Sudan University of Science and Technology

College of Engineering

Department of Electrical Engineering

CONTROL OF POWER GENERATION USING SOLAR ENERGY

التحكم في توليد الطاقة باستخدام الطاقة الشمسية

A Research Submitted In Partial Fulfillment for The Requirements of The Degree of B.SC. (Honor) In Electrical Engineering

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بسم الله الرحمن الرحيم

((قالوا سبحانك لا علم لنا إلا ما علمتنا إنك أنت العليم الحكيم))

صدق الله العظيم

سورة البقرة (آية ٣٢)

Dedication

I dedicate this piece of work

To my father, mother, sisters and brothers.

To my teachers

With great respect for all

Acknowledgement

Thankful to Allah for giving me the courage to complete this research, also I wish to express my thanks to my supervisor doctor ***Abuelnuor Abdien Ali*** for his help and valued mentoring.

I would like also to extend my thanks to My College staff who show the portfolio of work .

Abstract

The PV module of book shop is the interface which converts light into electricity. Modeling this device, necessarily requires taking weather data (irradiance and temperature) as input variables. The output can be current, voltage, power or other. However, trace the characteristics I(V) or P(V) needs of these three variables. Any change in the entries immediately implies changes in outputs. That is why, it is important to use an accurate model for the PV module. This project presents a detailed modeling of the effect of irradiance and temperature on the parameters of the PV module. The cho-sen model is the single diode model with both series and parallel resistors for greater accuracy. The detailed modeling is then simulated step by step using MATLAB/Simulink software due to its frequent use and its effectiveness.

المستخلص

وحدات الطاقة الشمسية المستخدمة في تغذية مكتبة توصل لتحويل الضوء الى كهرباء ’لتوصيل هذه المعدات من الضروي اخذ طبيعة الجو في الإعتبار (الإشعاع والحرارة) .ويكون الخرج في هذه عبارة عن تيار وفولتية وقدرة ، ولمعرفة خصائص الجهد والتيار نحتاج إلى هذه المتغيرات .أي تغيير في هذه المدخلات مباشرة يدل على تغيير في الخرج . هذا يحدث لأهمية الدقة في تركيب هذه الخلايا .هذا المشروع يوضح تأثير الضوء والاشعاع على المعدات المستخدمة في الطاقة الشمسية ، يتم توصيل هذه الخلايا على التوالي أو التوازي بدقة كبيرة ، هذه التفاصيل تمت خطوة بخطوة بإستخدام برنامج محاكاة يسمى الماتلاب.

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CHAPTER ONE

INTRODUCTION

1.1 Overview

Developing countries face an overall situation of limited energy resources and applications, particularly in rural areas, and there is an urgent need to address this situation. Limited energy resources and applications pose a serious constraint and barrier to social and economic development, and present significant challenges and opportunities for renewable energy. Renewable energy sources include biomass, solar energy, wind and hydropower. Many of these energy sources have been used for millennia — the sun and wind in drying and other direct or ‘passive’ applications, while biomass has been the ‘active’ staple energy source since our ancestors discovered fire. Moreover, water and wind power have been used as energy sources since the earliest driven machinery. Most recently, the use of solar power in photovoltaic systems has become synonymous with renewable energy at the smaller household level. [1]

Renewable energy is also synonymous with sustainable development and has been linked, more recently, with poverty reduction. While the use of renewable energy is the epitome of sustainability, whether and to what extent such applications will reduce poverty is a more complex question. Solar PV systems are most applicable in rural and remote areas that have no access to electricity grids — places that are often the habitats of poor people in developing countries. But PV systems are very expensive for these people, who also have other priorities such as water, housing and education. Although there are undoubted benefits, a crucial issue in the introduction of PV household systems is the need for suitable financial support systems. If the need for such loan or rental arrangements is not recognized and addressed, the users will undoubtedly face additional burdens. Other forms of renewable energy also require promotion as part of an overall approach to energy sustainability and poverty reduction. These include biomass stoves, ovens and related applications, solar drying, water heating, wind and hydropower — the form of energy chosen depending on the local situation.

Measures to address the problems of global warming and sea-level rise and promote sustainable development have been strongly advocated since the Earth Summit in Rio in 1992, and have cited the development, innovation and utilization of renewable energy technologies as an effective means of addressing these problems. There have been widespread calls for the reduction of greenhouse gas emissions, highlighting the importance of domestic actions and the benefits of encouraging renewable energy and energy efficiency. This was again a focus of the World Summit on Sustainable Development in Johannesburg in 2002, with renewable energy forming a component of the WEHAB agenda.

The challenge is to translate high-level political commitments into concrete activities that are of benefit to the world as a whole.

Fifty years from now, few will doubt the important role that renewable energy plays in sustainable development. [2]

1.2 Problem Statement

The importance of renewable form of energy increases with the increase in population as well as the style of living. Among the renewable sources of energy, solar photovoltaic has proved to be promising because of its easy and efficient way of energy production. Sun is a huge source of solar energy and it is time that we utilize it to the maximum level. Though this form of energy is very easy to generate but at the same time its efficiency is very less due to many reasons. One of the confusions or dilemmas that engineers face is the tilt angle of the panels, whether to keep it fixed or to vary it according to the season The advantage with the latter is that if the panel follows the sun, it can collect all the energy and hence give high energy output. But at the same time the equipments used to track the sun are so expensive that even after the increase in efficiency, they are not feasible to be installed in huge solar photovoltaic plants.

A lot of research hasbeen done at attempts to make this system feasible.

1.3 Objective

Solar PVof bookshop is used primarily for grid-connected electricity to operate residential appliances, commercial equipment, lighting and air conditioning for all types of buildings. Through stand-alone systems and the use of batteries, it is also well suited for remote regions where there is no electricity source. Solar PV panels can be ground mounted, installed on building rooftops or designed into building materials at the point of manufacturing. This project solar PV use of book shop.

1.4 Methodology

Maximum Power Point Tracking (MPPT) is used between the array and load to help better utilize the available array maximum power output and also for matching the impedance of the electrical load to the maximum power output of the PV array.

An example of direct coupled solar PV systems is in agriculture applications, solar PV module can be directly connected to run the pump. Depending upon the capacity of the pump, the module can be connected in series/parallel configurations. In such application, surge protector is needed to be connected between the positive and negative supply provides protection against lightning surges. Batteries are used for energy storage in many stand-alone PV systemsshows the block diagram of a typical stand-alone PV system powering DC and AC loads with battery storage option.

The solar PV array configuration, a DC load with battery backup, is essentially the same as the one without the battery except that there are a few additional components that are required to provide battery charge stability. PV panels are connected in series to obtain the desired increase in DC voltage, such as 12, 24, or 48 V. The charge controller regulates the current output and prevents the voltage level from exceeding the maximum value for charging the batteries. The output of the charge controller is connected to the battery bank by means of a dual DC cutoff disconnect. Apart from this a cutoff switch can be provided, when turned off for safety measures, disconnects the load and the PV arrays simultaneously.

During the sunshine hours, the load is supplied with DC power while simulta-neously charging the battery. The controller will ensure that the DC power output

from the PV arrays should be adequate to sustain the connected load while sizing the batteries. Battery bank sizing depends on a number of factors, such as the duration of an uninterrupted power supply to the load when there is less or no radiation from the sun. The battery bank produces a 20–30 % power loss due to heat when in operation, which also must be taken into consideration. When designing a solar PV system with a battery backup, the designer must determine the appropriate location for the battery racks and room ventilation.

1.5 project Layout

This research consist of an abstract of an five chapter represents as includes:

Chapter one introduction consist of Overview, problem stasement, Methodology and project layout.

Chapter two solar pv consist of Introduction, solar energy, energy from the sun, the apparent motion of the sun, advantages of solar energy, disadvantages of solar energy, the physics behind PV modules and types of pv systems.

Chapter three matlab simulink consist of Introduction,

System flow chart and system components.

Chapter four application consist of introduction and powering the system.

Chapter five conclusion and recommendation consist conclusing and recommendation.

CHAPTER TWO

SOLAR PV

2.1 Introduction

The number of unknown parameters increases when the equiv-agent circuit of the chosen model becomes more convenient and far from being the ideal form. But most of the manufacturers' data sheets do not give enough information about the parameters which depend on weather conditions (irradiance and temperature).

physical nature of the cell behavior are necessary to establish a mathematical model of the PV cell and the PV module, in addition of course, to the use of that information given by the constructors. The objective of this paper is to present use-ful work to those who want to focus their attention on the PV module or array as one device in a complex ‘‘electro-energetic system’’. So, the goal is to obtain at any time, the maximum power but also the more precise, therefore, the closest to the experimental value.

