بسم الله الرحمن الرحيم

A Review work on Renewable Energy MPPT Solar Energy Cell

A DISSERTATION SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR DEGREE OF BACHELOR OF SCIENCE IN ELECTRICAL & ELECTRONICS ENGINEERING

PREPARED BY:

MAHER KALIL (160021170)

ALI FAQEEH (160021176)

ABDELRAHMAN Z. S. ABUHAIBA (160021177)

Department of Electrical and Electronic Engineering

Islamic University of Technology (IUT)

Board Bazar, Gazipur

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Declaration

This is to certify that this thesis paper is a review work on Study of Renewable Energy Based on Solar Energy Cell. To facilitate our learning, in few places we took directions from other researcher's work available online citing diligently in the bibliography section. The outcome of the research is done by us and neither of this thesis nor has any part thereof been submitted in other place else for the award of any degree or diploma or for any publication.

AUTHORS

Signature(s)

Maher Kalil
Student ID: 160021170

Ali Faqeeh
Student ID: 160021176

Abdelrahman Z. S. Abuhaiba
Student ID: 160021177

Project advisor

Approved by

Safayat Bin Hakim

Assistant Professor

Department of EEE, IUT

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ABSTRACT

As Photovoltaic solar (PV) capacity has become an increasingly important part of clean power in the future. For the direct detection of electricity from a solar Power system, this study explores the production and transfer of solar Photovoltaic power through systems to power grid. Firstly, this dissertation will focus on the Current–Volte and Power–Volt functionality that is from Photovoltaic cells, particularly it is sorted a part from uneven, and its counted that the two physical and electrical dynamics, the photovoltaic system in the improvement of that model. The thesis explores ways of various diode configurations can influence the peak energy extract characteristic related to a photovoltaic module. After, that to establish a professional technique to the extract in an efficient way of energy to do this for a photovoltaic system, this study explores the traditional control techniques for most power point monitoring (MPPT) will be applied photovoltaic industry. Our research pointed to particularly how traditional and modern MPPT tech operate under highly fluctuating weather conditions in a digital system. Using Mat Lab Simulation Power Systems and Opal-RT, a computational experiment method is built for rapid and precise investigation on extraction of maximum power in this system. A physical experiment framework that has been designed to compare and test traditional and modern MPPT approaches by a realistic way. Benefit and drawbacks of various MPPT strategies was analyzed and assessed.

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Chapter 1

Background Study

Solar Cells

A solar cell or the other name is photovoltaic cell is a eukaryon that is developed which supply power from sun by the means of the photovoltaic effect. The cells will be connected together to form a [CITATION 1 \l 1033]power generator, also recognized as a photovoltaic panel, to provide a sufficient supply of accessible electricity. Generally the solar panels are used standalone or in a class of array and the output voltage (nominal) is 12 volts. The amount of light available and the amount of energy needed would dictate the number and size of cells required.

Solar electric panel

Solar PV efficient? And inexpensive? How is it possible! While still providing energy as a friendly source. Understanding how solar energy work is good point to start, the way the solar panels are invented and parts manufactured. The majority of panels on the market are made of monocrystalline, polycrystalline, or thin film ("amorphous") silicon [2].

Types of solar panels

1. Mono
2. Poly
3. Thin film

How are solar panels made?

The unique way solar photovoltaics are made with applying a different types of layers, the Caribbean the one of the famous places that manufacture the solar pales. The component which helps make it work, is silicon or sand which come from rocks found in a quarry, it's out of the quarry into the fire. The first stage is to get the silicon and the rocks (that will be done in enormous furnace) where the temperature reach well over 2,000 degrees Celsius, a huge barrels will care it around the factory. In this form it is liquid molten silicon, for any additives need to be applied to the solar panels.

The oil will have the state of crystallized which occurs in the cooling machine, within this stage the silicon is so hot and the oil could melt right through it, by the time puffins have made a solution, to pump cold water around it as it works which will allow it to act as watery air-conditioning, the extra heated crystallized silicon It comes from the unit, if you are imagining how this will harness energy form the sun, thin slices of silicon which have two unique layers in them, they are created using two chemical processes which effect the silicon at different times during production for stage one where the first chemical is added it will help make the silicon more conductive together, after furnace is complete it will be open and the silicon block emerges. It's turn now to be slash into size. Cutting solid crystal is another process it can be very dangerous so a protective shield is raised to keep safety for the staff who is manufacturing the panels, diamond tip blades then slice through it cutting individual panel sized columns ready for the next stage, is to cut them more to be fit in apposition that will allow Spinning wires that slowly cut into each column would leave behind a thin layer of silicone crystals that is suitable for solar panels, the slices will be washed by hand because they are delicate and delicate. The newly sliced slices must be carefully cleaned before they can be processed with the second chemical to be treated.

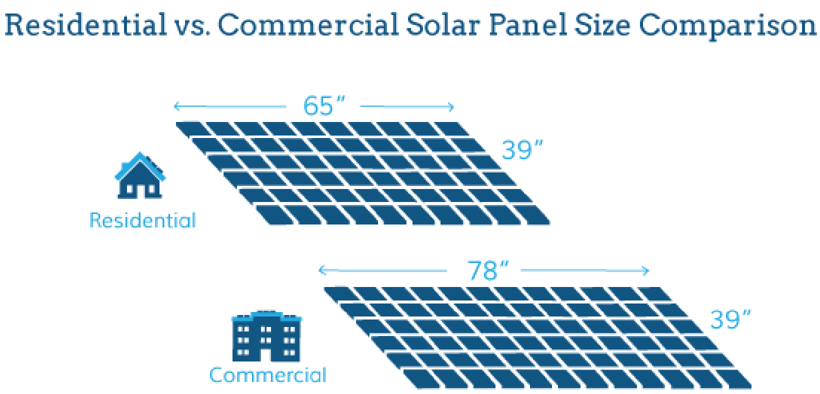


Fig. 1.0 Image of typical solar panel [15]

Storing of Power

When solar panel produces the most electrical energy by the amount of light falling on them, it will be at the morning when the sun is shining in the sky, but in night there is no any source of sun so that the panels will not be able to work, for this issue we have the batteries, that is the solution when the battery is connected to the circuit of PV panel though the system will store kinetic power in the batteries during day time “sun-light”, in our system the kind that is famous to use for storing of energy is the lead-acid battery. When night will arrive the store of power in batteries will be used by the consumers and they will benefit from it the, the way each one will see it serving his/her own demand. type and quantity of batteries it depend on the amount of energy will be storage.

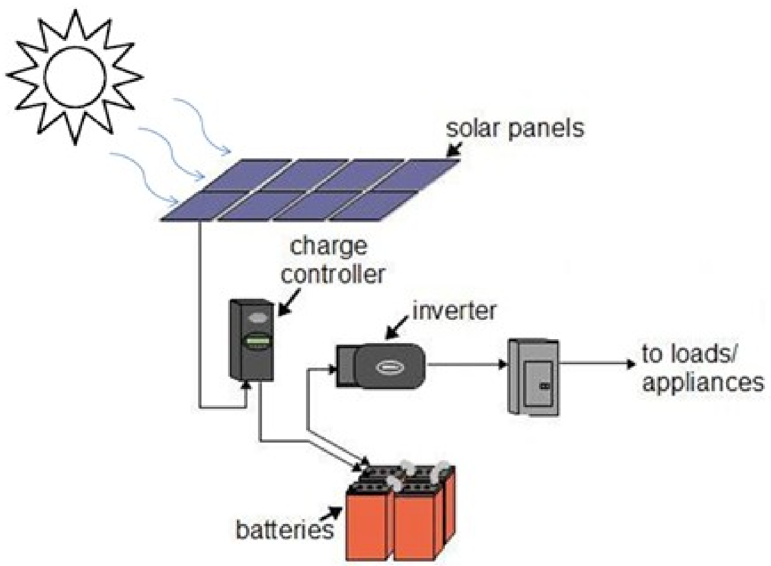


Fig.1.2 Solar panel storing power [13]

Solar Power Batteries

After sunset the batteries provide the house with electric power, in this way in this way solar power provides around 80 percent of a family homes annual electricity needs.

If solar power is both produced and consumed within households that reduces the amount of electricity that has to flow thorough the powerlines. This leads to improved network bandwidth, allowing way for more solar energies, and maybe in the future we will just turn on the sun when it gets dark.

We use photovoltaic modules, also known as solar cells, to transform sunlight directly into energy. These individuals will be attached to each other forming PV panels, which can be mounted on rooftops or [39] on large scale fields, transforming several acres to power cities. After the solar panels collect the energy in its electrical form it will store it in batteries, and the best type for this case is the lead-acid battery it is made up of individual cells; each cell in lead-acid battery [94] generates approximately two V - DC, so a twelve V battery requires 6 cells. It has the advantage of being exposed to inadequate charging during regular service, as we have in our solar system, where the insufficient charging is caused by the direction of the sun during the process. In addition, the lead-acid battery contain:

Cell of 2.1 V
Charge/discharge efficiency of 51–96%
Temperature: Min. −35 °C.
Power: 180 W/kg

They are sufficient and strong enough to use them in such a place and in this kind of work. Also they are used in power outage. Hospitals, etc.

Types of Solar Cells

In general the main types of solar cells [44] that we can use in a solar system for providing electrical power are:

a. Amorphous Solar Cells
b. Crystalline solar
c. Thin-film solar cell

Amorphous photovoltaic

Amorphous silicon (a-Si) is the non-crystalline form of silicon used for solar cells and thin-film transistors in LCDs [41].

Indoor solar cell thickness 1.1mm

Outdoor solar cell thickness 3.2mm.

Amorphous silicon (a-Si solar cell) are [42] deceives that convert light energy into electrical energy through photoelectric effects. Amorphous silicon cells are solar cells made of amorphous silicon thin films deposited on conductive glass substrates. One layer of silicon on an amorphous solar cell can be as thin as 1 micrometer. Structure is having first layer of ordinart glass, that base on a-Si solar cell. Second layer is TCO that transport oxide conductive film. Formed by deposting 2 layers as substrates. Finally, back electrode and AI / Ag electrode. Efficiency of such a cell is high volume process, rage from 6% to 9%.

Advantages of Amorphous Silicon Solar Cell

As the amorphous silicon solar cell [43] is low cost of materials and manufacturing process it have other advantages as will.

Thickness of a-Si solar cell: less than 0.5um

Sturdiness of c-Si solar cell: 240-270um

The material is silane, which can be suppled in large quantities and the price is very cheap

Manufactured at a temperature of about 200^{o}C, so thin films can be deposited on glass. High light absorption coefficient 90% of the useful solar energy can be absorbed. The optimal band preferrable for mass production is 0.3-0.75 um, which is also termed as visible light band. In this range the production methods are characterized by high automation and high production efficiency. wide applications, due to the high absorption coefficient and low dark conductance, it is suitable for the production of micro-low-power power supplies for indoor use, such as watch batteries, wireless sensors, and calculator batteries etc .good high temperature performance, when the solar cell operating temperature is higher than the standard test temperature [44] of 25ºC; the temperature of amorphous silicon solar cell is much less affected than of crystalline silicon solar [45] cells. Good response to low light, the absorption coefficient of amorphous silicon material is in the entire visible light range ,and it has a good adaptation to low light intensity in practical use.

