPT algorithm based on the specific application and operating conditions.

3) Utkarsh Sharma, Shailendra Kumar and Bhim Singh (2018) "Solar Array Fed Water Pumping System using Induction Motor Drive" proposes a solar array-fed water pumping system that utilizes an induction motor drive for water pumping applications. The authors highlight the need for sustainable and renewable energy solutions for water pumping systems, particularly in rural areas with no access to grid electricity. Sharma, Kumar, and Singh evaluate the performance of the proposed system using simulation and experimental results. They analyze the system's efficiency, stability, and response time under different operating conditions, such as varying solar irradiance and load conditions. The paper concludes with a discussion on the advantages of the proposed system, such as its high efficiency and low maintenance requirements, and its potential for deployment in remote and off-grid areas. The authors also highlight the need for further research to improve the performance of the system, particularly in terms of the MPPT algorithm and the control strategy for the induction motor drive. Overall, the paper presents a novel and promising approach for solar-powered water pumping systems, which can provide a sustainable and cost-effective solution for rural communities.

4) A.Tomar and S. Mishra (2020), "PV energy benefit estimation formulation for PV water pumping system" addresses the estimation of energy benefits provided by a photovoltaic (PV) water pumping system. The authors recognize the significance of PV systems in providing sustainable and clean energy for water pumping applications, particularly in areas where grid electricity is unreliable or unavailable. The authors describe the mathematical model used to estimate the energy benefits, incorporating variables such as the PV array characteristics, the water pump characteristics, and the water demand profile. They provide a detailed explanation of the calculations involved in determining the energy benefits, taking into account the variation in solar irradiance and the corresponding power output of the PV system. The paper also discusses the validation of the proposed estimation formulation using simulation results and compares the estimated energy benefits with actual performance data from a PV water pumping system. The authors analyze the accuracy and reliability of the estimation formulation and discuss its practical applicability.

5) R. Shaikh and Prof A. M. Jain t , Mrs.S.P.G.Bhavani (2019) “A literature survey of Photovoltaic Water Pumping System” provides a comprehensive survey of literature on photovoltaic water pumping systems, focusing on the recent developments in this field. The authors highlight the potential of photovoltaic systems in providing sustainable and reliable energy for water pumping applications, particularly in remote and off-grid areas. The paper also discusses the challenges associated with the design and implementation of photovoltaic water pumping systems, such as the sizing of the PV array and the pump, the selection of the MPPT algorithm, and the optimization of the system's performance under varying solar irradiance and load conditions. In conclusion, the paper provides a comprehensive overview of the recent advancements in photovoltaic water pumping systems, highlighting the potential of these systems in providing sustainable and reliable energy for water pumping applications.

CHAPTER 3
EXISTING SYSTEM

3.1 INTRODUCTION

The Buck-boost and Cuk converters, in their basic form, produce the output voltage, whose polarity is reversed from the input voltage.The problem can be corrected by incorporating an isolation transformer into the circuits, but this will inevitably lead to the increased size and cost of the converters.On the other hand, in implementing DC micro grid, the existing devices in building such as heating, ventilation, and air conditioning.Different types of renewable energy have been mentioned briefly in this chapter and the main attention was on the photovoltaic systems (PV). Therefore, advantages and disadvantages of photovoltaic system were included in this part of the thesis in addition to basic types of PV cells and types of photovoltaic systems .Characteristics of PV systems was a key thing to understand the operation of PV systems and how they are affected by ambient weather conditions. Mathematical modeling of PV system was implemented and tested in MATLAB/SIMULINK based on the fundamental equations of an equivalent circuit of PV cells. Finally, the desired PV system was simulated according to manufacturer datasheet along with maximum power point tracking system (MPPT).With expected depletion of fossil fuels in coming years, renewable energy has become the most important topic to focus on because it is clean and sustainable energy. Renewable energy is the energy that is existed in natural resources such as solar power, wind power, hydropower, biomass power, geothermal, and wave power. These energy sources are considered renewable sources because they are continuously replenished on the earth. Unlike other non-renewable energy sources, such as crude oil, natural gas and uranium, renewable sources have almost zero carbon emissions which decrease the global warming problem and greenhouse effect phenomena. Regardless the pollutants that are produced by non-renewable resources, fossil fuels reserves are going down quickly, and this causes continuous increasing in its price whereas renewable and its equivalents of non-renewable energy generators. energy resources are free. Renewable energy has alternative source of fossil fuels.

3.2 SOLAR POWER

The advantage of solar power can be taken by two main ways, the first way is to collect the sun heat by using curved mirrors and concentrate it on pipes to exchange the solar heat with a certain fluid and then it can be used to produce electricity , Figure demonstrates this method of solar power. The second way is a generating electricity directly from the falling sunlight by using photovoltaic cells as shown in figure

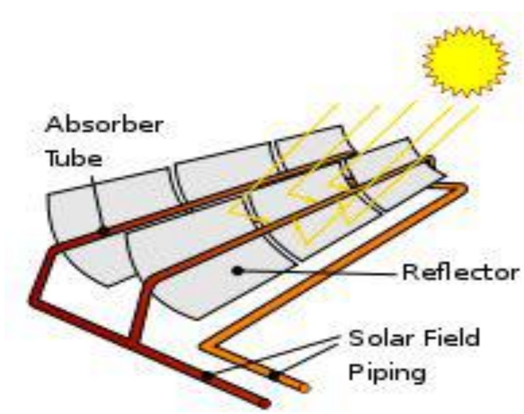


Figure 3.1:Parabolic trough systems using mirror

Figure 3.2: PV panels to generate electricity directly from the sunlight.

3.3 SOLAR-PHOTOVOLTAIC ENERGY

Solar photovoltaic (PV) energy, often referred to as solar power, is a renewable energy technology that converts sunlight into electricity. It involves the use of solar panels or modules composed of photovoltaic cells to capture the energy from the sun and convert it into usable electrical power. Unlike energy generated by hydro and wind, solar energy is not restricted by geography. In fact, solar energy can be generated in most areas of the world. Photovoltaics are also spreading worldwide ,as they are proving to be the best means of producing solar-generated electricity. Figure displays renewable energy. Solar photovoltaic energy has experienced significant growth and advancements in recent years, leading to increased efficiency, improved aesthetics, and broader adoption worldwide. It plays a crucial role in transitioning towards a cleaner and more sustainable energy future.

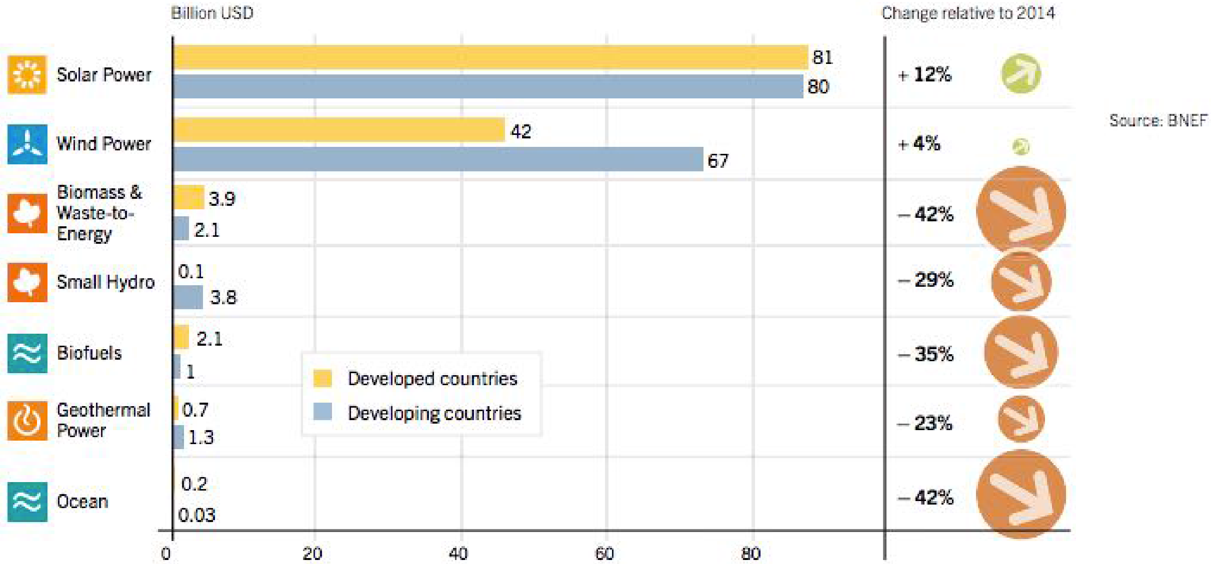


Figure 3.3: Average annual growth rates of renewable energy capacity and bio-fuel's production in 2015 .