The characteristic I(V) is a non-linear equation with multi-ple parameters classified as follows: those provided by con-structures, those known as constants and the ones which must be computed. Sometimes, searchers develop simplified meth-ods where, some unknown parameters cannot be calculated.Fig 2.1 represent solar cell energy. [3]

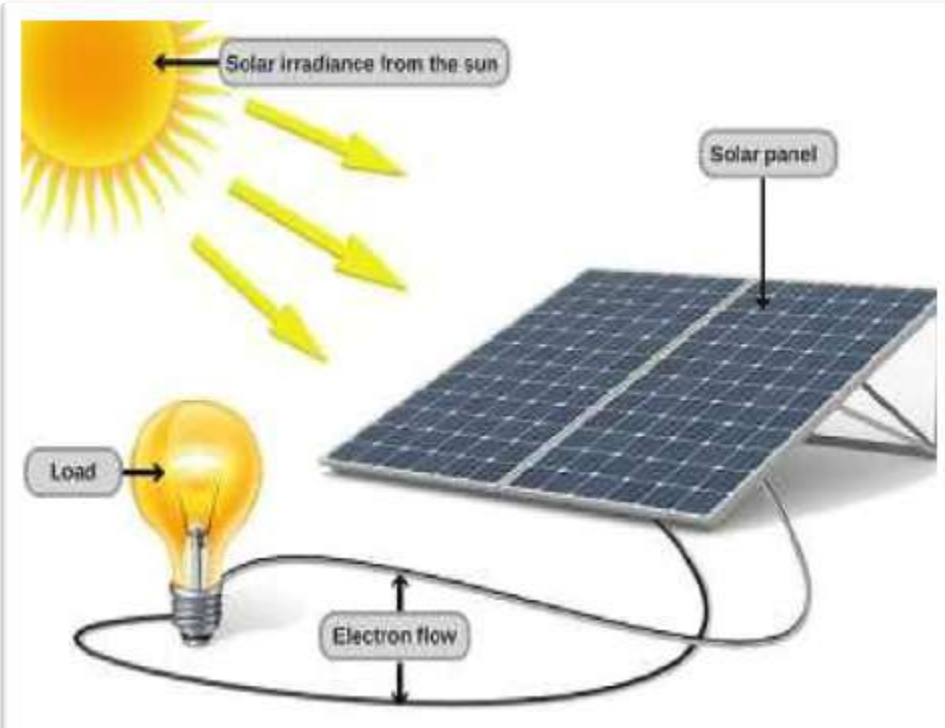


Figure 2.1 show solar cell energy.

Prior to discussing global energy production and consumption, it is prudent to have a look at the physics associated with energy. Although many people are familiar with the term energy, surprisingly only a few people can appreciate energy's true nature. In everyday language, the word energy is used very slackly; words like work, power, fuel and energy are often used interchangeably and erroneously. Energy forms the basis of human life. There is hardly any activity that is independent of energy. In olden days man used muscle power, then fire and animal power. Later, man learnt to harness energy, convert it to useful form and put it to various uses. Over the past few decades, energy has become the backbone of technology and economic development. Not counting men, machines and money, 'energy' is now the fourth factor of production. Without energy, no machine will run and electricity has become a necessity. Hence, the energy requirements have increased in the years following the industrial revolution. This tremendous increase in use of energy has created troubles of ‘demand and supply’. If this mounting world energy demand is to be metwith fossil fuels, they will not be available for energy production in few years. It is a need of today’s world to concentrate on renewable energy sources to satisfy the demand and conserve our finite natural resources for the generations to come. This is an endeavor to present an overview of the concerns about energy demand and supply ratio and how to conserve energy as well how to make best use of renewable energy. [4]

Energy is vital in the entire process of evolution, growth and survival of all living beings. Energy plays a fundamental role in the socio-economic development and human welfare of a country. The term strategic commodity is commonly used in countries to define energy. Any ambiguity in the supply of energy would cause a pressure to the economy of the country. Such energy security is important not only to the country’s economic growth, but also for the vision of a country with reference to the activities related to human development. These activities include removal of poverty, providing employment and satisfying the Millennium Development Goals (MDGs). The issues related to the demand in energy are related to energy demand, energy poverty and environmental effects of energy growth. In this chapter, we will discuss the energy scenario, global and Indian energy crisis, energy efficiency, classification of energy sources, solar energy, wind energy, benefits of renewable energy, trends in energy consumption, worldwide potentials of renewable energy sources, and the need for new energy technologies. In addition an introduction to MATLAB and SIMULINK is provided with application of soft computing techniques in solar and wind energy generation systems.

Electricity generation from renewable sources of energy is an important element in the Government’s development of a low-carbon economy. There are ambitious renewable energy targets in place and a significant increase in generation from large-scale renewable energy infrastructure is necessary to meet the 15% renewable energy target .

There are many types of renewable for example wind energy. Wind mills and horizontal-axis and vertical-axis turbines are used to convert the kinetic energy of the wind into electricity. The electricity produced by wind energy can be supplied to the grid. The technology is beneficial for locations where wind velocity is high. The wind energy start from the sun when the sun heat certain zone from the earth air absorbed other of heat after that air raise above because low density of hot air and hot air molecular have faster motion than cold air that help to replace the air and make air current to moving the mills .Fig 2.2 represent propeller type.

Figure 2. 2 propeller type

2.2 Solar energy

Solar energy is the energy that sustains life on earth for all plants, animals and people. It provides a compelling solution for society to meet their needs for clean and abundant sources of energy in the future. Energy has played a key role in bringing about our modern civilization. In the era of modern civilization, energy demands are likely to increase for power generation for industrial and domestic usage. Solar energy is the most important source of renewable energy in the globe. The greatest advantage of solar energy comparing with other forms of energy is that it is clean and can be supplied without environmental pollution. Over the past century, fossil fuels provided most of our energy, because it was much cheaper and more convenient than energy from alternative energy sources, and until recently, environmental pollution has been of little concern. The limited reserves of fossil fuels cause a situation in which the price of fuels will accelerate as the reserves are decreasing. [5]

2.3Energy From The Sun

The sun is a vast and hot sphere of gas: the temperature in the interior of the sun is approximated to be around 15 million kelvins, its diameter is 1.4 million kilometers and its mass is $2.0 \cdot 10^{30}$ kilograms. Comparatively, for the earth these figures are 12800 kilometers and $6.0 \cdot 10^{24}$ kilograms, respectively. The sun consists mainly of helium and hydrogen; by mass approximately 80% is hydrogen and 20% is helium.

The energy of the sun emerges from fusion reactions where four hydrogen nuclei fuse into one helium nucleus in the hot interior of the sun. In this reaction, the mass of the reactants is more than the mass of the products, and thus energy is released. The energy moves by radiation and convection to the

the surface of the sun, from which it radiates to the surrounding space To approximate the sun's radiation energy it is considered as a blackbody.

2.4The Apparent Motion Of The Sun

Resulting from the motion of the earth around the sun and its own axis, the position of the sun in the sky varies both daily and annually, as seen from the perspective of any point on the earth's surface. As figure 6 illustrates, the earth travels in space on an elliptical orbit around the sun, with its axis tilted – which furthemore causes the seasonal variations in the sun's path across the sky. Simultaneously the earth makes 24-hour full circles around its axis[1], causing the sun to rise and set every day. The apparent motion of the sun complicates the work of people in the field solar energy, as maximizing the energy production from a solar collector would require at least partial tracking of the sun. To get familiar with the subject, this section introduces first the seasonal variation of the altitude angle of the sun at solar noon, and then the daily variations in the sun's position.

2.5 Advantages of Solar Energy

- Solar energy is a renewable energy source and is something we will never run out of as opposed to non-renewable energy sources such as coal, oil and gas. The sun will be around for billions of years to come, making it one of the most sustainable energy sources available to mankind. The fact that solar energy is renewable makes it one of the most important factors in our list of pros and cons.
- Solar panels give off no pollution making them an environmentally friendly option for producing electricity.

Although pollution is produced during the manufacturing and transportation of solar panels, once they are up and running they will help to offset these effects by providing a source of clean electricity that might otherwise have been produced using less environmentally friendly options.

- A large proportion of the earth receives enough sunlight to make solar panels a viable option for generating electricity. You will Þnd this technology being used everywhere from Alaska to Australia. Even the South Pole is investing in solar energy technologies.

- Not only can solar energy be used to generate electricity, it also has a number of other uses. By using a different design of solar panel, solar energy can be used to help heat a buildings water supply. This can help to reduce the energy needed from other sources, such as a buildings gas or electricity supply.

A more basic use of solar energy is how owners of outdoor swimming pools often install solar covers that help to increase the water temperature of the pool. Solar pool covers can also help to keep this heat inside the pool.

Once solar panels are installed and producing electricity, there is little noise associated with the technology. Whilst you might hear a slight hum if you get close to the inverters or transformers used in these systems, this is generally unnoticeable from a short distance away.

Other renewable energy technologies are considerable louder than those that make use of solar energy. Wind turbines for example are notorious for the noise pollution they create, which can be measured at signiÞcant distances away from the turbines themselves.

- Another advantage of solar panels is that they are low maintenance. Once installed, a solar panel can happily sit there for years generating power without any problems. With no moving parts in a residential solar energy system, maintenance is decreased signifcantly.

Although solar panels do need cleaning at regular intervals to ensure peak efÞciency, they are generally considered very low maintenance when compared with rival technologies.

- A major advantage of solar panels is their ability to provide power in the most remote locations. Areas where it might be impossible or expensive to run power cables to can beneÞt from investing in solar energy technologies.

Solar energy is also advantageous when portable power sources are required. Devices that can charge your smartphone from solar energy are readily available and used across the globe. The recent Solar Impulse venture (where a solar powered plane ßew 40,000km around the world) is helping to pave the way for a new generation of portable solar powered applications.

