DAFFODIL INTERNATIONAL UNIVERSITY

Dhaka, Bangladesh

Thesis Report
On

STUDY ON GRID CONNECTED SOLAR PV SYSTEM

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Certification

This is to certify that this project and thesis entitled "**STUDY ON GRID CONNECTED SOLAR PV SYSTEM**" is done by the following students under my direct supervision and this work has been carried out by them in the laboratories of the Department of Electrical and Electronic Engineering under the Faculty of Engineering of Daffodil International University in partial fulfillment of the requirements for the degree of Bachelor of Science in Electrical and Electronic Engineering. The presentation of the work was held on 27 June 2021.

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The project and thesis entitled "**STUDY ON GRID CONNECTED SOLAR PV SYSTEM**" submitted by MD. MEHEDI HASAN ID: 171-33-400, SULTAN AHMED SOJIB ID: 173-33-588, Session: Fall 2020 has been accepted as satisfactory in partial fulfillment of the requirements for the degree of **Bachelor of Science in Electrical and Electronic Engineering** on 27 June 2021.

APPROVAL LETTER

This thesis report titled “**STUDY ON GRID CONNECTED SOLAR PV SYSTEM**” **,** submitted by MD. MEHEDI HASAN ID: 171-33-400, SULTAN AHMED SOJIB ID: 173-33-588 to the Daffodil International University's Department of Electrical and Electronic Engineering has been approved as a partial supplement to the postgraduate scientific phase of electrical and electronic engineering, as well as its style and content. The presentation has been held on 27 June 2021.

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DECLARATION

We declare that this thesis is based on the results we receive. The work materials found by other researchers are referred by reference. This thesis is submitted to Daffodil International University for achieving BSc degree of Electrical and electronics engineering. This thesis has not been fully submitted for any degree prior to the degree.

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ABSTRACT

This study uses MATLAB/Simulink to simplify the modeling of a grid-connected photovoltaic (PV) system. The proposed model consists of a PV array, Maximum power point tracker, Boost converter and Inverter. A precise PV module electrical model is displayed dependent on the Shockley diode condition. A photograph current source, a single diode intersection, and an arrangement opposition are included in the basic model, which also includes temperature circumstances. For a typical 60W solar board, the approach for parameter extraction and model assessment in MATLAB is demonstrated. This model is used to investigate the range of maximum power points as a function of temperature and lighting. A comparison is given between buck and help most extreme power point tracker (MPPT) topologies, as well as a direct connection with a stable voltage inverter. This research discusses the design and recreations of a photovoltaic framework that utilizes the most extreme power point following (MPPT) method with assistance converter and a bother and watch approach. In addition, this study deals with the design and simulation of a three-phase inverter in MATLAB SIMULINK, which is a component of solar matrix-related frameworks. The modeling of these components has been thoroughly discussed and proven. The effects of solar irradiance and temperature on total power generation in a grid-connected PV system have been investigated. Phase locked loops and regulators have been built and modelled to maintain constant voltage at the inverter output and to synchronize the output frequency with the electric utility grid. The modeling approach is straightforward and may be used to investigate system characteristics under a variety of temperature and sun insolation circumstances.

Contents

Chapter 1

Generation of Electric Energy

1.1 Introduction

Electricity is a collection of physical miracles involving the presence and flow of electric charge. Electricity is vitality that is delivered by converting different sorts of vitality; electricity provides a diverse range of well-known sources, including synthetic vitality, warm vitality, dynamic vitality, atomic vitality, rotating vitality, sunlight-based vitality, wind vitality, and geothermal vitality. Certain electricity sources are sustainable, whereas others are non-sustainable. The vitality source, kind of age framework, unit and plant rating, and plant site are all key parameter selections that must be selected for each new electric power-producing plant or unit. These decisions must be based on a variety of specialized, economical, and natural factors.

1.2 Sustainable power

The term "sustainable power source" refers to energy derived from assets that are generally replenished on a human timeline, such as sun, wind, rain, tide waves, and geothermal. Around 16 percent of the world's last vitality is derived directly from inexhaustible resources, with traditional biomass accounting for 10% of total vitality (mostly used for warming) and hydroelectricity accounting for 3.4 percent. New inexhaustibles (small hydro, modern biomass, wind, sunlight-based, and geothermal) account for additional 3% of the total and are rapidly developing. At the national level, at least 30 nations around the world today have a sustainable power source that contributes more than 20% of their energy supply. National markets for sustainable power sources are expected to grow rapidly in the future decade and beyond. Sustainable energy sources are available in a variety of configurations, including wind, solar, and biomass management. We intend to educate people about the importance and benefits of adopting natural energy sources. This is critical since the world's oil and coal reserves are rapidly depleting, despite a massive increase in demand. As a result, it has gotten very important for people to appreciate the significance of preserving these little wellsprings of vitality and figuring out how to effectively manage energy.

1.3 Solar Energy

Solar energy, dazzling light, and warmth from the sun are harnessed by a variety of constantly evolving innovations, including solar warming, solar photovoltaics, solar warm electricity, solar engineering, and phony photosynthesis. Solar innovations are commonly classified as either disconnected solar or dynamic solar, depending on how they capture, convert, and circulate solar energy. To supply the energy, dynamic solar processes include the use of photovoltaic boards and solar warm gatherers. Detached solar systems entail aligning a structure with the Sun, selecting materials with optimum thermal mass or light scattering qualities, and laying out areas where air naturally flows.

A solar cell, often known as a photovoltaic cell (PV), is a device that converts light into electricity by the photoelectric effect. During the 1880s, Charles Fritts invented the primary solar cell. The German entrepreneur Ernst Werner von Siemens was one of the first to recognize the value of the information. Despite the fact that the model selenium cells converted less than 1% of incoming light into energy, German designer Bruno Lange developed a photograph cell using silver selenide instead of copper oxide in 1931. Following Russell Ohl's invention in the 1940s, Gerald Pearson, Calvin Fuller, and Daryl Chapin developed the silicon solar cell in 1954. These early solar cells cost 286 dollars a watt and had efficiency of 4.5 to 6%.

1.4 Solar Electric Systems That Are Connected To The Grid

Solar Electric Frameworks with Network Ties generate power invisibly and without moving components. The solar display (blue, on the housetop) receives sunlight, supplying DC energy. The converter converts the DC current into household 120V cooling power (blue and diminish, on the divider). The electricity from your forced air system is provided by your electric meter and electrical switchboard (diminish, on the divider). Electricity is directed to your mechanical assembly and lights, the cross section, or a combination of both. All of this occurs in an unobtrusive and predictable manner. Those who are (or will be) involved with administration association electrical linkages will benefit from lattice intelligence control frameworks (the "Network"). They want to use the Framework to improve what they can produce using renewable energy sources such as the sun and wind.

Create using sustainable energy sources such as the sun or the wind.

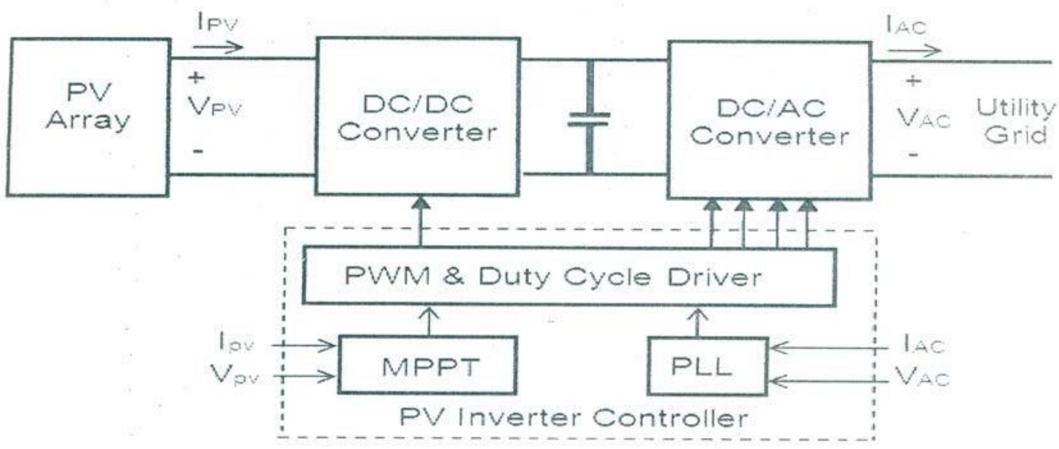


Figure 1.1:- Grid Tie Solar System

1.4.1 Grid-Tied Solar System Components

- Solar Panel.
- Maximum Power Point Tracking (MPPT) .
- DC To DC Converter .
- DC To AC Converter (Inverter) .
- Utility Grid.

1.5 Solar Panel

Photovoltaic Solar Panels are the sort of solar panels you've undoubtedly seen on people's roofs. Photo means light, and voltaic means energy. Photovoltaic (or PV) panels convert light directly into electrical energy, as its name implies.

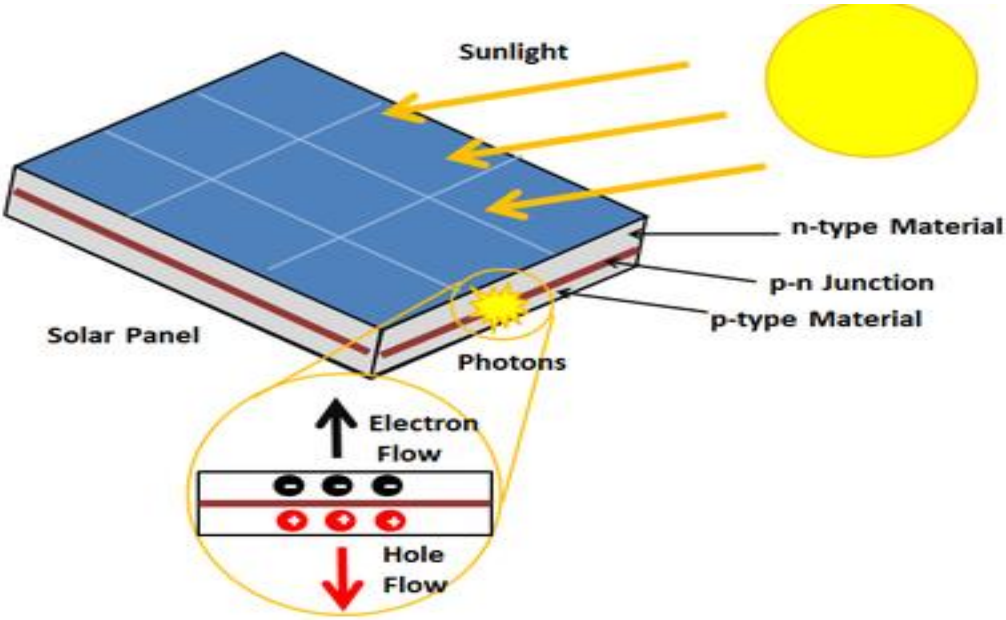


Figure 1.2: - Solar Panel

1.6 Basic Principal of Solar Panel

A solar cell, also known as a photovoltaic cell, is a device that uses the photovoltaic effect to convert sunlight directly into energy. The photovoltaic effect is a way of turning solar energy into direct current energy using specially constructed p-n junctions that show the photovoltaic effect. When electromagnetic irradiation strikes such a junction, it transfers energy to a valence band electron and promotes it to the conduction band, resulting in the formation of an electron-hole pair. The formed electrons and holes can now operate as mobile charge carriers, resulting in the generation of a current. This process across a p-n junction is shown in figure

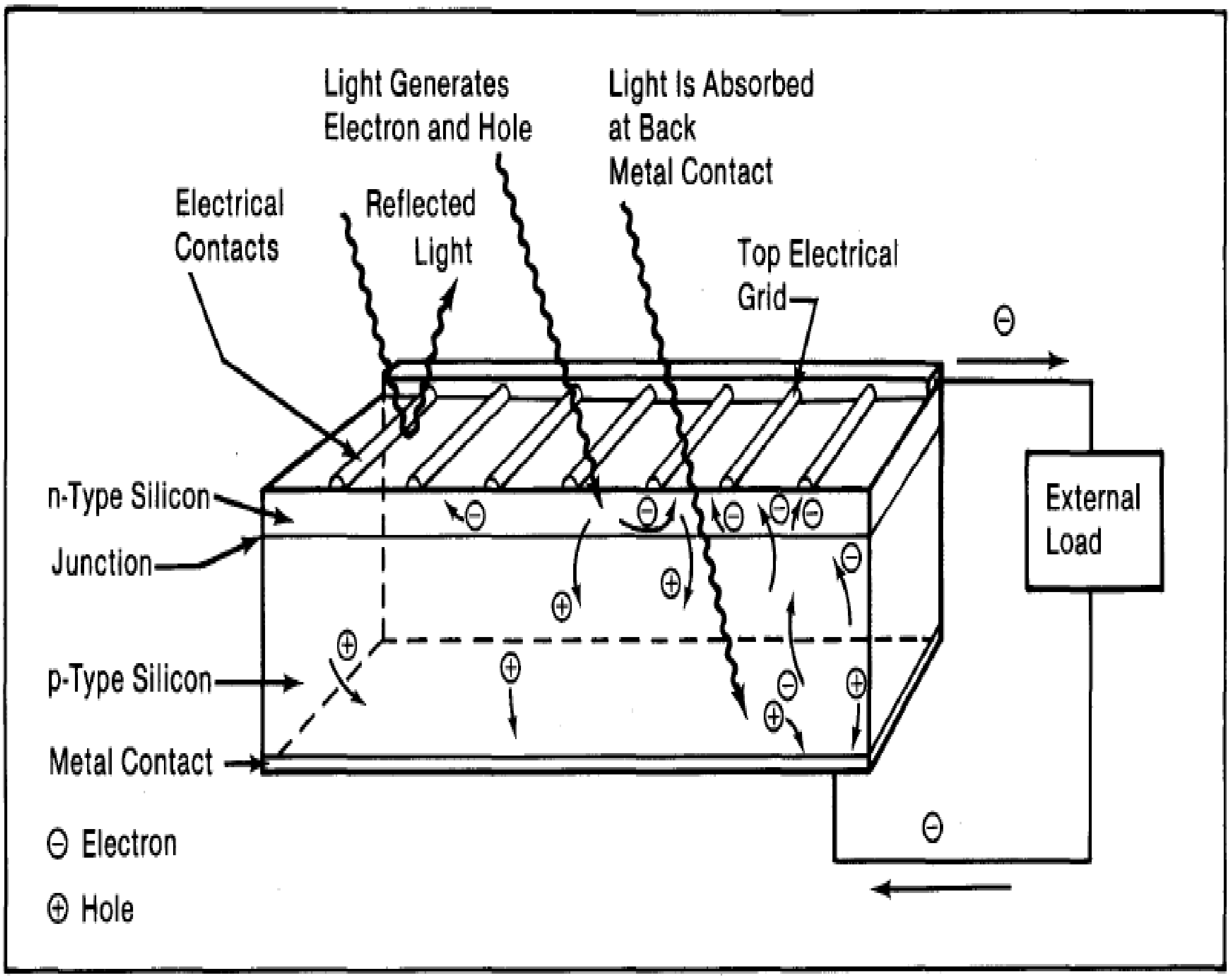


Figure 1.3:- Creation of Electron-Hole Pairs by incident electromagnetic irradiation