Disadvantages of Amorphous Silicon Solar Cell

Short life with stability problems & efficiency lower from that in crystalline silicon.

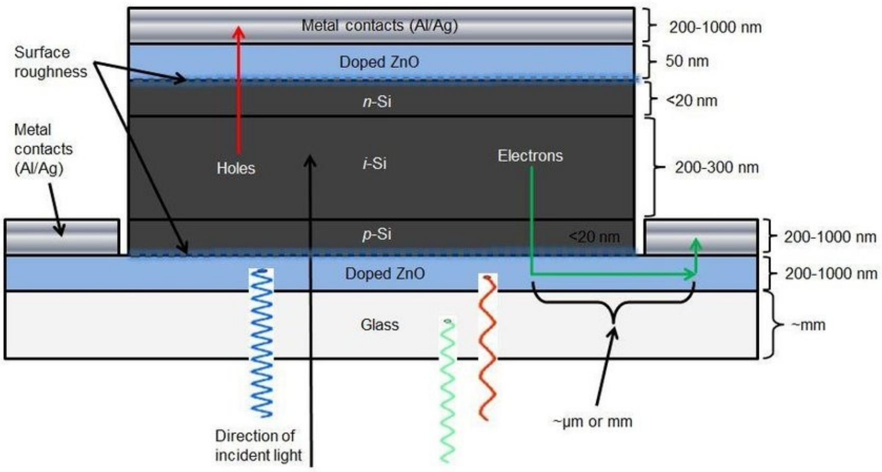


Fig 1.2 Amorphous Solar Cells [36]

Crystalline photovoltaic

For a single cell it will give an output voltage 0.5 and 0.6 V, 36 cells are used to produce an open-circuit voltage of about 20 Volts. It will be enough to charge a 12 V battery varying with several conditions [46]. Mono cells are made out of single ingot of silicon, cut out in wafers, whereas poly cells are made of multiple piece of silicon which are made melted together and cut into one wafer. Module look poly modules have a bluish tinge to them, mono modules are black in color, mono crystalline can be distinguished with the corner cut, and ploy solar panels are generally cheaper as compared to mono panels. Mono panels are more efficient, it means that it produces more power from the same size of panel performs better, mono crystalline panels perform better in low light situation, which means they may produce more power for a little bit longer duration each day during the dusk time. Heat tolerant ploy panel are less heat tolerant, which means the degradation of power they produce is more as temperature rises then mono. However of the bluish colour they absorb less heat, usually it won't affect much. How it will help! Is by choosing the right modules, prices and the available place.

Efficiency

While poly modules are little bit on the lower side when it comes to efficiency, their price is relative low as compared to mono

Capacity

However if you want to set up a higher capacity PV plant and you have less available space, then you should definitely go for mono modules

Returns

Despite being pricier, mono modules will give better returns in the longer run.

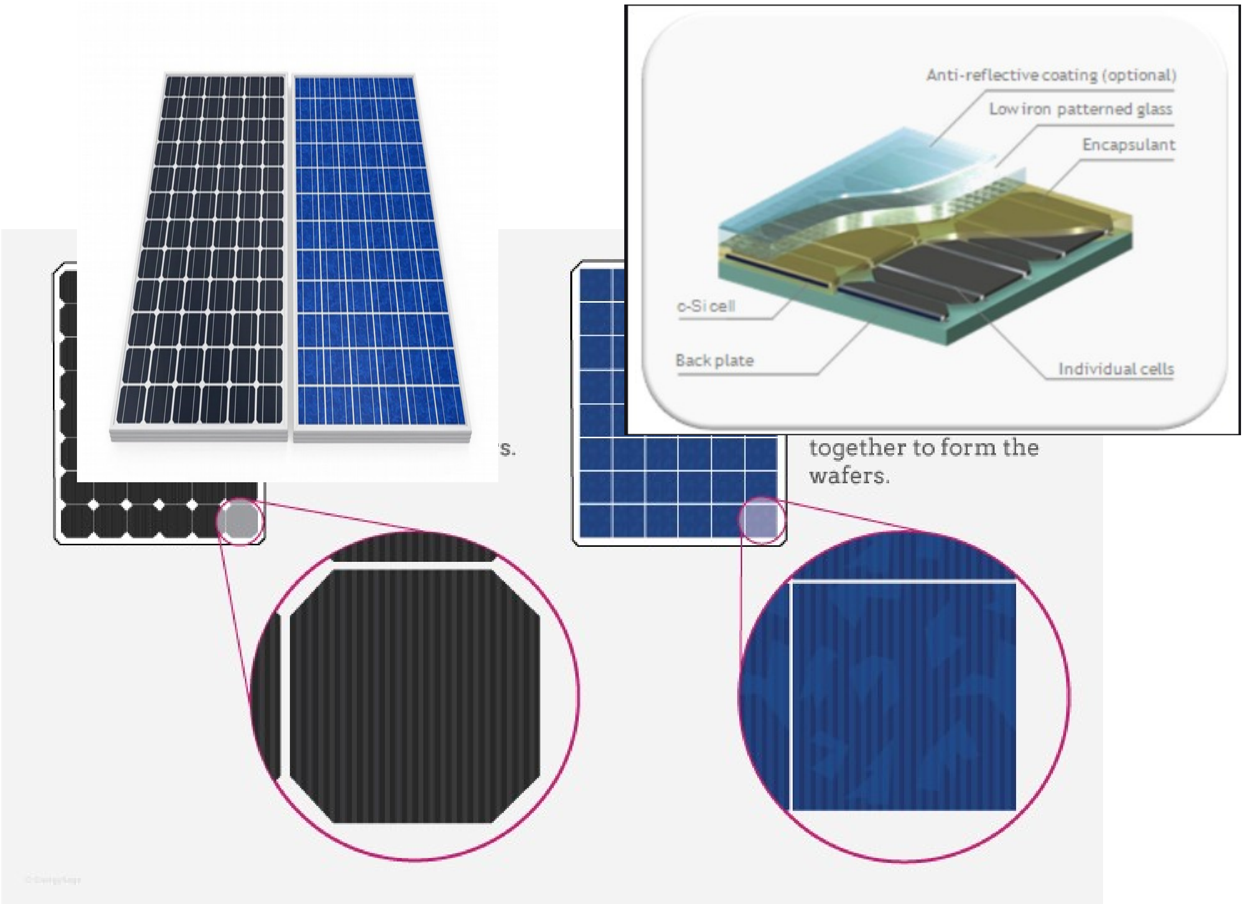


Fig 1.3 Crystalline Solar Cell [14]

ADVANTAGES OF SOLAR POWER

- Solar cells are noiseless.
  - Little maintenance that is required.
  - No moving pieces means less chance of damage.
- Thinking of having it's advantage strongly will comeback as an investment of electricity it will generate.
- Solar energy as sustainable green energy.
- Upon installation it's, electricity produced is free.
- Solar resources will last.
  - No emission is caused by solar energy.

DISADVANTAGES OF SOLAR POWER

The installation of photovoltaic panels may be costly, that have a good result, gap through the time by savings electricity costs by meeting current investments.

o Batteries may also be wide and bulky, having a room in addition they need to replace after some time.

The production of electricity relies solely on the exposure of countries to sunlight; this may be restricted by the atmosphere of countries.

PARY photovoltaic stations doesn't equal the out result that is be equivalent sizes of traditional power stations; they can also be very costly to install.

Environmental Impacts of photovoltaic

The entire world is concerned about the rising pollution due to the use of fossil fuels and the rapid warming of the [47] arctic region. We need to come up with technologies that can produce energy for us without damaging the earth's atmosphere. Photovoltaics are promising to lower greenhouse gas emission. However, after the lifecycle of a photovoltaic panel it is necessary to dump or recycle it without harming the environment.

Chapter 2

Battery Types

Batteries are used in a several places by the time battery it-self has evolved up to a stage that we are using it to run cars, trucks, drone and a lot of other thing as their power source.

Cycle life calculated by numbers of times battery is charged and discharged again that's how suitability is defined. One of the most popular kinds of lead-acid batteries are car batteries.

1. Lead Acid Batteries can produce significant amount of electrical energy that can be discharged very quickly if some kind of conductor is put across their terminals.
2. This type of batteries does contain sulphuric acid, which is corrosive in nature.
3. Aforementioned type batteries emit hydrogen when packed, which is volatile when combined with oxygen, which can be sparked by a small spark.

Figure 2.0 Battery Types. [16][17]

1. **Lead acid Batteries**

They are undesirable with our activities. When the applications are used in the solar system, the battery have to handle this type of work so it will be drained a lot of times. These type of batteries are a deep-cycle cell, here the various forms are rent dies are detailed below.

2. **Leisure batteries**

Or the other name is trailer batteries, typically they have a low cost kind of deep-cycle batteries. the Installation of the rental plate. Their output is usually between 60 and 120 Ah at 12 volts, the batteries are more appropriate for mine devices. Life cycle of leisure batteries is reduced by much numbers of cycles, which means the batteries are the best suited to the system.

3. **Traction Batteries**

Name of traction battery refers to the batteries that are find in fuel electric vehicles. What we relays that in this domain is this kind of batteries are found in mobility scooter to a fork-lift vehicle, but the capacity from thirty to forty Ampere-hour. Tiny cell is mostly 6 and 12 volts; large one is 2 V. This kind is suitable to the applications with high power. Expectation of completely released in addition to refueled on every day basis. Greater cells can be discharge thousands of times. Semi-traction batteries, are conceived by a relatively high recreation batteries with longer cycle span. Marine batteries fell under that same group as well.

Figure 2.1 Traction Batteries [18]

Sealed Batteries

Several varieties of thus batteries. Range 1 - 2 Ah up by reaching 100 Amp-hour singular traction batteries. The benefits of them, leak-proof and maintenance is not required. However, disadvantages; costly comparing to different forms of batteries, need more precise charging power and can have a shorter lifespan., There are several varieties, range is from one or two Ah to 100 Amp-hour single-cell traction batteries. The drawbacks of sealed batteries are readily apparent; they do not undergo degradation and are leak-proof. However, they may have drawbacks; they are more costly than other forms of batteries, need more precise charging power and could have a shorter lifespan;

Figure 2.2 Sealed Battery [19]

Charge Controllers

Many grid - connected solar energy require a charge controller. Intention will be guarantee battery will not be overcharged by redirecting the flow of energy away from it until it is fully powered. It is mostly sufficient to accomplish this without a controller if there is a tiny solar panel, like a battery saver, it charges large battery. Most charge controllers always seem to have a mechanism to disconnect the low-voltage, that doesn't allow it of ever be fully discharged. This is achieved by turning some DC equipment as the battery voltage is reduced critically low.