- Using solar or other renewable energy sources to produce your own electricity reduces your dependency on external energy supplies of which you have no control over. This helps to increase your 'energy security', a term that is used to describe the association between national security and the availability of natural resources for energy consumption.

War, sanctions and other political issues can all have an effect over the energy supply of any given country. If your country buys electricity or natural resources (such as coal, oil or gas) from another, have you ever thought what could happen to your energy supply if this ßow of electricity or resources were to stop? By producing your own energy, you are less reliant on such issues and would be better placed than most in this scenario.

- Technological advancements in the solar energy industry are helping to drive the effciency of solar panels. Modern solar cells are much more effcient than those produced only pve or ten years ago and solar cells are on track to get even more effcient over the coming years[6]

2.6 Disadvantages of Solar Energy:

- The initial cost of installing a residential solar energy system can run into the tens of thousands of dollars. This upfront capital is hard for many homeowners to fnd, withsome choosing to take out loans to fund their project, a process that would add cost to the overall project and slow any return on investment.

Whilst return on investment can be achieved under the right conditions, the initial cost of purchasing a solar energy system is considered the most signiÞcant disadvantages of solar energy and one of the most important factors in our list of pros and cons of solar energy.

- Another key disadvantage of solar energy is that it is only present during daylight hours. Solar panels can’t generate electricity during the night, making them in effect useless when it’s dark. To combat this, battery storage units are often combined into the design of a solar energy system for use at night, however these units are often expensive, take up lots of space and don’t have enough capacity to provide a household’s energy supply all through the night.

This disadvantage is further inßuenced by seasonal ßuctuations in daylight hours. A solar energy system won’t produce as much electricity when the nights are long as it would when the nights are short.

- Solar panels are affected by certain atmospheric conditions. Long-lasting periods of signiÞcant heat and humidity can affect the performance of solar cells, with delamination of the cells occurring in some cases.

Pollution also decreases the efÞciency of solar panels, making them a less attractive option for those living in highly-populated towns and cities, or those situated close to heavy industries. Cloud cover and fog will also reduce a solar panels efÞciency

- Solar energy systems often require a large footprint in order to provide an adequate source of power to a home or business. Compared with other renewable energy technologies, solar energy systems have the largest footprint for the power that is generated. A large footprint will be of concern to most, especially those where real estate is at a premium.

- Although solar panels will generally provide a source of clean and environmentally friendly energy for years to come, pollution is still generated during the manufacturing of solar cells. Solar cells contain silicon, an element that is extracted from raw materials in a blast furnace, a process that produces signiÞcant quantities of greenhouse gases. [7]

2.7 The physics behind PV modules

Fundamentally, the operation of photovoltaic (PV) cells is based on the pho-toelectric effect. The photoelectric effect is the emission of electrons from the surface of a material (usually a metal) when light strikes the surface, and it was first discovered in 1887 by Heinrich Hertz. A correct explanation for the effect was not found until in 1905, when Albert Einstein postulated that light consists of quanta of light, called photons, and a photon with enough energy can give an electron energy sufficient to escape from the potential field of its nucleus. The number of escaped electrons depends on the number of photons, the intensity of light, and energy of the electrons depends on the energy of the photons

To exploit the photoelectric effect for electricity production we need a voltage difference to drive the liberated electrons.

2.8 Types of pv systems

Based on the electric energy production, PV modules can be arranged into arrays to increase electric output. Solar PV systems are generally classified based on their functional and operational requirements, their component configurations. It can be classified into grid-connected and stand-alone systems.

2.8.1 Grid-Connected Solar PV System

The primary component of grid-connected PV systems is power conditioning unit (PCU). The PCU converts the DC power produced by the PV array into AC power as per the voltage and power quality requirements of the utility grid. A bi-directional interface is made between the PV system AC output circuits and the electric utility network, typically at an on-site distribution panel or service entrance. This allows the AC power produced by the PV system to either supply on-site electrical loads or to back-feed the grid when the PV system output is greater than the on-site load demand. This safety feature is required in all grid-connected.Fig 2.3 represent block diagram of grid-connected solar pv system.

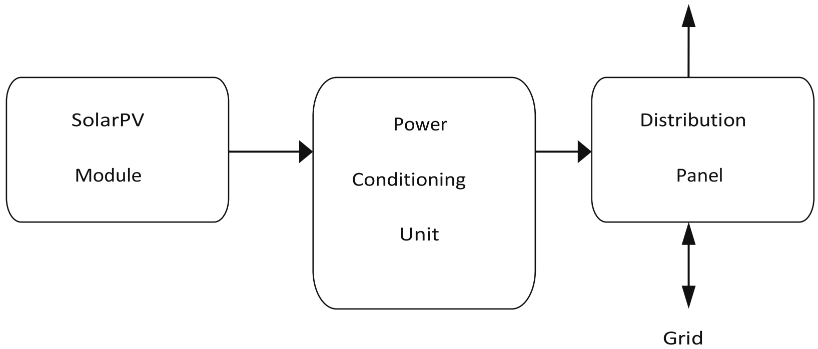


Fig 2.3 block digram of grid-connected solar pv system

PV systems, and ensures that the PV system will not continue to operate and feed back into the utility grid when the grid is down for maintenance or during grid failure state. Figure 2.3shows the general block diagram of the grid connected solar PV system. In grid-connected systems, switching of AC power from the standby generator and the inverter to the service bus or the connected load is accomplished by internal or external automatic transfer switches. [8]

One of the important components of a grid-connected system is net metering. Standard service meters are odometer-type counting wheels that record power consumption at a service point by means of a rotating disc, which is connected to the counting mechanism. The rotating discs operate by an electro physical principle called eddy current. Digital electric meters make use of digital electronic technology that registers power measurement by solid-state current and voltagesensing devices that convert analog measured values into binary values that are displayed on the meter using liquid crystal display (LCD) readouts.

Inverters are the main difference between a grid-connected system and a standalone system. Inverters must have line frequency synchronization capability to deliver the excess power to the grid. Net meters have a capability to record consumed or generated power in an exclusive summation format. The recorded power registration is the net amount of power consumed—the total power used minus the amount of power that is produced by the solar power cogeneration system. Net meters are supplied and installed by utility companies that provide grid-connection service systems. Net metered solar PV power plants are subject to specific contractual agreements and are subsidized by state and municipal governmental agencies.

2.8.2 Stand-Alone Solar PV System

Stand-alone PV systems or direct coupled PV systems are designed and sized to supply DC and/or AC electrical loads. It is called direct coupled systems because, the DC output of a PV module or array is directly connected to a DC load. There is no electrical energy storage (batteries) in direct-coupled systems as because of that, the load only operates during sunlight hours. The maximum power point tracker.Fig 2.4 represent direct solar pv system.Fig 2.5 represent block diagram of stand-alone pv system with battery storage. [9]

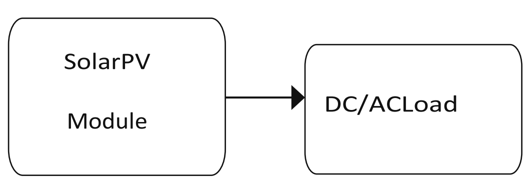


Fig 2.4 Direct coupled solar pv system

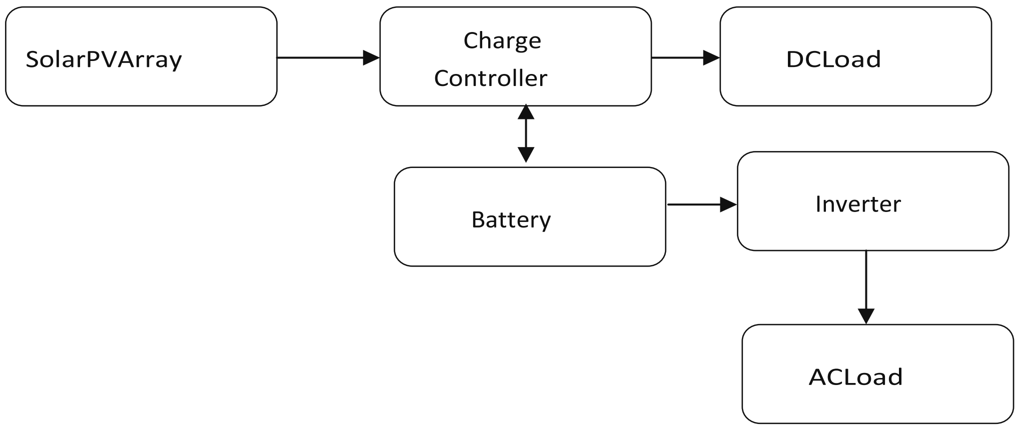


Fig 2.5 block diagram of stand-alone pv system with battery storage

(MPPT) is used between the array and load to help better utilize the available array maximum power output and also for matching the impedance of the electrical load to the maximum power output of the PV array. Figure 2.4shows the general block diagram of the stand alone solar PV system.

An example of direct coupled solar PV systems is in agriculture applications, solar PV module can be directly connected to run the pump. Depending upon the capacity of the pump, the module can be connected in series/parallel configurations. In such application, surge protector is needed to be connected between the positive and negative supply provides protection against lightning surges. Batteries are used for energy storage in many stand-alone PV systems. Figure 2.5shows the block diagram of a typical stand-alone PV system powering DC and AC loads with battery storage option.