1.7 Solar Cell

A solar cell (also known as a photovoltaic cell) is an electrical device that converts light energy directly into electricity using the photovoltaic effect. It is a sort of photoelectric cell (one whose electrical properties, such as flow, voltage, or opposition, change when exposed to light) that, when exposed to light, can make and sustain an electric flow without being connected to any external voltage source, but requires an external burden for control.

The term "photovoltaic" comes from the Greek (phos) for "light," as well as "volt," the unit of electro-thought process power, and the volt, which comes from the last name of Alessandro Volta, an Italian scientist and inventor of the battery (electrochemical cell). Since 1849, the term "photograph voltaic" has been used in English. The field of innovation and research associated with the functional use of photovoltaic cells in providing energy from light is known as photovoltaic, however the term is commonly used to imply to the age of power from daylight. When the light source isn't actually daylight, cells might be presented as photovoltaic in any case (lamplight, fake light, and so on.). The phone is sometimes used as a picture identifier (for example, infrared finders), identifying light or other electromagnetic radiation near to the visible range, or calculating light force in such instances.

1.7.1 Photovoltaic (PV) Cell Operation

The operation of a photovoltaic (PV) cell required

* The absorption of light, generating either electron-hole pairs or exactions.
* The separation of charge carriers of opposite types.
* The separate extraction of those carriers to an external circuit.

A solar thermal collector, on the other hand, absorbs sunlight to provide heat for either direct heating or indirect electrical power generation. On the other hand, a "photo electrolytic cell" (photo electro chemical) is a device that divides water straight into hydrogen and oxygen using just sun irradiation (such as the one established by Edmond Becquerel and modern dyesensitized solar cells).

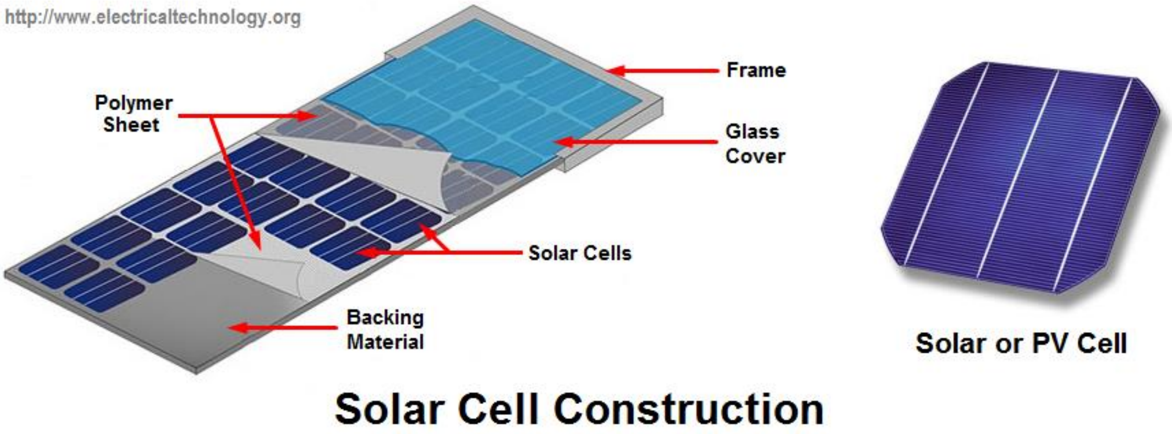


Figure 1.4: - Construction of Photovoltaic Solar Panel

1.8 Modules

PV modules are the basic building blocks of photovoltaic systems, consisting of PV cell circuits sealed in an environmentally protective laminate.

1.9 Array

A PV array is a power-generating system made up of any number of PV Modules and panels.

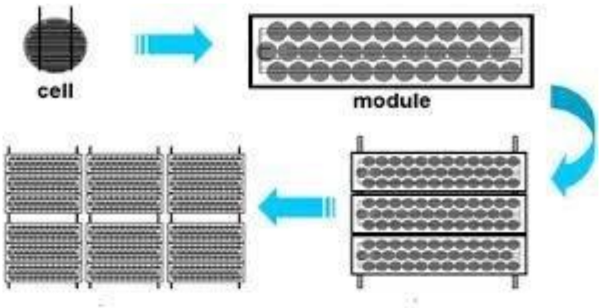


Figure 1.5: - Photovoltaic Array

Chapter 2

MATLAB PV Model for MPP Evaluation

2.1 Introduction

A "network tie" solar system is one that connects to the electrical grid and draws electricity from it. Depending on the Shockley diode state, a specific PV module electrical model is shown. A photograph current, current source, a single diode intersection, and an arrangement obstacle are included in the basic model, which also includes temperature conditions. For a standard 60W solar board, the approach for parameter extraction and model assessment in MATLAB is demonstrated. This model is used to investigate the relationship between temperature and light levels and the number of greatest power points.

2.2 Photovoltaic Modules

A p-n intersection is formed in a fragile wafer or layer of semiconductor in solar cells. The I-V yield normal for a solar cell has an exponential signature, similar to that of a diode, in the dark. When a semiconductor is exposed to light, photons with a higher energy than the semiconductor's band hole energy are absorbed, forming an electron-gap pair. These carriers are separated by the p-n intersection's inward electric fields and form a flow in relation to the occurrence radiation. This current flows in the outside circuit while the cell is short-circuited; when the cell is open-circuited, this current is shunted inside by the natural p-n intersection diode. Along these lines, the diode's characteristics determine the cell's open-circuit voltage properties.

2.3 PV Module is included in the Standard Test Conditions (STC).

Standard Test Conditions is the corporate standard by which all PV modules are evaluated and compared (STC).

• Irradiance (daylight force or power) falling on a flat surface, measured in Watts per square meter. The benchmark for estimate is 1 kW per square meter (1,000 Watts/m2).

• Air Mass refers to the "thickness" and clarity of the air that the sunlight passes through on its way to the modules (sun point influences this worth). The industry norm is 1.5.

• Cell temperature, which varies depending on ambient air temperature.
STC defines cell testing temperature as 25 degrees C.

Each solar display board has a total of 36, 72, or even 96 conventional solar cells. In the past, cell sizes have averaged around 5" square (125mm) in size. Thick-film silicon solar cells are the most commonly used kind, with efficiency ratings of up to 20% for polycrystalline cells and up to 25% for monocrystalline cells. In real life, cells are wired together in order to generate enough voltage from the 0.6V that a normal cell provides to deliver useable voltage levels. For security, modern evaluation solar modules are made up of single cells that are buried with wire and sandwiched between glass plates and polymer. Tiny film cells can also be seen in large linked exhibitions, and even in self-situating carriers.

2.4 Solar Cell Simulation

As a result, the simplest identical solar cell circuit is a current source in series with a diode. The current source's yield is directly proportional to the amount of light falling on the cell. The cell's I-V characteristics are determined by the diode.

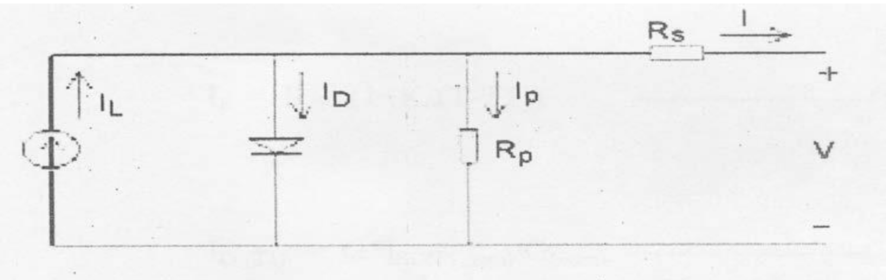


Figure 2.1: - The Circuit Diagram of the PV Model

By gradually adding to the model, you may increase its sophistication, accuracy, and complexity.

• The diode saturation current I0 is temperature dependent.
• The photo current IL is temperature dependent.
• A more precise shape between the highest power point and the open circuit voltage is achieved by using series resistance Rs.
• In parallel with the diode, shunt resistance Rp
• Either making the diode quality factor n a configurable parameter (rather than a constant 1 or 2) or using two parallel diodes (one with A = 1 and the other with A = 2) with separately determined saturation currents.

A model of modest complexity was used for this investigation. The temperature dependence of the photograph current k and the immersion current of the diode IO were incorporated in the model. There was a succession of Rs obstructions, but no shunt opposition. To get the optimum bent coordinate, a single shunt diode was used with the diode quality factor set. This model is a simplified modification of Gow and Keeping an eye on's two-diode model. The wiring diagram for the solar ceiling is shown in the diagram above.

The criteria that represent the cell's I-V characteristics are as follows:

$I= I_L-I_o(e_{q(V+IRs)/nkT}-1)$ -----------(I)

$I_L= I_{L(T1)}(1+K_0(T-T1))$--------------------(11)

$I_{L(Tl)} = G*I_{SC(Tl,nom}/G(nom)$ --------------------(III)

$K_o = (I_{sc(T2)}-I_{sc(Tl)}))/(T2-T1)$ --------------------(IV)

$I_0= I_{0(T1)} *(T/T1)_{3/n} * e_{-qVg/nk*(1/T-l/Tl)}$ ------------(V)

$I_{0(T1)} = I_{sc(T1)}/(e_{qVoc(T1)/nKT1}-1)$-----------------(VI)

$Rs = -dV/dI_{voc}-1/Xv$-----------------------(VII)

$Xv = I_{0(T1)}*q/nkT1*e_{qVoc(T1)/nkT1}$-------------(VIII)

Where,

I_L = Photo Current

1_0=Diode Saturation Current
R_s =Series Resistance
R_p = Shunt Resistance
n = Diode Quality Factor
K= Boltzmann's Constant
I_{sc} =Short Circuit Current
v_g = Bandgap Voltage
V_{oc} = Open Circuit Voltage
q = Charge of Electron
T = Temperature
G= Irradiation

All of the constants in the above equations may be found by looking at the PV array's manufacturer's ratings, followed by the array's published or measured I-V curves. The Solar "reusa" 60W array will be used as an example to show and test the model. The photocurrent IL (A) is proportional to the amount of irradiance G. (Wm-2). When the cell is short-circuited, the diode receives very little current. As a result, the proportionality constant in equation (III) is adjusted to produce the rated short circuit current Isc at rated irradiation (typically 1 Sun = 1000Wm2). Isc = 3.8A at 1 Sun at Tl = 25 °C (298K) for the "reusa," hence IL(T1) =3.8 A/sun. The photo-current and temperature connection is linear (eqn, II), as seen by the shift in to 3.92A (3 percent) as T alters photo-current with temperature change (eqn. IV). IL changes from 3.80 at 25°C to 3.80 at 75°C for the "reusa." The Shockley equation describes the connection between the cell's terminal voltage and current when it is not lit. The photo-current flows totally through the diode when the cell is open circuited and lit. The photo-generated current IL shifts the I-V urve further from the origin (eqn I).

The Shockley equation describes the connection between the cell's terminal voltage and current when it is not lit. The photo-current flows totally through the diode when the cell is open circuited and lit. The photo-generated current IL shifts the I-V curve farther from the origin (eqn I). The open circuit voltage and short circuit current at 25°C are used to compute the value of the saturation current 10. (eqn VI). The unknown "ideality factor" n has to be estimated. Green claims that it takes a value between 1 and 2, with large currents around one and low currents toward two. A number of 1.3 is indicated as usual in normal operation and can be used as a starting point until a more precise number may be determined later through curve fitting. The "reusa" model illustrates the effect of changing the ideality factor; larger values soften the curve's knee. The link between 10 and temperature is complicated, but there are no factors to consider (eqn V). As seen in figure (eqn VII), the panel's series resistance has a significant influence on the slope of the I-V curve at V = Voc. Equations (eqn VII) and (eqn VIII) are obtained by differentiating (eqn I), evaluating at V = Voc, and rearranging in terms of Its. The total panel series resistance Rs= 8m was computed using the values received from the "reusa" manufacturers' curves.