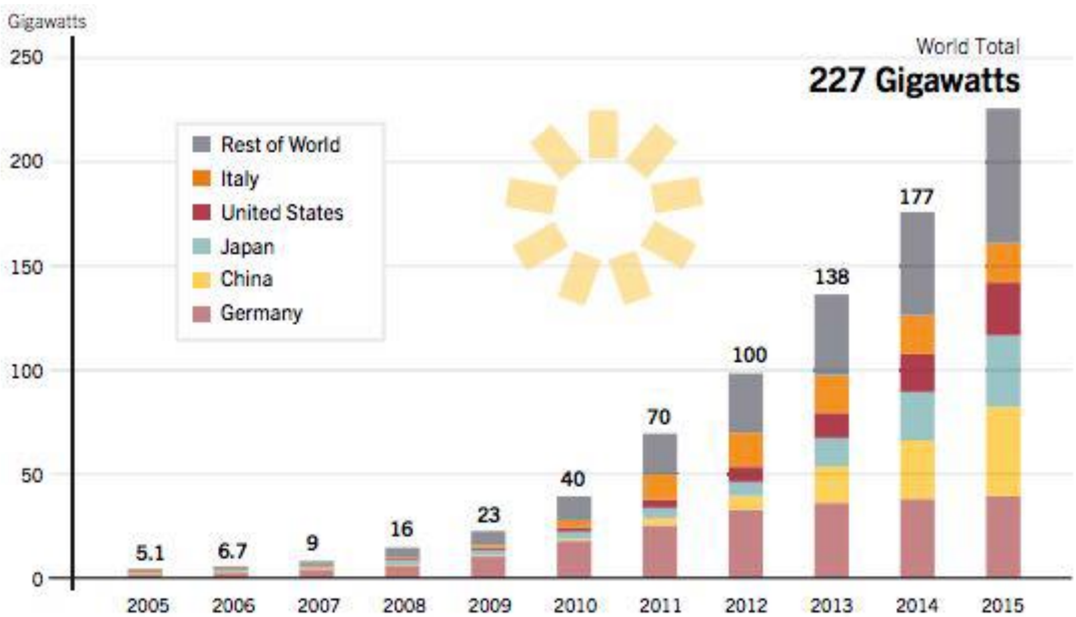


Figure 3.4: Solar PV existing world capacity 2005-2015 .

3.4 PV SYSTEM BENEFITS

Photovoltaic systems have several benefits over other systems , as explained below:

1) PV systems are pre-packaged and installment-ready. Furthermore, because the modules are free of moving parts, they require no serious maintenance.
2) The systems come in a different sizes and outputs, which make them operable across a range of applications. Moreover, because PV systems are relatively light, transportation is not an issue.
3) The systems can expand simply by including additional modules. This can be done either in parallel (i.e., to strengthen the current) or in series (i.e., to strengthen the voltage).
4) The system modules can handle excessive climatic conditions, such as extreme temperatures (hot or cold) and strong winds. They can also withstand excessive amounts of atmospheric moisture as well as salt. Furthermore, even in sunless conditions (e.g., night time or inclement weather), PV systems continue to function due to their storage capabilities, which enable them to generate consistent high-quality power with or without sunshine.
5) The systems are free of noise and carbon emissions, meaning they do not pollute.

Despite their many benefits, PV systems still have a few disadvantages, as follows:

1) Compared to alternative renewable resources, PV systems are quite expensive to produce.
2) There are still issues regarding maximum power point.
3) The systems must remain as free as possible from dust, thus requiring regular cleaning.

CHAPTER 4
PROPOSED SYSTEM

4.1 INTRODUCTION

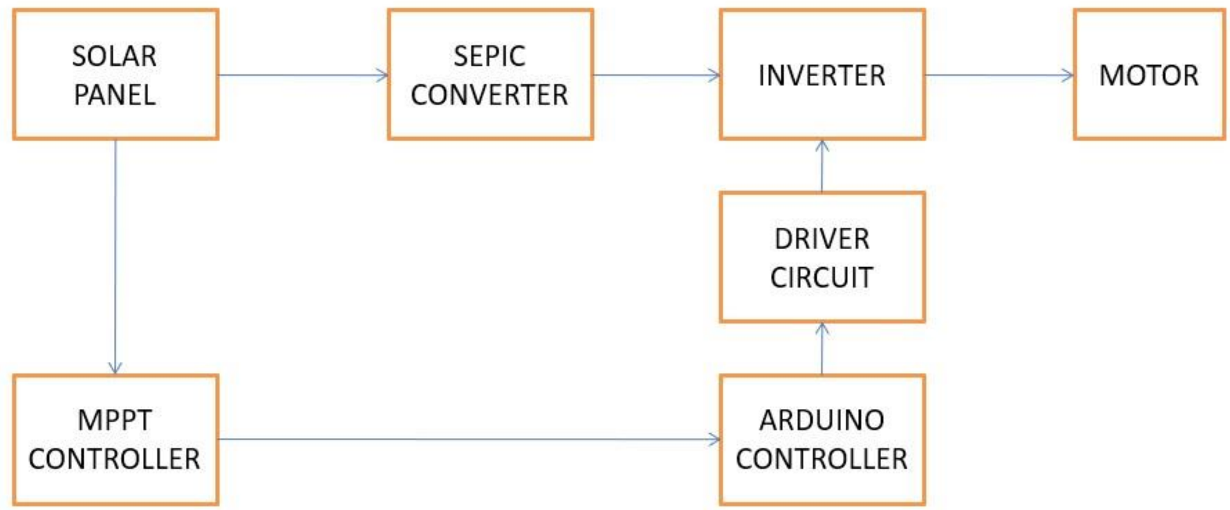


Figure : 4.1 Block diagram of proposed system

The proposed MPPT systems and other technique used in the past is that PV array output power is used to directly control the dc/dc converter thus reducing the complexity of the system.In previous method fuzzy logic controller was used in our concept we are going to use Arduino controller. Arduino controller is used to for gate pulse for the MOSFET. In this method we have used SEPIC converter which is attached to the solar panel.Photovoltaic cells are produced in a variety of types, each of which has different benefits. Below is a list of the most common forms of PVs . 1-Mono-crystalline (single crystalline) cells:As shown in Figure 4.1 these types of cells derive from a single crystal of silicon and are quite smooth in texture. Although they are the most efficient of the PV cells, mono-crystalline cells are also the most costly to manufacture 2-Poly-crystalline (multi-crystalline) cells:

As their name implies, polycrystalline cells are several crystals combined, they are cut from a block of silicon. Although PV solar panels made from poly-crystalline cells types are less efficient than mono-crystalline cells, they are less expensive.

3-Amorphous cells:

As demonstrated in Figure, amorphous cells are produced by setting a thin film of non crystalline (i.e., amorphous) silicon on top of different surfaces.

4.2 PV CELL

These are three types of PV cells listed here, amorphous cells provide the least efficient type of photovoltaic solar panels, but they are also atleast expensive to produce and have the characteristic of making PV panes flexible

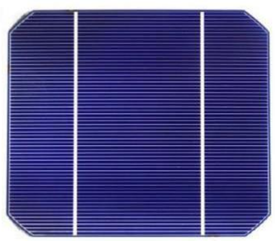


Figure 4.2:Mono-crystallinPVcell.

Figure 4.3: Poly-crystalline PV cell.

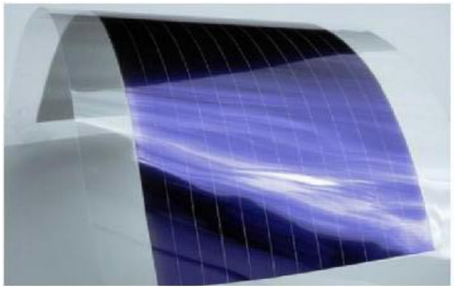


Figure 4.4: Non-crystalline (amorphous) PV cell .