The solar PV array configuration, a DC load with battery backup, is essentially the same as the one without the battery except that there are a few additional components that are required to provide battery charge stability. PV panels are connected in series to obtain the desired increase in DC voltage, such as 12, 24, or 48 V. The charge controller regulates the current output and prevents the voltage level from exceeding the maximum value for charging the batteries. The output of the charge controller is connected to the battery bank by means of a dual DC cutoff disconnect. Apart from this a cutoff switch can be provided, when turned off for safety measures, disconnects the load and the PV arrays simultaneously.

During the sunshine hours, the load is supplied with DC power while simultaneously charging the battery. The controller will ensure that the DC power output.

from the PV arrays should be adequate to sustain the connected load while sizing the batteries. Battery bank sizing depends on a number of factors, such as the duration of an uninterrupted power supply to the load when there is less or no radiation from the sun. The battery bank produces a 20–30 % power loss due to heat when in operation, which also must be taken into consideration. When designing a solar PV system with a battery backup, the designer must determine the appropriate location for the battery racks and room ventilation.

2.8.3 PV-Hybrid Systems

Hybrid systems generally refers to the combination of any two input sources, here solar PV can be integrated with Diesel Generator, Wind Turbines, Bio-mass or any other renewable on non-renewable energy sources. Solar PV systems will generally use battery bank to store energy output from the panels to accommodate a pre-defined period of insufficient sunshine, there may still be exceptional periods of poor weather when an alternative source is required to guarantee power production. PV-hybrid systems combine a PV module with another power sources typically a diesel generator, but occasionally another renewable supply such as a wing turbine. The PV generator would usually be sized to meet the base load demand, with the alternate supply being called into action only when essential. This arrangement offers all the benefits of PV in respect of low operation and maintenance costs, but additionally ensures a secure supply. [10]

Hybrid systems can also be sensible approach in situations where occasional demand peaks are significantly higher than the base load demand. It makes little sense to size a system to be able to meet demand entirely with PV if, for example, the normal load is only 10 % of the peak demand. By the same token, a diesel generator-set sized to meet the peak demand would be operating at inefficient part-load for most of the time. In such a situation a PV-diesel hybrid would be a good compromise. Figure 2.6shows the block diagram of Solar PV hybrid system.

2.8.4StandAloneHybridACSolarPowerSystemwithGenerator and Battery Backup

A stand-alone hybrid solar PV configuration is essentially identical to the DC solar power system. In this alternating current inverters are used to convert DC into AC. The output of inverter is square waves, which are filtered and shaped into sinusoidal AC waveforms. Any waveform, when analyzed, essentially consists of the superimposition of many sinusoidal waveforms known as harmonics..Fig 2.6 represent block diagram of photovoltaic hybrid system.

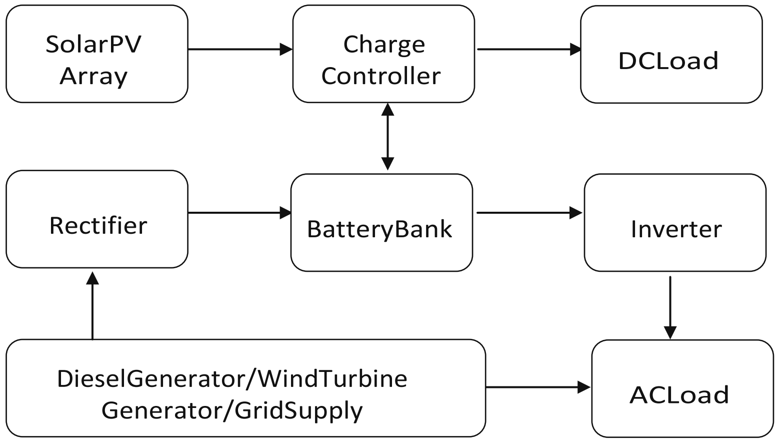


Fig 2.6 block diagram of photovoltaic hybrid system

The first harmonic represents a pure sinusoidal waveform. Additional waveforms with higher frequencies, when superimposed on the base waveform, add or subtract from the amplitude of the base sinusoidal waveform.

The combination of base waveform and higher harmonics produce a distorted wave shape that resembles a distorted sinusoidal wave. Converted DC output, derived from the solar power, is considered to be a numerous superimposition of odd and even numbers of harmonics. To obtain a relatively clean sinusoidal output, most inverters employ electronic circuitry to filter a large number of harmonics. Filter circuits consist of specially designed inductive and capacitor circuits to block certain unwanted harmonics. In general, DC-to-AC inverters are intricate electronic power conversion equipment designed to convert direct current to a single or three-phase current that replicates the regular electrical services provided by utilities.

Most inverters, in addition to PV module input power, accept auxiliary input power to form a standby generator, used to provide power when battery voltage is dropped to a minimum level. A special type of inverter, referred to as the grid-connected type, incorporates synchronization circuitry that allows the production of sinusoidal waveforms in harmony with the electrical service grid. When the inverter is connected to the electrical service grid, it can effectively act as an AC power generation source. Grid-type inverters used in grid-connected solar power systems are strictly regulated by utility agencies that provide net metering. Some inverters incorporate an internal AC transfer switch that is capable of accepting an output from an AC-type standby generator. In such designs, the inverters include special electronics that transfer power from the generator to the load.[11]

CHAPTER THREE

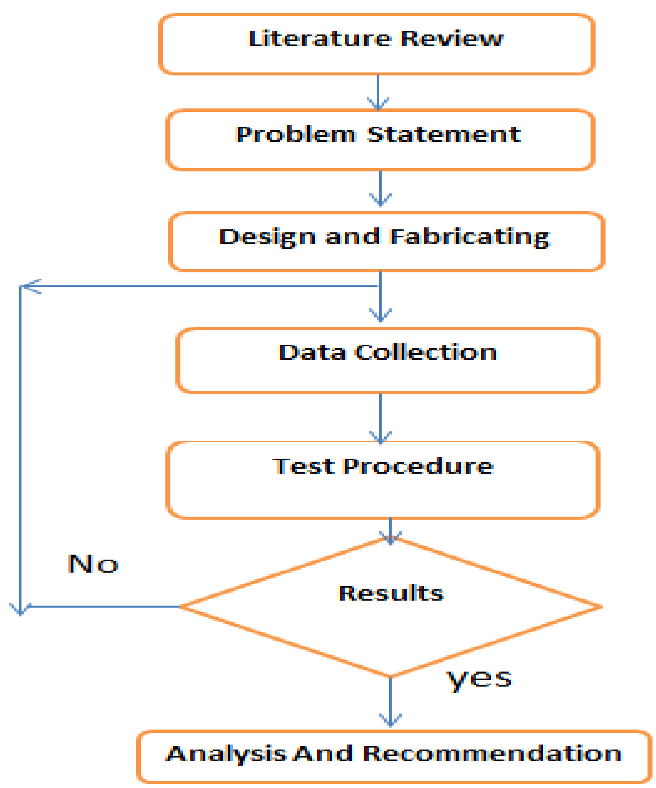
MAT LAB SIMULINK

3.1 Introduction

The methimatical laboratory simulink is a very good tool used to simulate electrical power, control and communication system to reduce losses that occurred in the industrial application and helped to avoid errors and mistakes that can be happended during the system operation system.

3.2 System Flow chart

System flow chart are a away of displaying how data flows in a system and how decisions are made to control events. To illustrate this, symbols are used. They are connected together to show what happens to data and where it goes. the system flow chart can be represend by the diagram represented in Fig 3.1[10]



3.3 System Components

Pre-engineered photovoltaic systems can be purchased that come with all the components you will need to use in bookshop, right down to the nuts and bolts. Any good dealer can size and specify systems for you, given a description of your site and needs. Nevertheless, familiarity with system components, the different types that are available, and criteria for making a selection is important.

Basic components of grid-connected PV systems with and without batteries are:

- Solar photovoltaic modules
- Array mounting racks
- Grounding equipment
- Combiner box
- Surge protection (often part of the combiner box)
- Inverter
- Meters – system meter and kilowatt-hour meter
- Disconnects:
- Array DC disconnect
- Inverter DC disconnect
- Inverter AC disconnect
- Exterior AC disconnect

If the system includes batteries, it will also require:

- Battery bank with cabling and housing structure
- Charge controller
- Battery disconnect

3.3.1 Solar Modules

The heart of a photovoltaic system is the solar module. Many photovoltaic cells are wired together by the manufacturer to produce a solar module. When installed at a site, solar modules are wired together in series to form strings. Strings of modules are connected in parallel to form an array.

3.3.2 Array Mounting Racks

Arrays are most commonly mounted on roofs or on steel poles set in concrete. In certain applications, they may be mounted at ground level or on building walls. Solar modules can also be mounted to serve as part or all of a shade structure such as a patio cover. On roof -mounted systems, the PV array is typically mounted on fixed racks, parallel to the roof for aesthetic reasons and stood off several inches above the roof surface to allow airflow that will keep them as cool as practical.

3.3.3 Grounding Equipment

Grounding equipment provides a well-defined, low-resistance path from your system to the ground to protect your system from current surges from lightning strikes or equipment malfunctions. Grounding also stabilizes voltages and provides a common reference point. The grounding harness is usually located on the roof.

