A

Project Report On

"Design & Analysis of Solar PV Power Plant"

Submitted in partial fulfilment of the requirements

for the degree of

Bachelor of Engineering in Electrical Engineering

Submitted by

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During the academic year **2017-18** in partial fulfilment of the requirements for the award of degree of **Bachelor of Engineering in Electrical Engineering** from **University of Mumbai.**

Date-

Approved by- (Prof. ANKUR UPADHYAY)

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In a manner satisfactory to warrant is acceptance as a pre-requisite to their Degree in Bachelor of Electrical Engineering.

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DECLARATION

We declare that this written submission represents my ideas in my own words and where others ideas or words have been included;We have adequately cited and referenced the original sources. We also declared that we have adhered to all principles of academic honesty and integrity and have not represented or fabricated or falsified any idea/data/fact/source in my submission. We understand that any violation of the above will be cause for disciplinary action by the Institute and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission have not been taken when needed.

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Abstract

Nowadays, there is a demand to increase the power generation capacity because of steadily rising electrical energy consumption. In order to achieve this, renewable energy sources are the best option. Among all the renewable energy sources, solar power generation system tops the list.For this purpose the energy generation is done via solar panels and large capacity power plants are also established. The establishment of this is not simple, So in order to generate electricity form solar panel calculations are done and proper steps and measures are taken for getting maximum benefit from it. The project also deals with the simulations which shows as an approx. output form the plant we are going to prepare and the commercial aspect of that which payback period and saving related to it.

CONTENTS

Chapter 1

1.1 Introduction

Solar energy is the energy provided by the sun. It is the radiant light and heat from the Sun, harnessed using technologies such as solar heaters, solar photovoltaic, solar thermal electricity.

Energy is produced in Sun by nuclear fusion during a series of steps proton-proton (P-P) chain reaction, I this process hydrogen is converted to helium. The core is the only part of the Sun that produces heat through fusion about 99%. Hydrogen nuclei in Sun's core fuse together to form helium nuclei and release energy, this process is called nuclear fusion. In this state, some 120 million tons of matter--mostly hydrogen convertes into helium on the sun every minute, with some of the mass being converted into energy.

Electromagnetic energy from the sun comes to Earth in the form of radiation. The sun radiates energy equally in all directions, and the Earth intercepts and receives part of this energy. The power flux reaching the top of the Earth's atmosphere is about 1400 Watts/m2. This simply means on an average, one square meter on the side of the Earth facing the sun receives energy from the sun equal to that from fourteen 100 Watt light bulbs every second. The Earth receives 174petawatt of incoming solar radiation at the upper atmosphere. Approximately 30% is reflected back to the space while the rest is absorbed by the clouds, oceans and land masses. The spectrum of solar light at the earth’s surface is mostly spread across the visible and near-infrared ranges with a small part in the near-ultraviolet.

1.2 SOLAR POTENTIAL

Most people around the world live in areas with insolation levels of 150 to 300 watts per square meter or 3.5 to 7.0 kWh/m2 per day. The total solar energy absorbed by Earth's atmosphere, oceans and land masses is approximately 3,850,000 exajoules (EJ) per year. The amount of solar energy reaching the surface of the planet is so vast that in one year it is about twice as much as will ever be obtained from all of the Earth's non-renewable resources of coal, oil, natural gas, and mined uranium combined. Geography effects solar energy potential because areas that are closer to the equator have a greater amount of solar radiation.

However, the use of photovoltaics that can follow the position of the sun can significantly increase the solar energy potential in areas that are farther from the equator. Time variation effects the potential of solar energy because during the nighttime there is little solar radiation on the surface of the Earth for solar panels to absorb. This limits the amount of energy that solar panels can absorb in one day. Cloud cover can effect the potential of solar panels because clouds block incoming light from the sun and reduce the light available for solar cells.

In addition, land availability has a large effect on the available solar energy because solar panels can only be set up on land that is unowned and suitable for solar panels. Roofs have been found to be a suitable place for solar cells, as many people have discovered that they can collect energy directly from their homes this way. Other areas that are suitable for solar cells are lands that are unowned by businesses where solar plants can be established.