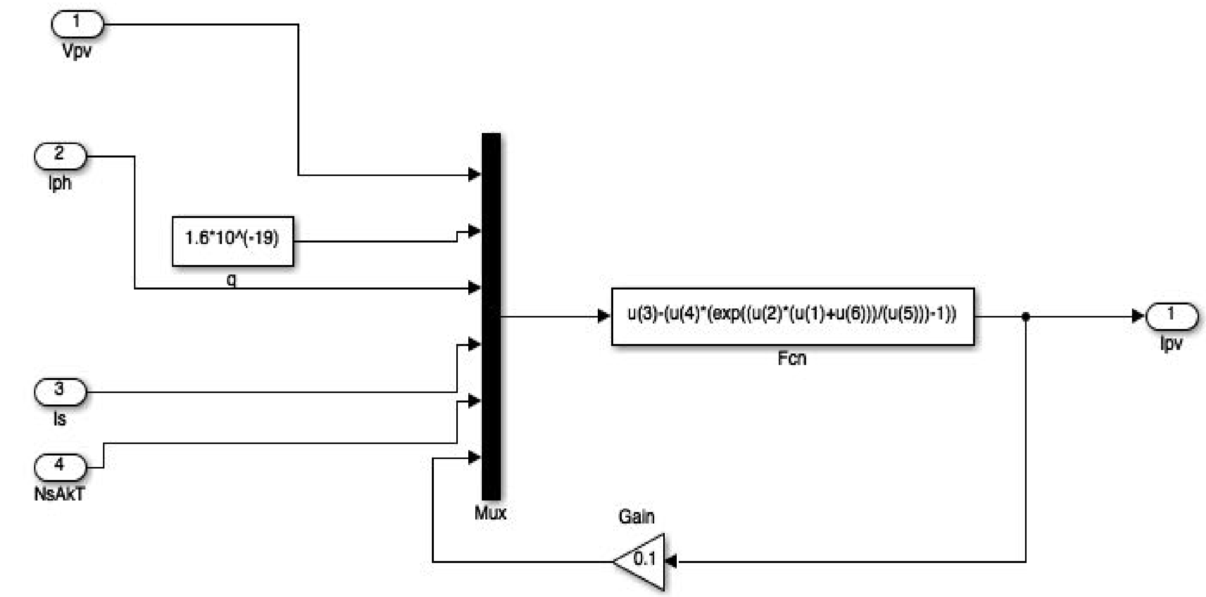


Figure 4.5: Generating PV module output current by using equation

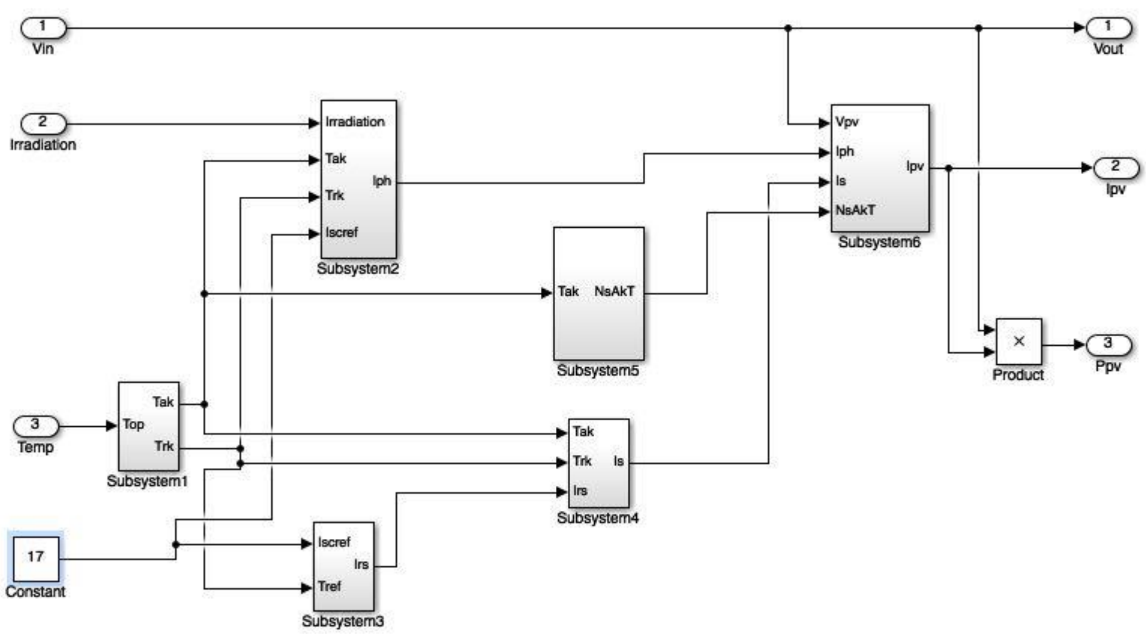


Figure 4.6: The output current, voltage and power of PV module.

4.3 EXTRACTING OF IPV, Vout, PPV OF PV MODULE

As demonstrated in all 6 models featured above are interconnected in order to extra IPV, Vout and PPV.

4.4 ACTUAL PROPOSED PV MODEL

The economic development, industrial progress, societal growth, access to affordable and sustainable electric power is the fundamental requirement of any country. The demand for electricity in India is growing continuously, due to the industrialization and urbanization **(BAGHZOUZ,YAHIA** 2015). Being a growing country, India's total installed power capacity addition comes from different sources is 1.362 GW in 1947 to 326.849 GW up to 31st March 2017 (Central Electricity Authority, 2017a.

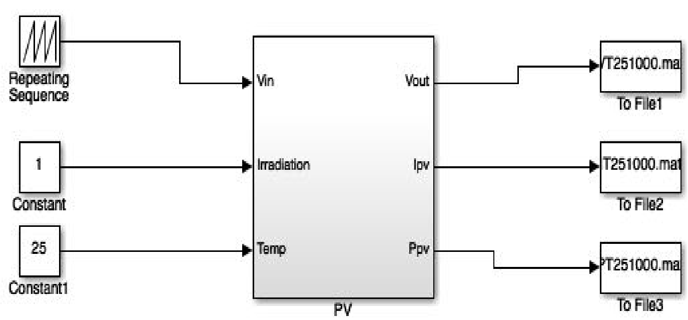


Figure 4.7: Actual Proposed PV Panel

CHAPTER 5
SIMULATION RESULTS

5.1 INTRODUCTION

A photovoltaic module was modeled in MATLAB/Simulink. When the results of the simulation were compared to the manufacturer-supplied data, they were discovered to be similar. Hence, we propose that the model is sufficiently detailed and thus could be used to model any type of solar panel by using information given in the manufacturer's data sheet. The model was then used in Chapter 4 to develop an entire MPPT model based P&O.

5.2 SEPIC CONVERTER OPERATION

SEPIC or single-ended primary inductor converter is a type of Buck/Boost DC-DC Converter that provides a DC output greater than, less than, or equal to its DC input. It consists of two inductors, one is at the input and another one is connected to the ground and these two inductors are connected by a coupling capacitor. The major advantage of a SEPIC converter is that its output voltage has the same polarity as that of the input voltage. This is called no-polarity inversion.

Key benefits of SEPIC Converters:

When compared with a conventional buck-boost converter, the SEPIC converter offers benefits such as providing non-inverting output voltage, superior input current purity, and higher efficiency.

When compared with a flyback converter (isolated buck-boost) that uses a transformer for isolation, the SEPIC converter offers benefits such as lower switching losses, low output voltage noise, higher efficiency, and allows the high frequency of operation.

5.3 SPECIFICATION OF PV ARRAY

Peak power, P_m (W)	-	224.75
Open circuit voltage, V_{oc} (V)	-	41.79
Voltage at MPP, V_{mp} (V)	-	33.9
Short circuit current I_{sc} (A)	-	7.13
Current at MPP, I_{mp} (A)	-	6.63

5.4 SPECIFICATION OF SEPIC CONVERTER

Duty ratio	-	0.61
Inductance L1 and L2	-	2.12 mH
Capacitors C1 and C2	-	1100μF
Switching frequency	-	24 kHz

5.5 SPECIFICATION OF INDUCTION MOTOR

Rotor type	-	Squirrel cage
Model	-	5 HP 460V 60Hz 1750 RPM
Mechanical input	-	Torque
Reference frame	-	Rotor
Stator resistance	-	1.115 ohm
Rotor resistance	-	1.083 ohm
Stator inductance	-	0.005974 H
Rotor inductance	-	0.005974 H

5.6 SPECIFICATION OF DC MOTOR

Model	-	5 HP 240 V 1750 RPM field : 300 V
Mechanical input	-	Torque
Field type	-	Wound
Stator resistance	-	1.115 ohm
Rotor resistance	-	1.083 ohm
Stator inductance	-	0.005974 H
Rotor inductance	-	0.005974 H

5.7 SIMULATION OF SEPIC CONVERTER

The SEPIC converter seamlessly switches between these two modes to maintain a regulated output voltage regardless of the input voltage variations. By adjusting the duty cycle of the switches, the output voltage can be controlled.

