MULTI LEVEL INVERTER BASED GRID CONNECTED SOLAR PHOTO VOLTAIC SYSTEM WITH POWER FLOW CONTROL

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A Project Report
Submitted in partial fulfilment of the
Requirement for the award of the degree of

Bachelor of Technology in
Electrical and Electronics Engineering
by

M Sairam Patel 20951A0226

Under the Esteemed Guidance of
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May, 2024

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SUPERVISOR **HEAD OF THE DEPARTMENT**
(Mr. P. Shiva Kumar)

DATE:

APPROVAL SHEET

This project report entitled “**Multi level inverter based grid connected solar photo voltaic system with power flow control** submitted by **M. Sairam Patel** approved for the award of the degree bachelor of technology in Electrical and Electronics Engineering.

Examiners **Supervisor**
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(Dr L V Narsimha Prasad)

Date:

Place:

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With Gratitude,

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ABSTRACT

This article utilizes the MATLAB SIMULINK platform to simulate a 3.25 kWP grid-connected single-stage solar photovoltaic system. The system includes a multilevel inverter and takes into account real-time meteorological conditions. The use of a DC-DC converter is entirely disregarded in favor of a multilayer inverter, which ensures voltage stability, tracks the maximum power point, and converts DC to AC. There is a five-level multilevel inverter that has five switches; to add two more levels to the result voltage waveform, simply add another switch. The result of the 1-level inverter is mixed with the 1-level, 230V, 50 Hz grid supply. The only purpose of a shunt active current controller is to limit the system to actual power flow. The inverter is controlled utilizing a multi transporter sinusoidal heartbeat width regulation framework, and the overall harmonic distortion of the output voltage is just 1.18% up to the 100th harmonic content, which is very low. Daily energy production from a grid-connected conventional inverter verifies the simulated findings. The proposed work is in good agreement with existing empirical evidence, and it improves power quality.

Keywords: Active power flow, shunt current controller, multilayer inverter, solar photovoltaic system, simplified switching, pulse width modulation using sinusoidal waveforms.

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LIST OF FIGURES

LIST OF ABBREVIATIONS

MLI	Multi-level Inverter
MPPT	Maximum Power point Tracking
SPV	Solar Photo Voltaic
INC	Incremental Conductance
CHB MLI	Cascaded H Bridge Multi level Inverter
SPWM	Sinusoidal Pulse Width Modulation
MPP	Most Extreme Power Point

CHAPTER-1

1.1 INTRODUCTION

In developing countries like India rapid growth in electricity demand leads to more than 70% of electricity generation by fossil fuels. The global warming is rapidly increasing and the power sector is one of the major potential pollutant source. Solar Photovoltaic (SPV) system can be one of the alternative for the fossil fuels, as it is clean and green energy source. The weather conditions in India supports SPV to generate enough electricity. The parameters like solar irradiance and the panel temperature of the sun based PV board are variable and as such the result of the sun oriented PV is moreover variable [1-2]. To make the generated energy in to the useful form, its voltage is to be stabilized, that is constant DC or constant AC form [3]. Anyway the major part of the grid is in the form of AC, so the generated energy should convert in to AC [4]. At any weather condition the best possible amount of electricity should be grabbed and is possible through Maximum Power Point Tracking (MPPT) is a technique. The Perturb and Observation (P&O), Incremental Conductance (INC), and Constant Voltage approaches are only a few of the many MPPT algorithms available [5-6].

Researchers are paying great attention towards Multilevel Inverters (MLIs), as they are good in high and medium power and voltage conversion. Now a days MLIs are even being used for low power applications. Cascaded H- Bridge Multilevel Inverters (CHB-MLIs) suits best for the SPV or Renewable Energy based systems, as they requires, multiple the sun based PV board are variable and as such the result of the sun oriented PV is moreover [7-8]. To reduce the switch requirement in the cascaded MLIs researchers are still trying by following ways 1. By asymmetrical sources, 2. By making changes in the topologies and 3. Combination of asymmetrical sources and the topological changes [9-11]. Part of the second kind, this study employs a symmetrical five-level cascaded MLI with a decreased number of switches. The initial development of a five-level MLI requires five switches; subsequent increases in level need simply the installation of a single switch.

SPV systems may be classified into two types: one that uses a single stage conversion and another that uses two stages. An inverter and a DC converter are both utilized in a two-stage conversion system. A grid-connected system allows for full control over power flows in addition to the inverter's exclusive responsibility of converting DC to AC.

Whereas the voltage stabilization at DC busbar and the MPPT tracking are completely done by DC-DC converter. In single stage conversion only inverter is present and DC-DC converter is avoided. All the functions discussed before are done through inverter only. The study presents a one step conversion mechanism.
. In this technology at off time (during night time), the DC busbar capacitors can be used as static compensators by using the proper algorithm.

Various open loop and closed loop control techniques are available for the inverters. Multicarrier Sinusoidal Pulse Width Modulation (SPWM) control schemes are used because of simplicity in design, easy to control and can be achieved least output voltage THD [12-14].

Chapter 2: Literature Survey

1. Ghosh, A., Rajagopal, R., Ranganathan, V. T. Published in: Solar Energy, 2018.

"Performance Analysis of Cascaded H-Bridge Multi-Level Inverter for Grid-Connected Solar PV Systems with Power Flow Control". This study presents a comprehensive performance analysis of a cascaded H-bridge multi-level inverter used in grid-connected solar PV systems. It discusses power flow control techniques, such as proportional-integral (PI) control, and evaluates the inverter's performance in terms of grid synchronization, power quality, and efficiency.

2. Patel, P., Shah, R., Joshi, D. Published in: Electric Power Systems Research, 2019.

"Improved Power Flow Control Strategy for Diode-Clamped Multi-Level Inverter-Based GridConnected Solar PV Systems". This paper proposes an improved power flow control strategy for diode-clamped multi-level inverters in grid-connected solar PV systems. It introduces a modified control algorithm to enhance power quality, reduce harmonics, and regulate the grid current and voltage. The performance of the proposed technique is validated through simulation.

3. Singh, R., Chandra, A., Al-Haddad, 2015.

Power Flow Control Strategies for Multi-Level Inverter-Based Grid-Connected Solar PV Systems" This paper investigates various power flow control strategies, including active and reactive power control, voltage control, and harmonic mitigation techniques, specifically applied to multi-level inverter-based grid-connected solar PV systems. It discusses the performance, advantages, and limitations of different control techniques.

4. Gaonkar, D., Kulkarni, A., Pandya,2017.

"Optimal Power Flow Control of Grid-Connected Multi-Level Inverter-Based Photovoltaic Systems". This research paper proposes an optimal power flow control technique for multilevel inverter-based grid-connected solar PV systems. It focuses on maximizing power extraction from PV arrays while regulating the grid voltage and ensuring power quality. The study employs an optimization algorithm to achieve the desired objectives.

5. Kumar, S., Sharma, S., Chaturvedi, 2020.

"Experimental Investigation of Power Flow Control Techniques in Neutral Point Clamped Multi-Level Inverter-Based Grid-Connected Solar PV Systems". This research paper presents an experimental investigation of power flow control techniques in neutral point clamped multi-level inverter-based grid-connected solar PV systems. It evaluates the performance of control strategies.

6. D. Das et al., "A Comprehensive Review on Multi-Level Inverter Topologies for Grid-Tied Photovoltaic Systems," IEEE Access, 2018.

This paper provides an in-depth review of various multi-level inverter topologies and their applicability to grid-tied photovoltaic systems. It discusses the advantages, challenges, and performance characteristics of different configurations, aiding researchers and practitioners in selecting suitable inverters for solar PV integration.

7. P. Sharma et al., "Advanced Control Strategies for Power Flow Management in MultiLevel Inverter-based Grid-Connected Photovoltaic Systems," Solar Energy, 2019.

Focusing on control strategies, this study explores advanced methods for managing power flow in grid-connected photovoltaic systems with multi-level inverters. The paper delves into the effectiveness of different control techniques in optimizing energy production, grid stability, and overall system performance.

8. H. Chen et al., "Model Predictive Control for Power Flow Management in Grid-Tied Photovoltaic Systems with Multi-Level Inverters," IEEE Transactions on Power Electronics, 2022.

This paper introduces model predictive control as a method for power flow management in grid-tied photovoltaic systems employing multi-level inverters. It delves into the application of predictive control algorithms, their advantages, and their potential in enhancing the dynamic response of the integrated system.

CHAPTER-3
METHODOLOGY

3.1 NONCONVENTIONAL ENERGY SOURCES

This chapter provides a high-level overview of the project's non-conventional energy sources, such as the wind system, hydro system, PV system, batteries, and so on. With relevant definitions and basic information about them.