Solar technologies are broadly characterized as either passive or active depending on the way they capture, convert and distribute sunlight and enable solar energy to be harnessed at different levels around the world, mostly depending on distance from the equator. Although solar energy refers primarily to the use of solar radiation for practical ends, all renewable energies, other than geothermal and tidal, derive their energy from the Sun in a direct or indirect way.

Active solar techniques use photovoltaics, concentrated solar power, solar thermal collectors, pumps, and fans to convert sunlight into useful outputs. Passive solar techniques include selecting materials with favorable thermal properties, designing spaces that naturally circulate air, and referencing the position of a building to the Sun. Active solar technologies increase the supply of energy and are considered supply side technologies, while passive solar technologies reduce the need for alternate resources and are generally considered demand side technologies.

In 2000, the United Nations Development Programme, UN Department of Economic and Social Affairs, and World Energy Council published an estimate of the potential solar energy that could be used by humans each year that took into account factors such as insolation, cloud cover, and the land that is usable by humans. The estimate found that solar energy has a global potential of 1,575–49,837 EJ per year.

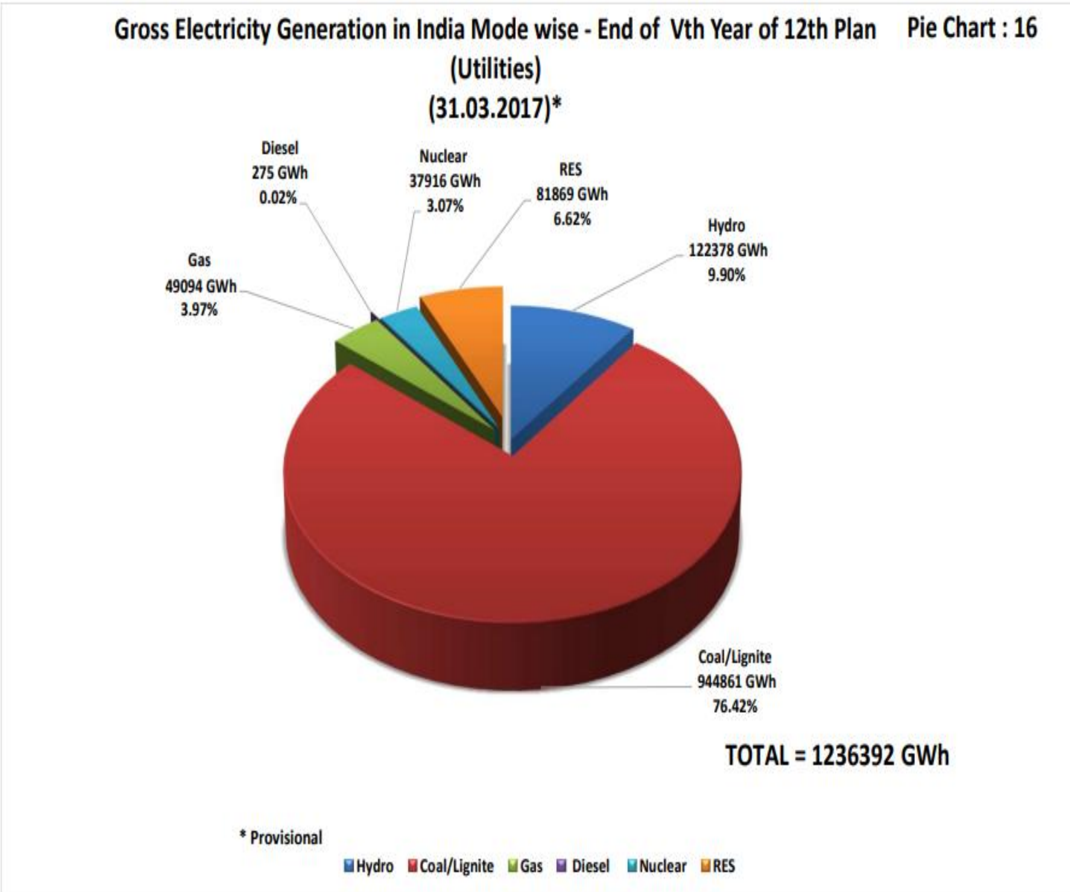


Fig 1.1 Electricity generation provision wise in India

Chapter 2

2.1 History

Solar power in India is a fast developing industry. As of September, 2017 the country's solar grid had a cumulative capacity of 16.20 GW. India quadrupled its solar-generation capacity from 2,650 MW on 26 May 2014 to 12,289 MW on 31 March 2017. The country added 3.01 GW of solar capacity in 2015-2016 and 5.525 GW in 2016-2017, the highest of any year, with the average current price of solar electricity dropping to 18% below the average price of its coal-fired counterpart.