2.5 PV Module Model in MATLAB

For modeling, the Solar "reusa," a common 60W PV module, was utilized. The module is made up of 36 polycrystalline cells that are coupled in a series. The essential specifications are shown in the table below. MATLAB was used to test the model. Using the equations stated in the previous part and the aforementioned data points stored in the script, the model parameters are assessed during execution. These factors, as well as the variables voltage, irradiation, and temperature, are then used to calculate the current I. The output variable (current) is a vector if one of the input variables is a vector. Because the model includes a series resistance, the solution for current is a recurrent equation (refer to eqn. I). Initially, a simple iterative approach only converged for positive currents. The Newton Raphson approach, which is used for both positive and negative currents, converges morefaster.

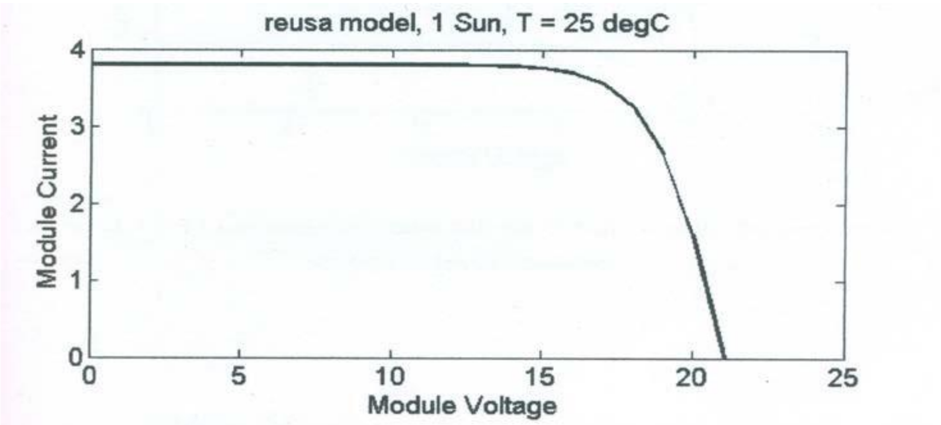


Figure 3.2 Solar Cell V-I Characteristics Curve with Constant Temperature and Irradiation

At Temperature	T	25	C
Open Circuit Voltage	V_{OC}	21.0	V
Short Circuit Current	I_{SC}	3.74	A
Voltage, Max Power	V_m	17	V

Current, Max Power	I_m	3.52	A
Maximum Power	P_m	59.84	W

Table 2.1:- The most important features of the Solar "reusa" PV panel.

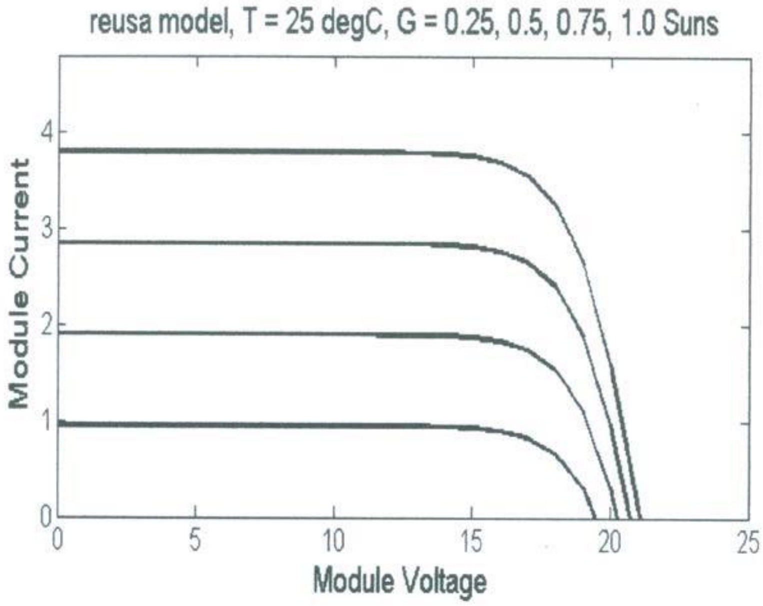
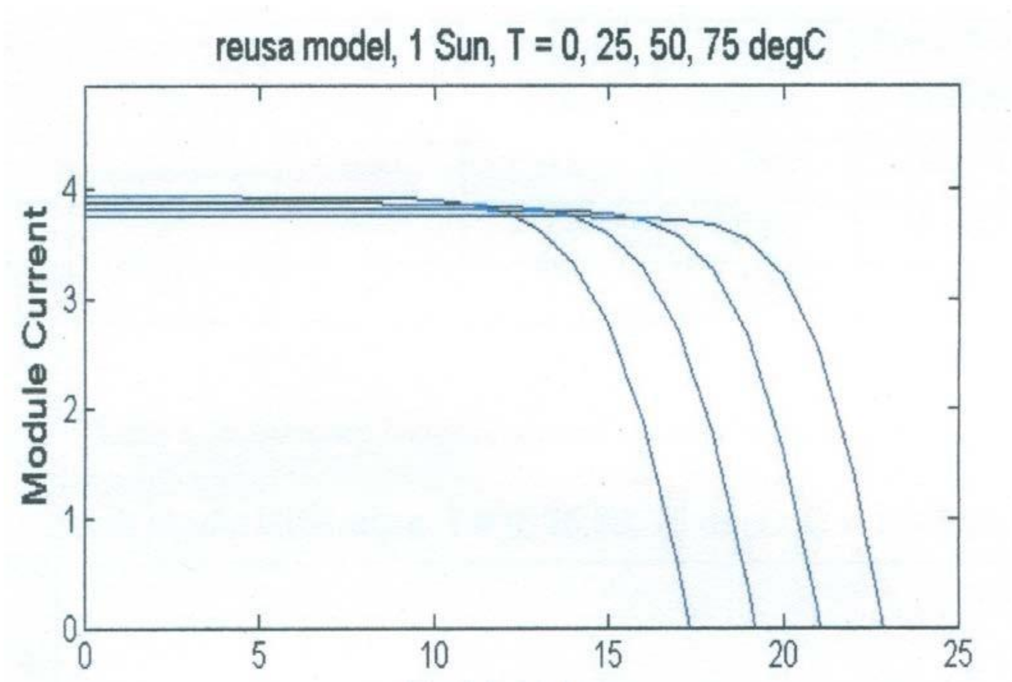
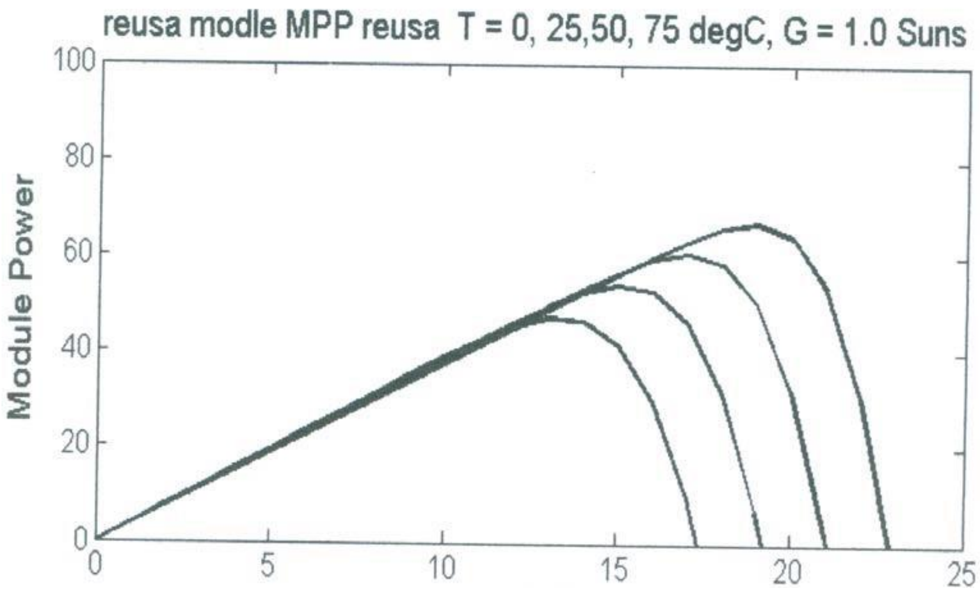


Figure 3.3 Solar Cell V-I Characteristics Curve with Constant Temperature and Various Irradiation Values.



Module Voltage

Figure 2.4: - Solar Cell V-I Characteristics Curve at Various Temperatures and Constant Irradiation



Module Voltage

Figure 2.5: - Characteristics of the V-P Solar Cell Curve with Constant Temperature and Various Irradiation Values

20

Serial No.	Temperature	Sun	Voltage	Current	Power Max.
01	25	0.25	16	0.8999	14.3978
02	25	0.50	17	1.7869	29.6971
03	25	0.75	17	2.6569	45.1681
04	25	1	17	3.5200	59.9000

Table 2.2:- Variable Sun Values and Constant Temperature

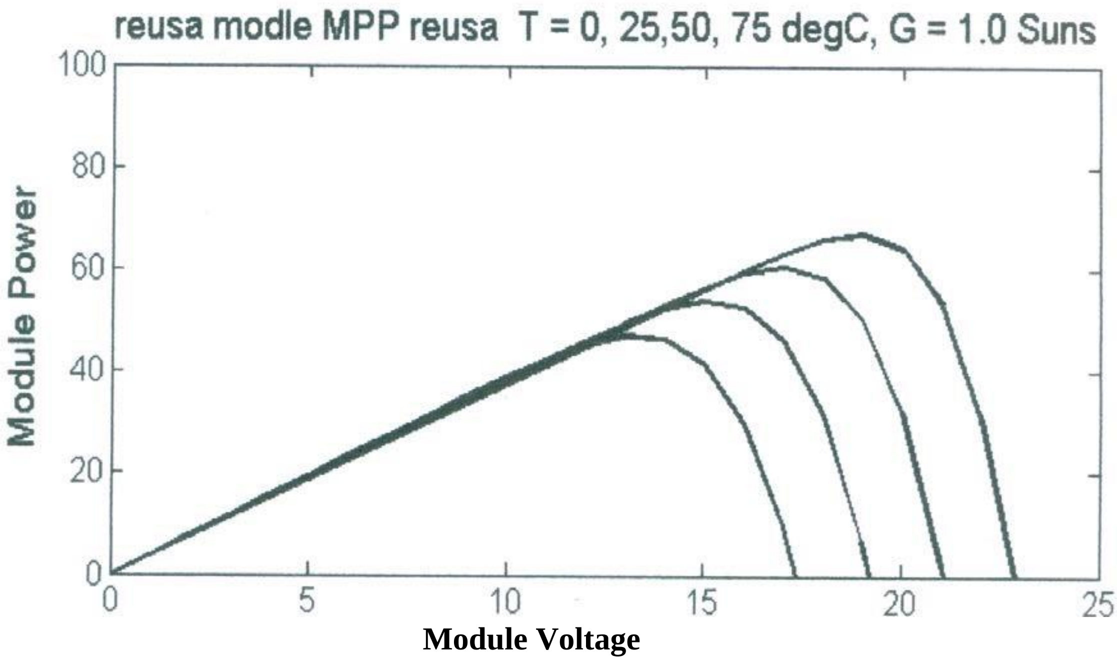
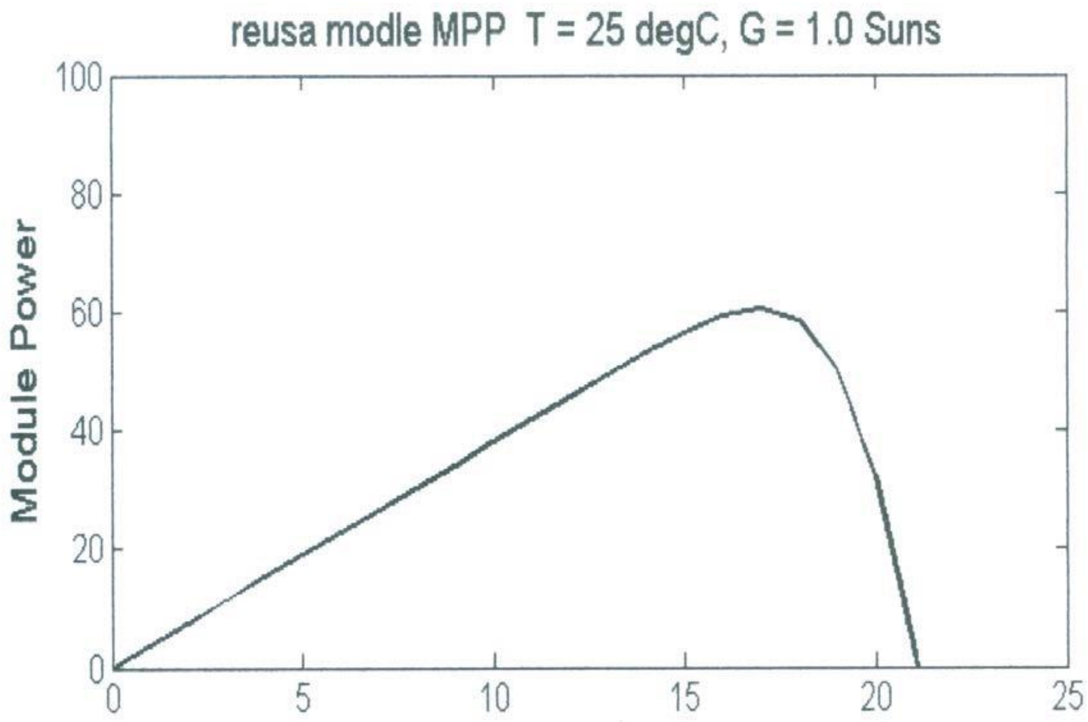


Figure 2.6: - Characteristics of the V-P Solar Cell Curve at Various Temperatures and Constant Irradiation

Serial No.	Temperature	Sun	Voltage	Current	Power Max.
01	0	1	19	3.5210	66.8993
02	25	1	17	3.5200	59.9000
03	50	1	15	3.5909	53.8631
04	75	1	13	3.6221	47.0875

Table 2.3: - Variable Temperatures and a Constant Sun



Module Voltage

Figure 2.7: - Solar Cell V-P Characteristics Curve with Constant Irradiation and Temperature

Serial No.	Temperature	Sun	Voltage	Current	Power Max.
01	25	1	17	3.5200	59.9000

Table 2.4:- Temperature and Sun Constant

Chapter 3

MATLAB Simulink is used to assess MPPT converter topologies

3.1 Introduction

The topologies of buck and boost maximum power point tracker (MPPT) are compared, as well as a direct connection to a constant voltage load.
Because of its high efficiency and output voltage, the boost converter is the most ideal and widely used for solar systems.