3.2 BLOCK DIAGRAM

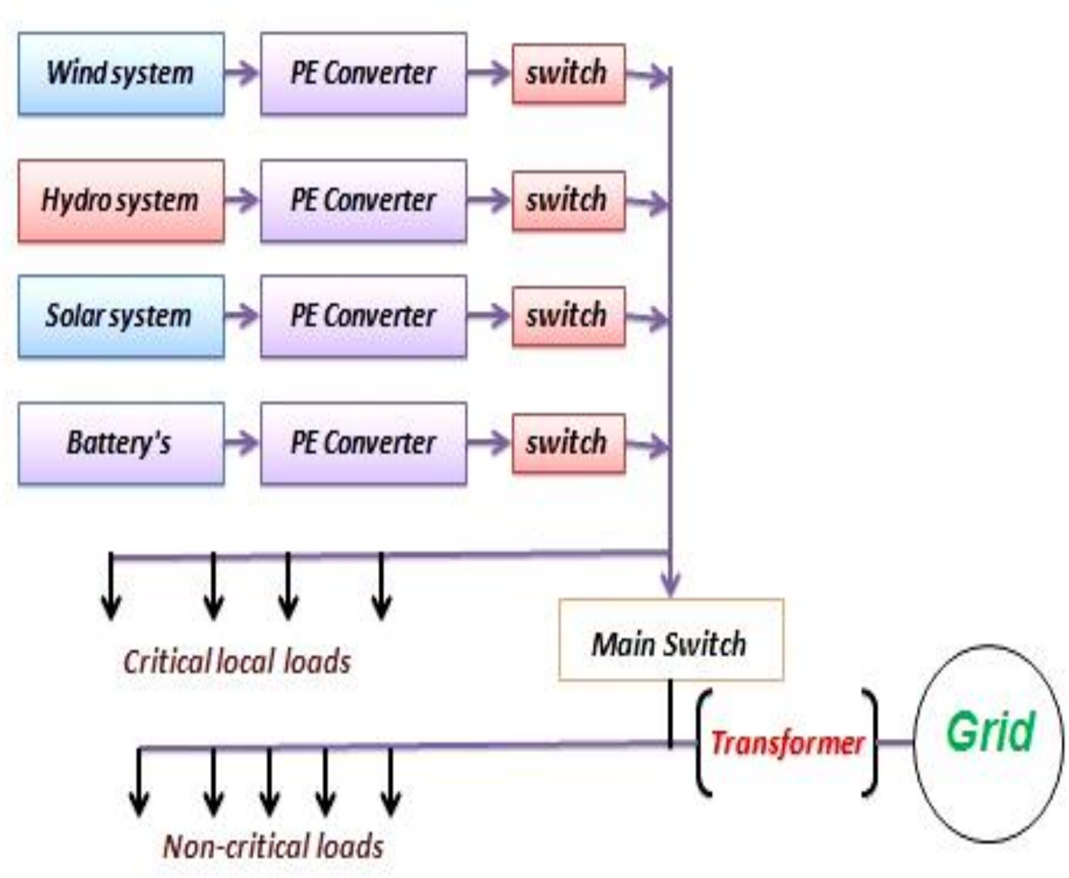


Fig: 3.1 Block diagram

3.3 SOLAR PHOTOVOLTAICS

3.3.1 Introduction

In what was first noted by Becquerel called the photovoltaic effect, solar radiation is transformed. A simple definition is the making of an electric expected qualification between two cathodes related with major areas of strength for a liquid system when light is shone upon it.Sunlight may be used to generate energy via the photovoltaic effect, and this process is known as solar cell technology. A sun cell, also known as a photovoltaic cell, is a single converter cell. A solar module, or array, is a group of solar cells meant to maximize the electric power production. Solar cells may be organized into extensive configurations known as arrays. These arrays, which consist of thousands of individual cells, have the potential to serve as central power stations, transforming solar radiation into electricity and distributing it to homes, businesses, and industries. Solar cell panels, or just panels, are popular names for solar cells arranged in much smaller forms. In order to generate a photovoltaic voltage, almost every photovoltaic device uses a semiconductor with a P-N junction. The solar panels are mostly made of semiconductors, the most prevalent of which being silicon..

3.3.2 Basics of Solar Cells

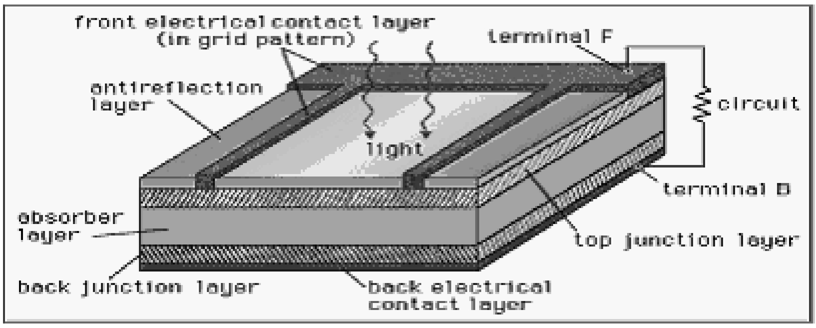


Fig: 3.2 Basics of solar cell

Amorphous (non-crystalline), polycrystalline, and crystalline (single crystal) silicon are the three main types of this material, and they all contribute to the decreasing cost and rising efficiency of solar cells. Electric generators rely on chemical processes and fuel to generate electricity; solar cells, in contrast, do not rely on any of these factors and do not include any moving components.

By reducing the amount of light lost via reflection, an optical coating—also known as an antireflection layer—allows light to enter the device and, in turn, increases the amount of light that reaches the solar cell, allowing it to be more efficiently converted into energy. It is common practice to use spin coating or vacuum deposition to deposit an oxide of silicon, tantalum, or titanium onto the outer layer of the cell to act as the antireflection layer.

After the antireflection layer, there are three energy-change layers: the top intersection, the safeguard (the gadget's center), and the back intersection. On the off chance that the electric flow is to be conveyed from the cell to an outer burden and back once more, two more electrical contact layers are required. On the outer layer of the cell, where light enters, there is an electrical contact layer frequently made of a decent conveyor, such metal, and organized in a network design. Since metal retains light, the lattice lines should be as slender and broadly isolated as conceivable with the goal that the cell's current might be gathered. Restrictions of this kind are not present in the rear electrical contact layer. The only thing it needs to do is cover the whole rear surface of the cell structure and operate as an electrical contact. As with the front layer, the rear layer must be an excellent electrical conductor, which is why metal is usually used. An ideal solar cell absorber would have a high absorption efficiency for visible light, the spectrum that comprises the vast majority of both natural and artificial light. Substances that are classified as semiconductors are those that absorb visible light with a high degree of intensity. A solar cell's thickness is basically that of the absorber, since all incoming visible light may be absorbed by semiconductors with thicknesses of one tenth of a centimeter or thinner. This is due to the much smaller junction-forming and contact layers. Semiconducting materials such as gallium arsenide, indium phosphate, silicon, and copper indium selenide are used in solar cells.

Electrons in the absorber layer of a solar cell are changed from their lower-energy "ground state," where they are bound to specific molecules in the material, to a higher-energy "energized state," where they might stream unreservedly across the material, when light hits the cell. Without the layers that create junctions, these electrons that are "free" are moving around aimlessly, making it impossible to have directed direct current. Still, the photovoltaic effect is generated by the incorporation of layers that create junctions, which stimulate an inherent electric field. Electrons are effectively propelled into collective motion by an electric field. This motion carries them beyond the electrical contact layers and into an outer circuit, where they might accomplish important work

Factors influencing the efficiency and cost of solar cells include the kind of semiconductor used in their fabrication and the crystal structure that is used. Temperature, lighting, shade, and other environmental elements all have an impact on the output of the solar panel. In spite of variations in weather and solar cell performance, the goal is to create a system that can maximize power extraction.

3.3.3 Solar Cell Characteristics

Find the greatest power point with difficulty because solar cells have non-linear current-to-voltage and capacity to-voltage attributes. By seeing that the halfway of the current-voltage trademark is where the most power is communicated, finding the greatest power point on a direct bend Is simple. As demonstrated in Figure 2.3, a typical V-I characteristic of solar cells.