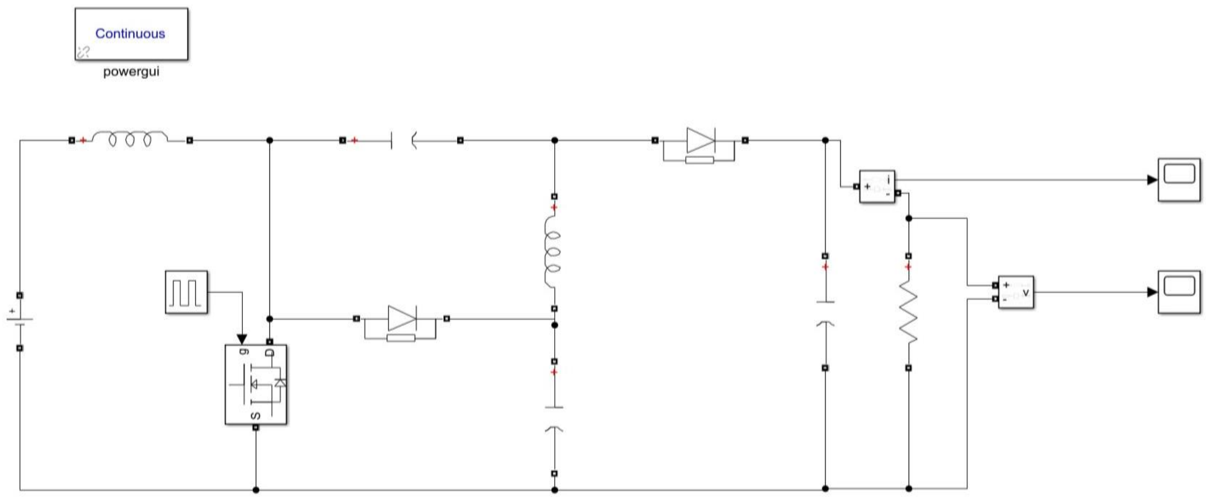


Figure 5.1 : Simulation Of SEPIC Converter

5.8 SIMULATION OF MPPT WITH P&O ALGORITHM

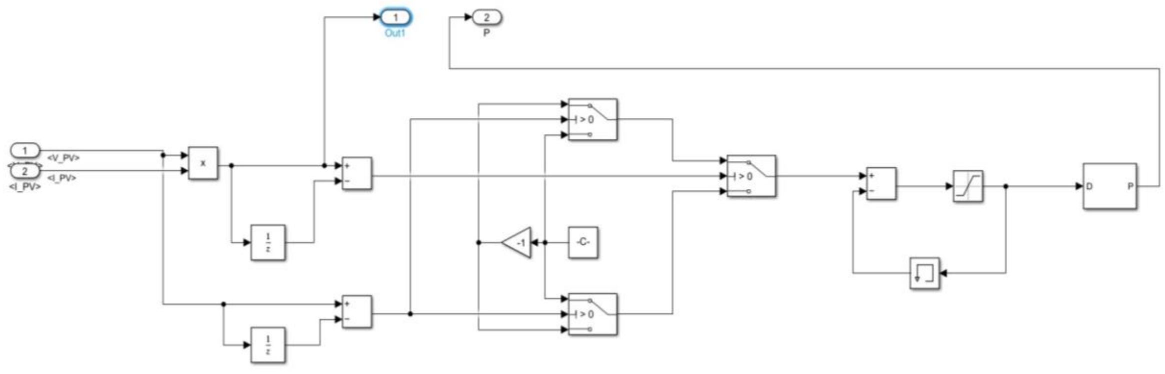


Figure 5.2 : Simulation Of MPPT with P&O Algorithm

5.9 INVERTER CIRCUIT SIMULATION

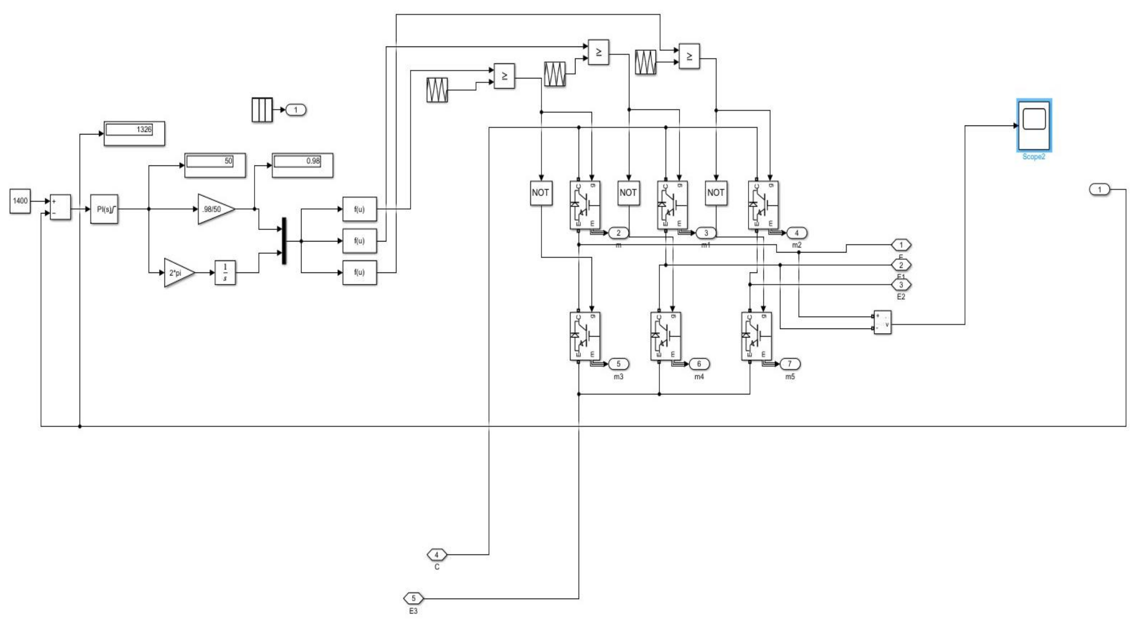


Figure 5.3 : Inverter Circuit Simulation

5.10 SIMULATION OF INDUCTION MOTOR

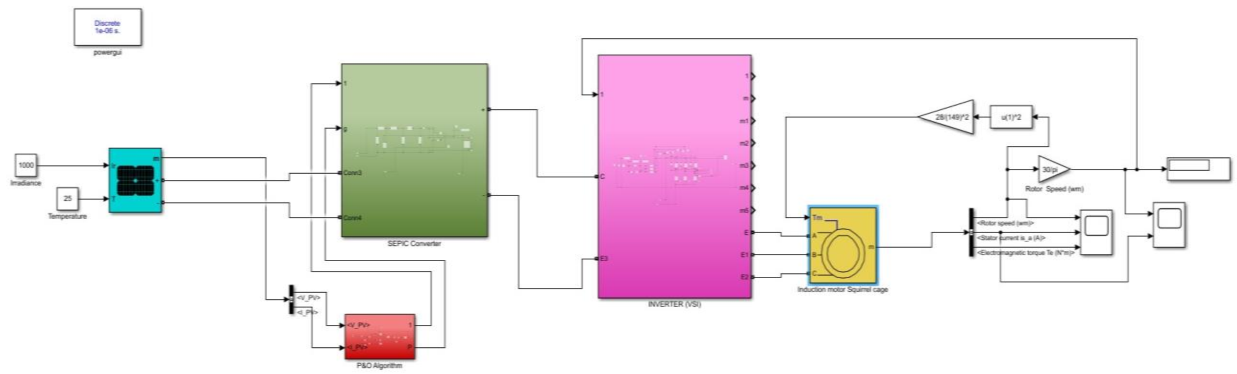


Figure 5.4 : Induction motor Simulation diagram

5.11 SIMULATION OUTPUT OF INDUCTON MOTOR

VSI-fed Induction Motor can evaluate steady-state and dynamic performance, assess the control system's response to different operating conditions, analyze efficiency, and study the impact of parameter variations or disturbances.