3.2 Tracker for Maximum Power Points (MPPT)

The employment of an MPPT, which comprises of a power section and a control section, is required to optimize the generator's electrical working conditions. The power part is usually a DC/DC converter, whereas the control part can be built using logic or analog circuits. Several methods for driving AC or DC loads at the MPPT have been proposed. These methods work by regulating the output voltage or current of the PV module based on a reference voltage or current signal that is either constant or generated from the PV generator parameters. The direct use of the DC/DC converter duty cycle as a control parameter and forcing the derivative dP/d to zero, where P is the PV output power and is the duty cycle, distinguishes these approaches, requiring just one control loop as shown in figure.

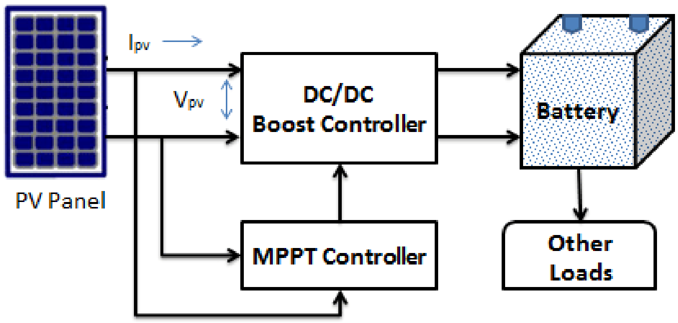


Figure 3.1: - MPPT Control Block Diagram

The duty cycle is adjusted based on the results of the comparison, and the procedure is repeated until the maximum power point is attained.

3.3 Maximum Power Point Tracking Methodologies

The maximum power is achieved by altering the duty cycle of a dc/dc converter. The difficulty now is how to change the duty cycle and in which direction to get maximum power. Is it better to use manual or automatic tracking?

Automatic tracking is chosen over manual tracking since manual tracking is not practicable. Various algorithms can be used to achieve automated tracking.

- ✓ Perturb and observe.
- ✓ Incremental Conductance
- ✓ Parasitic Capacitance
- ✓ Voltage Based Maximum Power Tracking
- ✓ Current Based Maximum Power Tracking

3.3.1 Method of Perturbation and Observation

In this algorithm, the system is subjected to a little disturbance. The module's power changes as a result of this disturbance. If the perturbation increases the power, the perturbation continues in that direction. After the peak power is attained, the power lowers at the following moment, and the perturbation reverses.

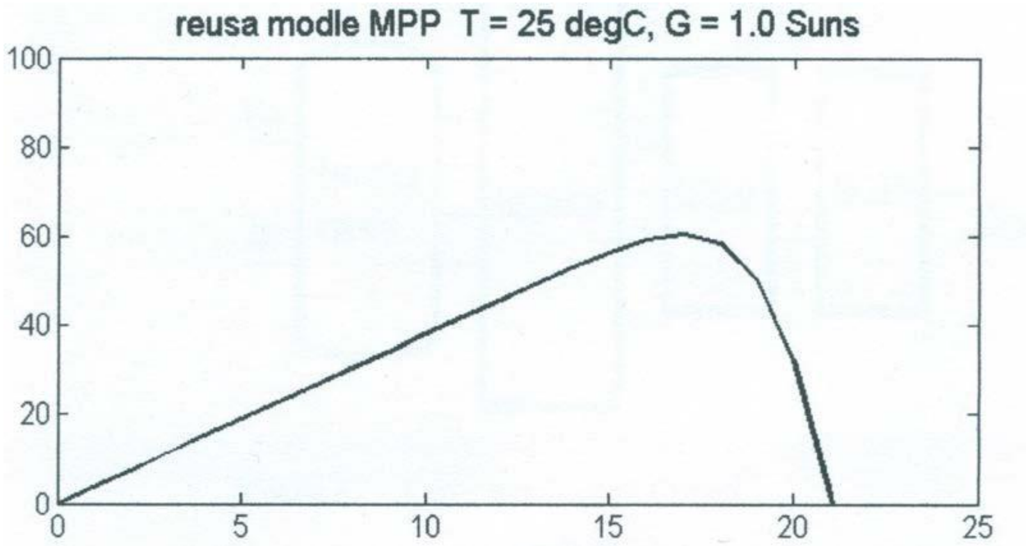


Figure 3.2: - Method of perturbation and observation

When the algorithm reaches a steady state, it oscillates about the maximum point. The perturbation size is maintained very minimal to keep the power variation modest. The technique is designed in such a way that it establishes a reference voltage for the module that corresponds to the module's maximum voltage. The operational point of the module is then moved to that voltage level by a microcontroller. It has been noticed that this disruption causes some power loss, as well as the failure to follow the power under rapidly changing air circumstances. Nonetheless, this approach is quite common and straightforward.

3.4 Control circuit for the converter

The PIC Microcontroller is used in the system control circuit depicted in figure -14. The control circuit is made up of the following components:

√ Sensors and signal conditioners are linked to the microcontroller's A/D converter through interface circuits.

√ Microcontroller PIC 16F877

√ Line driver with quadruple differentials

√ The power GTOs' IC driver.

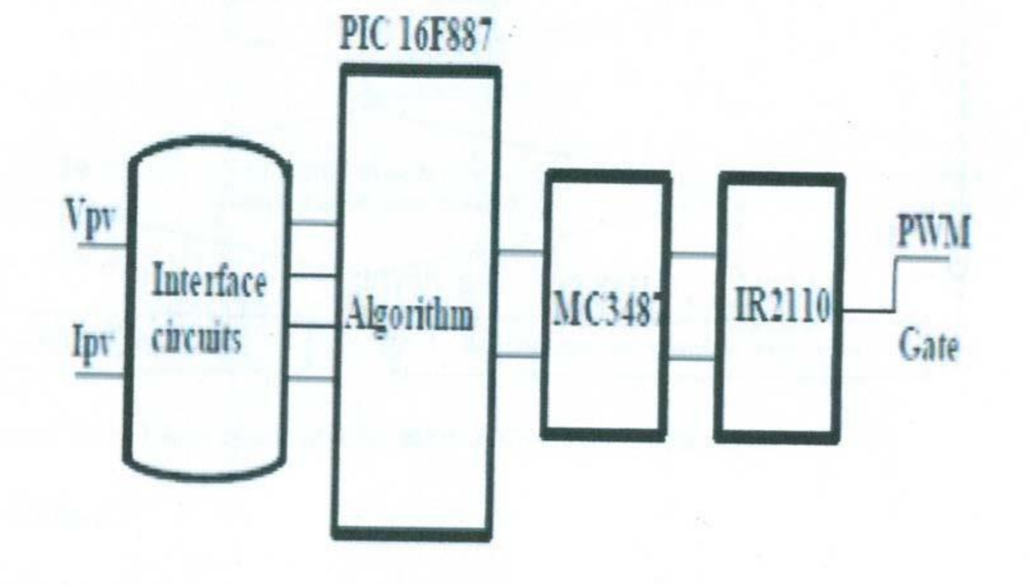


Figure 3.3: - Converter Control Circuit.

3.5 Control Techniques & Software Designs for MPPT

The voltage criticism control framework is used to achieve a constant yield voltage. The yield voltage will be computed and compared to a reference voltage, and the differential worth will be used to generate a PWM signal in this control framework. Any changes in the yield voltage will cause the obligation cycle to proceed in the PWM signal. A microcontroller is used to generate a large number of PWM signals. Because it has a progressive estimate simple to advanced converter, comparator, and PWM generator, the PIC16F877 microcontroller was chosen. When the PIC16F877 is controlled by a 20 MHz clock cycle, it may generate a PWM signal with a repetition of 20 kHz. The control approach for the voltage criticism control stream diagram shown in Figure has been written and loaded into the PIC 16F877 microcontroller.

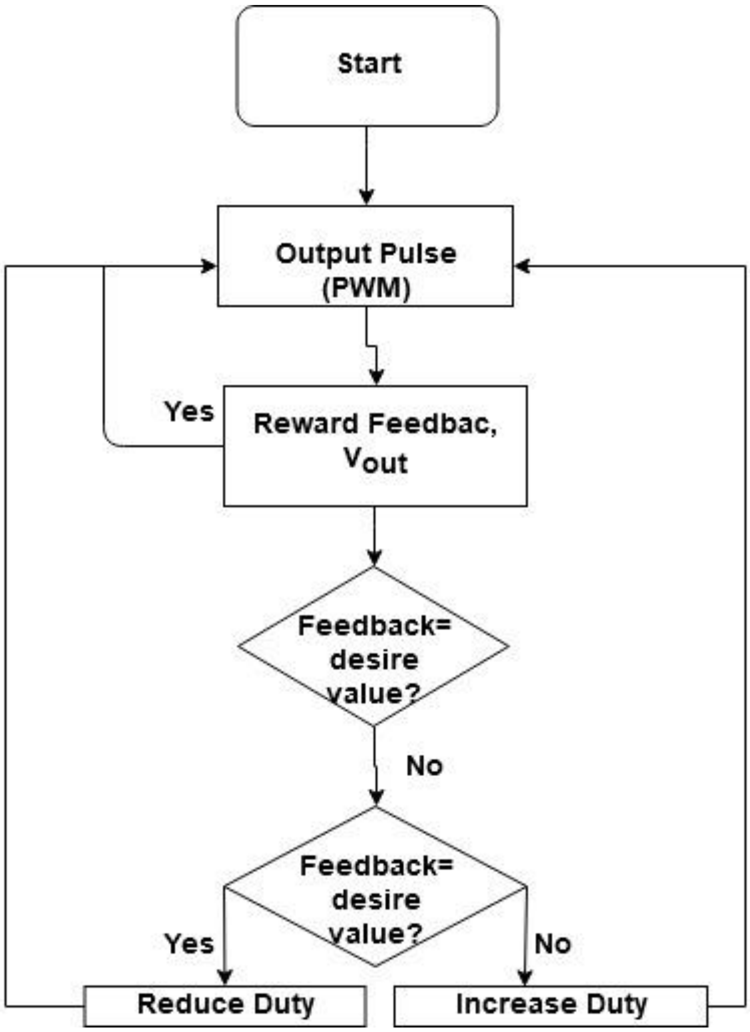


Figure 3.4: - The MPPT Control Technique is depicted as a flowchart below.

3.6 Converting Boost

The boost converter is a power transmission medium that allows energy to be absorbed and injected from a solar panel to a grid-tied inverter. In a boost converter, the energy absorption and injection operation is carried out by a combination of four components: inductor, electronic switch, diode, and output capacitor. Figure 3.5 depicts the attachment of a boost converter. A switching cycle will be formed through the process of energy absorption and injection. In other words, the switching on and off time length controls the average output voltage. PWM switching is the process of altering the on and off time of a switch at a consistent switching frequency. The ratio of the on duration to the switching time period is described as the switching duty cycle, k. The energy absorption and injection will run the converter in two different modes, known as continuous conduction mode (CCM) and discontinuous conduction mode (DCM), depending on the relative length of the switching period (DCM).