3.3.4 Combiner Box

Wires from individual PV modules or strings are run to the combiner box, typically located on the roof. These wires may be single conductor pigtails with connectors that are pre-wired onto the PV modules. The output of the combiner box is one larger two-wire conductor in conduit. A combiner box typically includes a safety fuse or breaker for each string and may include a surge protector.

3.3.5 Surge Protection

Surge protectors help to protect your system from power surges that may occur if the PV system or nearby power lines are struck by lightning. A power surge is an increase in voltage significantly above the design voltage.

3.3.6 Meters and Instrumentation

Essentially two types of meters are used in PV systems:

- Utility Kilowatt-hour Meter
- System Meter

Utility Kilowatt-Hour Meter – The utility kilowatt-hour meter measures energy delivered to or from the grid. On homes with solar electric systems, utilities typically install bidirectional meters with a digital display that keeps separate track of energy in both directions. Some utilities will allow you to use a conventional meter that can spin in reverse. In this case, the utility meter spins forward when you are drawing electricity from the grid and backwards when your system is feeding or "pushing" electricity onto the grid.

System Meter – The system meter measures and displays system performance and status. Monitored points may include power production by modules, electricity used, and battery charge. It is possible to operate a system without a system meter, though meters are strongly recommended. Modern charge controllers incorporate system monitoring functions and so a separate system meter may not be necessary.

3.3.7 Inverter

Inverters take care of four basic tasks of power conditioning:

- Converting the DC power coming from the PV modules or battery bank to AC power
- Ensuring that the frequency of the AC cycles is 60 cycles per second
- Reducing voltage fluctuations
- Ensuring that the shape of the AC wave is appropriate for the application, i.e. a pure sine wave for grid-connected systems

Criteria for Selecting a Grid-Connected Inverter – The following factors Should be considered for a grid-connected inverter:

- A UL1741 listing of the inverter for use in a grid-interactive application
- The voltage of the incoming DC current from the solar array or battery bank.
- The DC power window of the PV array
- Characteristics indicating the quality of the inverter, such as high efficiency and good frequency and voltage regulation
- Additional inverter features such as meters, indicator lights, and integral safety disconnects
- Manufacturer warranty, which is typically 5-10 years
- Maximum Power Point Tracking (MPPT) capability, which maximizes power output
- Most grid-connected inverters can be installed outdoors, while most off-grid inverters are not weatherproof. There are essentially two types of grid-interactive inverters: those designed for use with batteries and those designed for a system without batteries.

Power Quality – Inverters for grid-connected systems produce better than utility-quality power. For grid-connection, the inverter must have the words "Utility-Interactive" printed directly on the listing label.

Voltage Input – The inverter's DC voltage input window must match the nominal voltage of the solar array, usually 235V to 600V for systems without batteries and 12, 24 or 48 volts for battery-based systems. 95 % or higher, and they feature a relatively low unit cost per watt. However, central inverters have multiple drawbacks.

This main disadvantage of this topology is the involvement of high voltage DC cable from the strings to the inverter and losses in string diodes. This structure is also limited from Maximum Power Point (MPP) Tracking and controlling.

This topology is not flexible and this makes it less appealing in mass production. With all these issues, this technology is not used in new solar PV systems installation. Central inverters cannot monitor the performance of individual PV modules, so damaged or otherwise compromised modules often go undetected. Finally, central inverters limit the design and site selection of PV systems, particularly in residential applications. They require co-planar module layouts and a lack of partial shading from chimneys, trees, vent pipes, etc. PV installers may opt out of half or more of potential sites due to these restrictions.

The conversion efficiency of many central inverters is 95 % or higher, and they feature a relatively low unit cost per watt. Generally for high voltage PV systems central inverters are preferred mainly because for systems ranging from 5 kW to 1 MW, incentives are provided by government agencies. Certain centralized inverters uses common MPPT and IGBT based topology for enhancing power quality. In some power plants, central inverters were arranged in master slave configurations in order to use the most efficient combination of inverters according to total PV array output. Presently central inverters can be installed along with the DC-DC Optimizers. DC-DC optimizers supplement a central inverter with individual DC-DC converters installed for each PV module . DC-DC optimizers can be wired serially in strings and also it can be wired in parallel. The central inverter still converts the combined DC output from across the array to grid-compatible AC power, but the DC-DC optimizers perform MPPT at the module level. This allows each module to produce its full output without being held back by any under-performing modules in the array. DC-DC optimizers also permit module-level communications and performance monitoring. However, DC-DC optimizers retain a key disadvantage of central inverters–a failure of the central inverter still results in a complete loss of system output. Furthermore, some DC-DC optimizer systems also require a separate command-and-control device to operate, creating one more point of potential system failure in addition to the central

inverter. With additional equipment to purchase and install, DC-DC optimizers add to the initial cost of a PV system. The added module-level hardware also imposes a penalty on overall system-level efficiency by introducing an additional stage of loss power conversion

3.3.8 AC Power Output

Grid-connected systems are sized according to the power output of the PV array, rather than the load requirements of the building. This is because any power requirements above what a grid-connected PV system can provide is automatically drawn from the grid.

3.3.9 Surge Capacity

The starting surge of equipment such as motors is not consideration in sizing grid-connected inverters. When starting, a motor may draw as much as seven times its rated wattage. For grid-connected systems, this start-up surge is automatically drawn from the grid.

3.3.10 Frequency and Voltage Regulation

Better quality inverters will produce near constant output voltage and frequency.

3.3.11 Efficiency

Modern inverters commonly used in residential and small commercial systems have peak efficiencies of 92 percent to 94 percent, as rated by their manufacturers. Actual field conditions usually result in overall efficiencies of about 88 percent to 92 percent. Inverters for battery-based systems have slightly lower efficiencies.

3.3.12 Integral Safety Disconnects

The AC disconnect in most inverter models may not meet requirements of the electric utility (see section “Disconnects”). Therefore, a separate exterior AC disconnect may be required even if one is included in the inverter. All inverters that are UL listed for grid-connection include both DC disconnects (PV input) and AC disconnects (inverter output). In better inverters, the inverter section can be removed separately from the DC and AC disconnects, facilitating repair.

3.3.13 Maximum Power Point Tracking (MPPT)

Modern non-battery based inverters include maximum power point tracking. MPPT automatically adjusts system voltage such that the PV array operates at its maximum power point. For battery-based systems, this feature has recently been incorporated into better charge controllers.

3.3.14 Inverter-Chargers

For battery-based systems, inverters are available with a factory-integrated charge controller, referred to as inverter-chargers. Be sure to select an inverter-charger that is rated for grid-connection, however. In the event of a grid power outage, use of an inverter-charger that is not set up for grid-connection would result in overcharging and damaging the batteries, known as "cooking the batteries."

3.3.15 Automatic Load Shedding

For battery-based systems, the inverter can automatically shed any unnecessary loads in the event of a utility power outage. Solar loads, i.e. the loads that will be kept powered up during the outage, are connected to a separate electrical sub-panel. A battery-based system must be designed to power these critical loads.

3.3.16 Disconnects

Automatic and manual safety disconnects protect the wiring and components from power surges and other equipment malfunctions. They also ensure the system can be safely shut down and system components can be removed for maintenance and repair. For grid-connected systems, safety disconnects ensure that the generating equipment is isolated from the grid, which is important for the safety of utility personnel. In general, a disconnect is needed for each source of power or energy storage device in the system.

For each of the functions listed below, it is not always necessary to provide a separate disconnect. For example, if an inverter is located outdoors, a single DC disconnect can serve the function of both the array DC disconnect and the inverter DC disconnect. Before omitting a separate disconnect, however, consider if this will ever result in an unsafe condition when performing maintenance on any component. Also consider the convenience of the disconnect's location. An inconveniently located disconnect may lead to the tendency to leave the power on during maintenance, resulting in a safety hazard.

Array DC Disconnect – The array DC disconnect, also called the PV disconnect, is used to safely interrupt the flow of electricity from the PV array for maintenance or troubleshooting. The array DC disconnect may also have integrated circuit breakers or fuses to protect against power surges.

Inverter DC Disconnect – Along with the inverter AC disconnect, the inverter DC disconnect is used to safely disconnect the inverter from the rest of the system. In many cases, the inverter DC disconnect will also serve as the array DC disconnect.

Inverter AC Disconnect – The inverter AC disconnect disconnects the PV system from both the building's electrical wiring and the grid. Frequently, the AC disconnect is installed inside the building's main electrical panel. However, if the inverter is not located near the electrical panel, an additional AC disconnect should be installed near the inverter.

Exterior AC Disconnect

Utilities commonly require an exterior AC disconnect that is lockable, has visible blades and is mounted next to the utility meter so that it is accessible to utility personnel. An AC disconnect located inside the electrical panel or integral to the inverter would not satisfy these requirements. One alternative that is as acceptable to some utilities as an accessible AC disconnect is the removal of the meter itself, but this is not the norm. Prior to purchasing equipment, consult the electric utility to determine their requirements for interconnection.

Battery DC Disconnect – In a battery-based system, the battery DC disconnect is used to safely disconnect the battery bank from the rest of the system.