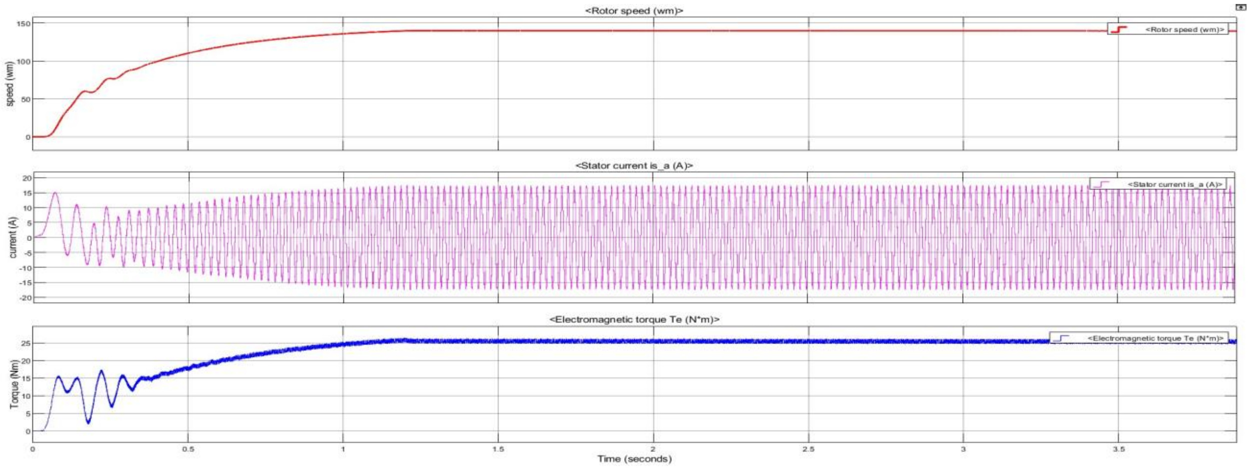


Figure 5.5 : Simulation Output of induction motor

5.12 SIMULATION OF DC MOTOR

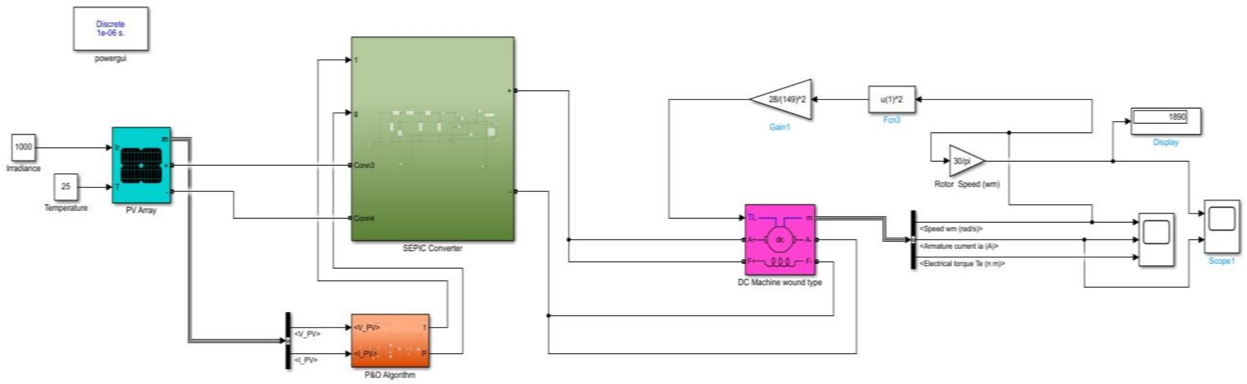


Figure 5.6 : DC motor simulation diagram

5.13 SIMULATION OUTPUT OF DC MOTOR

The simulation output of a DC motor can provide valuable insights into the motor's behavior and the performance of the control system.

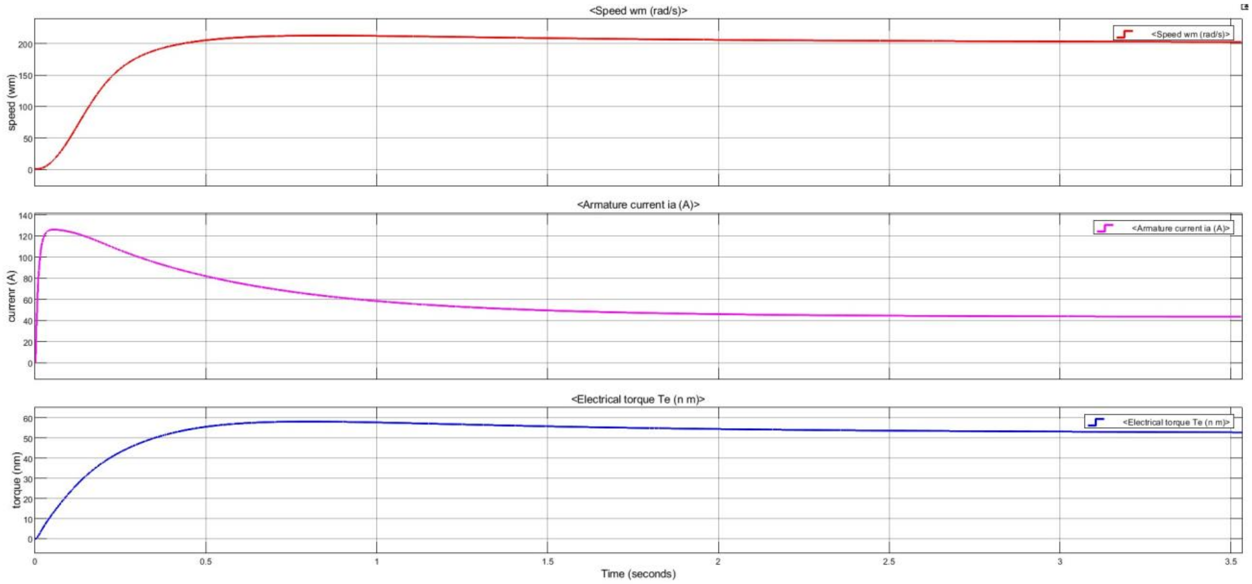


Figure 5.7 : Simulation Output of DC motor

CHAPTER 6
HARDWARE IMPLEMENTATION

6.1 INTRODUCTION

This chapter presents the real-time implementation of P&O logic controller based maximum power point tracking of photovoltaic system. The proposed controller was applied to the modified solar charge controller by replacing built in with a programmed Arduino to act as MPPT based Inc controller. Moreover, the produced duty cycle is used to drive a pulse width modulation (PWM) that operates dc-dc converter at the maximum power point. The purpose of this implementation is to evaluate the performance of P&O controller based MPPT system in comparison with a manufactured MPPT and validate the simulation results. More details about the hardware components and the operation are included below in this chapter.

6.2 HARDWARE COMPONENTS

This represents the whole real time system that was used in the thesis. The following devices are the main parts of the hardware implementation: This module is the main part of this system which was studied in order to enhance its produced power. In other words, PV module represents the electricity generate or that generates the power which the proposed controller was adjusted to extract the maximum power. Figure shows the exact PV that was worked on in the thesis and has the same specifications that was mentioned two chapters.Batteries are elements which store the electricity that produced from renewable energy (RE) sources such as: PV, wind, or hydro. These electric storages are used as a power source when there is no production of RE. Most batteries employed in renewable energy systems have almost the same electro-chemical reaction as the lead-acid battery in cars, but unlike car battery, they are specifically designed for deep cycling.

Figure 6.1 : PV array consisting of 12 v,130 watt modules

Also most RE systems have batteries that store between ten and hundreds of times more energy than a car battery demonstrates the type of battery. that employed in this experiment.

6.3 POWER SUPPLY UNIT

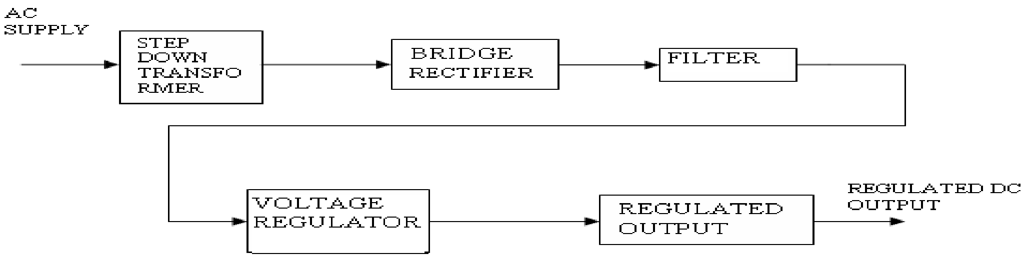


Figure 6.2: Block diagram of power supply unit.

As we all know any invention of latest technology cannot be activated without the source of power. So it this fast moving world we deliberately need a proper power source which will be apt for a particular requirement. All the electronic components starting from diode to Intel IC's only work with a DC supply ranging from -+5v to 0-+12v. We are utilizing for the same, the cheapest and commonly available energy source of 230v-50Hz and stepping down, rectifying, filtering and regulating the voltage. This will be dealt briefly in the forth-coming sections.