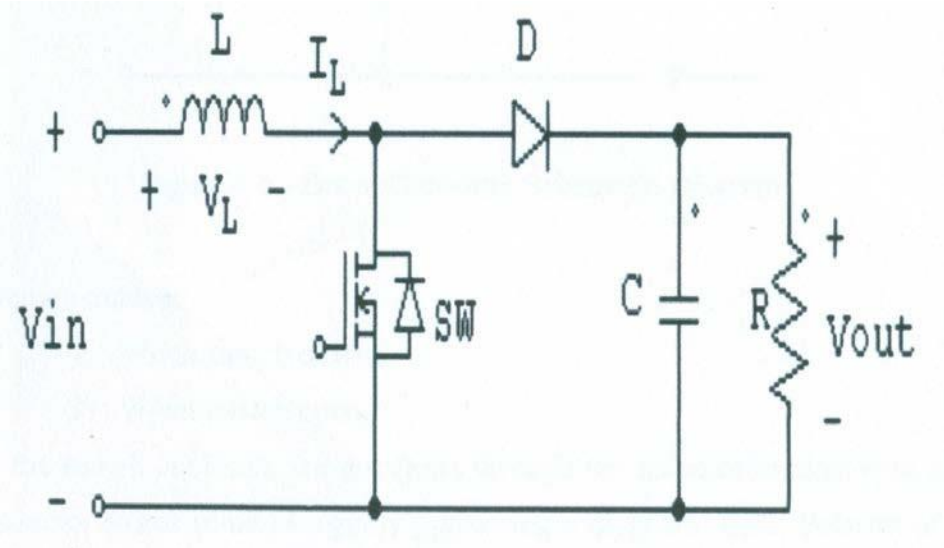


Figure 3.5: - Schematic of Boost Converter

3.7 Analyze the Boost Converter Mode of Continuous Conduction

The ability of an inductor to withstand current fluctuations by forming and destroying a magnetic field is the essential mechanism that powers the boost converter. The output voltage is always greater than the input voltage in a boost converter. Figure 1 depicts the schematic for a boost power stage (3.6)

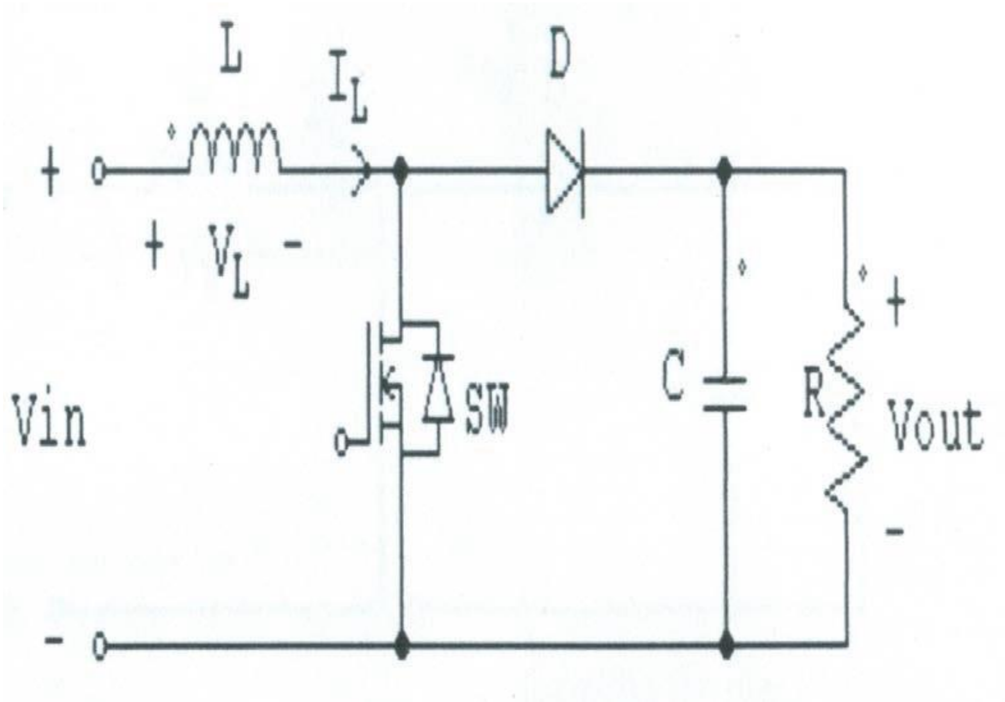


Figure 3.6:- Schematic Diagram of a Boost Converter

There are two modes
available:

1. When switch closed.
2. When switch open.

1. When the switch is closed, current flows in a clockwise direction via the inductor, storing energy in the form of a magnetic field. The inductor's left side has a positive polarity. As seen in the diagram

2. Because the impedance is larger when the switch is opened, current will be lowered. To keep the current flowing towards the load, the magnetic field that was previously formed will be eliminated. As a result, the polarity will be flipped (means left side of inductor will be negative now). As a result, two sources will be connected in series, causing the capacitor to be charged at a greater voltage through the diode D. Figure 3.6 depicts the situation (a)

When Mode 1

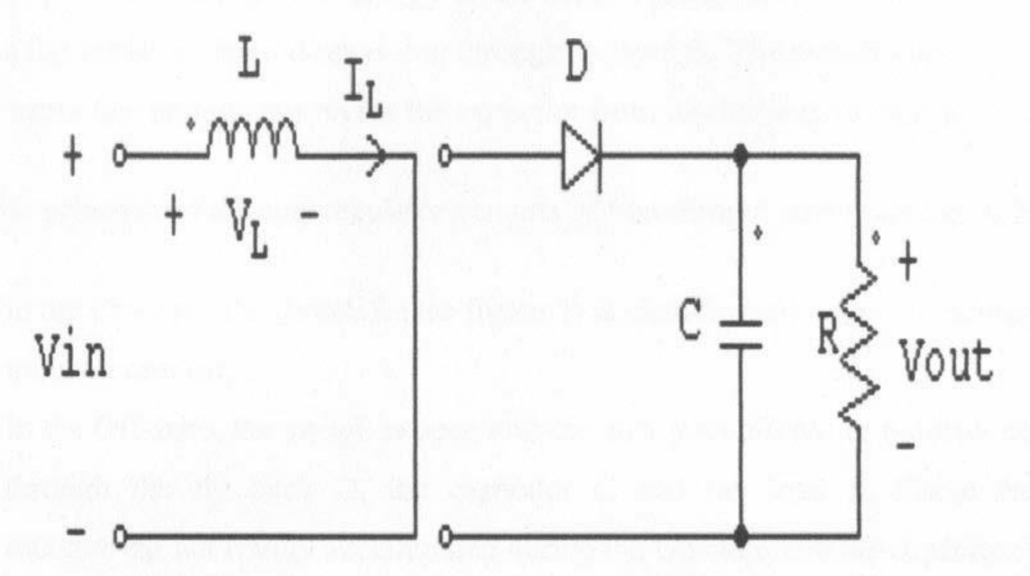


Figure 3.6(a): - Boost Converter Circuit Diagram in Mode 1

When Mode 2

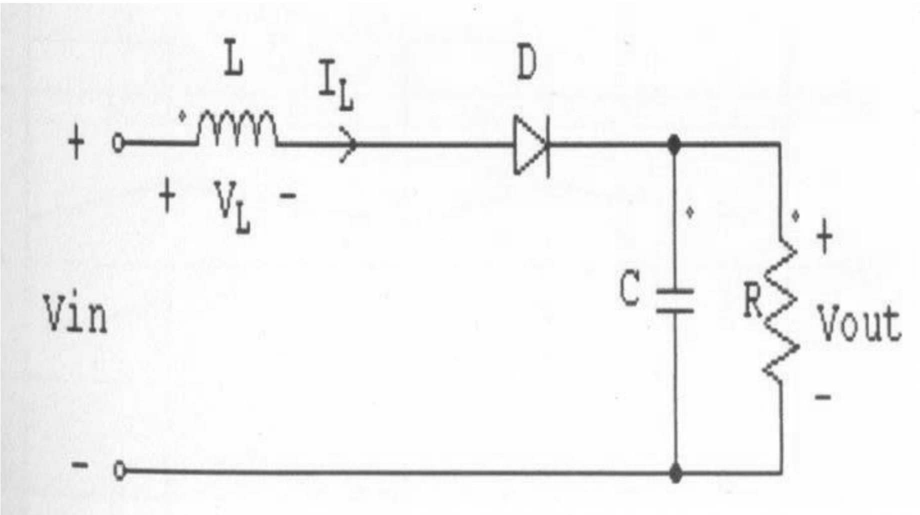


Figure 3.6(b):- Boost Converter Circuit Diagram in Mode 2

If the switch is cycled quickly enough, the inductor will not entirely release in the middle of charging phases, and the heap will always see a voltage higher than that of the information source alone when the switch is opened. In addition, the capacitor in parallel with the heap is charged to this combined voltage while the switch is open. When the switch is turned off and the right-hand side is shorted out from the left-hand sidethe capacitor is positioned along these lines, ready to provide the heap with voltage and energy. The blocking diode prevents the capacitor from releasing through the switch during this period. Obviously, the switch should be opened quickly enough to prevent the capacitor from leaking unduly.

A Boost regulator's main concept consists of two separate states (see picture b):

The switch 8 (see figure 1) is closed in the On state, causing the inductor current to rise.

1. The switch is open in the Off state, and the sole channel for inductor current is through the flyback D, capacitor C, and load R. This results in the energy collected during the On-state being transferred to the capacitor.

2. The input current is the same as the inductor current, as seen in figure 3.7; it is not discontinuous like in a buck converter, thus the input filter requirements are less stringent.

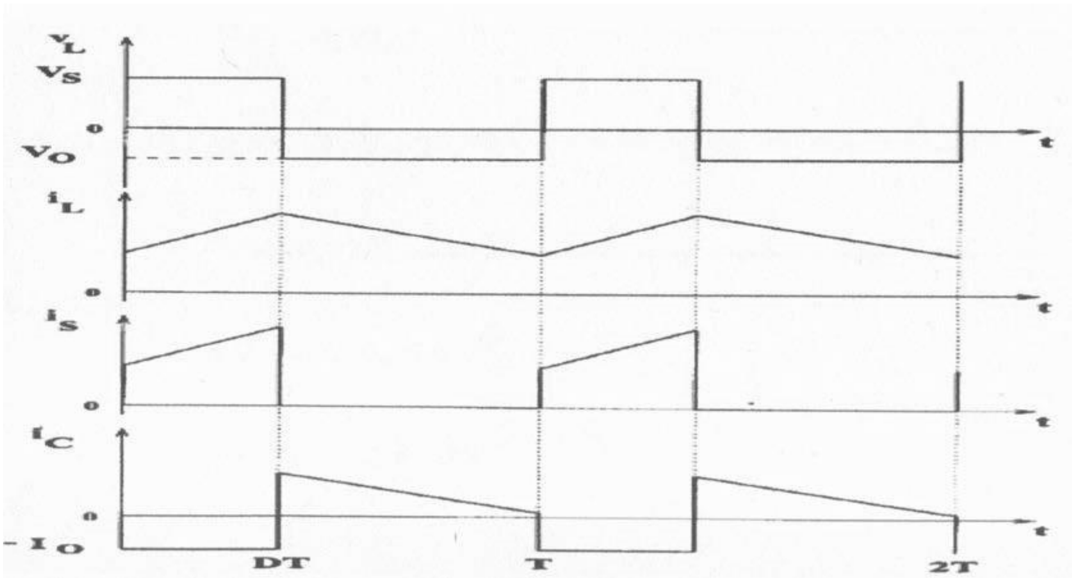


Figure 3.7: - Waveform of the Boost Converter's Output

3.8 MATLAB Simulink Boost Converter Circuit Simulation

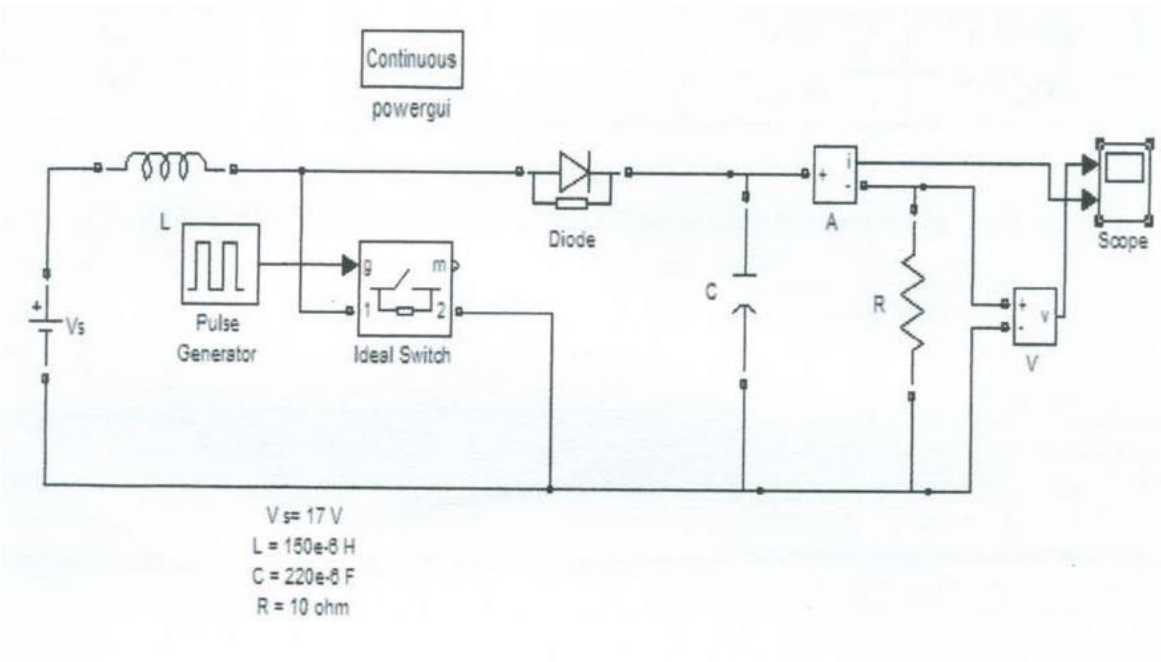


Figure 3.8: MATLAB Simulink Simulation of a Boost Converter Circuit

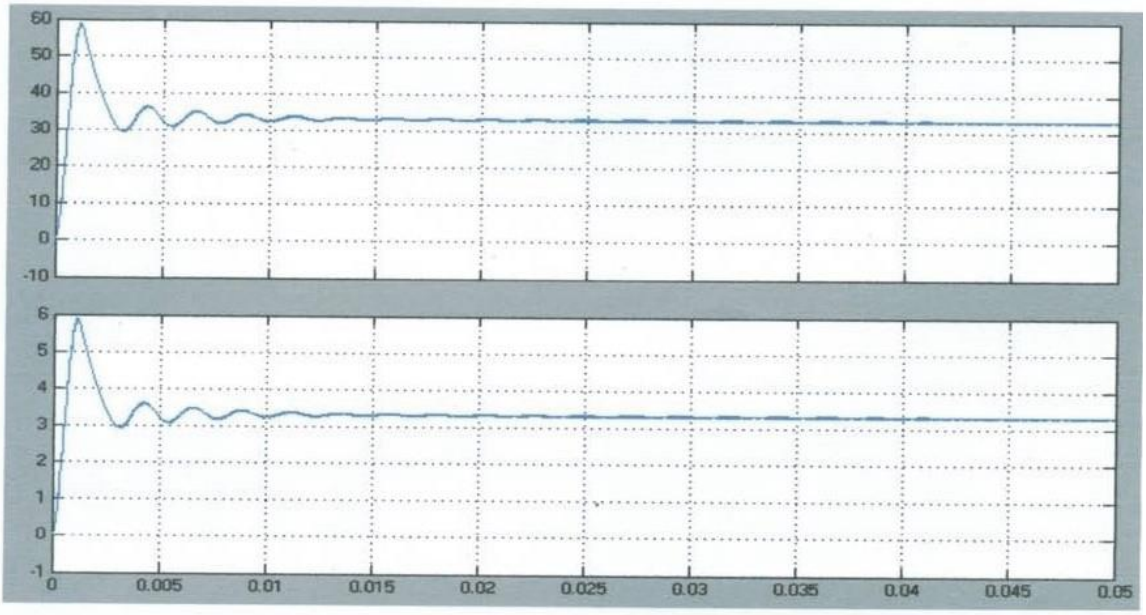


Figure 3.9: Voltage and Current Labels for Boost Converters

Serial No.	Vs	Vout	Iout	Pout
01	16	32.20	3.02	97.2440
02	17	33.00	3.30	108.9000
03	18	37.50	3.56	133.5000