3.3.17 Battery Bank

Batteries store direct current electrical energy for later use. This energy storage comes at a cost, however, since batteries reduce the efficiency and output of the PV system, typically by about 10 percent for lead-acid batteries. Batteries also increase the complexity and cost of the system.

3.3.18 Charge Controller

A charge controller, sometimes referred to as a photovoltaic controller or battery charger, is only necessary in systems with battery back-up. The primary function of a charge controller is to prevent overcharging of the batteries. Most also include a low-voltage disconnect that prevents over-discharging batteries. In addition, charge controllers prevent charge from draining back to solar modules at night. Some modern charge controllers incorporate maximum power point tracking, which optimizes the PV array's output, increasing the energy it produces

Types of Charge Controllers – There are essentially two types of controllers: shunt and series. A shunt controller bypasses current around fully charged batteries and through a power transistor or resistance heater where excess power is converted into heat. Shunt controllers are simple and inexpensive, but are only designed for very small systems.

Series controllers stop the flow of current by opening the circuit between the battery and the PV array. Series controllers may be single-stage or pulse type. Single-stage controllers are small and inexpensive and have a greater load-handling capacity than shunt-type controllers. Pulse controllers and a type of shunt controller referred to as a multi-stage controller (e.g., three-stage controller) have routines that optimize battery charging rates to extend battery life.

Most charge controllers are now three-stage controllers. These chargers have dramatically improved battery life.

Selection – Charge controllers are selected based on:

- PV array voltage – The controller's DC voltage input must match the nominal voltage of the solar array.
- PV array current – The controller must be sized to handle the maximum current produced by the PV array.

Interaction with Inverter – Since the majority of charge controllers have been installed in off-grid systems, their default settings may not be appropriate for a grid-connected system. The charge controller must be set up such that it does not interfere with the proper operation of the inverter. In particular, the controller must be set up such that charging the batteries from the

PV array takes precedence over charging from the grid.

Interaction with Batteries – The charge controller must be selected to deliver the charging current appropriate for the type of batteries used in the system.

3.3.19 PV Module Performance Measurements

Peak watt rating is a key performance measurement of PV module. The peak watt (W_p) rating is determined by measuring the maximum power of a PV module under laboratory Standard Test Conditions (STC). These conditions related to the maxi-mum power of the PV module are not practical. Hence, researchers must use the NOCT (Nominal Operating Cell Temperature) rating. In reality, either of the methods is designed to indicate the performance of a solar module under realistic operating conditions.

Another method is to consider the whole day rather than "peak" sunshine hours and it is based on some of the factors like light levels, ambient temperature, and air mass and also based on a particular application.

Solar arrays can provide specific amount of electricity under certain conditions.

In order to determine array performance, following factors to be considered: (i) characterization of solar cell electrical performance (ii) degradation factors related to array design (iii) assembly, conversion of environmental considerations into solar cell operating temperatures and (iv) array power output capability. The following performance criteria determines the amount of PV output.

Power Output Power output is represented in watts and it is the power available at the charge controller/regulator specified either as peak power or average power produced during one day.

Energy Output Energy Output indicates the amount of energy produced during a certain period of time and it is represented in Wh/m^2.

Conversion Efficiency It is defined as energy output from array to the energy input from sun. It is also referred as power efficiency and it is equal to power output from array to the power input from sun. Power is typically given in units of watts (W), and energy is typical in units of watt-hours (Wh).

To ensure the consistency, safety and quality of Solar PV system components and to increase consumer confidence in system performance IEEE, Underwriters Laboratories (UL), International Electrotechnical Commission (IEC), AM0 Spec- Push Pull converter system overview converter . As seen in the basic schematic of the converter in the secondary side is not isolated. As the input is a solar panel and that the output is dependent on the function of the converter, the rectifying diodes protects the solar panel from battery voltage. The battery will have addi-tional protection, therefore isolation is not needed in this application. Thereby the secondary voltage is put on top of the panel voltage, saving some turns on the transformer, getting higher efficiency. Fig 3.2 represent basic schematic of the converter [11]

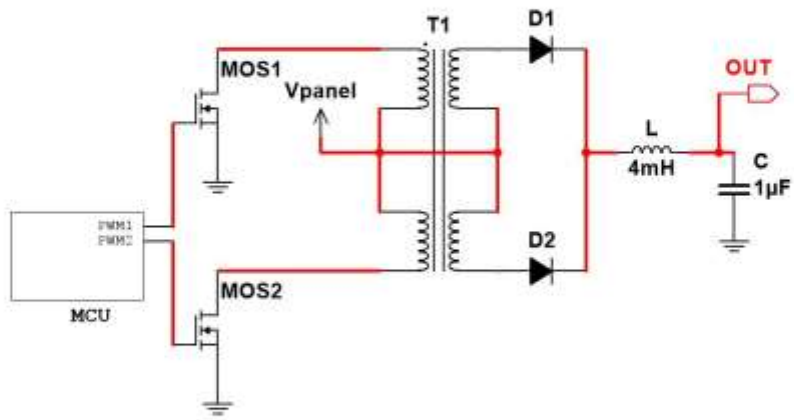


Figure3.2: Basic schematic of the converter.

When the controller "MCU" switches the transistors "MOS1" and "MOS2" alter-nately, the transformer "T1" will have the current from the solar panel going in alternating directions. Due to the alternating current, alternating flux is gener-ated through the transformer core. This transforms the voltage to the secondary side, where the diodes "D1" and "D2" rectify the transformed voltage and L and C filter it. "OUT" is connected to the load. The load is the battery. As the secondary side center tap is connected to panel voltage, it can be seen as a series circuit where output voltage equals transformed voltage plus panel voltage. Current in

secondary side is drawn from panel current and thus making current through transistors to decrease with the output current.

3.3.20 Transforme

To convert ac voltage up or down, a transformer is used. The relation between number of turns, voltage and current, between the two sides of the transformer where subindices 1 and 2 stands for primary and secondary side, N is number of turns, U is voltage and I is current of each side

All real transformers are non-ideal and have for example a leakage inductance due to the fact that some of the flux escapes the core and goes through the air. This leakage inductance is dependent on core shape, winding method, type of wire and more [6]. the leakage inductance becomes an unwanted parasitic induc-tor that does not interact with the rest of the transformer.

Secondary side - The secondary side of the transformer is rectified with two diodes and filtered with a LC-filter. Because of impedance transformation, an inductor is placed be-fore the output filter capacitor not to have a highly capacitive load on the transis-tors, as that would create high current peaks.

3.3.21 Oscillations

Parasitic inductive and capacitive elements create resonance circuits. This can create oscillations, for example when switching of the current to an inductor.

The derivative of the current. Because of this a high voltage will be built up over the switch when switched of due to the current inertia of the inductor, possibly leading to failure.

CHAPTER FOUR
APPLICATION

4.1. Introduction

Solar PV is used primarily for grid-connected electricity to operate residential appliances, commercial equipment, lighting and air conditioning for all types of buildings. Through stand-alone systems and the use of batteries, it is also well suited for remote regions where there is no electricity source. Solar PV panels can be ground mounted, installed on building rooftops or designed into building materials at the point of manufacturing. This chapter discussed the solar PV array, batteries, charge controllers, inverters, power conditioning unit and MPPT techniques along with their MATLAB/SIMULINK modules. [9]

4.2 Powering the system

The logic and transistor power can be drawn from the solar panel or from the battery. If the solar panel is the source of power to the logic, the system will not be able to take commands when the sun is out, but will not drain the battery without solar power. The transistors can be powered from the battery, but this creates extra expensive hardware, as the voltage must be converted down from up to 450 V to about 20 V or the maximum voltage of the transistor. Driving the system from the battery is important if the system must be installed during night time or when testing the communication without large solar panels, which eases service. There is however no requirement to be able to install the system without sun power at the moment and the solution with driving the logics and transistors from the solar panels is more cost efective.

4.2.1 Power loss

The power loss is divided into several different parts. The most significant includes transistor switching loss, transistor conduction loss.