In January 2015 the Indian government expanded its solar plans, targeting US$100 billion in investment and 100 GW of solar capacity (including 40 GW from rooftop solar) by 2022.. India's initiative of 100 GW of solar energy by 2022 is an ambitious target, since the world's installed solar-power capacity in 2014 was 181 GW.The improvements in solar thermal storage power technology in recent years has made this task achievable as the cheaper solar power need not depend on costly and polluting coal/gas/nuclear based power generation for ensuring stable grid operation.

In addition to its large-scale grid-connected solar PV initiative, India is developing off-grid solar power for local energy needs. The country has a poor rural electrification rate; in 2015 only 55 percent of all rural households had access to electricity, and 85 percent of rural households depended on solid fuel for cooking.Solar products have increasingly helped to meet rural needs; by the end of 2015 just under one million solar lanterns were sold in the country, reducing the need for kerosene. That year, 118,700 solar home lighting systems were installed and 46,655 solar street lighting installations were provided under a national program; just over 1.4 million solar cookers were distributed in India.

In January 2016, Prime Minister NarendraModi and French President François Hollande laid the foundation stone for the headquarters of the International Solar Alliance (ISA) in GwalPahari, Gurugram.

The ISA will focus on promoting and developing solar energy and solar products for countries lying wholly or partially between the Tropic of Cancer and the Tropic of Capricorn. The alliance of over 120 countries was announced at the Paris COP21 climate summit. One hope of the ISA is that wider deployment will reduce production and development costs, facilitating the increased deployment of solar technologies to poor and remote regions.