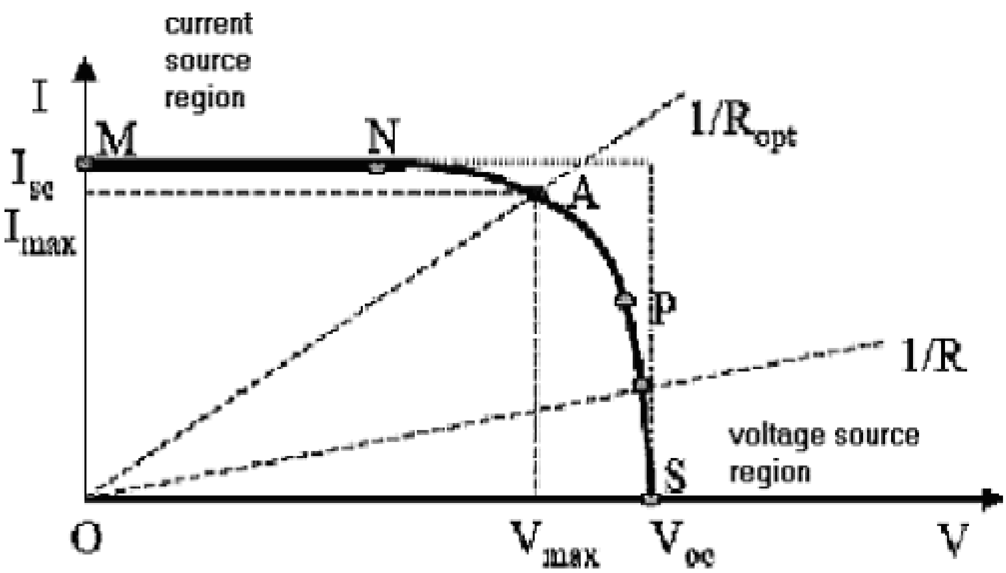


Fig: 3.3 Characteristics of solar cell

Working out the result of the voltage and result current is important to gauge the greatest power guide for a sun oriented cell due toward the non-linear connection. In order to get the most juice out of a solar cell, you have to keep it running at or near its maximum operating voltage and output current. Around the corner or 'knee' of the I-V trademark lies this point, which is known as the most extreme power point (MPP).

Sun oriented cells have two primary regions that add to its functional trademark: the ongoing source district and the voltage source area. In the ongoing source region, which is arranged on the left half of the current-voltage bend, the sun oriented cell's inward impedance is high. In the space where the inward impedance is negligible — the voltage source district — on the right half of the current-voltage bend shows up. In the ongoing source region, the trademark bend shows that the result current is practically consistent with changing terminal voltages, though in the voltage source area, the terminal voltage fluctuates very little with output currents across a large range.

At the point when the interior impedance of the source and the heap are equal, the maximum power transfer theory states that the load receives the greatest amount of power. The system has to run at or near the solar panel's maximum power point tracking (MPPT) efficiency, which can only be achieved if the input impedance is identical to the inner impedance of the board. By changing the result voltage of the sunlight based chargers to a worth at which they give the heap the most elevated measure of energy, the greatest power point following (MPPT) framework guarantees that the impedance saw by the framework remains a constant regardless of voltage ($V = I * R$). Since the operating point for maximum power is sensitive to changes in environmental factors like temperature and irradiance, keeping it at that level may be difficult. So, it's crucial to monitor the power bend and keep up with the working voltage of the sunlight based chargers at the greatest power extraction point.

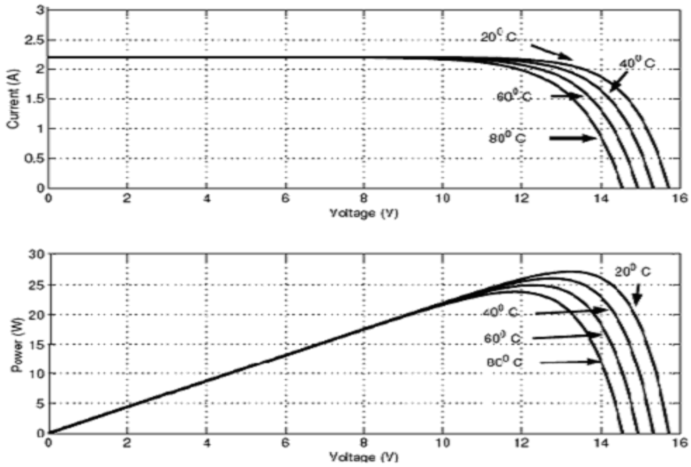
On an ideal day, the irradiance, a property of the Sun's energy that reaches Earth, is 1000 W/m2 at the equator. When the sun is directly above, the Earth's surface receives the most energy from the sun closer to the equator. Radiance, spectral irradiance, and irradiance are some fundamental quantities associated with irradiance. One definition of irradiance is the power gotten by a unit surface region at a given frequency, while one more characterizes otherworldly irradiance as the power got by a unit surface region at a specific frequency, etc. Radiation is the integral of irradiance over time, multiplied by some time interval.

The energy that a PV system can collect from the sun over an extended length of time at a specific area with a particular tendency point and direction is the essential thought in the plan cycle. The result of the sun powered charger is extremely delicate to varieties in irradiance since sun oriented radiation is the energy source utilized by the board. To represent the impacts of irradiance on the I-V and P-V properties.

No matter where you put the solar panels, the amount of light they let in is very sensitive to their orientation and inclination angles. In northern latitudes, orientation is often assessed with respect toward the south, while in southern scopes, it is estimated as for the north. Conversely, the horizontal is used to quantify the inclination angle. It is possible to determine the irradiation at any given place by using these two factors. You can get irradiance data for a lot of places all across the globe.

Tthe relationship between irradiance and output power is linear. That is why the solar panel's output power will be lower when the irradiance is lower. On the other hand, we see that irradiance alone influences the output current. This is rational, since the produced current is directly proportional to the photon flux according to the operating principle of the solar cell. Light intensity (or irradiance) determines the flow of photons; a lower value results in less.

As the temperature drops, the solar panel becomes more efficient in part because the semiconductor material allows for more mobility of electrons and holes. The mobility of electrons and holes in semiconductors diminishes dramatically with increasing temperature. As the temperature rises to 225ºC, the hole mobility drops from around 600cm2/volt-sec at 25ºC to 200cm2/volt-sec, and the electron mobility drops from approximately 1700cm2/volt-sec at 25ºC to almost a fourth of this amount. Although the higher reference temperatures are unrealistic for solar panels to operate at, they clearly demonstrate that electron and hole mobility decreases as temperature increases.



Similarly, semiconductor materials' band gap energies change as an element of temperature. The band hole energy of a material develops as its temperature increases. At the point when the energy contrast between the bandgap and the conduction band is bigger, more photon energy is expected to move electrons from the valence band to the conduction band. The result is a less powerful sunlight based cell in light of the fact that less electrons arrive at the conduction band and a more prominent number of photons need more energy to be consumed by the valence band.

The productivity of a sun based cell might be influenced by a number of external variables, the most important of which are temperature and irradiance. Solar cell efficiency is affected by a number of variables, including inclination, location, and season. Fig. 2.6 is an example of the highest power point, which allows us to explore further solar cell properties.

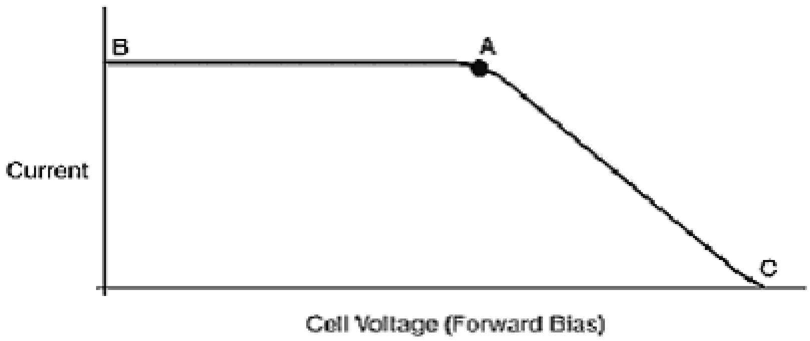


Fig.3.6: Illustration of maximum power point

At point B, the Y-axis meets as an element of temperature. The band hole energy of a material develops as its temperature increases. At the point when the energy contrast between the bandgap and the conduction band is bigger, more photon energy is expected to move electrons from the valence band to the conduction band. The result is a less powerful sunlight based cell in light of the fact that less electrons arrive at the conduction band and a more prominent number of photons need more energy to be consumed by the valence band.

The productivity of a sun based cell might be in order to achieve optimal efficiency. Points B and C shouldn't get any energy, and the majority of the energy should be provided when the operating point gets closer to point A. Load and source impedance matching is crucial in any electrical system, but it takes on added significance in a solar panel array. Sorting the cells into arrays according to their I-V properties allows them to be optimized for optimal energy transmission.