Fig 2.4: Controller Types.

Shows an image of controller to ensure that the battery never overcharges [20]

Controller Types

Charge regulator in this domain regulates volt that is equipped to run total power which can beard. Device volt normally twelve or twenty-four volts, or even forty-eight volts. Peak power measured by how many photovolatic cells are utilized and which scale do they have. Individual regarding will require a controller with a rating of between four to six Amps, but bigger clusters need a controller of forty Amps or more. Deci rental setting is required when the enclosed battery is used to avoid electrolyte loss by gasification. The sample controller shown is compatible with 8, 12, 20 and 30 Amp ratings and selects between 12 and 24 Volts automatically.

Working Principles

The theory behind solar charging control is basic. Indeed for the system circuit is to test the voltage of the battery whose triggers switch that will redirect electricity that is in the battery once the condition is completely charged. Since short or open-circuits does not affect photovoltaic panels, one technique of thuse can be used to stop the flowing of current to the batteries from hitting electricity. The device that brief the board is recognized as a shunt regulator. Alternately, we can find a switch that immediately charges or discharges electricity while the voltage of battery drops low in a dangerous level. It’s known as low voltage disconnected feature.

Chapter 3

Inverter for photovoltaic

We have seen many individuals utilizing solar inverters these days which implies that it is indeed

Requirement has risen in recent years. The power array near in structure to the usual electrical inverter, but using the sun energy, i.e. solar energy. Solar inverter assists by turning the [48] DC to AC form with the aid of solar power. DC is the type of energy that flows in one direction.

And inside module that allows to provide power this is when the electricity is gone. Direct currents will be used by a not a big number of appliances such as cell phones, Game consoles, and iPods, respectively. When power is composed of such a battery. In the field of alternate current, that is the force that flows back backwards and forwards within the circuit [49]. Alternative energy is commonly used for supplying electricity for the equipment of house. A solar inverter allows machines running on Dc voltage to operate as AC power so that the consumer uses AC power. If you're curious about whether to use a solar inverter instead of a standard electrical inverter, that's it. Since the solar takes such a use, it is accessible in abundance from sun and it's pure inanition it's free of emissions. Solar inverters are indeed referred to as photovoltaic solar inverters. This tools will save some cash so it can stay at your bank account. The limited grid has only two parts, i.e. inverters, when we find off grid network is complex involving of batteries that allow consumers using the equipment's during the night while Sunlight is not available. The panels and batteries are on the tops of buildings absorb the solar light and transform the sunlight into electrical energy. Batteries to pick up excess power it so it can be used to operate machines at evening.

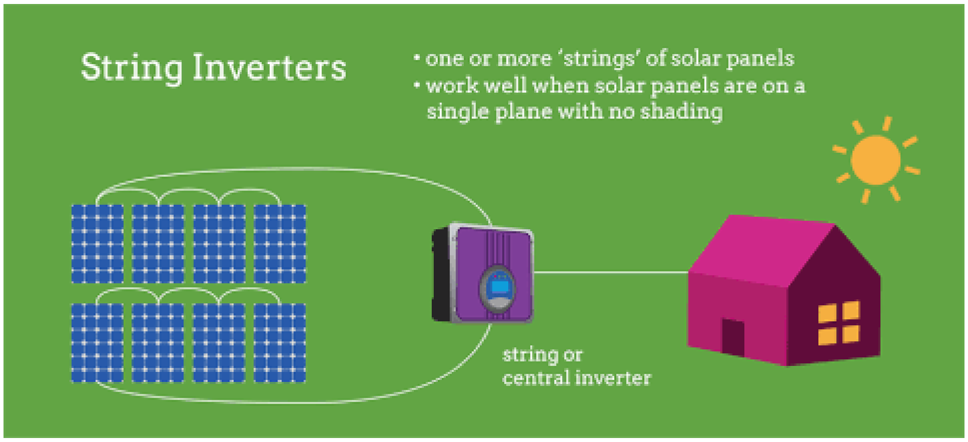


Fig.3.0 Solar Inverter [21]

Principle of Work of photovoltaic

Still, once we recognize how a solar inverter works, let us just present how it works. Solar panels generate direct energy with the assistance of electrons passing from ve (-) to ve (+) way [50]. Equipment's which used on alternate latest at living jobs. The whole AC is formed mostly by backward and forward from ve (-) to ve (+) of the electron movement. Voltage can be regulated anyhow to serve the application in AC electricity. Because solar panels contain DC current, use of photovoltaic inverter to transform direct-current to alternating current.

The inverter [51] emits square waves or a sine wave that is used to light the devises mostly used in home. Costly one's generate a sine waves in addition of use in living-places photovolatic inverters. Mainly, the inverters is good being big enough to provide the adequate power for the requisite lighting and machines.

The inverter seems to be purchase smoothly, it is far more essential to choose the correct photovoltaic inverter besides ones piece of equipment. Quite, prior to actually purchasing over, users also must consult a solar consultant. We understand which power produced by sunlight is photovoltaic power, it's among nicest way of producing power. Could also be used to supply light sources for residences.

Photovoltaic cells consist of ve (-) to ve (+) silicon, which mounted under glass pane. Sunlight protons strike the PV cells, hit neutrons that exist inside silicon. Still they retained within the magnetic field. This then provides room DC energy, to transfer it to alternative, the inverter in domain of allow household operate successfully. As we mentioned several times in our previous discussion, typical household appliances operate when AC current is supplied, therefore, an inverter is employed to convert DC to AC [52].

Users could even end up making us photovoltaic tiles which entice sun's energy and convert this into a clean production of electricity that can be used for lighting, housing, industry and business. Photovoltaic cells come in the form of ve (-) and ve (+) silicon, which positioned below a glass pane. Whenever Sunlight protons hit the Pv panels, they hit the neutrons throughout the silicon. Now that the negatively charge neutrons have been impressed to the silicon, but then they are [53] held within the magnetic field. This same wires affixed to the silicon stack up those other neutrons, and the current is formed when linked to a circuit. It then gave power for direct electricity and to convert it into an alternative.

Make a photovoltaic Inverter?

Sun-derived electricity is a green energy source that is absolutely free of cost. We've seen how the power array tends to provide power, and now we're going to figure out how to make a photovoltaic inverter. A photovoltaic array convers sun's heat or electricity into direct current.

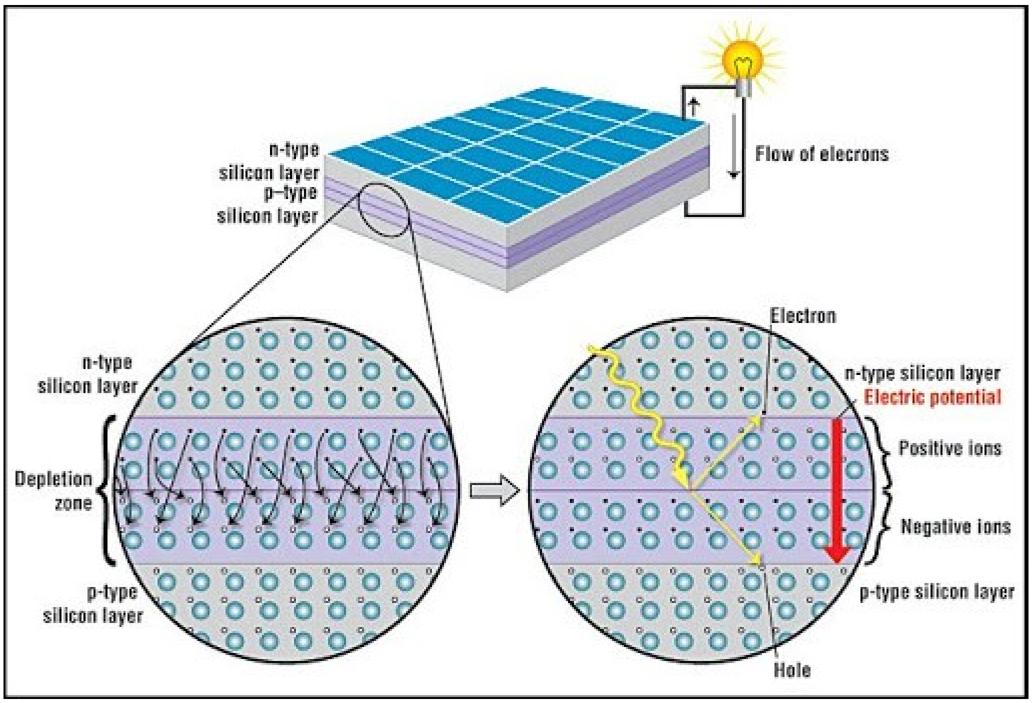


Fig.3.1 The solar panel transforms the Sun's heat or electricity into direct current. [22]

Designing a Solar Inverter

In order to explain the design of a solar inverter, let us address the following design sample:-

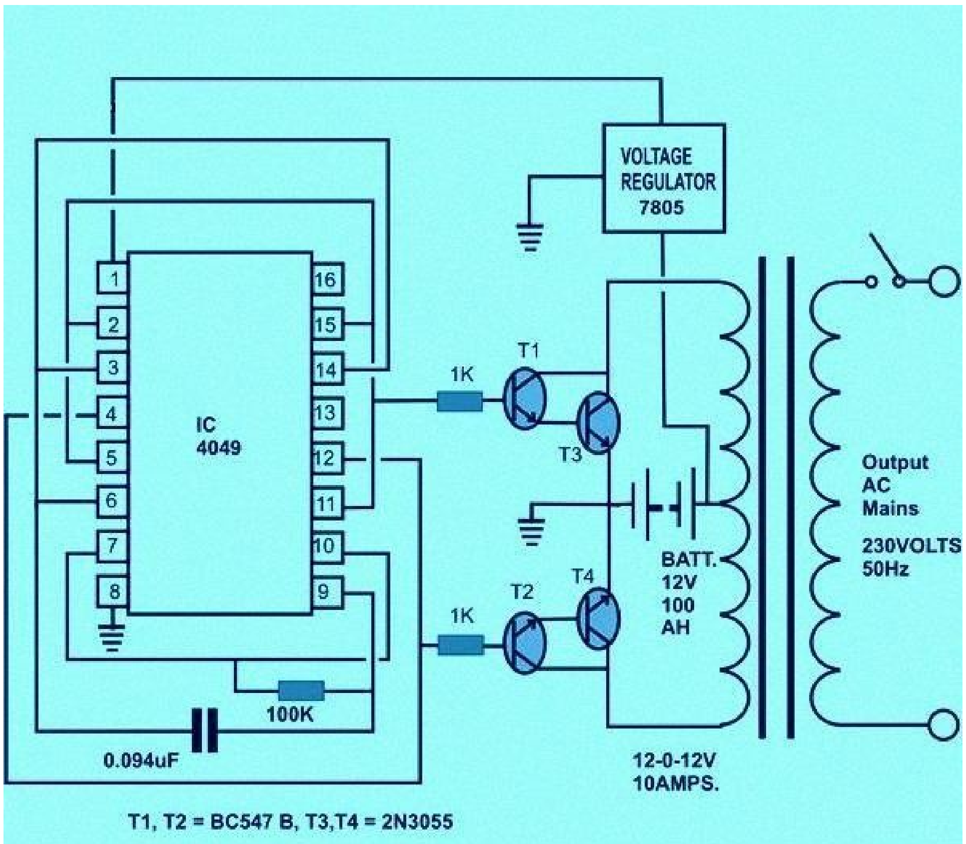


Fig.3.2 Making Solar Inverter [23]

1. Initially, as the reference is the diagram, the assembly of the oscillator portion consisting of tiny components and the IC is carried out. Finely done, the interlacing of the part leads itself and fuses the joints.