6.3.1 STEP DOWN TRANSFORMER

When AC is applied to the primary winding of the power transformer it can either be stepped down or up depending on the value of DC needed. In our circuit the transformer of 230v/0-12v is used to perform the step down operation where a 230V AC appears as 12V AC across the secondary winding. One alteration of input causes the top of the transformer to be positive and the bottom negative. The next alteration will temporarily cause the reverse. The current rating of the transformer used in our project is 1A. Apart from stepping down AC voltages, it gives isolation between the power source and power supply circuitries.

6.3.2 DIODE BRIDGE RECTIFIERS

The AC input from the main supply is stepped down using a 230 /30V step down transformer. The stepped down AC voltage is converted into dc voltage using a diode bridge rectifier. The diode bridge rectifier consists of four diodes arranged in two legs. The diodes are connected to the stepped down AC voltage. For positive half cycle of the ac voltage, the diodes D1 and D4 are forward biased (ref fig). For negative half cycles diodes D2 and D3 are forward biased. Thus dc voltage is produced to provide input supply to the DC-DC Converter.

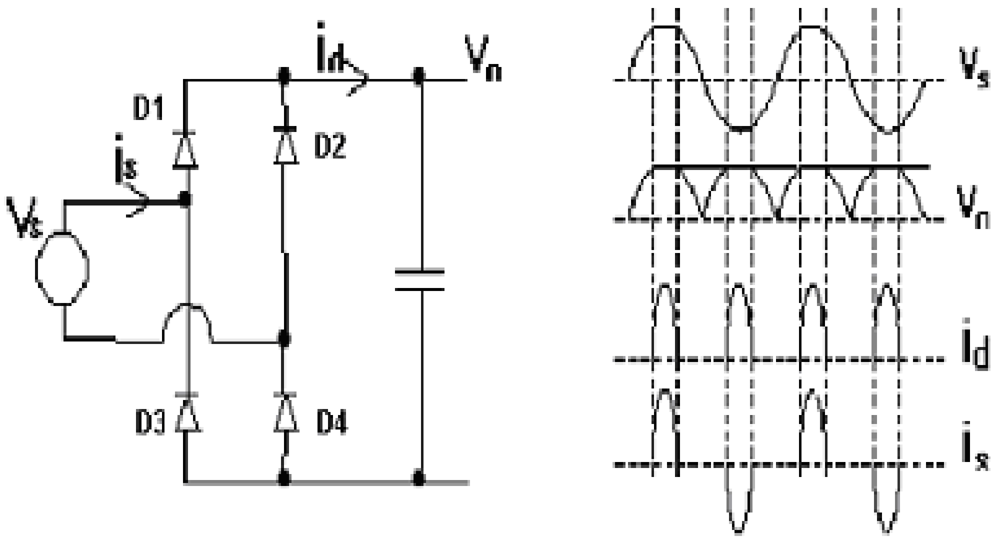


Figure 6.3 :Diode Bridge Rectifier

When the positive half cycle is applied to the diode bridge rectifier, the diodes D1 and D4 are forward biased. The diodes start conducting and the load current flows through the positive of the supply, diodeD1, the load, the diode D4 and the negative of the supply. The diode D2 and D3 are reverse biased and do not conduct.During the negative half cycle, the diodes D1 and D4 areb reverse biased and they stop conducting. The diodes D2 & D3 are forward biased and they start conducting. The load current flows in the same direction for both the half cycles. Thus the ac supply given to diode bridge rectifier is converted into pulsating dc.

6.3.3 FILTERING UNIT

Filter circuits which are usually capacitors acting as a surge arrester always follow the rectifier unit. This capacitor is also called as a decoupling capacitor or a bypassing capacitor, is used not only to ‘short’ the ripple with frequency of 120Hz to ground but also to leave the frequency of the DC to appear at the output. A load resistor R1 is connected so that a reference to the ground is maintained. C1R1 is for bypassing ripples. C2R2 is used as a low pass filter, i.e. it passes only low frequency signals and bypasses high frequency signals. The load resistor should be 1% to 2.5% of the load.

6.3.4 DRIVER CIRCUIT COMPONENTS

The driver circuit is used to amplify the pulses. It consists of three main components they are:

1.OPTOCOUPLER

2.BUFFER IC

3.TRANSISTOR

6.4 MOSFET SWITCH-IRFP250N

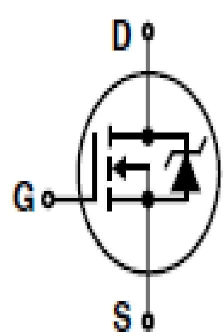


Figure 6.4: MOSFET Switch Diagram.

(**M**etal **O**xide **S**emiconductor **F**ield **E**ffect **T**ransistor). The most popular and widely used type of field effect transistor (see FET). MOSFETs are either NMOS (n-channel) or PMOS (p-channel) transistors, which are fabricated as individually packaged discrete components for high power applications as well as by the hundreds of millions inside a single chip (IC).

6.4.1 GENERAL DESCRIPTION

In our project the MOSFET switch is connected to the main circuit.Here we have two switches namely

- Main switch Sm
- Auxiliary switch
- The pulse to these switches is given using micro controller PIC16F877A through a driver circuit. In PIC16F877A the pulse of 5V is generated which is sent to driver circuit, these signal is amplified to about 12V DC, that is sent to the MOSFET switch S_m and S_a respectively.

6.4.2 USING MOSFET AS A SWITCH

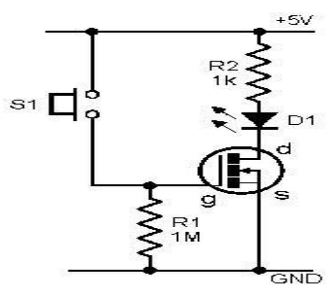


Figure 6.5: Systematic Diagram Of MOSFET Switch.

A field effect transistor operates in a very similar way to the transistor that we have just experimented with except that the main current flow is controlled by an electrostatic field. An FET has the great advantage that no current flows into the control input (called the gate), the main current is turned on and off by the level of FETs are available in many different types and with various drive level requirements. We are going to keep it simple and not get into these complications. The MOSFET that we will be using is a logic level MOSFET - they are designed to be driven directly from the output lines of microcontrollers - that is all we need to For these experiments we will be using the BS270 N channel MOSFET. As it is designed for logic level inputs we know that when the gate is connected to ground it is turned off and when the gate is connected to 5 volts it is turned on. We do not need to use a resistor between the push button switch and the gate because the current is very very low whatever the input voltage (if kept within 0 to 5 volts).

6.4.3 FEATURES

• Ultra Low On-Resistance

- r DS(ON) = 0.052Ω (Typ),VGS =10V

• Simulation Models

-Temperature Compensated PSPICE® and SABER©

Electrical Models

-Spice and SABER©Thermal Impedance Models

• Peak Current vs Pulse Width Curve

• UIS Rating Curve

6.5 DC GEAR MOTOR

A DC gear motor is a type of electric motor that combines a DC motor with a gear train. It is widely used in various applications that require precise and controlled motion, torque multiplication, and speed reduction. The gear train, consisting of gears with different sizes and configurations, helps to modify the output speed and torque of the motor to meet specific requirements. DC gear motors offer several advantages. Firstly, they provide high torque output, making them suitable for applications that require heavy lifting or moving objects. The gear reduction mechanism allows the motor to generate increased torque while reducing the rotational speed. This torque multiplication capability makes DC gear motors ideal for applications such as robotics, conveyor systems, and industrial machinery.

Secondly, DC gear motors offer precise control and positioning. The gear reduction mechanism enables finer control of motor speed and enhances the motor's ability to maintain a steady rotational position. This feature is valuable in applications that require accurate positioning, such as automated guided vehicles, camera gimbals, and precision equipment. Furthermore, DC gear motors are known for their efficiency. The gear train helps to distribute the load across multiple gears, reducing the strain on individual components and enhancing overall efficiency. By operating at higher gear ratios, the motor can achieve the desired output torque with reduced power consumption, making it energy-efficient and cost-effective.

DC gear motors are available in various configurations, including parallel shaft, planetary, and worm gear designs. Each design offers unique characteristics and performance advantages, allowing for versatility in different applications.

Parallel shaft gear motors are commonly used in low-speed, high-torque applications, while planetary gear motors excel in applications that require compact size, high torque, and efficiency. Worm gear motors are known for their self-locking capability and are often employed in applications that require holding the load in a fixed position when the motor is not powered.