The forward biased p-n junctions seen in most solar cells are associated with high capacitance due to the near proximity of the charged carriers. As the connection area and solar cell size grow, the undesirable capacitance also increases. Fast I-V measurements, which include as an element of temperature. The band hole energy of a material develops as its temperature increases. At the point when the energy contrast between the bandgap and the conduction band is bigger, more photon energy is expected to move electrons from the valence band to the conduction band. The result is a less powerful sunlight based cell in light of the fact that less electrons arrive at the conduction band and a more prominent number of photons need more energy to be consumed by the valence band.

The productivity of a sun based cell might be incoming light. An external circuit's current is defined by the sum of its voltage and the amount of light that strikes it.

3.3.4 Solar Cell Modelling

It is crucial to comprehend the operation of solar cells in order to create an accurate model of one. Solar cells are mostly composed of semiconductors, which, when exposed to light, undergo a series of reactions including photon absorption and reflection, free carrier production, and charge separation, ultimately leading to the creation of an electric field. We can tell how well this works by looking at the characteristics of the semiconductor. The reflectance of the semiconductor surface, the retention coefficient, the float dissemination boundaries, and the surface recombination speeds are vital features.

One solar cell often doesn't provide enough voltage to power most practical power applications. A "Solar Module" consisting of 20–80 solar cells linked in series is often needed to provide the appropriate power. In their Data Sheet, solar cell manufacturers include a few important solar module properties. Standard Test Conditions (STC) are used to determine the module's rated output power, which is expressed as Wp (Watt peak). The STC include 1000 W/m2 of light (sunlight), a spectrum that is comparable to 1.5 m/s of air, what's more, a module temperature of 25 °C all through the test. A further snippet of data that might be found on the information sheet is the voltage across the result terminals when the cell isn't directing current and the short out current, which is the ongoing produced when the result voltage is zero.

Solar cells may be represented by simplified equivalent circuits that include an ongoing source and a diode that are exchanged in equal. In an immediate proportionality connection between sun powered irradiance G and the ongoing source, the photograph current IPh is produced. Like a diode, the sun oriented cell's p-n change region

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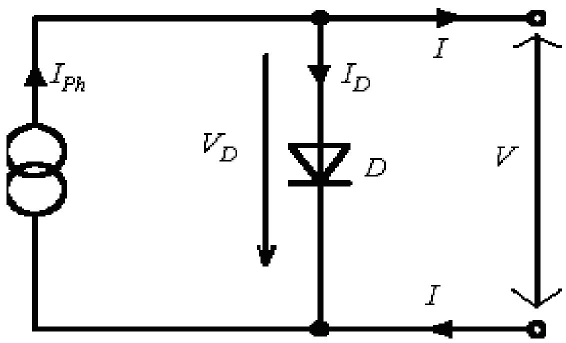


Fig.3.7: Solar cell equivalent circuit

Using Kirchhoff's current law, one might construct the V-I equation for the simplified equivalent circuit.

$$I = I_{Ph} - I_D = I_{Ph} - I_S \cdot (\exp(\frac{V}{m \cdot V_T}) - 1)$$ **…(2.1)**

Where

I_{Ph} --- Photo current

I_D --- Diode current

I_S --- Diode reverse saturation current

m --- Diode ideal factor

V_T = (k*T)/q is Thermal voltage (25.7 mV at 25°C)

k = Boltzmann Constant=1.3824*e-23

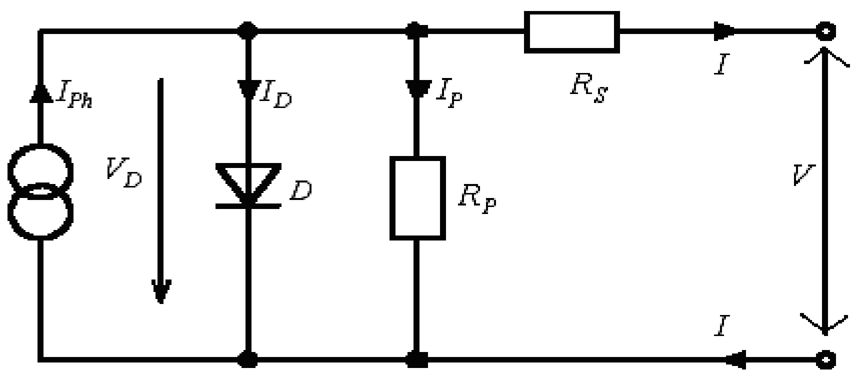
T = Absolute Temperature

q = charge of an electron=1.60*e-19 couloumbs

V = output voltage of the solar cell

I = output current through the solar cells

There is room for improvement in the worked on comparable circuit's portrayal of the sun oriented cell's electrical process. A voltage drop throughout the path to the outside contacts is seen in actual solar cells. A series resistor, denoted as RS, might be used to represent this voltage loss. In addition, leakage currents, which may be represented by the parallel resistor RP, might be detected. See Figure 2.8 for reference.



It is possible to get the equation for the extended I-V curve from Kirchhoff's first law.

$$I = I_{Ph} - I_D - I_P \quad \text{... (2.2)}$$

$$I_P = {V_D}/{R_P} = \left\{ \frac{(V + IR_S)}{R_P} \right\} \quad \text{... (2.3)}$$

$$I = I_{Ph} - \left\{ I_S \left(\exp\left(\frac{q(V + IR_S)}{mkTN_S} \right) - 1 \right) \right\} - \left(\frac{V + IR_S}{R_P} \right) \quad \text{... (2.4)}$$

Where

I_{Ph} is the photo current

I_D is the Diode current

R_S is the cell's series resistance, R_P is the shunt resistance

3.4 WIND SYSTEM

3.4.1 Introduction

Worldwide, GRID-connected wind power is increasing at a pace of 20–25% per year, far outpacing all other forms of energy production. If any other energy technology had expanded at this pace, it would be surprising. Between 2004 and 2005, the world's installed capacity increased from 47.6 GW to 58.9 GW. More and more, wind power is becoming considered a viable option for the widespread generation of energy. Because of its potential as a reliable source of renewable energy, some nations have set lofty goals for wind power generation.

Worries about how to coordinate this significant measure of discontinuous, uncontrolled, and non-dispatchable age without upsetting the finely-tuned balance that network frameworks request have filled lately as wind power entrance levels in power supply frameworks have expanded in a couple of nations.

Wind power growth is hindered in some nations due to grid integration concerns. In order to increase the penetration of wind power into the grid, measures including wind turbine aggregation, burden and wind determining, and reenactment studies are anticipated.

3.4.2 Power from Wind

A wind energy converter's effective area Ar determines the amount of electricity it can harvest from the wind, which is provided by

$$P = \frac{1}{2}\rho_{air} C_p A v_w^3 \qquad \text{….(1)}$$

The so-called power coefficient, denoted as Cp, is dependent on the design and orientation of the breeze converter and is straightforwardly corresponding to the air mass thickness, which is expressed in kilograms per cubic meter, and the wind speed, denoted as Vw. The theoretical upper bound, or Betz limit, is 0.593, which equals 16/27. It can be shown that, for a breeze turbine with determined cutting edges, the power coefficient Cp not set in stone by the tip speed proportion l, which is characterized as the proportion of the tip speed (Vt) in meters each second separated by the breeze speed (Vw) in meters each second, and the supposed cutting edge contribute point q degrees. The pitch point is the point framed between the edge's harmony and the breeze rotor's plane. One potential elective definition of (1) for a breeze rotor of range r is:

$$P = \frac{1}{2}\rho_{air} C_p(\lambda,\theta)\pi r^2 v_w^3 \qquad \text{…..(2)}$$

Figure shows that the power coefficient Cp is determined by the blade pitch angle q and the tip speed ratio l for a certain blade. With this specific blade, q=0 and l little over 6 are the sweet spot for wind energy capture. In order to keep Cp at its ideal worth while wind speed changes, the rotor speed ought to be precisely corresponding to the breeze speed. Both steady l (evolving pace) and consistent speed activity are often used.

The ideal tip speed for on-shore turbines is restricted to around 70 m/s due to the shape of the blades. Reason being, when the blade tips are moving at faster speeds, they generate an overwhelming amount of acoustic noise. Offshore turbines operate at greater speeds, where noise is less of a concern, resulting in somewhat higher ideal values of Cp.

The power curve, indicates the relationship between wind speed and produced power. If you plug in the right values for l and q into equation (2), you can get the power curve. Both constant-speed and variable-speed turbines fall into one of four distinct operating areas shown by the power curve:

1. Wind energy is too low to generate any electricity.
2. Output power falls short of the rated value. Here, we strive toward the pinnacle of aerodynamic efficiency and power harvesting. The evaluated breeze speed is the breeze speed at the boundary of locales 2 and 3, and any factor that has the addendum appraised addresses the plan values at this breeze speed.
3. Rated power generation, since the wind's energy content is sufficient. Here, reducing aerodynamic efficiency is essential to avoid overloading the electrical system.
4. 4.Producing no electricity. The turbine is shut down to avoid damage caused by the high wind speeds.
5.