2. Now put the power transistors in the acutely penetrated aluminum heat sinks. This is done by slicing aluminum sheets into previously specific sizes and folding their corners such that they could be [54] held securely.

3. Attach the congregation of heat sink to ventilated, solid, metal gauge sealed space.

4. In addition, fasten the power transformer next to the aluminum heat sink by allowing use of the screws and bolts.

5. Now connect the necessary points of the assembled circuit board and power transistors to the aluminum heat sinks.

6. At last, link the output of the power transistor to the corresponding winding of the power transformer.

7. End the assembly by fastening and interlocking the exterior electrical fittings, such as [55] the switch the mains cable, the fuse, the connectors and the battery inputs.

Solar Inverter

Scheme:

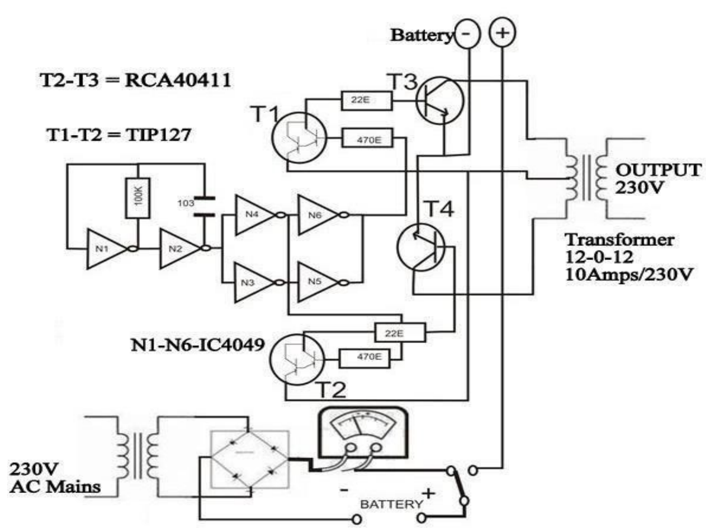


Fig.3.3 photovoltaic inverter scheme [24]

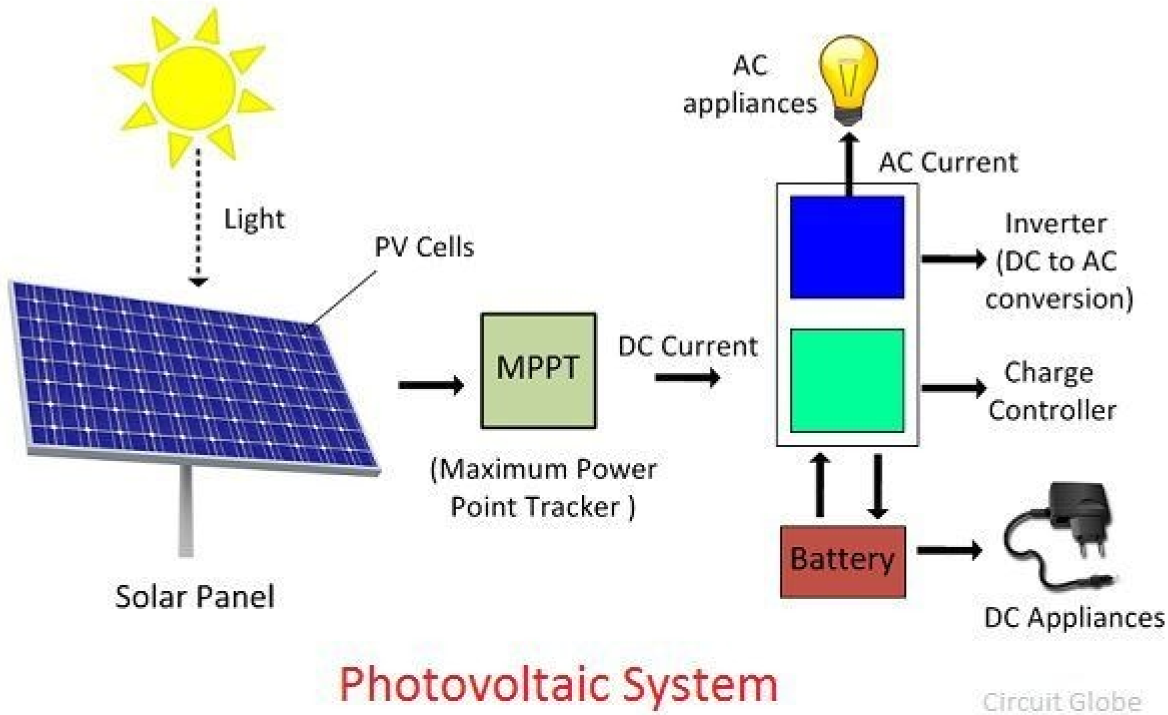


Fig.3.4 solar devices and the equipments of solar energy [37]

Chapter 4

Maximum Power Point Tracking (MPPT)

The earth is moving round the sun. On a sunny day, if we take a specific location the intensity of sunlight is not same on different time of the day [15]. It is high may be during the noon time. The solar panel generate its rated power when it is exposed to sunlight when it has highest intensity. Therefore, to have maximum efficiency it is necessary to [56] position the photovoltaic cells to a particular position where it will be able to harness the energy of the sunlight most.

MPPT Solar Charge Controllers

It is not technically recommended to plug-in the battery after it is fully charged. On some occasion it is recommended not to charge batteries if it is already 90% charged to evade carrier bloating. A charge controller can easily perform the job by controlling the charge into the battery

Model	ML2420	ML2430	ML2440
System voltage	12V/24V auto		
No-load loss	0.7W to 1.2W		
Battery voltage	9 to 35		
Max solar input voltage	100V (25°C), 90V (-25°C)		
Max power point voltage range	Battery voltage +2V to 75V		
Rated charging current	20A	30A	40A
Rated load current	20A		
Max capacitive load capacity	10 000uF		
Max photovoltaic system input power	260W / 12V 520W / 24V	400W/12V 800W/24V	550W/12V 1100W/24V
Conversion efficiency	≤ 98%		
MPPT trancking efficiency	> 99%		
Temperature compensation factor	-3.0mv/°C / 2V (default)		
Operating temperature	-35°C to +45°C		
Protection degree	IP32		
Weight	1.4 kg	2 kg	2 kg
Communication method	RS232		
Altitude	≤ 3000m		
Product dimensions	210*151*59.5 mm	238*173*72.5 mm	238*175*72.5 mm

Fig.4.0 Basic charge controller simply performs the necessary function of ensuring that your batteries cannot be damaged by over-charging [25]

and thus, preventing overcharging.

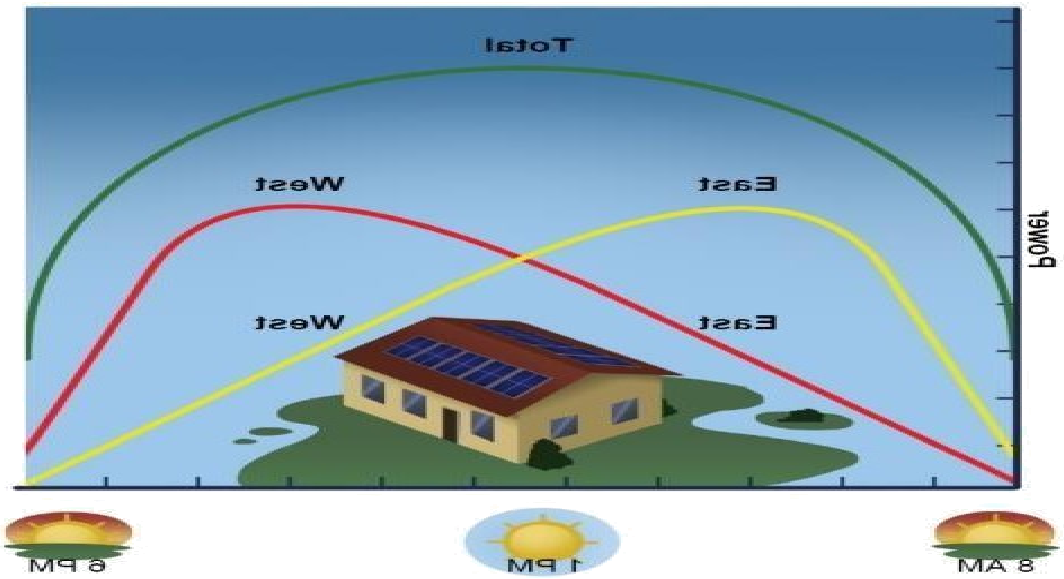


Fig.4.1 PV systems, all strings face the same way [26]

MPPT AND MONITORING

Single MPPT stream transfer tracking information to full array. If more than one the information selection is the total I\P of the array. The inverter will provide tracking information at the MPPT channel level [57] with separate dual MPPT channels.

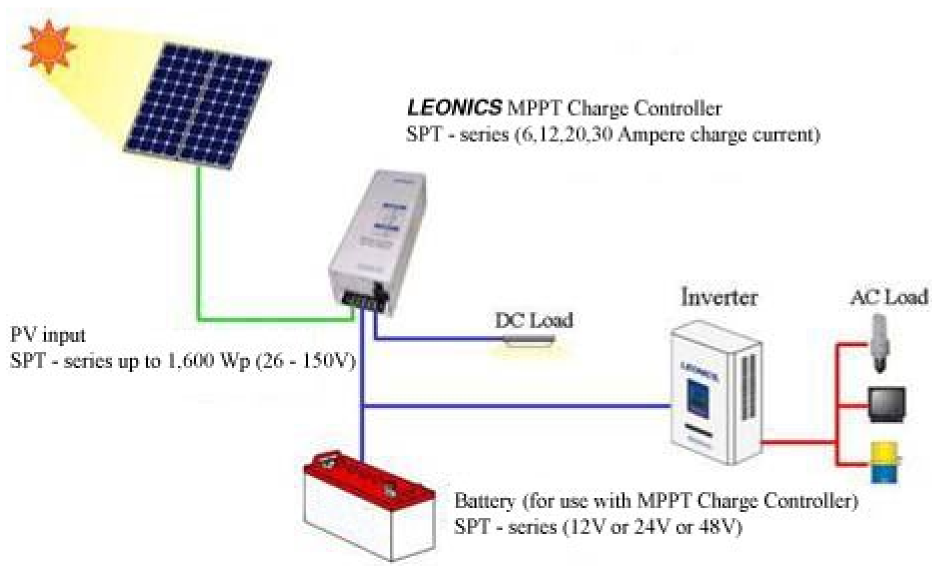


Fig.4.2 Maximum power point tracker and monitoring [27]

The **RM6** is a compact **unit** combining all MV functional **units** to enable the connection, supply and protection of transformers on an open **ring** or radial network [38]. It is a complete solution to meet the needs of the energy, infrastructure and building industries [58].