In conclusion, DC gear motors are reliable, efficient, and versatile solutions for applications requiring controlled motion, torque multiplication, and speed reduction. Their ability to provide high torque output, precise control, and energy efficiency makes them well-suited for a wide range of industries, including robotics, automation, automotive, aerospace, and more. With various gear configurations available, DC gear motors can be tailored to meet specific application requirements and provide optimal performance.

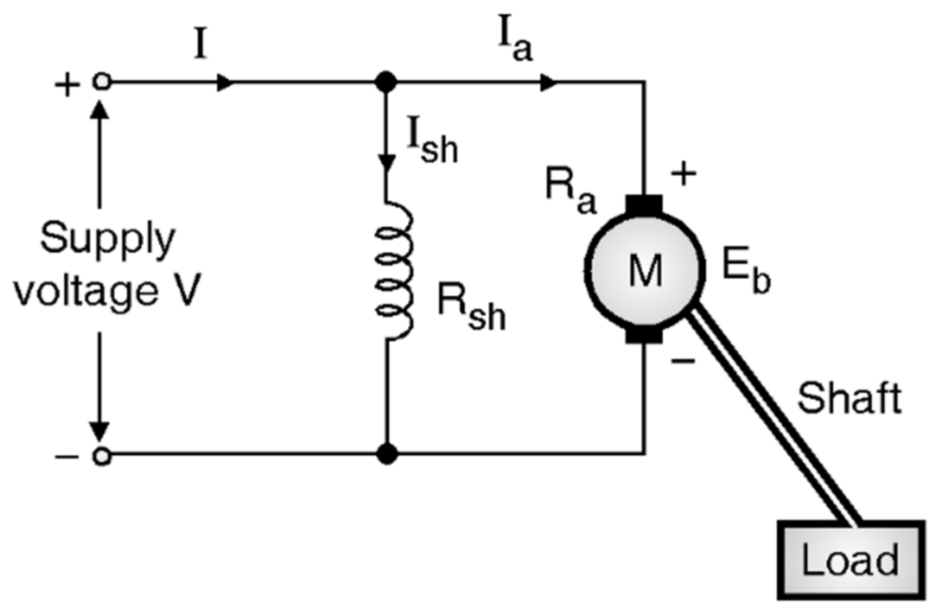


Figure 6.6 :Circuit diagram of DC motor.

6.5.1 Torque

Torque (also known as moment), etymologically derived from the Latin word twist, is defined as a force that produces or tends to produce rotation or torsion. A torque is created when a perpendicular force is applied at the end of a shaft, as is shown in the torque diagram below. The value of the torque is then given by the product of this force times the radius (the distance from the pivot to the location where the force is applied), also called the moment arm.

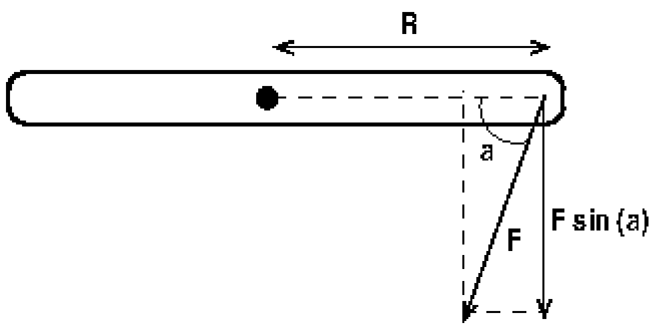


Figure 6.7 : The perpendicular component of F produces the torque.

A force *F* is applied to the shaft at an angle *a*, as shown. The perpendicular component of this force is Fsin(a) and the moment arm is R. Thus the torque is given by

$$T = FR(\sin a) \qquad (1)$$

6.5.2 Rotational speed

Rotational or angular speed is measured in terms of the number of revolutions a shaft makes per unit time. The Greek letter omega, ω, is typically used to represent this quantity, and the units are radian/second (rad/s, SI unit), revolution/second (rps), or, among others, revolution/minutes (rpm). When using this parameter in calculations, we must use rad/s if all the other units are in the SI system, and degrees/sec if we are using the English system. An important conversion to remember is the relationship between rpm and rad/sec, given by

$$\omega_{rad/s} = \omega_{rpm}(\frac{2\pi}{60}) \quad \text{……………………………………..…(2)}$$

6.5.3 Power

In rotational motion, power is defined in terms of the torque, as follows

$$P = T\ \omega \quad \text{……………………………………………………..(3)}$$

The standard SI unit of power is watts (W), which is equal to N-m/s, and in the English system we normally use ft-lb/s, or horsepower (hp).

6.5.4Acceleration of the motor

An equation similar to the last equation can be developed relating the torque and the armature current. It happens that the torque is directly proportional to this current, and given by

$$T = K_t I_a \quad \text{…………………………………………………….(4)}$$

The current flow through the armature is limited only by its resistance, and given by the Kirchhoff current law (KCL):

$$I_a = \frac{E - E_b}{R_a} \quad \text{…………………………………………………..(5)}$$

At the very start of the motor ω = 0, and the induced voltage is $E_b = 0$. Then the starting current is

$$I_a = \frac{E}{R_a} \quad \text{……………………………………………………..(6)}$$

6.6 ARDUINO UNO

This device is a type of microcontrollers which represents the brain of the MPPT controller. Further more, its operation depends on the code that already programmed and uploaded into the board by using open source Arduino software (IDE). shows the basic Arduino Unoboard and Arduino code window.

The true computer on a chip is nothing but a Arduino microcontroller. The design incorporates all of the features found in a microprocessor CPU, ALU, PC, SP and registers. It also had added the other features needed to make a complete computer. ROM, RAM, parallel I/O, serial I/O, Counters and a clock circuits. Microprocessors are intended to be general-purpose digital computers whereas Arduino microcontrollers are intended to be special-purpose digital Controller. Microprocessor contains a CPU, memory-addressing circuits and Interrupt handling circuits. Arduino microcontrollers have these features as well as timers, parallel and serial I/O, and internal RAM and ROM. Arduino microcontroller models vary in data size from 4 to 32 bits. Four-bit units are produced in huge volumes for very simple applications; and8-bit units are the most versatile. 16 and 32-bit units are used in high-speed control and signal processing applications. Many models feature programmable pins that allow external memory to be added with the loss of I/O capability.

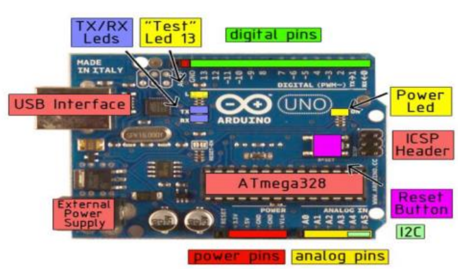


Figure 6.8 : Arduino Uno board

6.6.1 ARDUINO PROGRAM OF P&O ALGORITHM

```
// Constants
const int panelPin = A0; // Analog pin for solar panel voltage
const int dutyCyclePin = 9; // PWM pin for duty cycle control
const int setPointVoltage = 17; // Setpoint voltage (adjust as needed)

// Variables
int panelVoltage = 0;
int previousVoltage = 0;
int dutyCycle = 0;

void setup() {
  // Initialize serial communication
  Serial.begin(9600);

  // Configure PWM pin for output
  pinMode(dutyCyclePin, OUTPUT);
}

void loop() {
  // Read solar panel voltage
  panelVoltage = analogRead(panelPin);

  // Convert analog value to voltage
  float voltage = (panelVoltage * 5.0) / 1023.0;

  // Print the voltage
```

```
  Serial.print("Panel Voltage: ");
  Serial.print(voltage);
  Serial.println(" V");

  // Perturb and Observe algorithm
  if (voltage > previousVoltage) {
    // Increase duty cycle
    dutyCycle++;
  } else if (voltage < previousVoltage) {
    // Decrease duty cycle
    dutyCycle--;
  }

  // Set duty cycle limits (0-255)
  if (dutyCycle < 0) {
    dutyCycle = 0;
  } else if (dutyCycle > 255) {
    dutyCycle = 255;
  }

  // Update duty cycle
  analogWrite(dutyCyclePin, dutyCycle);
  // Store previous voltage
  previousVoltage = voltage;
  // Delay for stability
  delay(1000);
}
```

6.7 HARDWARE SPECIFICATION OF SOLAR PV

Open circuit voltage	-	12V
Short circuit current	-	1A
Rated maximum power	-	12W
Nominal operating cell temperature	-	45^{o}C

6.8 HARDWARE SPECIFICATION OF SEPIC CONVERTER

Input voltage	-	10V to 15V
Output voltage (nominal)	-	14V
Inductor	-	0.008µH
Capacitor	-	3300µF
Switching frequency	-	30kHz
Nominal resistive load	-	4.7Ω