3.4.4. Energy yield

An electric wind turbine's yearly energy output, E, is determined by the power bend, P(vw), and the likelihood thickness conveyance capability, u(vw), of the breeze speed at the shaft area:

$$E = \int_0^\infty P(v_w) \cdot u(v_w) dv_w \quad ....(3)$$

Figure 3.12 shows the relationship between wind speed (arbitrary units), power density (green), probability density (blue dots), and power P (red dashes).

3.4.5.1 Different types of generators ¬

Induction generator with squirrel cage for variable speed

Some companies have made squirrel cage induction generator wind turbines that can change speeds and use a converter to handle all of the electricity.

These benefits are associated with this technology as contrasted to the doubly-taken care of acceptance generator.

(a) The cost of the generator is lower,

(b) There are no brushes on the generator.

c) The framework is many times utilized as an ordinary modern drive,

(d) It's viable with both 50 Hz and 60 Hz matrices nevertheless, it does have the following drawbacks:

(e) The converter has larger losses due to the fact that it carries all of the power.

The solution's perceived drawbacks outweigh its perceived benefits, given that it is well-known yet never used.

- **Variable speed with outfitted simultaneous generator**

An outfitted breeze turbine including a brushless simultaneous generator and a total converter was recently created by the Spanish firm Made.

These benefits are offered by this generator system as contrasted to the doubly-fed induction generator.

a) It's more cost-effective,

b) It allows for brushless operation, and

c) The generator is more efficient; b) It's less expensive; and c) It doesn't have to have brushes.

d) The following drawbacks are present, and it is compatible with both 60 Hz and 50 Hz grids:

e) It is compatible with grids operating at 50 Hz and 60 Hz, and it has the following drawbacks:

f) A greater and costlier converter (100% of evaluated power rather than 35%) and

g) A bigger and costlier converter using 100% of its rated power instead of 35%; f) A greater level of conversion losses due to the converter carrying all of the power.

2.4.5.2. Trends in geared generator systems

First, for the reasons already stated, a large number of wind turbine manufacturers have recently shifted their focus from constant speed to variable speed systems in order to achieve the greater power levels.

Enhanced grid fault ride-through capabilities are now available in doubly-fed induction generator systems. Making the turbine appropriate to aid with the grid's voltage and frequency (V&f) regulation is the next logical step; this is doable in principle but has to be put into practice.

Geared wind turbines do not need much research and development since their generators are very common electrical equipment.

2.4.5.3. Trends in direct-drive generator systems

The majority of direct-drive generators being used today are simultaneous generators that are stimulated electrically (Enercon, Lagerwey). Zephyros, Jeumont, and Vensys are among the firms that focus on permanent-magnet synchronous generators.

In the mid nineties, when long-lasting magnets were restrictively expensive, Enercon and Lagerwey started growing direct-drive generators. In spite of a ten times decrease in magnet costs throughout the past ten years, Enercon is by all accounts staying with its reliable strategy.

less expensive misfortunes (no excitation misfortunes), less weight (roughly a consider 2 dynamic generator material), and less expensive expense are the advantages of extremely durable magnet excitation contrasted with electrical excitationThe fact that the stimulation is uncontrollable is a drawback. The superiority of permanent-magnet generators over electrically-excited synchronous generators was first mentioned in 1996. The permanent-magnet generator has only grown in popularity since then as magnet costs have dropped.

Standard, off-the-shelf devices are not direct-drive generators. As a result, investigating other generator topologies that may lead to even more weight and cost savings is a worthy endeavor.

In comparison to radial flux machines, the axial flux generators utilized by Jeumont tend to be smaller, heavier, and more costly. The reason for this is because axial flux machines do not always have the ideal force density and that the radius at which the force acts is not always at its greatest.

Because of the exceptionally high power densities expressed for this machine type in writing, cross over motion generators have been read up for expected use in wind turbines.Large direct-drive generators often have a big air gap, which makes this high force density vanish. The straightforward stator winding architecture of transverse flux generators allows for the application of high voltage insulation, which is a benefit.

Two potential drawbacks are the complicated design and very low power factor, both of which increase the likelihood of mechanical issues and noise pollution. Some issues with the construction of the rotor have been resolved in the TFPM machine that uses a toothed rotor, as suggested in.

When compared to conventional power plants, wind power offers many benefits.

- Making prices more competitive,
- Installation using modules,
- Quick building
- Generating in tandem,
- Enhanced system dependability, and

It does not contribute to pollution.

CHAPTER-4

MULTILEVEL VOLTAGE SOURCE INVERTER USING CASCADED-INVERTERS WITH SEPARATED DC SOURCES

This chapter will present the switching pattern and the construction of the multilayer inverter that uses cascaded-inverters with separated dc sources.

4.1 Introduction

In order to address the challenges that the conventional two-level inverter had in satisfying the demands of drives with high voltage ratings and low dv/dt values, multilevel inverters were created throughout the last 30 years. Up until recently, power transistors were sluggish and limited the switching frequency to values in the kHz range due to their lengthy on and off cycles and high switching losses. Furthermore, power transistors' voltage blocking performance was less than one kilovolt, ruling out their use in high-voltage two-level inverters and operating frequencies in the tens of kilohertz range for switching.

4.1.1 Introduction GTO

A three-level NPC inverter, which used darling ton power transistors and Gate Turn Off Thyristors (GTOs) in the early 1980s, could provide inverter voltage ratings twice as high as a two-level inverter with a switching frequency that was virtually doubled. Consequently, the three-level NPC inverter has found moment use in footing engines and modern drives, accomplishing power and voltage levels that outperform those of a two-level inverter.

4.1.2 Introduction IGBT

The indium gallium bipolar transistor (IGBT) was created in the 1990s as a quick on, quick off gadget that essentially diminished exchanging misfortune and got rid of the optional breakdown of the bipolar intersection semiconductor (BJT). Subsequently, two-level inverter appraisals have been extended to the kilovolt level utilizing IGBTs with more prominent impeding voltages and exchanging recurrence, permitting the two-level inverter to supplant portions of the three-level NPC inverters in specific applications possibly. In any case, the two-level inverter ended up being problematic due to the dv/dt stresses experienced during the quick exchanging of IGBTs,especially at voltage levels 400 V and above. Since the NPC inverter has a lower dv/dt rating than the two-level inverter, it has once again become the preferred option. This means that the three-level NPC inverter is the way to go for fast IGBTs at 400 V and beyond.

Currently, a multilayer inverter design is the most viable power converter topology for ratings over one megawatt, which translates to voltage ratings above 400 V. For over ten years, industries have made utilization of three-level NPC inverters in the lower megawatt range and flowed H-span geographies in the upper megawatt range.
In utility power gadgets, more significant level inverters like four, five, or more elevated level NPC inverters are utilized in applications like STATCOM, UPFC, and Realities, and the flying capacitor geography has additionally been thought of recently.

Staggered inverters are vital in utility power hardware applications due to the high voltage levels (kV range) that must be maintained. This can only be achieved by connecting an enormous number of force semiconductors in series or by utilizing staggered inverter geographies with many levels. The three-level inverter configuration is often adequate at the 400 V distribution system level.

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4.2 TYPES OF Multilevel inverters

To make the output waveform motor-friendly, staggered inverter geographies frequently integrate a variable-recurrence variable-voltage signal with low dv/dt, diminished familiar mode voltage, and low music. There are many different kinds of multilevel inverter topologies, but they all boil down to the same basic idea: using series connections of power transistors with low voltage ratings and various voltage levels of multistage DC capacitors to achieve higher output voltage levels with little incremental steps.
Due to their high voltage waveform quality, multilayer inverters reduce the impact of winding insulation failure in motor drives and provide almost no bearing current. As a result of the decreased stresses and electromagnetic interference, they provide a superior interface for DC voltage sources/burdens to the air conditioner utility framework when utilized as heartbeat width adjustment rectifiers and power conditioners.