Connection to the MV network can be made:

- By a single service cable or overhead line,
- By dual parallel feeders via two mechanically interlocked load-break switches
- Via a ring main unit including two load-break switches [59]

CREDIBLE APPROACH FOR MAXIMUM POWER POINT TRACKING

Fig.4.3 Quick and [60] accurate solution to full power point monitoring

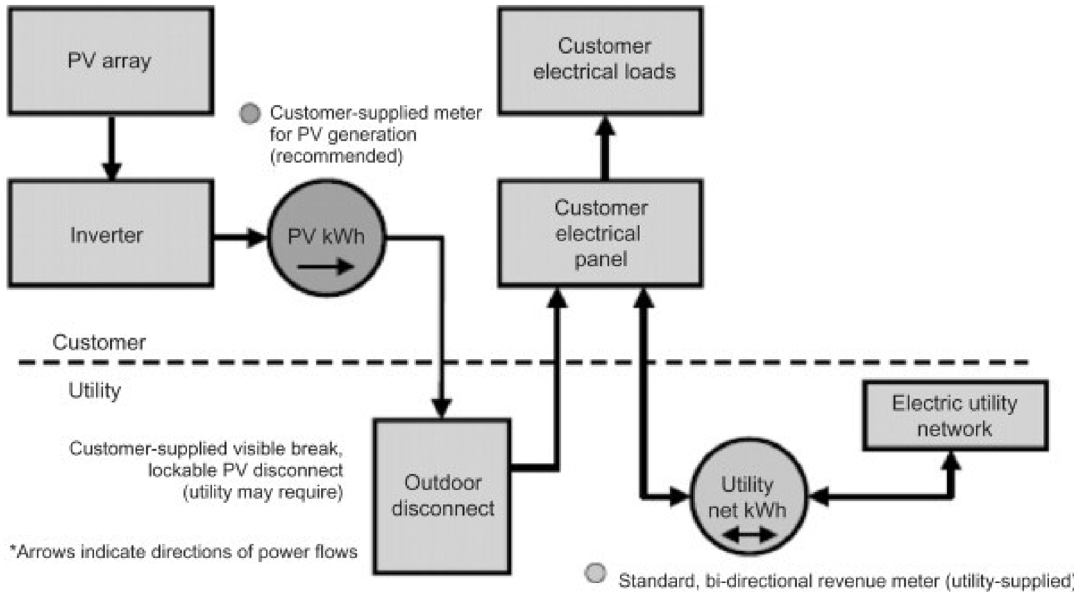
The system of PV have two main issues: the performance with electrical transfer. The result of energy is low in this stage (nine-seventeen %) particularly, electrical energy produced by photovoltaic arrays varies under weather conditions. Energy supplied from the photovoltaic system, depends to the radiance. Generally, a special point on the Current-Voltage and Power-Voltage curves called the Maximum Power Point (MPP) [61]. The positon of the MPP isn't specified, in the second hand it's locatation is specified either by cal. But it can be found either by modeling the equation.

There are several different ways to optimizing the capacity of the photovoltaic system. It varies between basic V-relationships to smarter one.

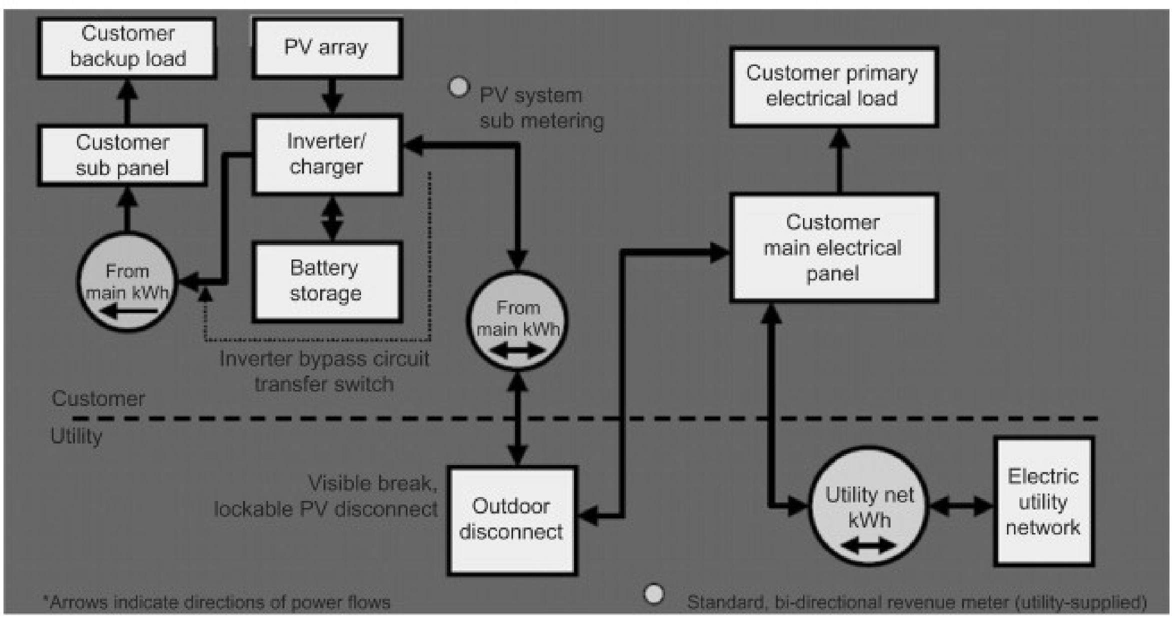
Typical techniques of MPPT introduced in the literature include short-circuit current method of open-circuit voltage disruption [62] and observation (P&O) methods of gradual conductance (IC) methods and adaptive P&O methods and intelligent and fuzzy logic methods. These techniques differ in many respects, including simplicity, speed of convergence, device reliability, and MPP monitoring performance. The key challenges for the full power point monitoring of the solar PV array include: 1) how to get to the MPP easily, 2) how to stable at the MPP, and 3) how to seamlessly transition from one MPP to another under sharply changing weather conditions [63]. Generally, a fast and stable MPP
In general, fast and stable MPPT is [64] essential to the production of solar PV electricity [65].

Characteristics of the extracted energy of a photovoltaic system

Grid-connected solar PV system consists of three parts [66] (Fig.): a solar cell array, an electronic power generator. Control device, that's from the photovoltaic array comprises double ways: MPPT and target of the grid interface. Both control functions are accomplished by the use of electronic power converters.



(a)



(b)

Fig.4.4 : a solar cell array, an electrical transformer and an integrated control system [28]

Temperature effect

Temperature influences the characteristics of the solar cells, primarily in the two following

Ways: directly through T in the exponential definition, and indirectly via its effect on T.

Reverse-mode saturation current I0 and photo-generated current IL.

This is the

Dependence of inverted diode saturation current I0 at temperature for inverted diode.

Solar Silicon Cell is [67]:

$q\ E_g$

$I_0 \quad K\ T^3 \ e^{m\,k\,T}$

Terminal voltage, please. During the day, solar radiation and temperature fluctuate.

Overtime that allows the MPP of the PV array to adjust continuously. As a result,

The operating point of the PV system [68] must be continuously modified to optimize its efficiency.

Production of energy.

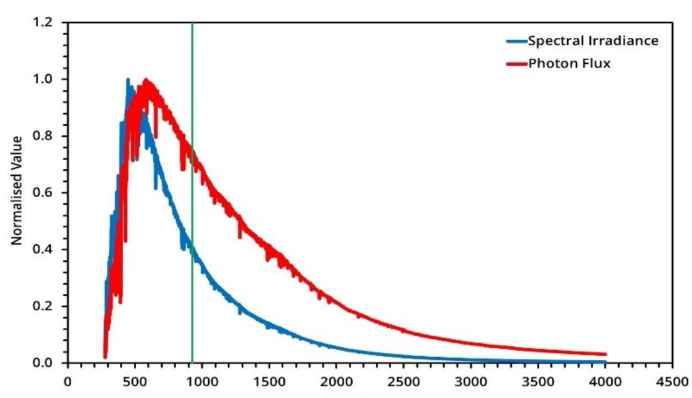


Fig. 4.5 Temperature impacts the properties of solar cells mostly in the following two ways [30]

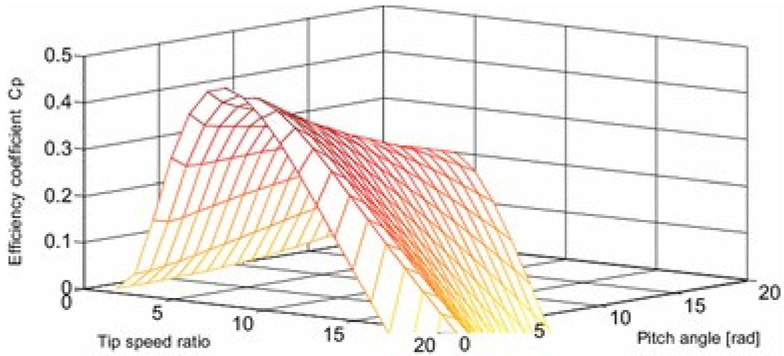


Fig.4.6 Disruption value varies during the hill climbing phase in traditional adaptive MPPT methods [31]