4.2.2 Internal converter losses

The components in the converter need different voltages. Therefore two smaller step down converters (5 V and 15 V, respectively) are connected to the input

Power of equipment for bookshop:

- Freon air condition 1000w
- Photocopier500w
- lamp 50w
- electric socket1000w
- fan 250w
- fan celing120w

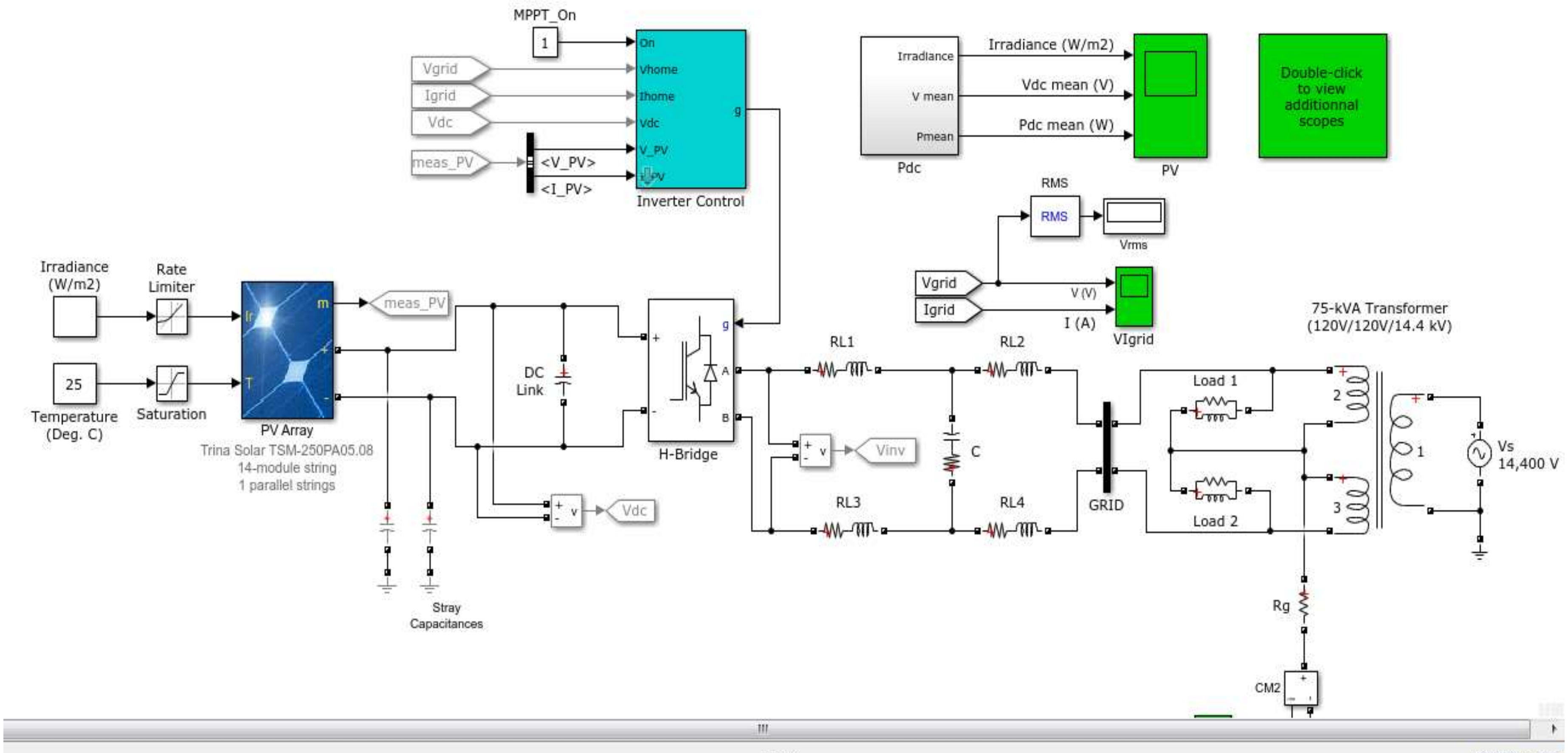


Figure 4.1 : The block parameters used in this SIMULINK implementation

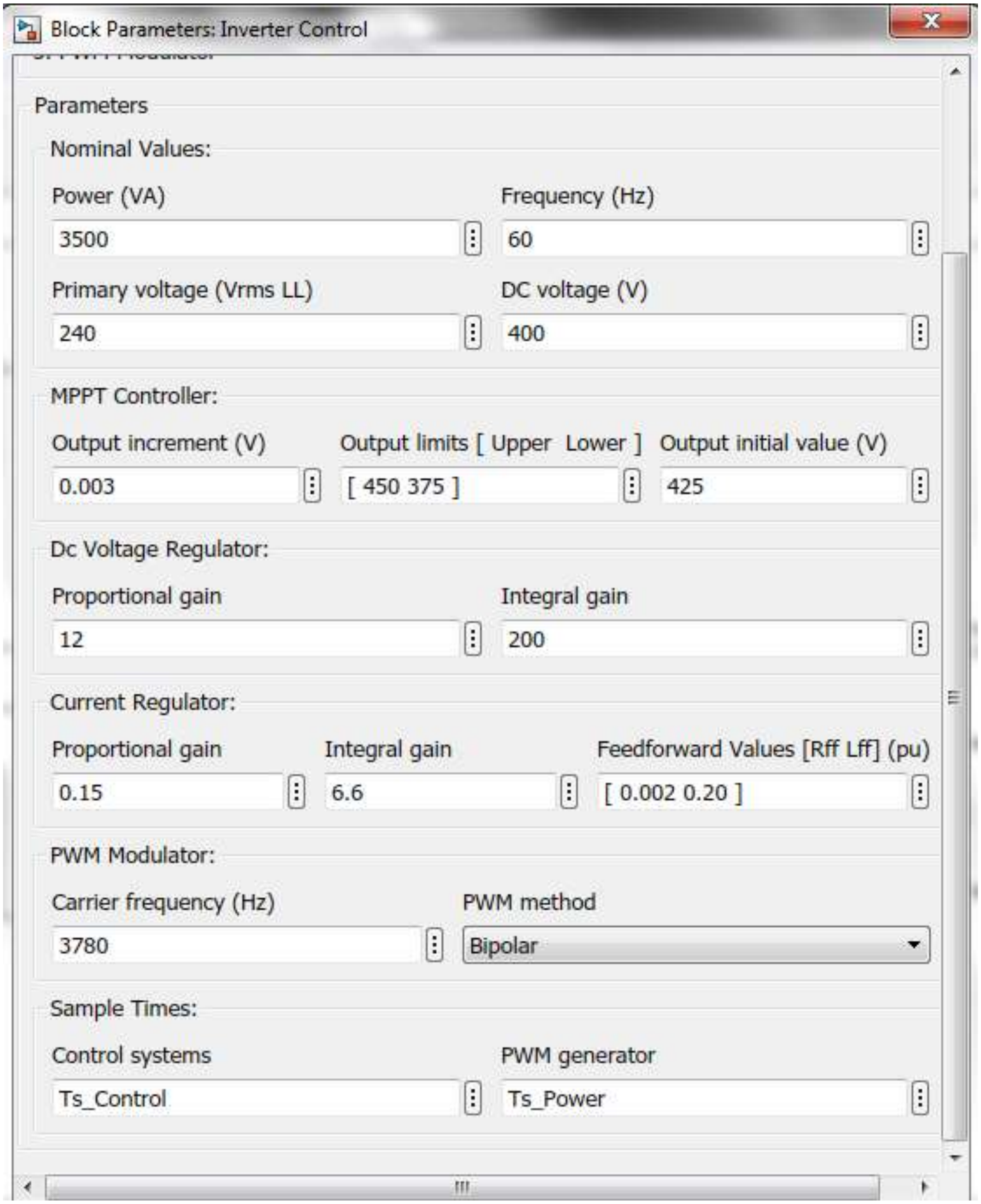


Figure 4.2 inverter control

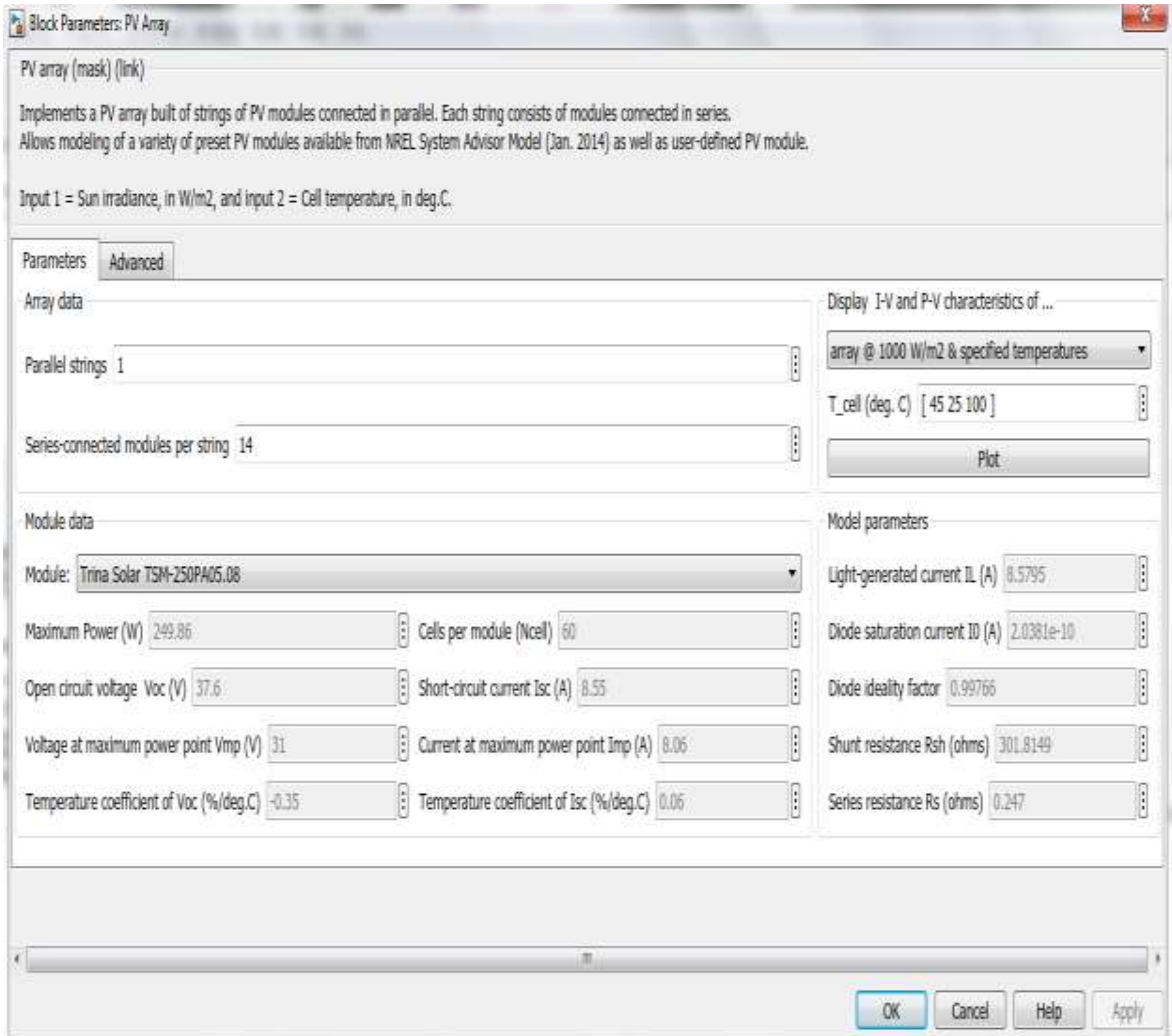


Figure 4.3 block parameter of pv array

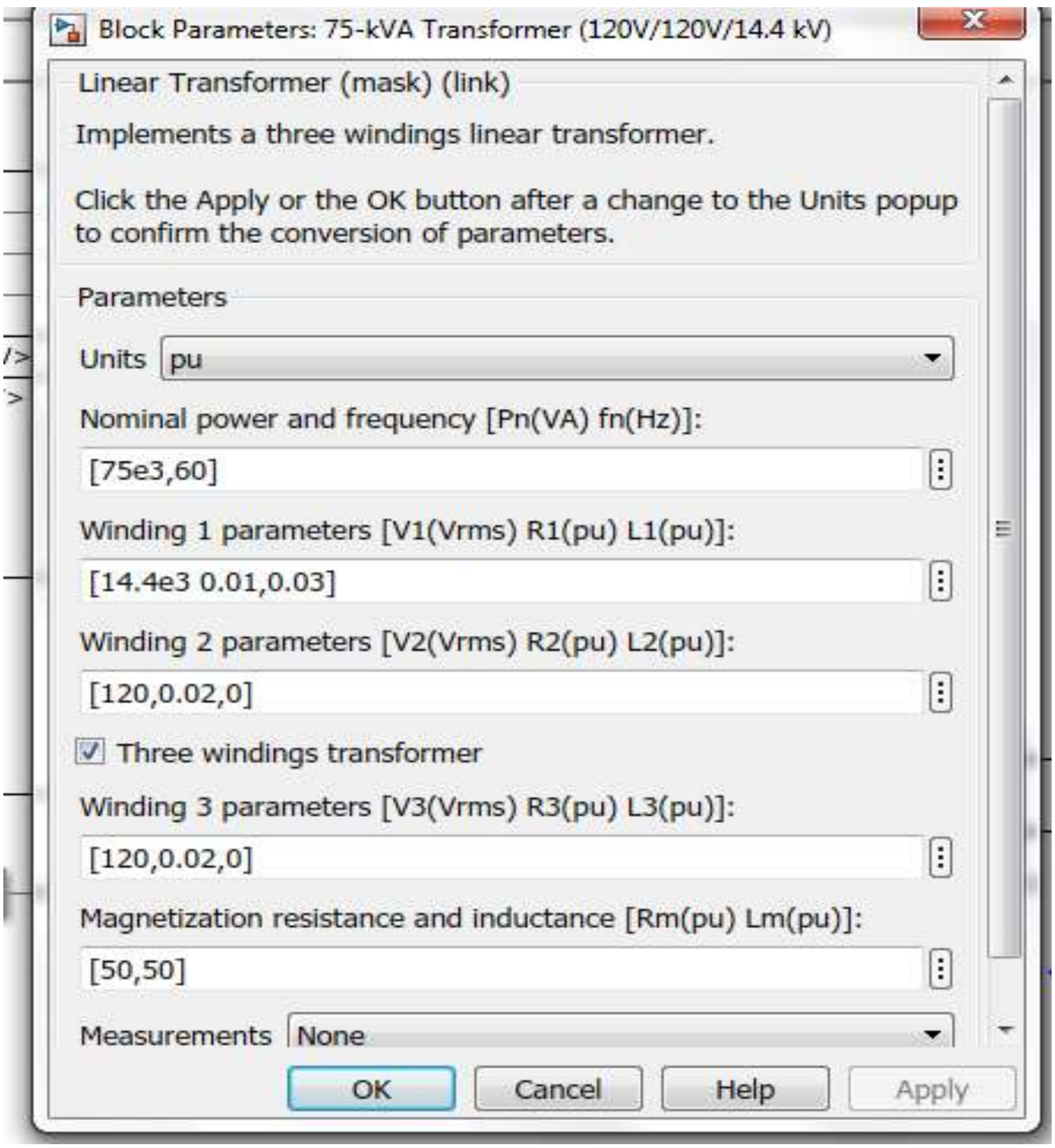


Figure 4.4 Block parameter of transformer

4.3 Comparison between P&O and INC MPPT Algorithms

The P&O and INC MPPT algorithms are simulated and compared using the same atmospheric conditions. When atmospheric conditions are constant or change slowly, the P&O MPPT oscillates close to MPP but in case of rapidly varying atmospheric condition P&O MPPT method is not effective but INC MPPT method finds the MPP accurately at rapidly changing atmospheric conditions also. Comparisons between the two algorithms for various parameters are given in table1:

G		Theoretical output of SPV array			SPV array output using P&O			SPV array output using INC		
		Voltage (Volts)	Current (Amps)	Power (Watts)	Voltage (Volts)	Current (Amps)	Power (Watts)	Voltage (Volts)	Current (Amps)	Power (Watts)
250	25	42.39	0.70	29.50	100.88	0.29	29.5	84.78	0.35	29.53
400	25	43.66	0.72	31.35	101.06	0.31	31.35	89.15	0.38	34.06
700	25	44.58	0.81	36.20	105.94	0.34	36.20	86.66	0.44	38.29
1000	25	45.10	0.96	43.18	107.73	0.40	43.29	90.42	0.53	47.39
800	30	44.12	0.90	39.87	103.95	0.38	39.79	86.95	0.45	39.07
600	35	42.50	0.87	37.65	100.72	0.37	37.65	85.32	0.44	37.86
700	50	40.50	0.70	28.27	96.34	0.29	28.27	81.10	0.36	28.91
800	50	40.80	0.70	28.55	97.20	0.29	28.55	81.62	0.36	29.03
900	50	41.10	0.70	28.65	97.78	0.29	28.69	82.18	0.35	29.09

TABLE 1. Comparison between P&O and INC MPPT algorithm

Discussion

- Basic components of Solar PV system and its merits and demerits.
- Involvement of power electronic devices in Solar PV components.
- MATLAB/SIMULINK model of different control strategies of power conditioning unit.
- Importance of MATLAB/SIMULINK model in improving the efficiency of the overall solar PV system.
- Characteristics of Solar PV panel and its MATLAB/SIMULINK model.
- Characteristics and MATLAB/SIMULINK model of Solar PV power conditioning unit.