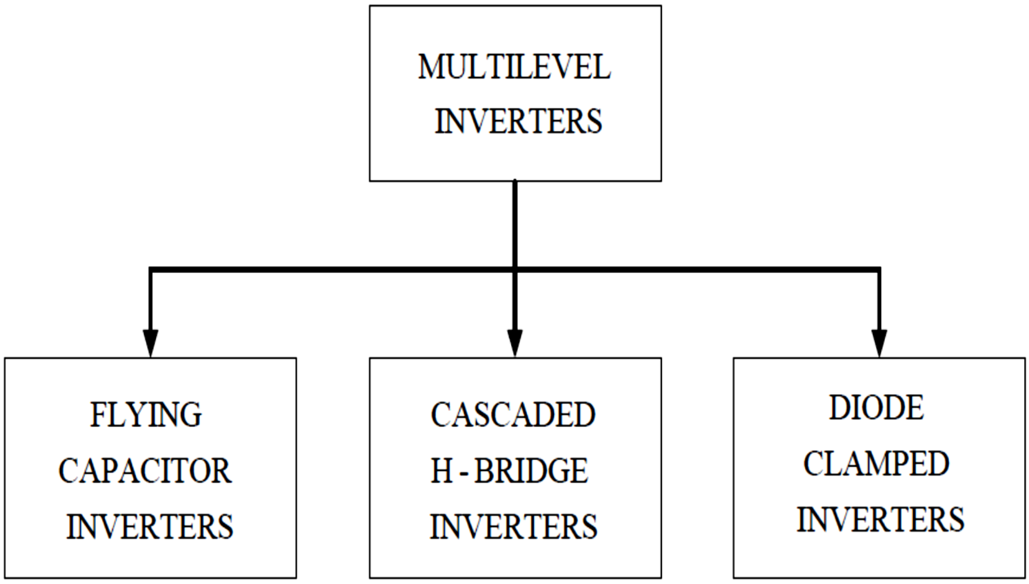

Figure 4.2.1 shows configurations for multilevel inverters.

Adding more semiconductor devices and capacitor voltage sources to staggered inverters will build the quantity of result voltage levels. Consequently, the multilayer inverter's power and control circuit grows in size, complexity, and expense. There are also major issues with voltage unbalance. There have been reports of inverters having up to five levels, however the most frequent is a three-level design. There are more limitations on the topology choice than on the level count. Figure 3.1 shows that three distinct topological structures are involved in multilevel inverter technology.

4.2.1 FLYING CAPACITOR MULTILEVEL INVERTER TOPOLOGY

In 1992, the configuration for multilayer inverters with flying capacitors was suggested. A "capacitor clamped multilevel inverter" is another name for the flying capacitor architecture. When switching at the fundamental frequency, the matching yield voltage waveform is displayed in Fig. 3.2.b, and Fig. 3.2.a showcases one stage leg of the three-level variant of this construction. Figure 3.3.a shows the construction of the five-level flying capacitor inverter circuit, while Figure 3.4.b shows the waveform of the result voltage.In a three-level flying capacitor inverter, all capacitor voltages are equal, and the result voltage VU0 might take on three qualities: -Vdc/2, 0, and +Vdc/2. To accomplish a voltage level of +Vdc/2, it is important to enact the semiconductor switches SU1 and SU2. Turning on either SU2 and SU4 or SU1 and SU3 will activate the 0 level of the semiconductor. To get -Vdc/2, flip the switches SU3 and

SU4 on. Using the same approach, we can generate a five-level result voltage waveform for the five-level scenario.

The flying capacitor inverter topology's capacitor charge management mechanism is complicated, including the fundamental control calculation to keep capacitor voltages inside a set reach. Capacitors utilized in the flying capacitor geography should be greater than those utilized in the diode-clipped staggered inverter DC transport. Thus, albeit the flying capacitor architecture has been studied for utility power electronics applications, it is not practical for ASD systems.

4.2.2 The Topology of Cascaded H-Bridge Multi-Level Inverters

The flowed H-span inverter engineering involves associating many single-deliberately work H-span inverters in series, each having its own autonomous DC source. One such unit is known as a cell. The result voltage waveform is displayed in Figure 3.4.b, and Figure 3.4.a portrays one phase of the five-level flowed H-span inverter plan. Applications involving the driving of medium voltage motors have made use of this topology in industry. At its output, each single-phase H-bridge inverter may produce -Vdc, 0, and +Vdc voltages. The capacitors are connected to the AC side sequentially using semiconductor switches, allowing this to happen. Figure 3.4.a shows the five-level cascaded inverter with two cells linked in series each phase. As long as the voltage in the same level cell is the same in both phases, the DC bus voltage in each of the two cells making up a phase might be different. It would therefore be possible to produce a variety of voltage step waveforms. Analysis and synthesis are made easier when all cells have the same voltage level. The possible discrete values of the phase output voltage in this scenario are 2Vdc, -Vdc, 0, +Vdc, and +2Vdc, which are determined by the individual cell output voltages.

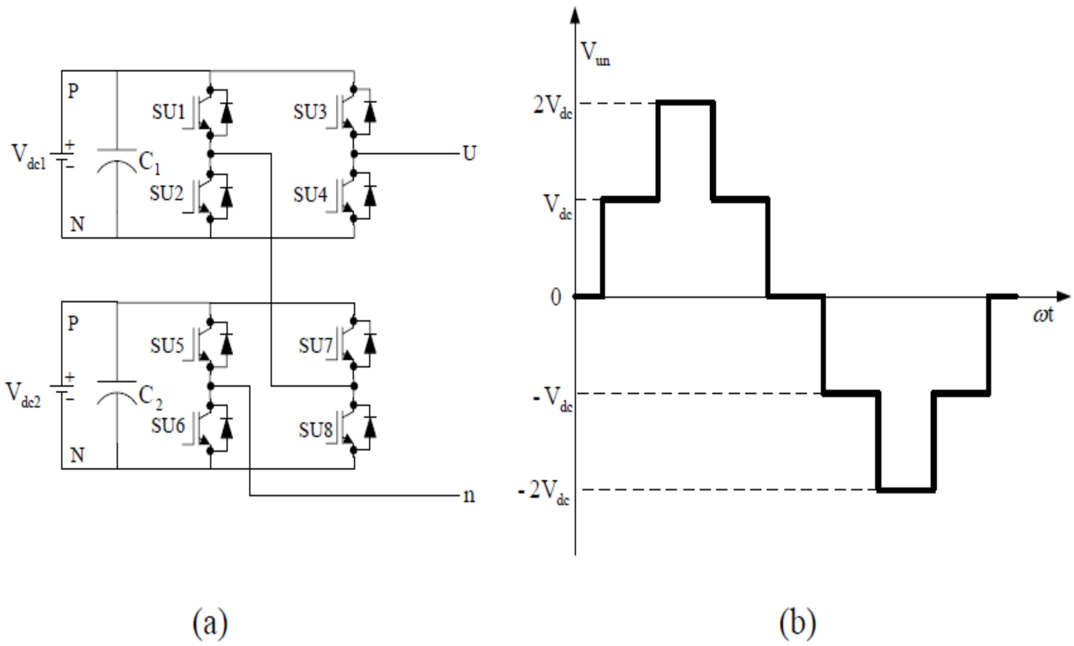

Figure 4.2.2 The five-level cascaded multilevel inverter's output voltage waveform (b) and the construction of one phase leg (a)

A low dv/dt rating and low symphonious substance at the engine terminal voltages portray the flowed H-span staggered inverter setup. It is plausible to accomplish great result voltage waveform quality even at exceptionally high voltage and power levels by picking different DC transport voltage levels for various cells and by choosing a sufficiently large cell count. The architecture of cascaded H-bridge inverters is resilient to faults. If there is a problem with a single-phase inverter, the ASD system may still function normally. This structure is designed to be easily maintained due to its versatility. By using multi-winding transformers, isolated DC voltages may be produced. By carefully designing rectifiers and transformers, the driving AC input current waveform can be of superior quality, resulting in performance that is friendly to utility lines. A massive and complicated input transformer, a plethora of separate H-bridge modules, and intricate control circuitry are all components of a cascaded H-bridge inverter design. This architecture finds use in motor drives with a megawatt power rating. The topology is too complicated and expensive for power ratings below one megawatt

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4.4FIVE LEVEL MULTILEVEL INVERTER

According to the schematic of the suggested multilayer inverter (Fig. 2), in order to create a five-level MLI, five switches are needed; however, to expand each level by two, only one more switch is needed. Here are the number of switches required for five, seven, nine, and eleven level MLIs: five, six, seven, and eight, individually.When describing the basic idea of how things function, the five-level MLI is considered. .