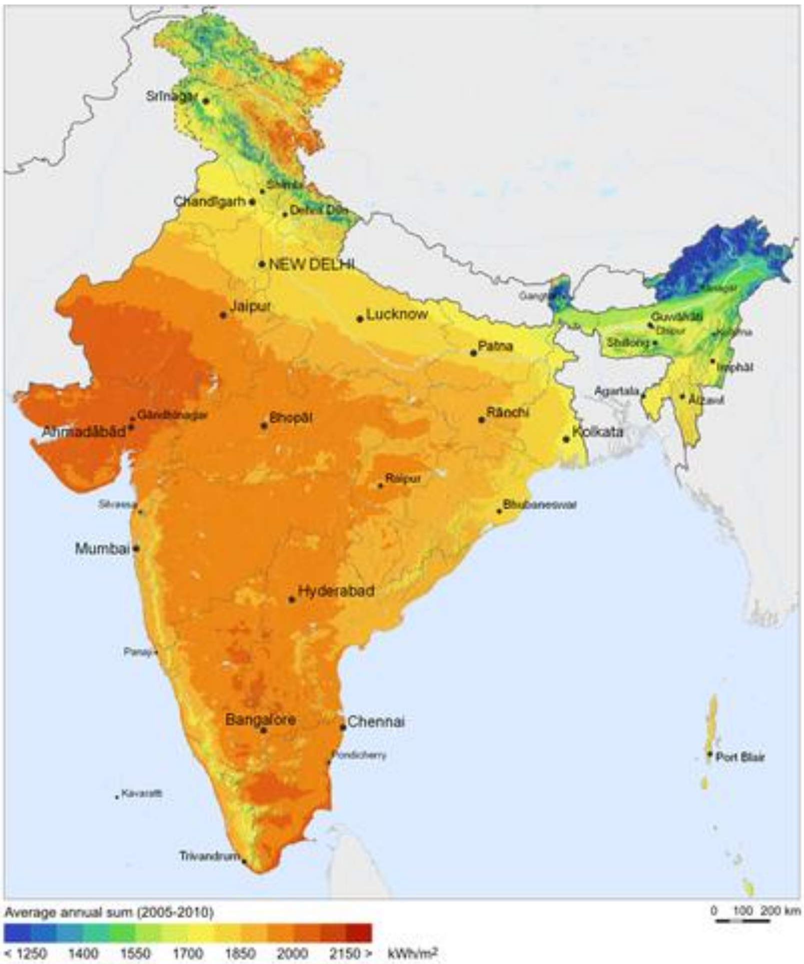


Fig 2.1Solar irradiance in India

2.2 Early commercial adaption

In 1897, Frank Shuman, a U.S. inventor, engineer and solar energy pioneer built a small demonstration solar engine that worked by reflecting solar energy onto square boxes filled with ether, which has a lower boiling point than water, and were fitted internally with black pipes which in turn powered a steam engine. In 1908 Shuman formed the Sun Power Company with the intent of building larger solar power plants. He, along with his technical advisor A.S.E. Ackermann and British physicist Sir Charles Vernon Boys, developed an improved system using mirrors to reflect solar energy upon collector boxes, increasing heating capacity to the extent that water could now be used instead of ether. Shuman then constructed a full-scale steam engine powered by low-pressure water, enabling him to patent the entire solar engine system by 1912.

Shuman built the world's first solar thermal power station in Maadi, Egypt, between 1912 and 1913. Shuman's plant used parabolic troughs to power a 45–52 kilowatts (60–70 hp) engine that pumped more than 22,000 litres (4,800 imp gal; 5,800 US gal) of water per minute from the Nile River to adjacent cotton fields. Although the outbreak of World War I and the discovery of cheap oil in the 1930s discouraged the advancement of solar energy, Shuman's vision and basic design were resurrected in the 1970s with a new wave of interest in solar thermal energy

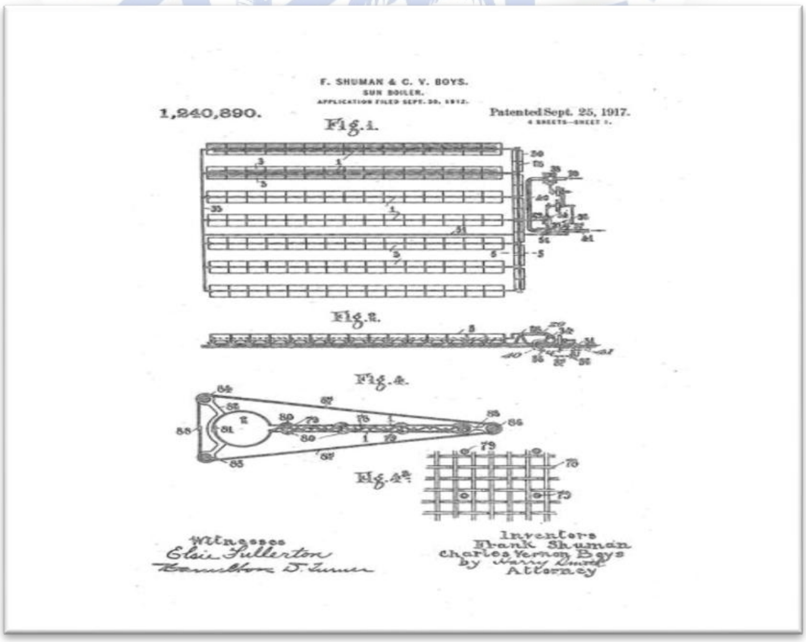


Fig 2.2 Sun-Boiler 1917 patent by Frank Shuman and Charles Vernon Boy

Chapter 3

3.1 Solar Panel

Solar panels absorb the sunlight as a source of energy to generate electricity or heat.

A photovoltaic (PV) module is a packaged, connect assembly of typically 6x10 photovoltaic solar cells. Photovoltaic modules constitute the photovoltaic array of a photovoltaic system that generates and supplies solar electricity in commercial and residential applications. Each module is rated by its DC output power under standard test conditions (STC), and typically ranges from 100 to 365 Watts (W).

The efficiency of a module determines the area of a module given the same rated output – an 8% efficient 230 W module will have twice the area of a 16% efficient 230 W module. There are a few commercially available solar modules that exceed efficiency of 22% and reportedly also exceeding 24%. A single solar module can produce only a limited amount of power; most installations contain multiple modules. A photovoltaic system typically includes an array of photovoltaic modules, an inverter, a battery pack for storage, interconnection wiring, and optionally a solar tracking mechanism.The most common application of solar panels is solar water heating systems.