Table 3.1:- With Various Solar Voltages, Boost Converter Output Power

Chapter 4

Design of a Grid-Tied Inverter

4.1 Introduction

An inverter is a DC to AC converter. Alternating current is the most common way to transmit and use electrical electricity. Direct current is produced by various types of electrical production and storage equipment, such as PV modules and batteries. An inverter is a power electronic device that transforms DC to AC, allowing the DC power generated by these generators to be utilised with standard AC appliances and/or combined with the current electrical system. Photovoltaic production is often connected to the grid using a PWM inverter, which generates a switch signal by comparing the intended sinusoidal output (i.e. the modulated signal or control signal) to a high frequency triangle wave (carrier signal). The GTOs or thyristors of the inverter are turned on by turn at the places of intersection of the modulating signal and the carrier signal.

4.2 Phase-Locked Loop

A phase-locked loop, often known as a phase lock loop (PLL), is a control framework that generates a yield signal with the same phase as an info signal. While there are a few variants, it's not difficult to see it as an electrical circuit consisting of a variable recurrence oscillator and a phase detector at first glance. The oscillator generates a symbol every now and then. The phase detector compares that sign's phase to that of the information intermittent sign and adjusts the oscillator to maintain the phases in sync. Because the yield is 'input' close to the information, forming a loop, bringing the yield signal back nearer the info signal for correlation is known as a critique loop.

Keeping the information and yield phases in sync also implies keeping the information and yield frequencies the same. A phase-locked loop might thus follow an information recurrence or create a recurrence that is a multiple of the information recurrence, notwithstanding the synchronizing sign. Individually, these features are used for PC clock synchronization, demodulation, and recurrence mix.

They can be used to demodulate a signal, recover a signal from a noisy communication channel, establish a constant recurrence at the products of an information (recurrence union), or circulate precisely designed clock beats in sophisticated logic circuits such as microprocessors.

Because a single coordinated circuit may provide a complete phase-locked loop building block, the method is widely used in modern electronic devices, with yield frequencies ranging from a few hundredths of a hertz to several gigahertzes.

4.3 PWM Inverter with Three Phases

A arrangement of six transistors and six diodes can provide a three-phase output. The transistors may be controlled by two sorts of signals: 180° conduction and 120° conduction. The recommended approach is 180° conduction, which makes better use of the switches. For grid-tied solar systems, we suggest a 180° conduction inverter. Explain the function of a grid tie inverter in the following paragraphs. The switching rate of the switches determines the frequency of the output voltage waveform, which may be changed across a wide range. Each switch conducts for 180 degrees in this mode of operation. As a result, three switches are always on at any one moment. When S1 is turned on, the terminal an is linked to the input DC source's positive terminal. When S4 is turned on, terminal an is linked to the input DC source's negative terminal. In a cycle, there are six distinct modes of operation, each of which lasts 60 seconds and is explained as follows: As a consequence, terminals a and c are linked to the input DC source's positive terminals, while terminal b is linked to the DC source's negative terminal.

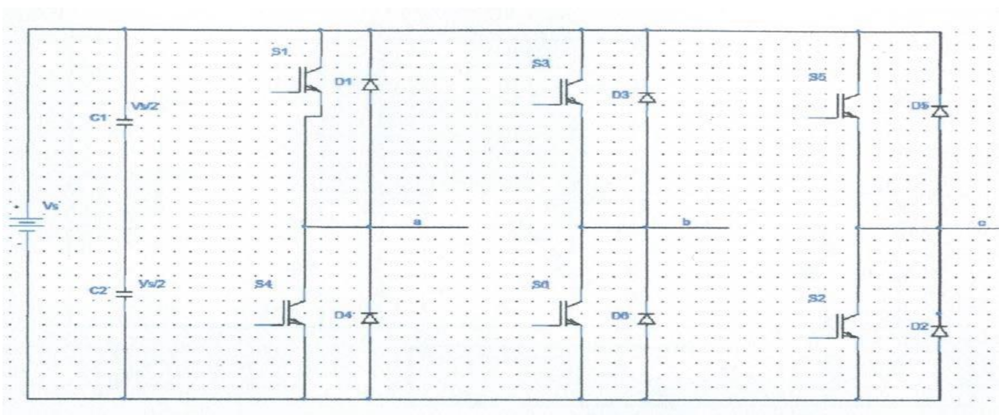


Figure 4.1: - Three-Phase DC-AC Inverter Configuration

4.4 180-Degree Conduction with a Resistive Load Connected to a Star

Figure 4.2 depicts the architecture of a three-phase inverter with a star-connected resistive load. The following rules are followed:

√ A positive current is expected to leave a node point a, b, or c and enter the neutral point n.

√ Ra=Rb, =Rc=R, all three resistances are equivalent.

Each switch conducts for 180 degrees in this mode of operation. As a result, three switches are always on at any one moment. When S1 is turned on, the terminal an is linked to the input DC source's positive terminal. When S4 is turned on, terminal an is linked to the input DC source's negative terminal. In a cycle, there are six potential modes of operation, each of which has a 60° duration and is explained as follows:

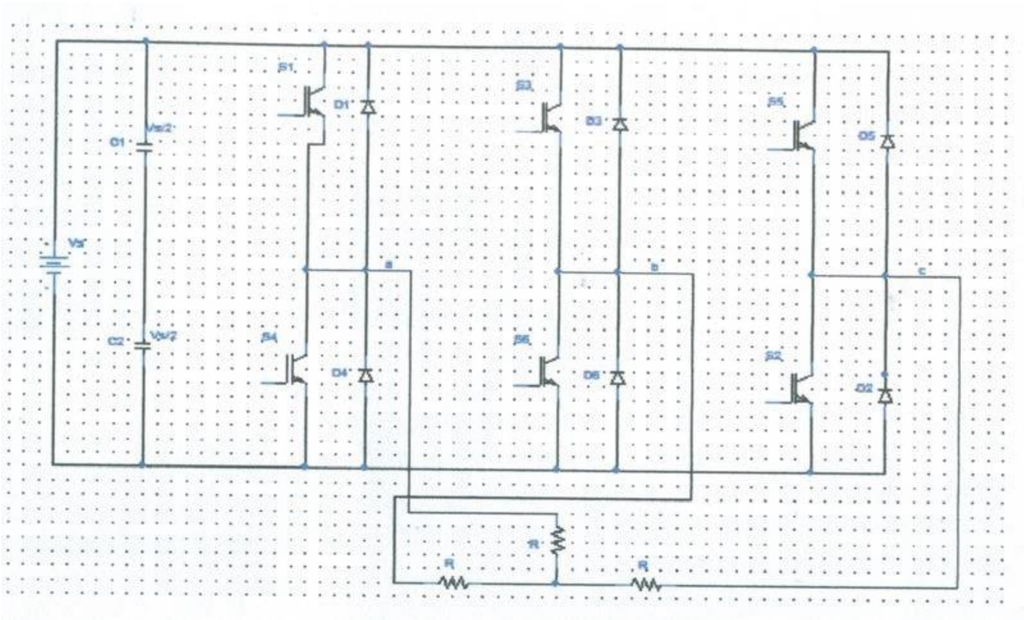


Figure 4.2: Star Connect Resistive Load Three-Phase DC-AC Inverter

Mode 1:
The switches S5, S6, and S1 are switched on for time intervals in this mode.

O≤***wt***≤π/***3.*** As a

As a result, terminals a and c are linked to the input DC source's positive terminal, while terminal b is linked to the DC source's negative terminal. Figure 5.2a depicts the current flow via Ra, R, and R, whereas Figure 5.2b depicts the corresponding circuit. Figure 4.2b shows the equivalent resistance of the circuit.

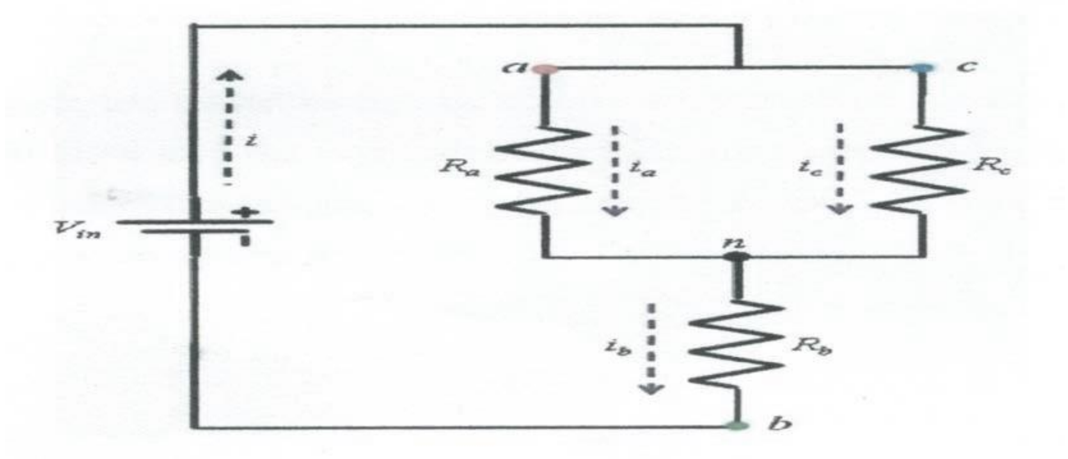
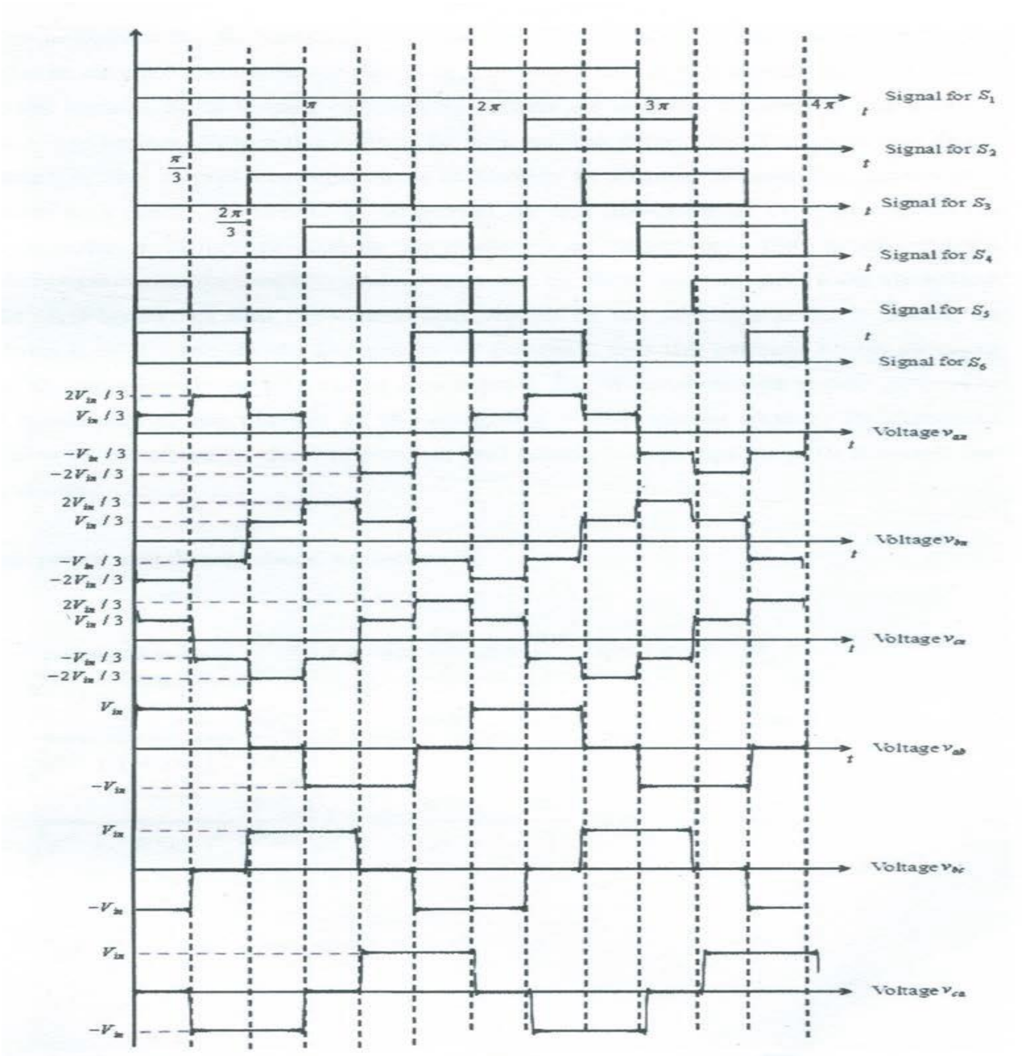


Figure 4.2 (a):- Mode 1 Equivalent Circuit



The switches S5, S4, and S1 are all switched on in mode 1. The mode before model 1 was mode 6, and in that mode, the switches S4, S5, and S6 were all turned on. The switch 84 is turned off and 8) is turned on during the shift from mode 6 to mode I, and the current I switches direction (outgoing phase). The current flowed from point n to point a when the switch 84 was turned on; the circuit arrangement is represented in Figure 7a, and the corresponding circuit is illustrated in Figure 7b. When 8) is turned on, the current should flow in the direction of point a to point n. However, because of the inductance, the current cannot change direction instantly and continues to flow in the same direction via diode D) (Figure 7c), and the equivalent circuit of the design is illustrated in Figure 7d. As seen in Figures 3a and 3b, when ia= 0, the diode D1 stops conducting and current begins to flow through S1. When one mode ends and the next begins, the current in the outgoing phase is unable to change direction due to the inductance present, and therefore completes its trip via the freewheeling diode.