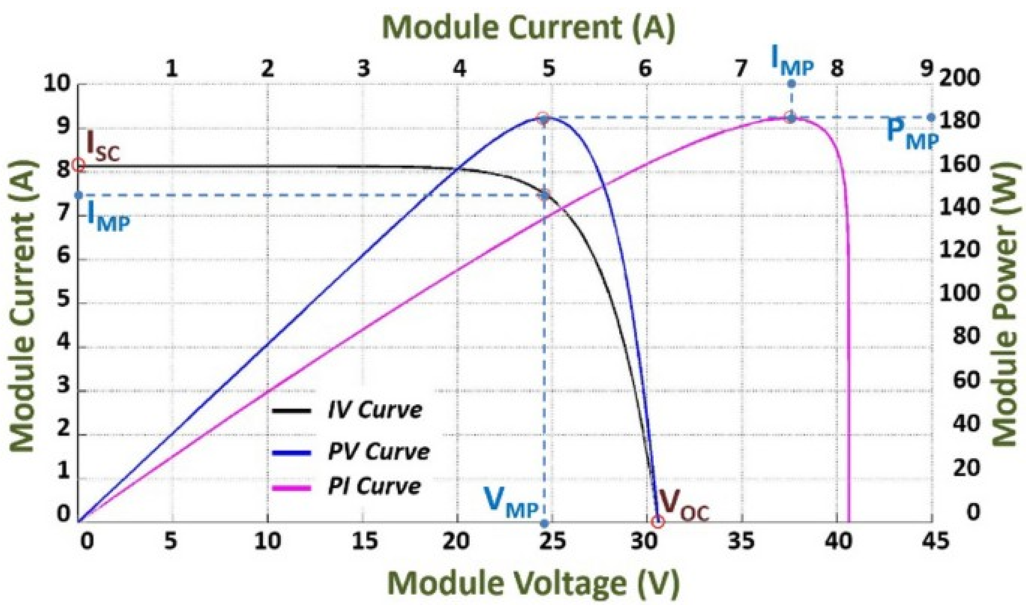


Fig.4.7 temperature to ensure that the PV system generates maximum power at all times [29]

THE THREE MOST Popular ALGORITHM MPPT ALGORITHM ARE:

1. Perturbation and Observation (P&O): This algorithm disrupts working voltage to ensure optimum power. Although there are many sophisticated and more optimized iterations of this algorithm, a simple P&O MPPT algorithm is [69] seen on the next page.

2. Incremental conductivity: This algorithm, seen below, contrasts incremental conductivity to instantaneous conductivity in the PV [71] scheme. Depending on the result, the voltage increases or decreases until the

Full power point (MPP) is obtained. Unlike the P&O algorithm, the voltage [70] stays unchanged until the MPP is achieved.

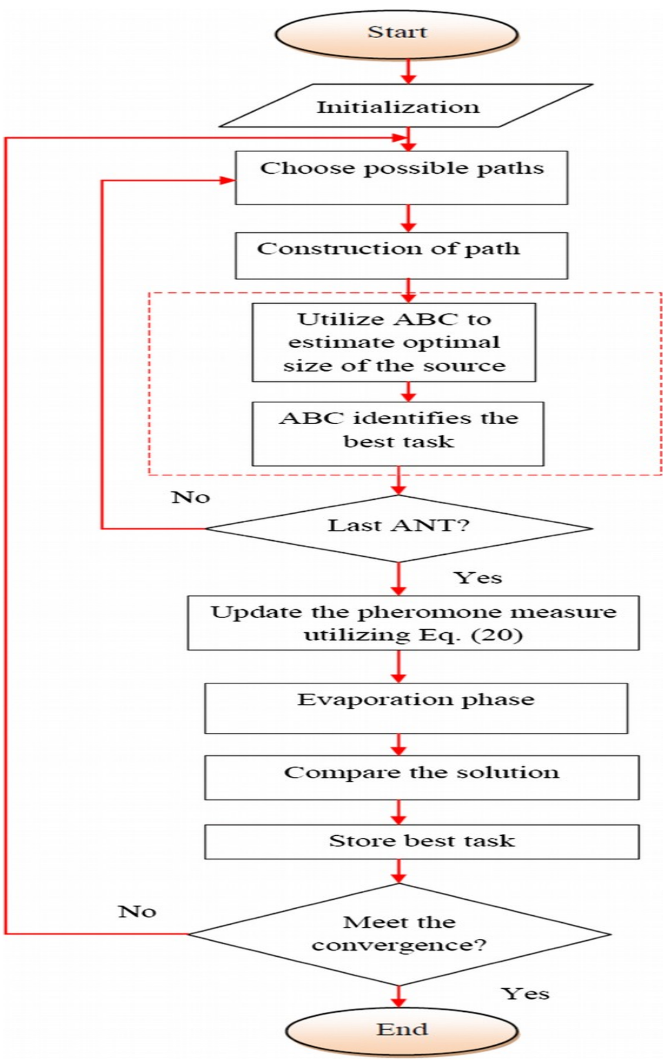


Fig.4.7 algorithm disrupts running voltage to ensure optimum power [32]

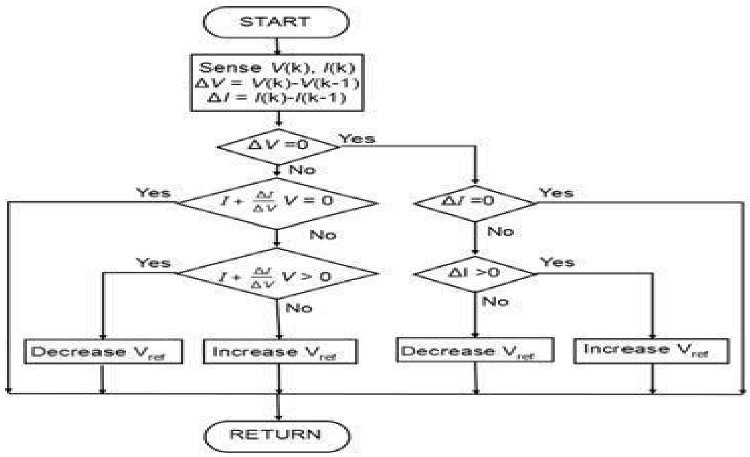


Fig 4.8 Incremental conductivity to instantaneous conductivity in the PV scheme [81].

3. Fractional open-circuit voltage: Assumption that the maximal power point voltage is always a constant fraction of the open-circuit voltage. The open circuit voltage of the cells in the photovoltaic array is measured and used as a reference to the controller [72].

How a Maximum Power Point Tracker Works:

According to the disgn of the MPPT it's from dc to dc with a high frequency. The DC current will be converted to AC by a converter, after that it will be converted to different DC current. The MPPTs works at an audio frequencies, usually [80] twenty to eighty kHz.
There are a few non-digital (linear) MPPT chargers controls on the market.
-Generally, there are no real smarts involved.
-Solar charge controllers will required the enough of smart coding and put them in a smart circuit to have more efficiency.

Smart power trackers

Intelligent IC's-controlled digital MPPT controllers. It gives the order when output to the battery needs to be adjusted, (less than 1 KW of panel). Several companies now make MPPT charge controls, like Outback Electricity, Anthrax XW-SCC, Blue Sky Energy, Apollo Solar, Midnight Solar, Morningstar, and a few others.

How to calculate the annual solar energy output of a photovoltaic system

The following is a general formula for estimating the amount of electricity produced by a photovoltaic system:

$$E = A * r * H * PR$$

Example: the solar panel yield of a PV module of 250 Wp with an area of 1.6 m² is 15.6%

- Inverter losses (4% to 15 %)
- Temperature losses (5% to 18%)
- DC cables losses (1 to 3 %)
- AC cables losses (1 to 3 %)
- Shadings 0 % to 80%!!! (Specific to each site)
- Losses weak radiation 3% to 7%
- Losses due to dust, snow... (2%)
- Other Losses (?)

Sunrise: 6:0 Sunsets: 18:0

Latitude: 0° North

Day: 1 (Jan 1)

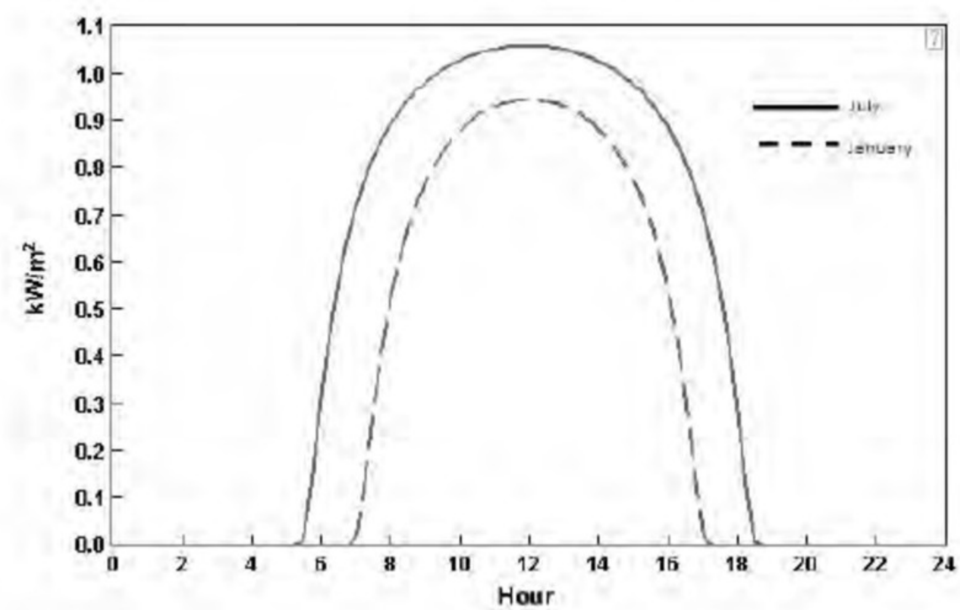


Fig.4.9 Intensity of direct radiation in W/m² throughout the day [33]

Graph portrays level of direct radiation in W/m2 [73]. In absence of cloud, this is the amount of power that a monitoring concentrator will get. The time is dependent on solar time in your area.

Latitude: 0° North

Array Tilt: 45°

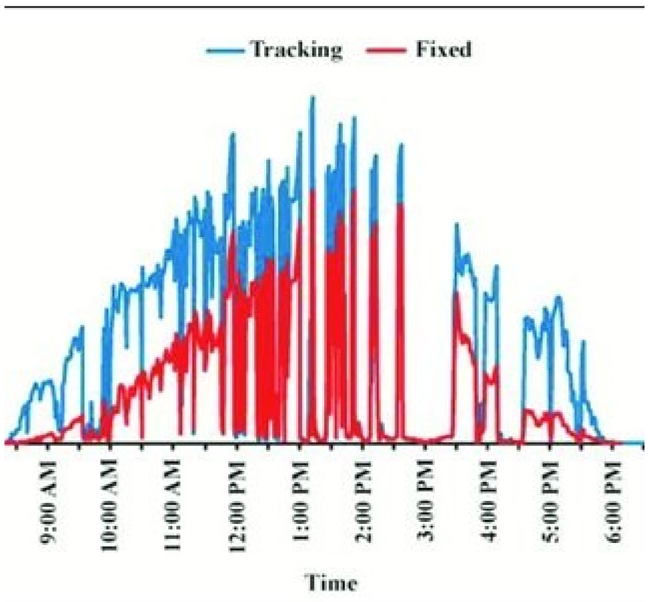


Fig.4.10 Amount of power that would be received by a tracking concentrator in the absence of cloud [34]

As a function of latitude, the average daily solar insolation. Tilt are the three curves. The [74] number of sun hours in a day [75] is used to measure daily insolation. The module is believed to face the equator, with the northern hemisphere facing south and the southern hemisphere facing north [76].