3.2 Theory and Construction

Photovoltaic modules use light energy (photons) from the Sun to generate electricity through the photovoltaic effect. The majority of modules use wafer-based crystalline silicon cells or thin-film cells. The structural (load carrying) member of a module can either be the top layer or the back layer. Cells must also be protected from mechanical damage and moisture. Most modules are rigid, but semi-flexible ones are available, based on thin-film cells. The cells must be connected electrically in series, one to another. Externally, most of photovoltaic modules use MC4 connectors type to facilitate easy weatherproof connections to the rest of the system.

Modules electrical connections are made in series to achieve a desired output voltage or in parallel to provide a desired current capability. The conducting wires that take the current off the modules may contain silver, copper or other non-magnetic conductive transition metals. Bypass diodes may be incorporated or used externally, in case of partial module shading, to maximize the output of module sections still illuminated.

Some special solar PV modules include concentrators in which light is focused by lenses or mirrors onto smaller cells. This enables the use of cells with a high cost per unit area (such as gallium arsenide) in a cost-effective way.

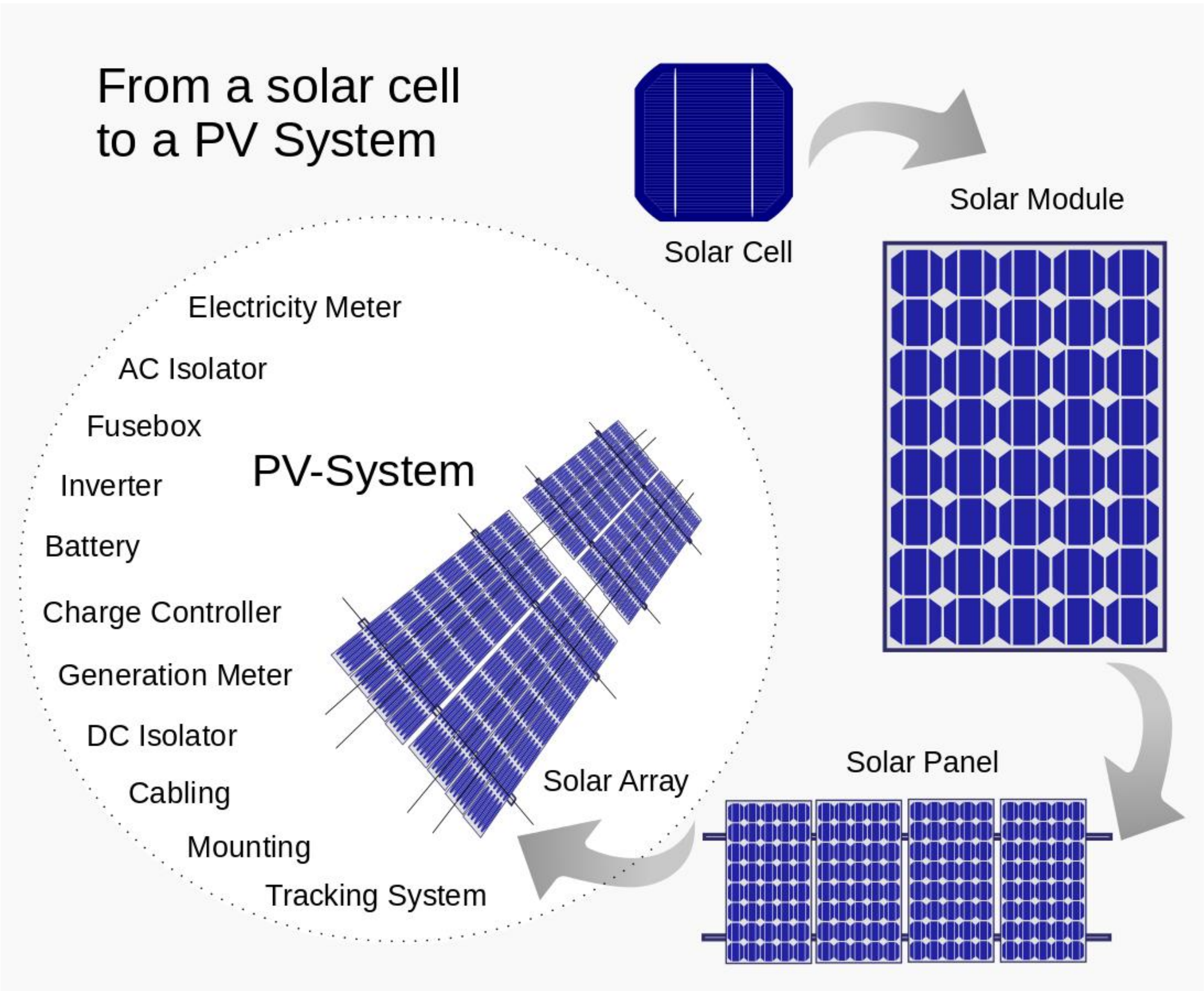


Fig 3.1 From a solar cell to PV system

3.3 Maintenance

Solar panel conversion efficiency, typically in the 20% range, is reduced by dust, grime, pollen, and other particulates that accumulate on the solar panel. "A dirty solar panel can reduce its power capabilities by up to 30% in high dust/pollen or desert areas", says Seamus Curran, associate professor of physics at the University of Houston and director of the Institute for NanoEnergy, which specializes in the design, engineering, and assembly of nanostructures.