The phase currents are calculated in the following way:

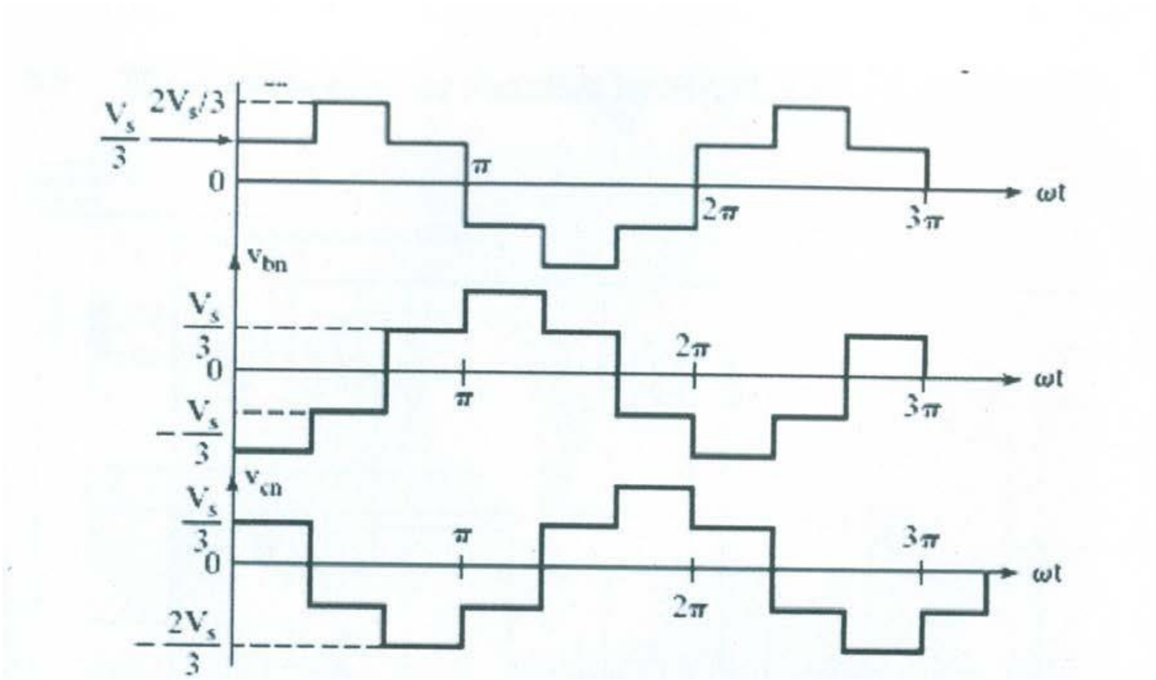
$$i_a = \sum_{n=1,3,5,\ldots}^{\infty} \frac{1}{\sqrt{R^2 + (n\omega L)^2}} \frac{4V_{in}}{3n\pi}\left[1+\sin\frac{n\pi}{2}\sin\frac{n\pi}{6}\right]\sin(n\omega t-\theta_n)$$

$$i_b = \sum_{n=1,3,5,\ldots}^{\infty} \frac{1}{\sqrt{R^2 + (n\omega L)^2}} \frac{4V_{in}}{3n\pi}\left[1+\sin\frac{n\pi}{2}\sin\frac{n\pi}{6}\right]\sin\left(n\omega t-\frac{2n\pi}{3}-\theta_n\right)$$

$$i_c = \sum_{n=1,3,5,\ldots}^{\infty} \frac{1}{\sqrt{R^2 + (n\omega L)^2}} \frac{4V_{in}}{3n\pi}\left[1+\sin\frac{n\pi}{2}\sin\frac{n\pi}{6}\right]\sin\left(n\omega t-\frac{4n\pi}{3}-\theta_n\right)$$

where

$$\theta_n = \tan^{-1}\left(\frac{n\omega L}{R}\right)$$



4.5 Simulink Three-Phase Inverter in MATLAB

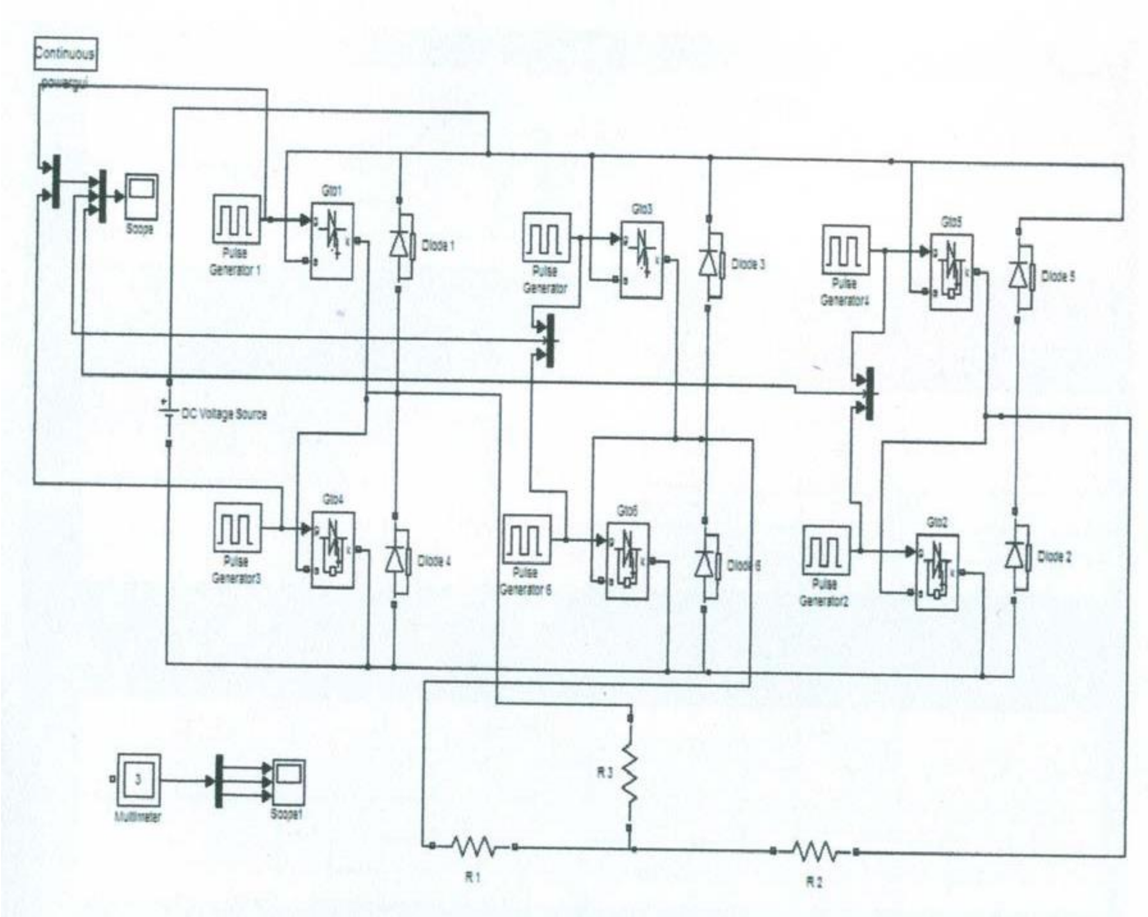


Figure 4.5: - Simulink Three-Phase Inverter in MATLAB

4.6 MATLAB Output Waveform of a Three-Phase Inverter

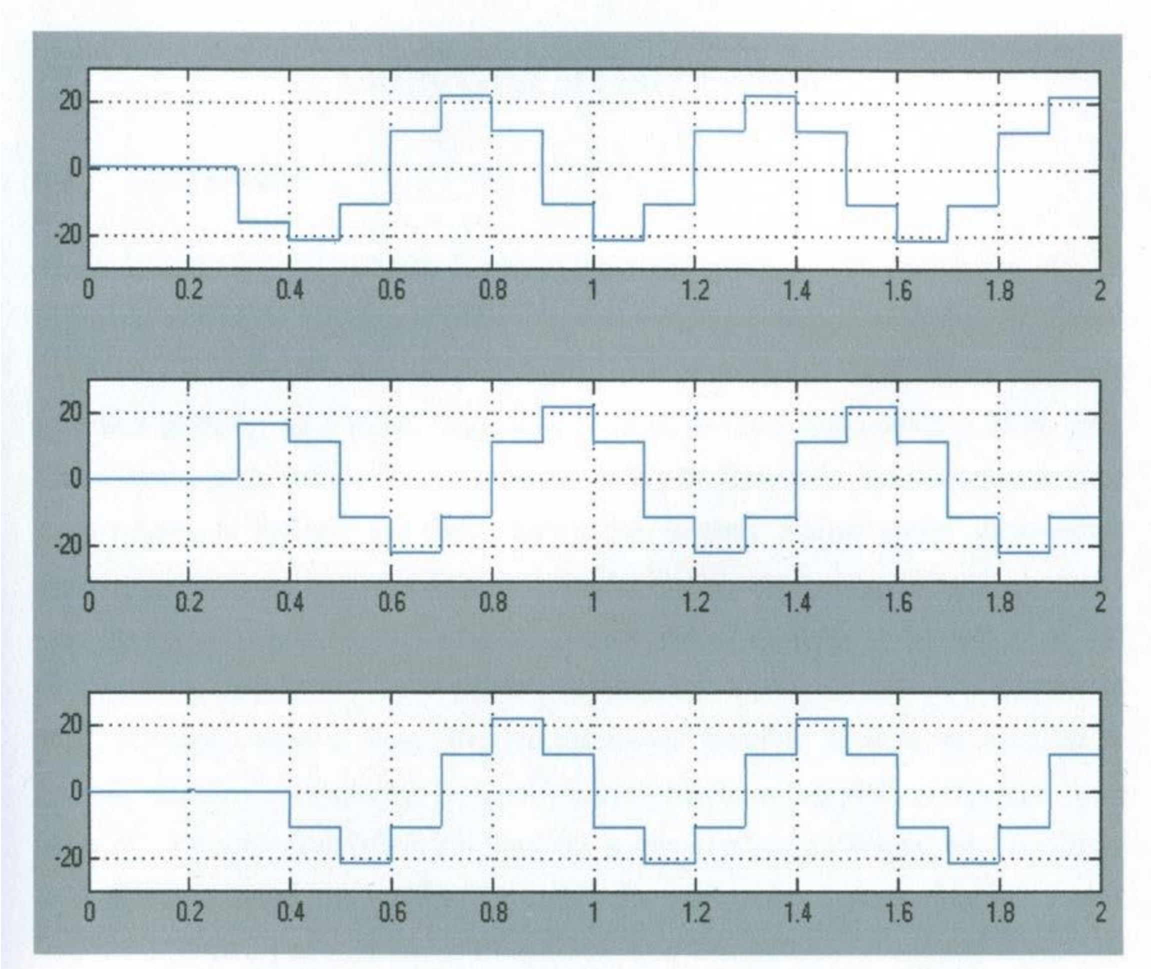


Figure 4.6: MATLAB Output Waveform of a Three-Phase Inverter

Chapter 5

Solar System Utility Grid

5.1 Introduction

Solar energy, often known as photovoltaic (PV), is one of the green energy sources that can help to reduce greenhouse gas emissions. Despite the fact that PV technology is costly, it is receiving tremendous support from different incentive schemes across the world. As a result, large-scale solar farms are becoming grid-connected. Due to their limited power transmission capacity, transmission networks throughout the world are now having difficulty integrating large-scale renewable systems and solar farms. Series compensation and different Flexible AC Transmission System (FACTS) devices are being proposed to expand the available power transfer limits/capacity of existing transmission lines. In a worst-case scenario, additional lines may need to be built at great expenditure. As a result, cost-effective methods for increasing transmission capacity must be investigated. A unique study has been published on the use of a PV solar farm as a Static Compensator, a FACTS device, for performing voltage regulation at night (when it is generally inactive), hence boosting system performance and enhancing grid connection of neighboring solar farms. Voltage control is recognized to help improve transient stability and power transmission limitations, and numerous shunt-connected FACTS devices, including as the Static Var. Compensator and static compensator, are used to improve transmission capacity across the world. This research provides a unique PV solar farm night-time application in which the solar farm inverter is used as a static compensator for voltage regulation to increase power transmission capacity throughout the night. During the daytime as well, while providing real power production, the solar farm is still designed to act as a static compensator and offer voltage regulation utilizing the remaining inverter MVA capacity (left after what is needed for real power generation). This daytime voltage management has also been demonstrated to improve stability and power transfer limitations significantly.