The module rotates in the opposite direction when latitude changed 0º as it reaches the equator.

Latitude: 0° North

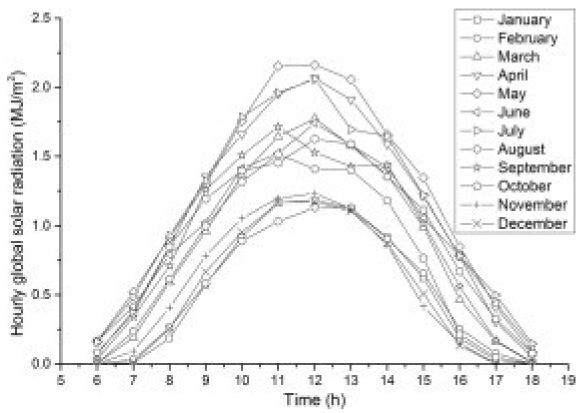


Fig 4.12 Average daily of solar insolation as a function of latitude [35]

CONCLUSIONS AND FUTURE WORK

The Dissertation's Contributions

This dissertation shows the generation and conversion of solar photovoltaic energy from equipment to grid.

To begin with, examines the efficiency of the photovoltaic system under uneven and different circumstances, focusing on the verification of Current-Voltage and Power-Voltage Shaded properties and sunshade cells by simulation tools and the Newton-Raphson algorithm. The performance of PV [77] devices with bypass diodes has been found to be more complicated and different from standard Power Voltage Current-Voltage and PV properties.

Second, based on both software / hardware experiments. Partnership takes into consideration that both sampling rate effects and the differing degrees of solar irradiance. The comparison of traditional and proposed adaptive reveals hyperbolic treatment of derivation is critical to the solar PV system's high performance.

Finally, with such an emphasis on erratic lighting, this study contrasts extraction features of solar system, such as core, string, and micro converter arrangements. As a response, a centralized converter-based on properly integrated bypass diodes is a cost-effective and reliable way for increase the PV system's power, performance, and reliability.

Finally, this article analyzes product properly for solar array photovoltaic systems for ESUs, as well as how to use power electronics to control all electrical devices in the system. GCC is designed to maintain a constant dc-link voltage and adjust the reactive power [78] in the proposed process, PVCC is designed to apply the PV series' MPPT [79], and ESU's connected converter control is designed to achieve overall system power balance. Finally, this dissertation addresses control designs for grid-connected photovoltaic systems with ESUs, as well as how power electronics should be used to run all of the system's electrical equipment. The GCC is built in the form indicated.

The PVCC is designed to implement the MPPT of the PV series in order to retain a stable dc-link voltage and respond to reactive power control, and the ESU's connected transformer control is intended to accomplish the overall power balance of the system. The simulation results suggest that these two implementations are of good quality.

Limitations and Future Work

Because of the unpredictable solar radiation, It was acknowledged that for functional control in future projects in gird-connected PV systems with ESUs, a dynamic ramp control configuration, rather than a fixed ramp, is needed.

Furthermore, since implementing ramp rate control, it has not yet been discussed keeping ESUs at optimal filling/empting pace. In this dissertation, the parameters of ESUs are set up in such a way that they can be used to calculate the effectiveness of ramp rate regulation no losing cost. Taking into account considerations such as the maximum power generation/absorption of the ESUs, the actual limit of the ESUs, and the state of charge of the ESUs. The demand for grid-connected renewable energy generation and enhancement is expected to grow further.

BIBLIOGRAPHY

1. Rappaport, P. (1959). The photovoltaic effect and its utilization. *Solar Energy*, *3*(4), 8-18.
2. Carlson, D. E., & Wronski, C. R. (1976). Amorphous silicon solar cell. *Applied Physics Letters*, *28*(11), 671-673.
3. Saxena, V., & Kumar, S. A Project Report On "CURRENT MODE BIQUAD FILTER" Submitted to The Department of Electronics Engineering In partial fulfilment of requirements for the award of the Degree of Bachelor of Technology In Electronics and Communication Engineering By.
4. The Futures of Renewable Energy Thesis is a research project that looks at the future of renewable energy. M.M. Hand; S. Baldwin; E. Demo; J.M. Reilly; T. Mai; D. Aren't; G. Porro; M. Meshek; D. Sandor, eds. 4 vols. Global Renewable Energy Laboratory, Golden, CO, NREL/TP-6A20-52409.
5. National Renewable Energy Laboratory (NR.EL). The Most Powerful Research-Cell Efficiencies.
6. IPC.C Special Report on Renewable Energy Sources and Climate Change Mitigation, 2011. Working Group III of the Intergovernmental Panel on Climate Change [O. Ed.enhofer, R. P.ichs-Madruga, Y. Sokon.a, K. Seybot.h, P. Machos, S. Kadne.r, T. Zwicke.l, P. Eckmeie.r, G. Hanse.n, S. Schlöme.r, C. von Stecho.w (ed.s)] prepared this report. 1075 pages, Cambridge University Press, Cambridge, UK and New York, NY, USA. (Chapter 7 & 9)
7. "Initial Operating Experience of the La Ola 1.2-MW Photovoltaic System," by Jay Johnson, Benjamin Schenkman, Abraham Ellis, Jimmy Quiroz, and Carl Lenox.
8. Crowhr.st, E.F. El-Saadan.y, L. E.l Chaaran.d LA. Lumont, "Single-Phase Grid-Tie Inverter Control Using DQ Transform for Active and Reactive Load Power Compensation", 2010 I.EEE International Conference on Power and Energy
9. Wheelock Mountain Publications, 2006, Phillip Hurley, Build Your Own Solar Panel, 0971012520,9780971012523
10. Solar and Space Physics Survey Committee, Committee on Solar and Space Physics, National Research Co, Sun To The Earth -- And Beyond: Panel, National Academies Press, 2003, 0309089727,9780309089722,9780309529389
11. Robert Smith, How To Build A Solar Panel And Solar Power System, 2009, c7fbf8b600a473cbc49fe78053c4c2a9
12. Solar Power DIY Handbook: So, You Want To Connect Your Off-Grid Solar Panel to a 12 Volts Battery?, Baiano Reeves, CreateSpace Independent Publishing Platform, 2008, 1720431647,9781720431640
13. biotecharticles.com, 'Importance of Solar in Agriculture', 2018. [Online]. Available: https://www.biotecharticles.com/Applications-Article/Importance-of-Solar-Energy-in-Agriculture-4448.html . [Accessed: 23-Mar-2021].
14. energysage.com, 'Monocrystalline and polycrystalline solar panels: what you need to know'. 2020. [Online]. Available: https://www.energysage.com/solar/101/monocrystalline-vs-polycrystalline-solar-panels/ . [Accessed: 23-Mar-2021]
15. Mousazadeh, H., Keyhani, A., Javadi, A., Mobli, H., Abrinia, K., & Sharifi, A. (2009). A review of principle and sun-tracking methods for maximizing solar systems output. *Renewable and sustainable energy reviews*, *13*(8), 1800-1818.

16. batterystuff.com, “Lifeline 6v 300 AH Deep Cycle Sealed AGM Battery - GPL-6CT”. 1997-2021. [Online]. Available: https://www.batterystuff.com/batteries/rv/6-volt-deep-cycle-batteries/gpl-6ct.html [Accessed: 23-Mar-2021]

17. fierceelectronics.com, “Battery group advocates lead-acid to meet energy storage needs”. Oct 9, 2019. [Online]. Available: https://www.fierceelectronics.com/electronics/battery-group-advocates-lead-acid-to-meet-energy-storage-needs [Accessed: 23-Mar-2021]

18. jskl-battery.com, “GB standard series traction with lead-acid batteries”.2006-2013. [Online]. Available: http://www.jskl-battery.com/en/index.php?m=content&c=index&a=lists&catid=27 [Accessed: 23-Mar-2021]

19. amazon.com, “UPG UBCD5745 Sealed Lead Acid Batteries”.1996-2021. [Online]. Available: https://www.amazon.com/UBCD5745-Sealed-Lead-Acid-Batteries/dp/B001DL7D1O [Accessed: 23-Mar-2021]

20. hinergy.net, “manual pwm price solar charge controller china supplier”. 2017. [Online]. Available: https://www.hinergy.net/product/solar-charge-controller [Accessed: 23-Mar-2021]

21. gogreensolar.com, “Grid-Tie String Inverters”. 2006-2021. [Online]. Available: https://www.gogreensolar.com/collections/grid-tie-string-inverters [Accessed: 23-Mar-2021]

22. earthsci.org, “how solar cells make electricity”. [Online]. Available: SOLAR ENERGY (earthsci.org) [Accessed: 23-Mar-2021]

23. electronicshub.org, “Solar Inverter Design to easily understand the construction of a solar inverter lets discuss the following construction sample”. [Online]. Available: Circuit Diagram of Solar Inverter for Home | How Solar Inverter Works? (electronicshub.org) [Accessed: 23-Mar-2021]

24. electronicshub.org, “Solar Inverter Circuit Diagram”. [Online]. Available: Circuit Diagram of Solar Inverter for Home | How Solar Inverter Works? (electronicshub.org) [Accessed: 23-Mar-2021]

25. Boxwell, M. (2010). *Solar electricity handbook: A simple, practical guide to solar energy-designing and installing photovoltaic solar electric systems*. Greenstream publishing.

26. Khan, O., & Xiao, W. (2017). Review and qualitative analysis of submodule-level distributed power electronic solutions in PV power systems. *Renewable and Sustainable Energy Reviews*, *76*, 516-528.

27. leonics.com, “How to set system configuration of MPPT solar charge controller”. [Online]. Available: http://www.leonics.com/support/article2_14j/articles2_14j_en.php [Accessed: 24-Mar-2021]

28. sciencedirect.com, “Energizing Renewable Energy Systems and Distribution Generation”. [Online]. Available: https://www.sciencedirect.com/topics/engineering/grid-connected-photovoltaic-systems [Accessed: 24-Mar-2021]

29. Ramos-Hernanz, Josean, et al. "Temperature based maximum power point tracking for photovoltaic modules." *Scientific Reports* 10.1 (2020): 1-10.