Paying to have solar panels cleaned is often not a good investment; researchers found panels that had not been cleaned, or rained on, for 145 days during a summer drought in California, lost only 7.4% of their efficiency. Overall, for a typical residential solar system of 5 kW, washing panels halfway through the summer would translate into a mere $20 gain in electricity production until the summer drought ends—in about 2 ½ months. For larger commercial rooftop systems, the financial losses are bigger but still rarely enough to warrant the cost of washing the panels. On average, panels lost a little less than 0.05% of their overall efficiency per day.

3.4 Recycling

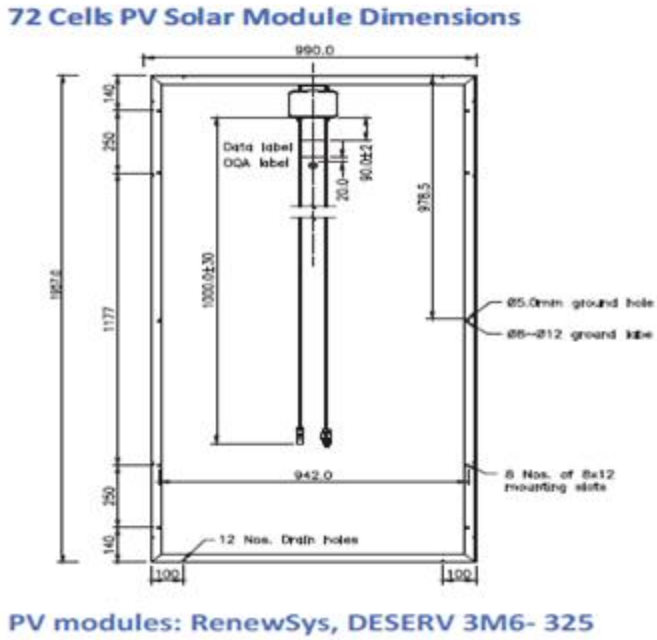
Most parts of a solar module can be recycled including up to 95% of certain semiconductor materials or the glass as well as large amounts of ferrous and non-ferrous metals.Some private companies and non-profit organizations are currently engaged in take-back and recycling operations for end-of-life modules.

Recycling possibilities depend on the kind of technology used in the modules:

- Silicon based modules: aluminum frames and junction boxes are dismantled manually at the beginning of the process. The module is then crushed in a mill and the different fractions are separated - glass, plastics and metals. It is possible to recover more than 80% of the incoming weight. This process can be performed by flat glass recyclers since morphology and composition of a PV module is similar to those flat glasses used in the building and automotive industry. The recovered glass for example is readily accepted by the glass foam and glass insulation industry.

- Non-silicon based modules: they require specific recycling technologies such as the use of chemical baths in order to separate the different semiconductor materials. For cadmium telluride modules, the recycling process begins by crushing the module and subsequently separating the different fractions. This recycling process is designed to recover up to 90% of the glass and 95% of the semiconductor materials contained. Some commercial-scale recycling facilities have been created in recent years by private companies.