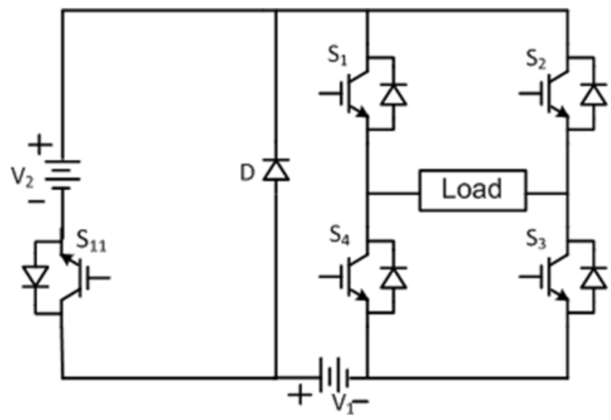
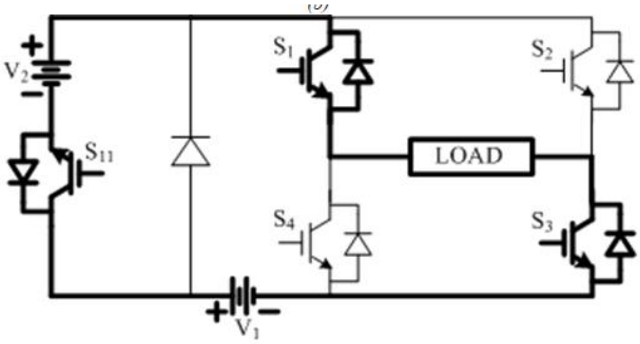


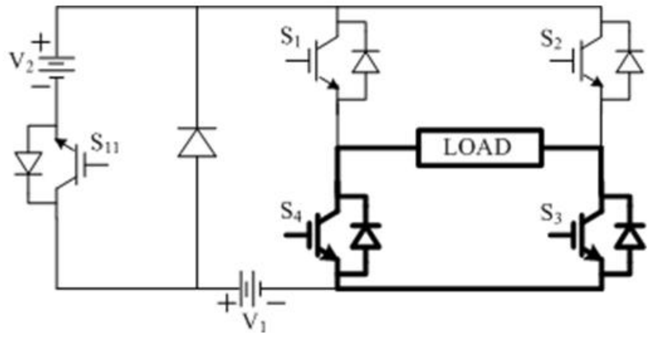
Figure 4.3 Suggested MLI with a single phase and five levels

WORKING PRINCIPLE

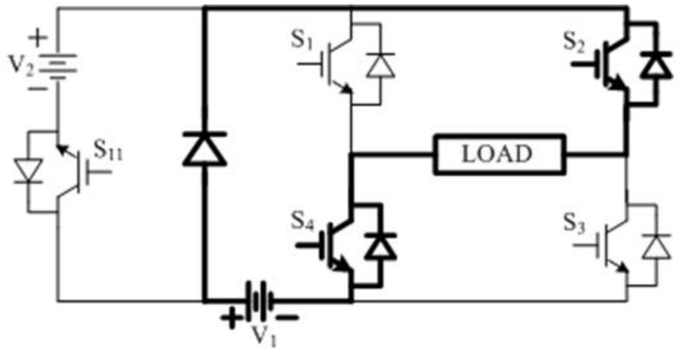
The five-level MLI's look-up table, which helps to illustrate the concept of operation. An array of five solar panels linked in series provides a separate DC power supply. With its six available modes of operation, the output voltage waveform may be adjusted to provide a wide range of values. +2V, +V, zero, -V, and -2V are some of the possible output voltage values. Different voltage levels are listed in Table 2. Figure 3 shows the conduction routes for six different operation modes.


V2
S11
S1
S2
LOAD
S4
S3
V1

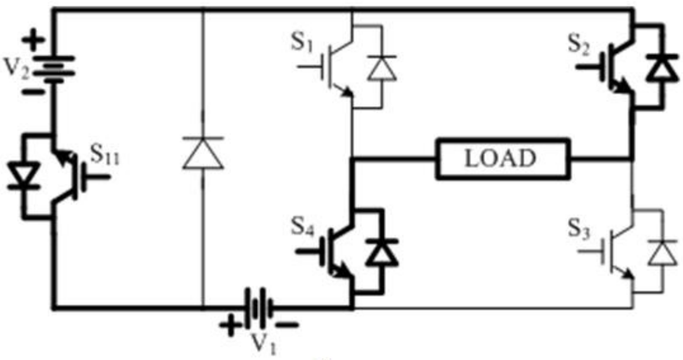
(c)


V2
S11
S1
S2
LOAD
S4
S3
V1

(d)


V2
S11
S1
S2
LOAD
S4
S3
V1

(e)


V2
S11
S1
S2
LOAD
S4
S3
V1

(f)

Chapter 5: Implementation of Simulink Model

5.1 Introduction:

Simulink, which is a piece of software that is used for modelling, simulate, and evaluatesystems that are dynamic. It permits modelling in continuous time, sampled time, or a mix of both nonlinear as well as linear systems. Simulink's modelling tool features a graphical user interface (GUI) that enables users to click and drag their way through block diagrams to develop models.

Because we can create them both top down and bottom up. The system may be viewedata very high level, and then we can double click on the blocks to descend through the layers and study the model in increasingly finer detail. This approach clarifies the internalorganization and relationships of a model's parts. Using a variety of integration techniques, we may simulate a model after it has been defined.

Having established a model, with a number of integration approaches, we could mimic it, either by typing instructions in the MATLAB command window or via the Simulink menus. When the simulation is running, With the aid of scope and other display blocks, the outcomes can be viewed. For "what if" investigation, we may also alter the settings and quickly observe the results.

The MATLAB workspace may be used to post-process and visualise the simulation results. A variety of dynamic systems seen in everyday life Simulink may be used to study a variety of mechanical, electrical, and thermodynamic systems, including circuitsfor electricity, shock absorption, braking networks, and a lot more.Simulink requires two steps to simulate a dynamic system. Using the model editor in Simulink system that will be mimicked is first represented graphically.

The system's behaviour is then simulated using Simulink over a given time period. Thesimulation is carried out by Simulink using the information that you entered into the model.

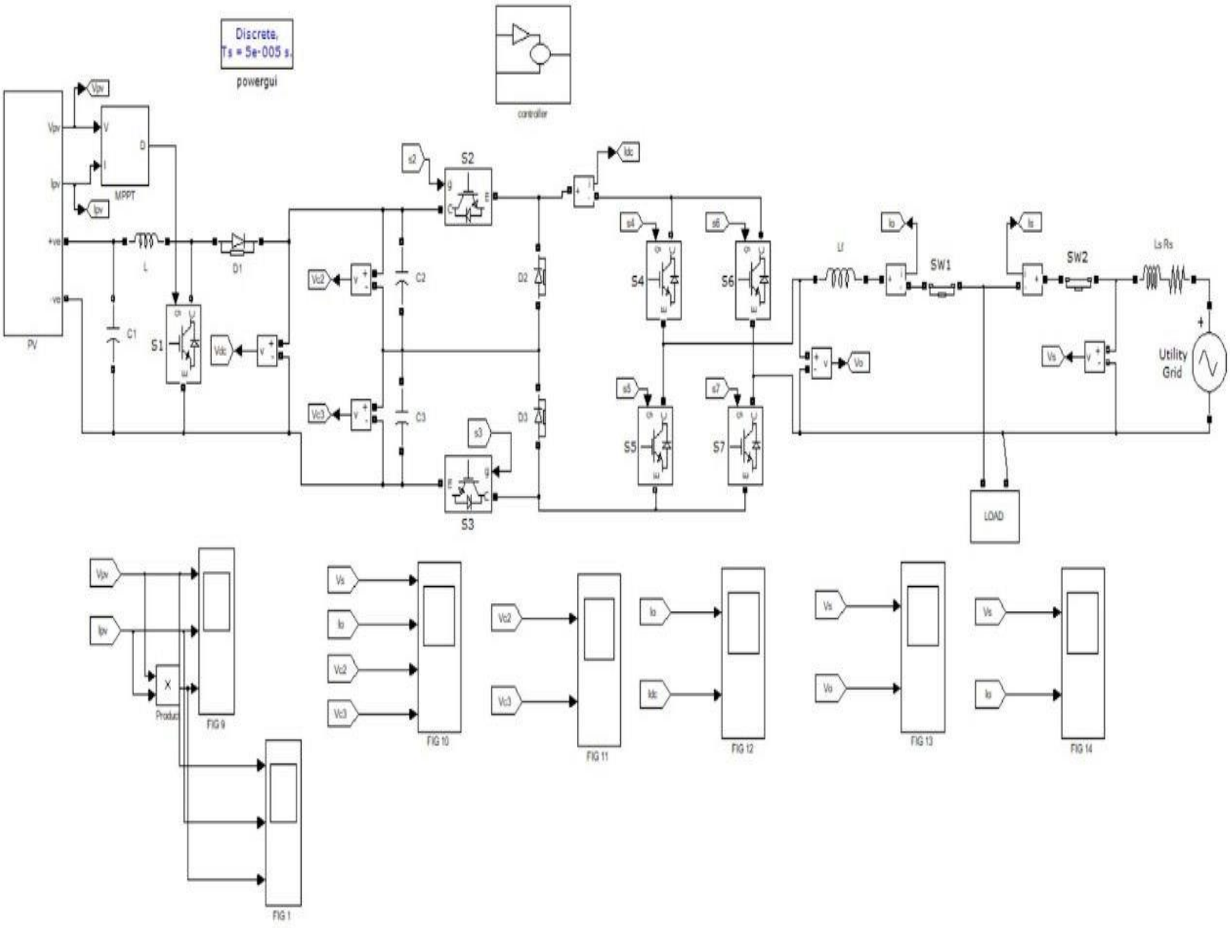


Fig. 5.1 Simulation circuit diagram.