5.2 Synchronizing Theory

Before shutting a circuit breaker between two activated sections of the electrical system, be sure the voltages on both sides of the breaker are equal. A power system disruption can occur if this matching or "synchronizing" procedure is not completed correctly, and equipment (including generators) can be destroyed.
Three separate components of the voltage across the circuit breaker must be closely monitored in order to synchronize correctly. The synchronizing variables are the following three properties of the voltage:

√ The magnitudes of the voltage
√ Voltages have a frequency
√ The Order of the Phases

5.3 Method of Synchronization

Automatic synchronizers are commonly used in modern power plants. It is impossible to overestimate the importance of synchronization. The theory and practice of synchronization should be understood by all system operators. A solar system can be seriously harmed if two power systems are synchronized via an open circuit breaker and the synchronization process is not done correctly.

5.3.1 Two Islands Are Synchronized

The first scenario implies that two islands are about to be linked via an open circuit breaker, as shown in Figure 5.1. Because the two islands have separate electrical systems, their frequencies will differ, thus all three synchronizing variables must be checked to verify they are within acceptable ranges before shutting the open circuit breaker.

To make the appropriate adjustment in frequencies and phase angles, the system operators for the two islands will most likely have to alter generator MW output levels (or alter island load magnitudes) on one or both islands. Voltage control equipment (reactors, capacitors, and so on) can be used to reduce voltage magnitudes to acceptable values as needed.

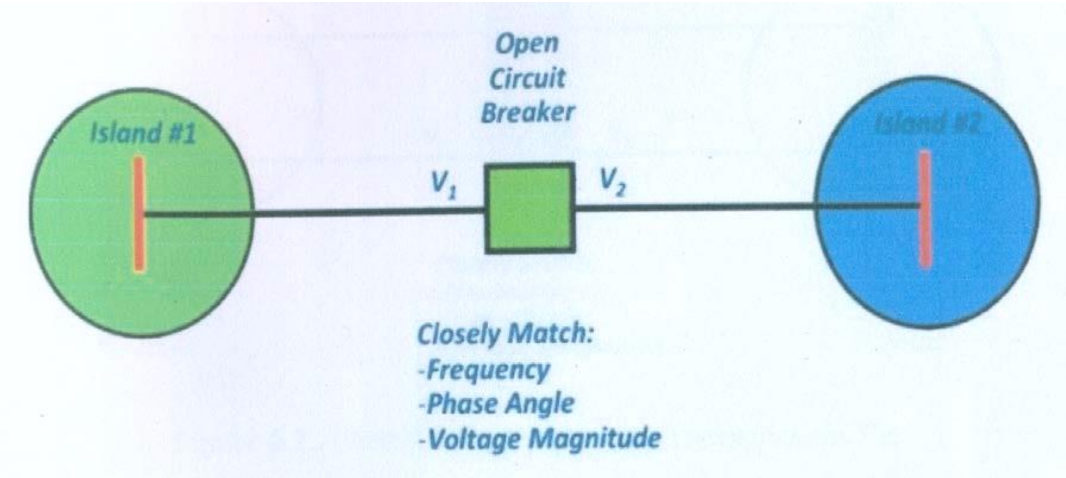


Figure 5.1: - Two Islands Are Synchronized

5.3.2 Creating the Second Tie

The frequency will be the same in both places once the first transmission line linking the two islands is completed. As a result, the frequency, one of the three synchronizing variables, is no longer a consideration. The other two synchronizing variables, as shown in Figure 5.2, must still be checked. Before shutting the second circuit breaker, generation and/or voltage control equipment may be used to confirm that the phase angle and voltage magnitude discrepancies are within acceptable limits. Because frequency isnoongera consideration, this approach should be easier than shutting the initial transmission line.

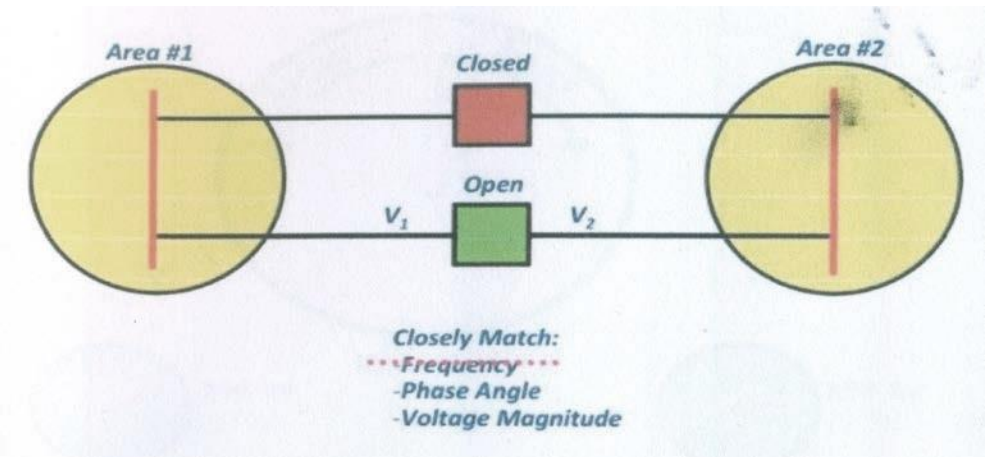


Figure 5.2: - Creating a Second Transmission Connection

5.4 Measuring Instruments That Synchronize

5.4.1 Synchronization scope

The three synchronizing variables are monitored using a synchro scope, which is a basic piece of equipment. The voltage waveforms from both sides of the open circuit breaker are sent into a simple synchro scope (shown in Figure 5.3). The synchro scope does not revolve if the voltage waveforms have the same frequency. The synchro scope spins in proportion to the frequency difference if the voltage waveforms are at different frequencies. The voltage phase angle difference is always indicated by the synchro scope needle.

A synchro scope is a manual device in which the operator must keep an eye on the "scope" to ensure the circuit breaker is closed at the proper moment. The synchro scope is usually positioned on a "synch panel" above eye level. The synch panel also has two voltmeters for comparing voltage magnitudes at the same time.

Figure 5.3 shows a synchro scope with a modest voltage magnitude mismatch and a stationary synchro scope with a phase angle of around 35 degrees. The lack of rotation of the synchroscope needle shows that the frequency is the same on both sides of the circuit breaker.

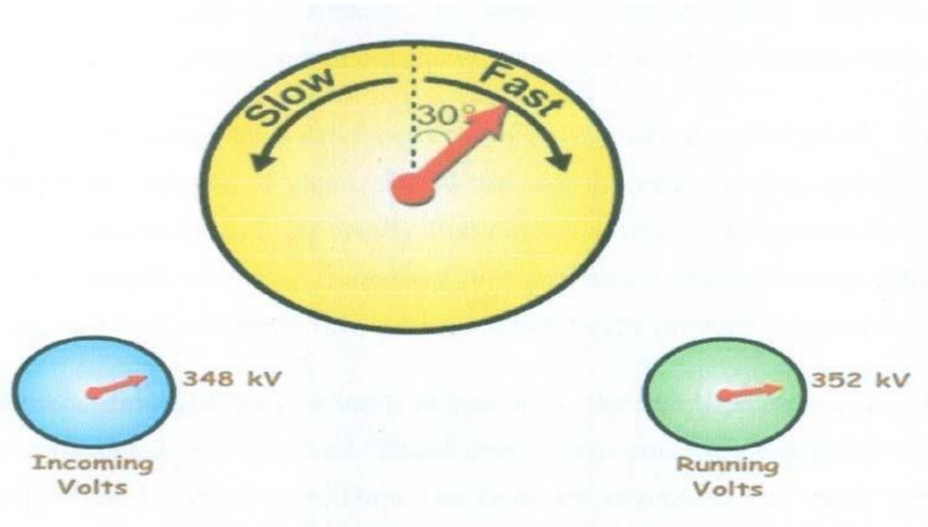


Figure 5.3:- A Synch Panel's synchronization scope

5.5 Monitoring of Photovoltaic Systems

Photovoltaic system monitoring and control are critical for a solar power system's reliable operation and optimal production. Reading readings on a display (typically LCD) is the easiest way to monitor an inverter. Displays (typically LCD) are included in practically every grid-connected inverter. PV array power, AC grid power, and PV array current are all commonly accessible values.

5.6 Switchboard (electric)

An electric switchboard is a device that allows electricity to be transferred from one source to another. It's a set of panels with switches on each one that allows power to be diverted.
A switchboard is defined by the National Electrical Code (NEC) as a large single panel, frame, or assemblage of panels on which switches, overcurrent and other protection devices, buses, and generally instruments are located on the face, back, or both.
A switchboard's job is to divide the main current supplied to it into smaller currents for distribution, as well as to provide switching, current protection, and metering for these different currents. Switch boards, in general, provide electricity to transformers, panel boards, control devices, and, eventually, system loads.

Safety switches and fuses safeguard the operator from electrocution. There may also be controls for the energy supplied to the switchboard by a generator or bank of generators, such as frequency control of AC power and load sharing controls, as well as frequency gauges and maybe a synchro scope. The quantity of power entering a switchboard must always be equal to the amount of power leaving the switchboard for the loads.

The switchgear is linked to a bank of bus bars, flat strips of copper or aluminum, within the switchboard. These are supported by insulators and transport enormous currents via the switchboard. Although bare bus bars are popular, many versions now come with an insulating cover, leaving only the connecting points visible.

Modern switchboards are metal-enclosed and "dead front" in design; when the covers and panels are closed, no electrified elements are visible. Open switchboards used to be manufactured with switches and other devices installed on slate, granite, or ebony asbestos board panels. For employee safety, the switchboard's metal casing is linked to earth ground. Large switchboards can be free-standing floor-mounted enclosures with incoming connections at the top or bottom. Incoming bus bars or bus duct for the source connection, as well as big circuits supplied from the board, may be found on a switchboard. A metering or control compartment may be isolated from the power distribution cables in a switchboard.

5.7 Board of Distribution

A distribution board (also known as a panel board) is an electrical supply system component that separates an electrical power input into subsidiary circuits while also providing a protective fuse or circuit breaker for each circuit in a single enclosure.
A primary switch is usually included, as well as one or more 'Residual-current devices (RCD) or Residual Current Breakers with Overcurrent Protection (RCBO) on more contemporary boards.

5.8 Busbar

A busbar (sometimes spelt bus bar or buss bar, with the name bus being a contraction of the Latin omnibus - meaning all) is a strip or bar of copper, brass, or aluminum that transmits electricity within a switchboard, distribution board, substation, battery bank, or other electrical device in electrical power distribution. Its primary job is to carry electricity rather than to serve as a structural part.

5.9 Meter for electricity

An electricity meter, also known as an energy meter, is a device that monitors the quantity of electricity used by a home, company, or other electrically powered item.

Electricity meters are usually calibrated in billing units, with the kilowatt hour [kWh] being the most prevalent.

Electricity meters were scanned on a regular basis to determine billing cycles and the amount of energy utilized during each cycle.

Chapter 6

Recommendation and Conclusion

6.1 Conclusion

The paper proposed the modeling a grid connected PV system. The comprehensive modeling of the system's components has been discussed in great depth. PV array modeling was demonstrated using datasheet values. The DC-DC boost converter was utilized in conjunction with incremental conductance with internal regulator method to enhance the output power of the PV array. We have show how we can connect solar energy to the national grid. Electricity is a crucial requirement for a country's economy. The increased consumption of electricity is closely tied to the expansion of industry and the improvement of people's living standards. When solar electricity is linked to the national grid, overall generating power increases. As a result, we're looking at how to link solar energy to the national grid. That system is sophisticated, but solar energy is free, has no negative impact on the environment, and is dependable.

The overall trends of improving solar cell efficiency, falling PV system prices, rising government incentive programs, and various other variables have all worked synergistically to lower the barriers to PV systems entering the market and expanding their contribution to the global energy portfolio during the last decade. The increased economic feasibility could not come at a better moment in terms of providing a clean option for generating energy to satisfy the fast expanding demand. However, tapping into the free resource comes at a cost: the resource's intermittent nature and the issues encountered when integrating it into electrical power networks. As a higher percentage of energy comes from renewable sources, the difficulties are only becoming worse. Rather than putting extra equipment along a feeder to assist offset some of the problems caused by PV systems, this thesis proposes a method that involves altering the inverter's controls to alleviate the issues. Voltage regulation, frequency response, and remote curtailment and ramping capabilities are among the various control elements built, modeled, and assessed in the MATLAB simulation environment.

6.2 Further Research Recommendations

The following points are worth investigating further:

- The recommended operating techniques can be tested and applied in a prototype.
- The findings of simulation studies can be used in the generation and security study of a grid system that includes one or more photovoltaic generators.

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