30. springer.com, “Adaptive hill-climb searching method for MPPT algorithm based DFIG system using fuzzy logic controller”. [Online]. Available: Adaptive hill-climb searching method for MPPT algorithm based DFIG system using fuzzy logic controller | SpringerLink [Accessed: 24-Mar-2021]

31. ossila.com, “The spectral irradiance and photon flux of the Sun. The green line represents the wavelength corresponding to optimum band gap energy (~930 nm). Data was provided by the National Renewable Energy Laboratory, Golden, CO. [Online]. Available: Solar Cells: A Guide to Theory and Measurement | Ossila [Accessed: 25-Mar-2021]

32. link.springer.com, “optimal task assignment in mobile could computing by queue based ant-bee algorithm”. [Online]. Available: Optimal Task Assignment in Mobile Cloud Computing by Queue Based Ant-Bee Algorithm | SpringerLink [Accessed: 25-Mar-2021]

33. researchgate.net, “The highest and the lowest intensity of direct radiation in W/m2”. [Online]. Available: The highest and the lowest intensity of direct radiation in W/m2 | Download Scientific Diagram (researchgate.net) [Accessed: 25-Mar-2021]

34. researchgate.net, “n a cloudy day, where it experienced frequent overcast, the result of power shows a very jagged graph due to the solar irradiance drop as demonstrated in The inclement resulted in power generation drop for the tracking and non-tracking " . [Online]. Available: (PDF) Power Feasibility of a Low Power Consumption Solar Tracker (researchgate.net) [Accessed: 25-Mar-2021]

35. sciencedirect.com, "Graphical abstractMonthly average hourly global solar radiation as a function of time."2021. [Online]. Available: New decomposition models to estimate hourly global solar radiation from the daily value - ScienceDirect [Accessed: 25-Mar-2021]

36. Yang, Terry Chien-Jen. *Transparent Conducting Aluminium Doped Zinc Oxide for Silicon Quantum Dot Solar Cell Devices in Third Generation Photovoltaics*. Diss. University of New South Wales SYDNEY, 2015.

37. Photovoltaic or Solar Cell. https://circuitglobe.com/photovoltaic-or-solar-cell.html [Accessed: 4-Apr-2021]

38. Bernard, G., Perrissin, G., & Marzocca, J. (1988, May). Use of an auto-expansion circuit breaker in a ring main unit. In *IEE Proceedings C (Generation, Transmission and Distribution)* (Vol. 135, No. 3, pp. 219-223). IET Digital Library.

39. Wang, D., Qi, T., Liu, Y., Wang, Y., Fan, J., Wang, Y., & Du, H. (2020). A method for evaluating both shading and power generation effects of rooftop solar PV panels for different climate zones of China. *Solar Energy*, *205*, 432-445.

40. Gonzalez-Pedro, V., Juarez-Perez, E. J., Arsyad, W. S., Barea, E. M., Fabregat-Santiago, F., Mora-Sero, I., & Bisquert, J. (2014). General working principles of CH3NH3PbX3 perovskite solar cells. *Nano letters*, *14*(2), 888-893.

41. Matsuda, A. (2004). Microcrystalline silicon.: Growth and device application. *Journal of Non-Crystalline Solids*, *338*, 1-12.

42. Takahashi, Kiyoshi, and Makoto Konagai. "Amorphous silicon solar cells." *New York* (1986).

43. Zeman, Miro. "Advanced amorphous silicon solar cell technologies." *Thin film solar cells: fabrication, characterization and applications* (2006): 1-66.

44. Landis, G., Jenkins, P., Scheiman, D., & Rafaelle, R. (2004, August). Extended temperature solar cell technology development. In *2nd International Energy Conversion Engineering Conference* (p. 5578).

45. Taguchi, M., Maruyama, E., & Tanaka, M. (2008). Temperature dependence of amorphous/crystalline silicon heterojunction solar cells. *Japanese Journal of Applied Physics*, *47*(2R), 814.

46. Green, M. A. (1984). Limits on the open-circuit voltage and efficiency of silicon solar cells imposed by intrinsic Auger processes. *IEEE Transactions on electron devices*, *31*(5), 671-678.

47. Zahedi, A. (2011). Maximizing solar PV energy penetration using energy storage technology. *Renewable and Sustainable Energy Reviews*, *15*(1), 866-870.

48. Sun, J. (2011). Impedance-based stability criterion for grid-connected inverters. *IEEE transactions on power electronics*, *26*(11), 3075-3078.

49. Zhu, Z. Q., Pang, Y., Howe, D., Iwasaki, S., Deodhar, R., & Pride, A. (2005). Analysis of electromagnetic performance of flux-switching permanent-magnet machines by nonlinear adaptive lumped parameter magnetic circuit model. *IEEE Transactions on magnetics*, *41*(11), 4277-4287.

50. Boxwell, M. (2010). *Solar electricity handbook: A simple, practical guide to solar energy-designing and installing photovoltaic solar electric systems*. Greenstream publishing.

51. Boxwell, M. (2010). *Solar electricity handbook: A simple, practical guide to solar energy-designing and installing photovoltaic solar electric systems*. Greenstream publishing.

52. Selvaraj, J., & Rahim, N. A. (2008). Multilevel inverter for grid-connected PV system employing digital PI controller. *IEEE transactions on industrial electronics*, *56*(1), 149-158.
53. Fehrenbacher, G., F. Gutermuth, and T. Radon. "Estimation of carbon-ion-caused radiation levels by calculating the transport of the produced neutrons through shielding layers." GSI Scientific Report 205 (2001): 2002.
54. Burger, Roland. "Solar Inverter and Photovoltaic Installation Comprising Several Solar Inverters." U.S. Patent Application No. 11/597,765
55. Lee, Chanseok, Sang Moon Kim, Young Joo Kim, Yong Whan Choi, Kahp-Yang Suh, Changhyun Pang, and Mansoo Choi. "Robust microzip fastener: repeatable interlocking using polymeric rectangular parallelepiped arrays." *ACS applied materials & interfaces* 7, no. 4 (2015): 2561-2568.
56. Ghosh, Amal K., and H. Paul Maruska. "Photoelectrolysis of water in sunlight with sensitized semiconductor electrodes." *Journal of the electrochemical society* 124, no. 10 (1977): 1516.
57. Pandey, A., Dasgupta, N., & Mukerjee, A. K. (2008). High-performance algorithms for drift avoidance and fast tracking in solar MPPT system. *IEEE Transactions on Energy conversion*, *23*(2), 681-689.
58. Pullins, S. (2019). Why microgrids are becoming an important part of the energy infrastructure.
59. Northcote-Green, J., & Wilson, R. G. (2017). *Control and automation of electrical power distribution systems* (Vol. 28). CRC press.
60. Masoum, M. A., Dehbonei, H., & Fuchs, E. F. (2002). Theoretical and experimental analyses of photovoltaic systems with voltageand current-based maximum power-point tracking. *IEEE Transactions on energy conversion*, *17*(4), 514-522.
61. Piegari, Luigi, and Rocco Rizzo. "Adaptive perturb and observe algorithm for photovoltaic maximum power point tracking." *IET Renewable Power Generation* 4, no. 4 (2010): 317-328.
62. Sinha, S., & Chandel, S. S. (2015). Review of recent trends in optimization techniques for solar photovoltaic–wind based hybrid energy systems. *Renewable and Sustainable Energy Reviews*, *50*, 755-769.
63. Hui, J. C., Bakhshai, A., & Jain, P. K. (2015). An energy management scheme with power limit capability and an adaptive maximum power point tracking for small standalone PMSG wind energy systems. *IEEE Transactions on Power Electronics*, *31*(7), 4861-4875.
64. Karami, N., Moubayed, N., & Outbib, R. (2017). General review and classification of different MPPT Techniques. *Renewable and Sustainable Energy Reviews*, *68*, 1-18.
65. Loutan, C., Klauer, P., Chowdhury, S., Hall, S., Morjaria, M., Chadliev, V., ... & Gevorgian, V. (2017). *Demonstration of essential reliability services by a 300-MW solar photovoltaic power plant* (No. NREL/TP-5D00-67799). National Renewable Energy Lab. (NREL), Golden, CO (United States).
66. Jiang, F., & Wong, A. (2005, December). Study on the performance of different types of PV modules in Singapore. In *2005 International Power Engineering Conference* (pp. 1-109). IEEE.
67. Demtsu, S. H., & Sites, J. R. (2006). Effect of back-contact barrier on thin-film CdTe solar cells. *Thin Solid Films*, *510*(1-2), 320-324.

68. Koutroulis, E., & Blaabjerg, F. (2012). A new technique for tracking the global maximum power point of PV arrays operating under partial-shading conditions. *IEEE Journal of Photovoltaics*, *2*(2), 184-190.
69. Harrag, A., & Messalti, S. (2015). Variable step size modified P&O MPPT algorithm using GA-based hybrid offline/online PID controller. *Renewable and Sustainable Energy Reviews*, *49*, 1247-1260.
70. Radjai, T., Gaubert, J. P., Rahmani, L., & Mekhilef, S. (2015). Experimental verification of P&O MPPT algorithm with direct control based on Fuzzy logic control using CUK converter. *International Transactions on Electrical Energy Systems*, *25*(12), 3492-3508.
71. Mirbagheri, S. Z., Aldeen, M., & Saha, S. (2015, June). A PSO-based MPPT re-initialised by incremental conductance method for a standalone PV system. In *2015 23rd Mediterranean Conference on Control and Automation (MED)* (pp. 298-303). IEEE.
72. Hsu, T. W., Wu, H. H., Tsai, D. L., & Wei, C. L. (2018). Photovoltaic energy harvester with fractional open-circuit voltage based maximum power point tracking circuit. *IEEE Transactions on Circuits and Systems II: Express Briefs*, *66*(2), 257-261.
73. Nightingale, K., McAleavey, S., & Trahey, G. (2003). Shear-wave generation using acoustic radiation force: in vivo and ex vivo results. *Ultrasound in medicine & biology*, *29*(12), 1715-1723.
74. Klein, S. A. (1977). Calculation of monthly average insolation on tilted surfaces. *Solar energy*, *19*(4), 325-329.
75. Baker, Alyssa. "How to Calculate Your Peak Sun-Hours." *Solar Power Authority* (2019).
76. Baker, A. (2019). How to Calculate Your Peak Sun-Hours. *Solar Power Authority*.
77. Khaldi, N., Mahmoudi, H., Zazi, M., & Barradi, Y. (2014, October). The MPPT control of PV system by using neural networks based on Newton Raphson method. In *2014 International Renewable and Sustainable Energy Conference (IRSEC)* (pp. 19-24). IEEE.
78. Reis, L. R. D., J. R. Camacho, and D. F. Novacki. "The Newton Raphson method in the extraction of parameters of PV modules." *International Conference on Renewable Energies and Power Quality*. Vol. 1. No. 15. 2017.
79. sciencedirect.com. **Link Voltage**. Catalogue 2015- 2019.
80. Tse, K. K., Ho, M. T., Chung, H. H., & Hui, S. Y. (2002). A novel maximum power point tracker for PV panels using switching frequency modulation. *IEEE transactions on power electronics*, *17*(6), 980-989.
81. Safari, A., & Mekhilef, S. (2010). Simulation and hardware implementation of incremental conductance MPPT with direct control method using cuk converter. *IEEE transactions on industrial electronics*, *58*(4), 1154-1161.