Chapter 6: Simulation Results

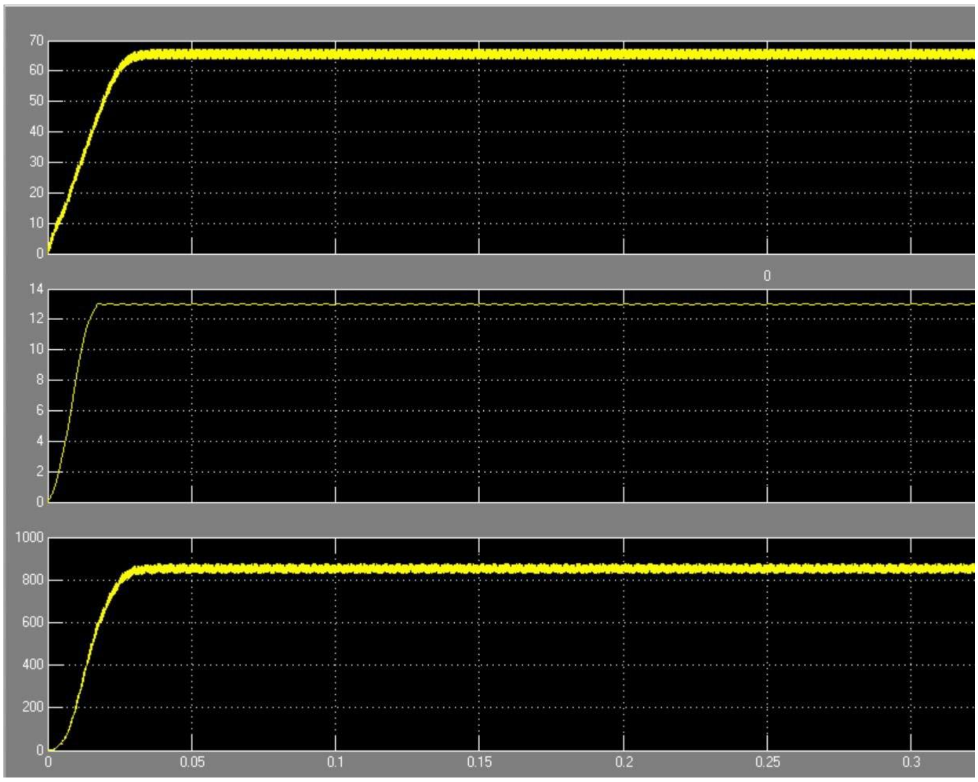


Fig. 6.1 PV Voltage,Current,Power.

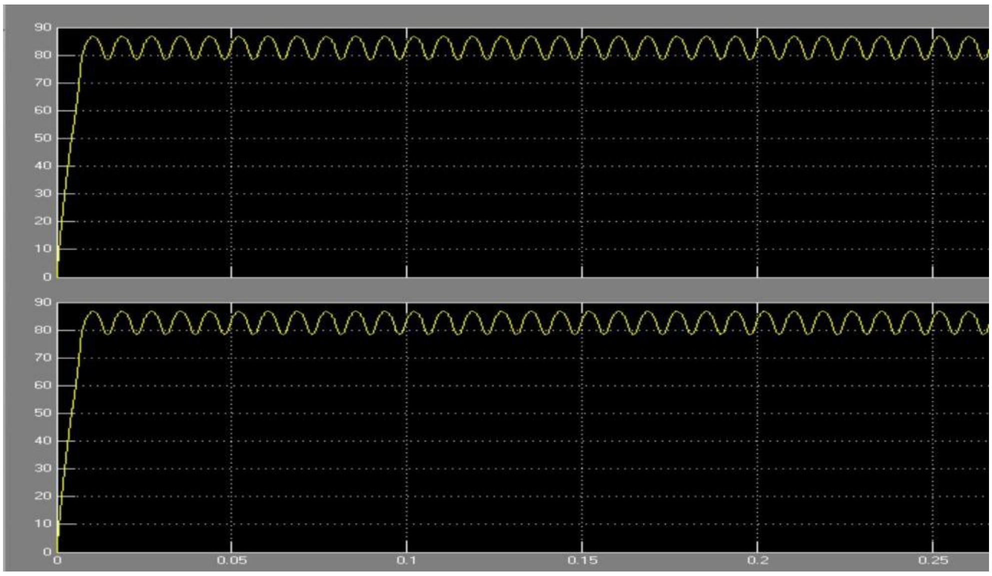


Fig. 6.2 PV Capacitor Voltages.

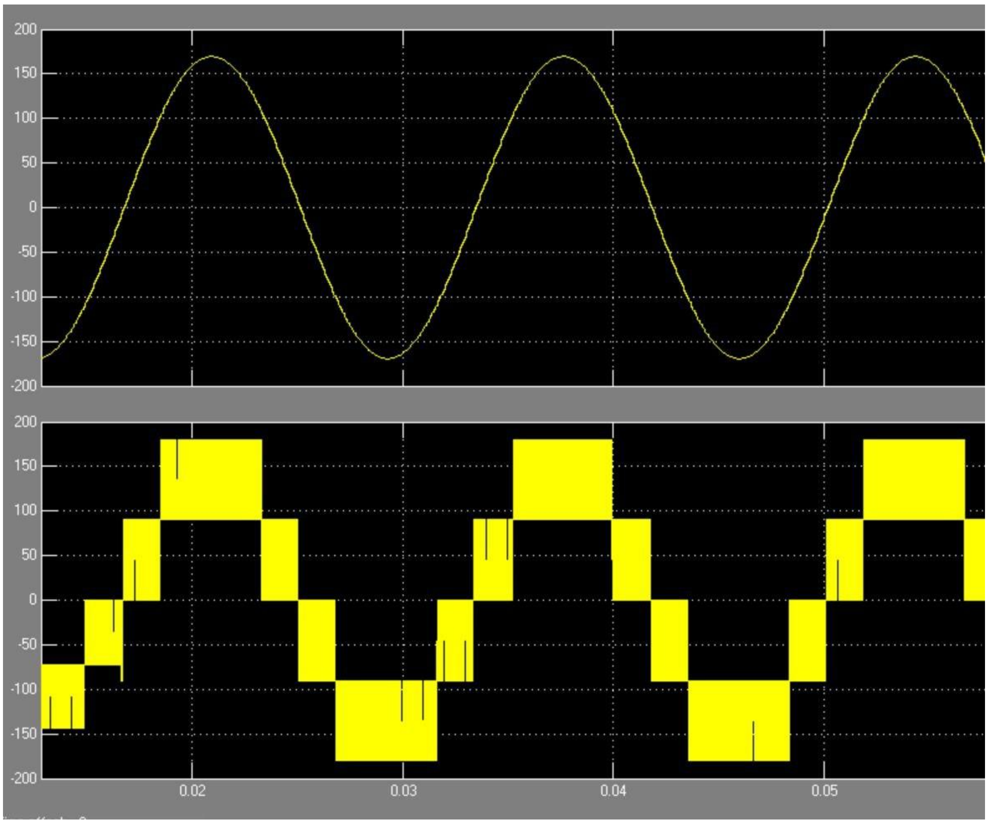


Fig. 6.3 Outputs of Multilevel inverter and Grid

Chapter 7: Conclusion

This study presents a solar PV system that uses a 3.25 kWP grid-connected multilevel inverter. Using the SIMULINK platform, we have modeled and simulated the system. In order to study the system's behavior, researchers have used real-time data like as sun irradiance and panel temperatures, as well as dynamic data such as these variables. The five-level MLI has been utilized to apply the MPPT approach, without the need for a DC-DC converter. The MLI is driven by multicarrier SPWM control schemes and the closed loop is employed through shunt current controller. The MLI output voltage THD obtained was only 1.18% and is very low till the 100th harmonic number consideration. Through the simulation it is proven that only active power flow is existing and there is no reactive power flow. Both AC and DC voltage, current profile behavior with the dynamic inputs to the SPV system is investigated.

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