MATLAB and Power electronics application ranges from power supplies to robotic controls, industrial automation, automotive, industrial drives, power quality, and renewable energy systems. In particular, before the installation of power plant, MATLAB finds applications in selecting the system based on the requirements and to choose particular components for the Solar PV application. This chapter is to explore the role and possibility of MATLAB along with its tool boxes in Solar PV Systems to promote Modeling ,and Simulation with emphasis on Analysis, and Design

CHAPTER FIVE
CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The importance of renewable form of energy increases with the increase in population as well as the style of living. Among the renewable sources of energy, solar photovoltaic has proved to be promising because of its easy and efficient way of energy production. Sun is a huge source of solar energy and it is time that we utilize it to the maximum level. Though this form of energy is very easy to generate but at the same time its efficiency is very less due to many reasons. One of the confusions or dilemmas that engineers face is the tilt angle of the panels, whether to keep it fixed or to vary it according to the season[1]. The advantage with the latter is that if the panel follows the sun, it can collect all the energy and hence give high energy output. But at the same time the equipments used to track the sun are so expensive that even after the increase in efficiency.

Solar PV is used primarily for grid-connected electricity to operate residential appliances, commercial equipment, lighting and air conditioning for all types of buildings. Through stand-alone systems and the use of batteries, it is also well suited for remote regions where there is no electricity source. Solar PV panels can be ground mounted, installed on building rooftops or designed into building materials at the point of manufacturing. This chapter discussed the solar PV array, batteries, charge controllers, inverters, power conditioning unit and MPPT techniques along with their MATLAB/SIMULINK modules. The future will see everyday objects such as clothing, the rooftops of cars and even roads themselves turned into power-generating solar collectors.

5.2 Recommendation

The future will see everyday objects such as clothing, the rooftops of cars and even roads themselves turned into power-generating solar collectors, we recommmend the next generation to do more research about the pv solar to make it less cost and available to everybody

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