6.9 HARDWARE SPECIFICATION OF DC GEAR MOTOR

Maximum torque	-	3.5 kg-cm at 12V-60 RPM
RPM	-	60 RPM at 12V
Maximum load current	-	350mA at 12V-60 RPM

6.10 HARDWARE PHOTOCOPY

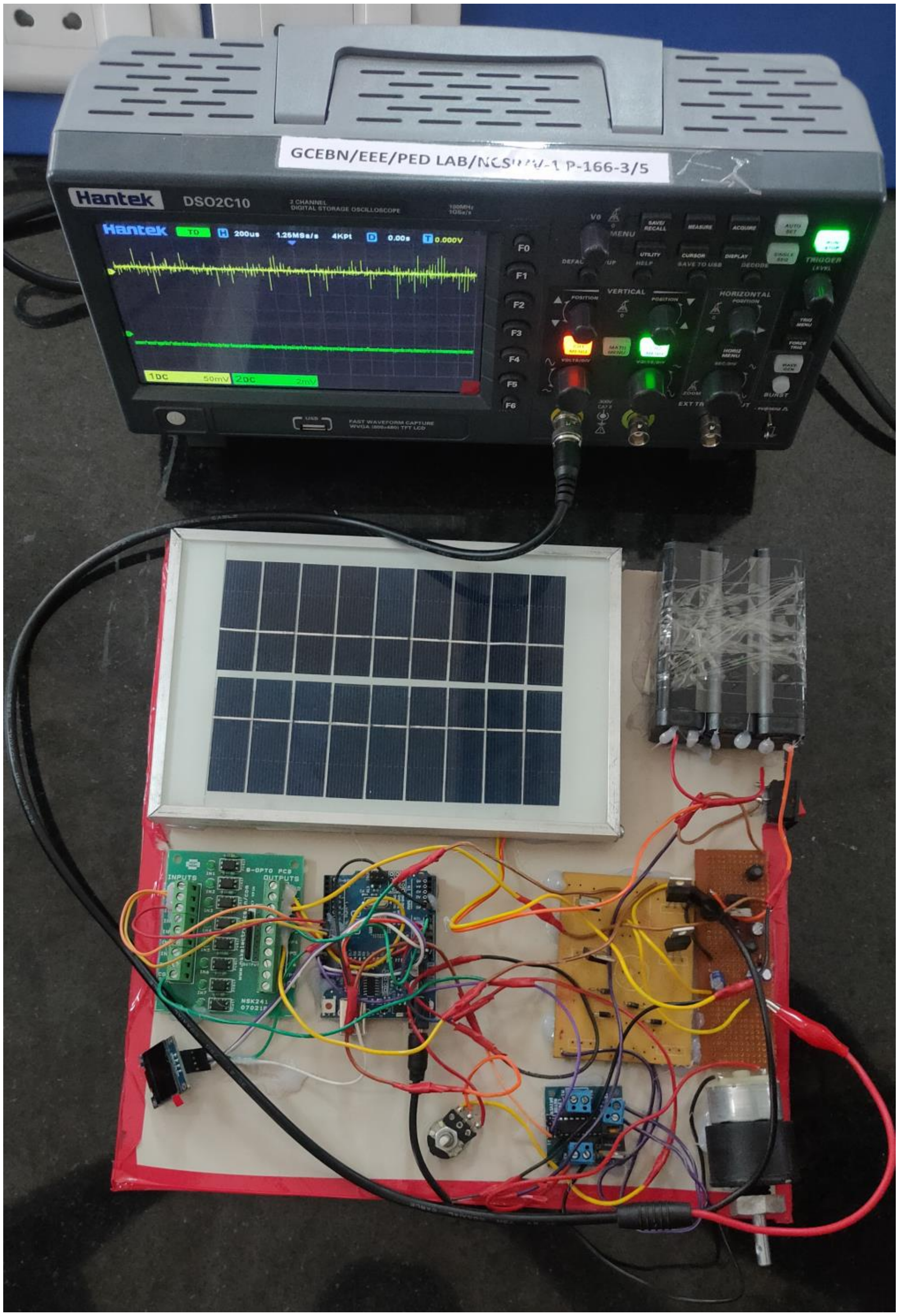
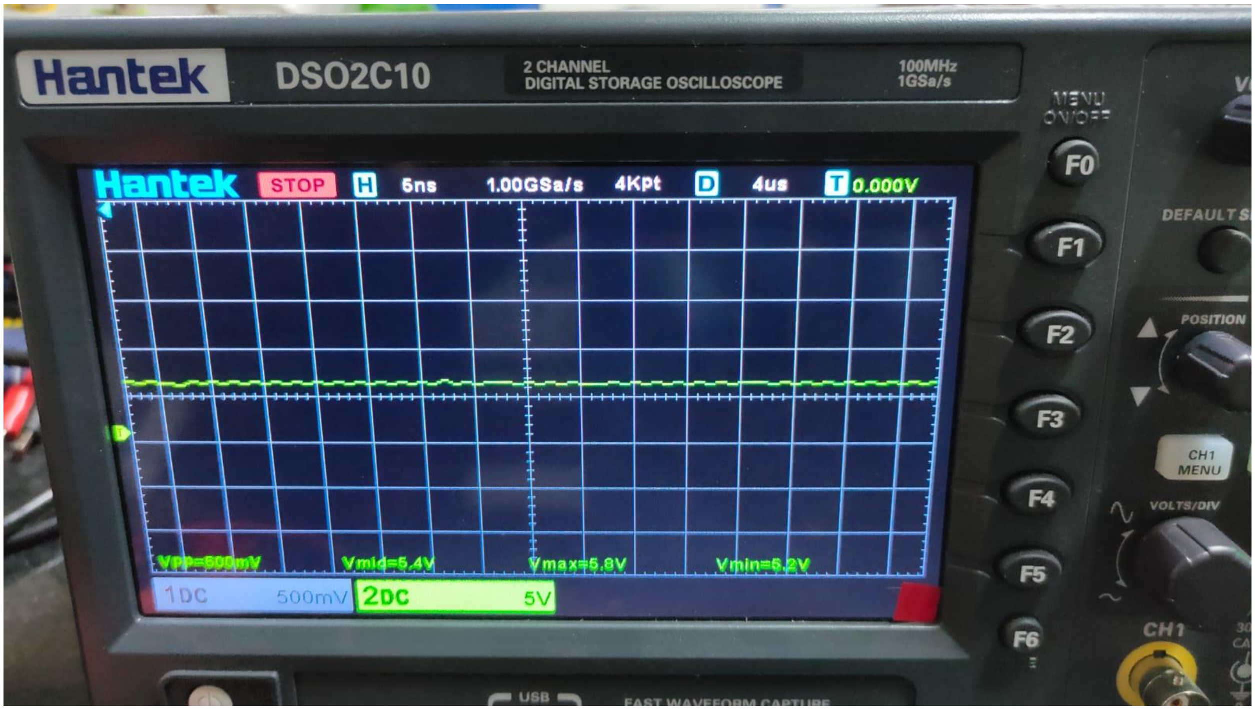


Figure 6.9 : Hardware prototype



V_{min} = 5.4V, V_{max} = 5.8V

Figure 6.10 : Output voltage of solar PV

V_{min} = 10V, V_{max} = 15V

Figure 6.11 : Output voltage of SEPIC converter

CHAPTER 7
CONCLUSION AND FUTURE SCOPE

7.1 CONCLUSION

This project emphasizes the viability of the solar PV-fed SEPIC converter for drive applications, offering a sustainable and efficient solution to integrate solar PV systems into various drive systems. The converter's ability to accommodate a wide input voltage range, provide galvanic isolation, and optimize power transfer makes it a promising choice for renewable energy-based drive applications, contributing to a greener and more sustainable future. In the simulation side, the input from PV panel is boosted to desired level by this converter. By using this converter, we can reduce switching voltage to half of the conventional boost converter and two loading capacitors are used instead of one in SEPIC converter, which will share the voltage stress and inrush current. From converter analysis it shows that it has a reduced switching loss. The v/f control technique is used for switching inverter. The waveforms of converter and motor are recorded and analyzed. In hardware side, for simplicity, the speed of DC motor is monitored and controlled.

7.2 FUTURE SCOPE

Future work could include methods for applying a P&O logic algorithm in a dedicated single-chip microcontroller. As well, a Galileo board could be used rather than two Arduino boards to satisfy memory space restrictions and boost microcontroller speed when testing and comparing two types of MPPTs. This would also shorten the time required for hardware setup.

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