Since 2010, there is an annual European conference bringing together manufacturers, recyclers and researchers to look at the future of PV module recycling.



Performance under standard test conditions (1000W/m² AM 1.5, 25°C)

	DESERV 3M6-320	DESERV 3M6-325
Rated power (Pmax), Wp	320	325
Max power voltage (Vmp), V	37.20	37.41
Max power current (Imp), A	08.61	08.69
Open circuit voltage (Voc), V	46.23	46.21
Short circuit current (Isc), A	09.06	09.18
Module efficiency (%)	16.51	16.77

Fig 3.2 PV module with specification(STD condition)

Chapter 4

4.1 Maximum power point tracking(MPPT)

Maximum power point tracking (MPPT or sometimes just PPT) is a technique used commonly with wind turbines and photovoltaic (PV) solar systems to maximize power extraction under all conditions.

Although solar power is mainly covered, the principle applies generally to sources with variable power: for example, optical power transmission and thermophotovoltaics.

PV solar systems exist in many different configurations with regard to their relationship to inverter systems, external grids, battery banks, or other electrical loads. Regardless of the ultimate destination of the solar power, though, the central problem addressed by MPPT is that the efficiency of power transfer from the solar cell depends on both the amount of sunlight falling on the solar panels and the electrical characteristics of the load. As the amount of sunlight varies, the load characteristic that gives the highest power transfer efficiency changes, so that the efficiency of the system is optimized when the load characteristic changes to keep the power transfer at highest efficiency. This load characteristic is called the maximum power point and MPPT is the process of finding this point and keeping the load characteristic there. Electrical circuits can be designed to present arbitrary loads to the photovoltaic cells and then convert the voltage, current, or frequency to suit other devices or systems, and MPPT solves the problem of choosing the best load to be presented to the cells in order to get the most usable power out.

Solar cells have a complex relationship between temperature and total resistance that produces a non-linear output efficiency which can be analyzed based on the I-V curve. It is the purpose of the MPPT system to sample the output of the PV cells and apply the proper resistance (load) to obtain maximum power for any given environmental conditions. MPPT devices are typically integrated into an electric power converter system that provides voltage or current conversion, filtering, and regulation for driving various loads, including power grids, batteries, or motors.

- Solar inverters convert the DC power to AC power and may incorporate MPPT: such inverters sample the output power (I-V curve) from the solar modules and apply the proper resistance (load) so as to obtain maximum power.
- The power at the MPP (P_{mpp}) is the product of the MPP voltage(V_{mpp}) and MPP current(I_{mpp}).

4.2 MPPT Implementation

When a load is directly connected to the solar panel, the operating point of the panel will rarely be at peak power. The impedance seen by the panel derives the operating point of the solar panel. Thus by varying the impedance seen by the panel, the operating point can be moved towards peak power point. Since panels are DC devices, DC-DC converters must be utilized to transform the impedance of one circuit (source) to the other circuit (load). Changing the duty ratio of the DC-DC converter results in an impedance change as seen by the panel. At a particular impedance (or duty ratio) the operating point will be at the peak power transfer point. The I-V curve of the panel can vary considerably with variation in atmospheric conditions such as radiance and temperature. Therefore, it is not feasible to fix the duty ratio with such dynamically changing operating conditions.

MPPT implementations utilize algorithms that frequently sample panel voltages and currents, then adjust the duty ratio as needed. Microcontrollers are employed to implement the algorithms. Modern implementations often utilize larger computers for analytics and load forecasting.

4.3 MPPT placement

Traditional solar inverters perform MPPT for the entire PV array (module association) as a whole. In such systems the same current, dictated by the inverter, flows through all modules in the string (series). Because different modules have different I-V curves and different MPPs (due to manufacturing tolerance, partial shading, etc.) this architecture means some modules will be performing below their MPP, resulting in lower efficiency.

Some companies are now placing maximum power point tracker into individual modules, allowing each to operate at peak efficiency despite uneven shading, soiling or electrical mismatch.

Data suggests having one inverter with one MPPT for a project that has east and west-facing modules presents no disadvantages when compared to having two inverters or one inverter with more than one MPPT.

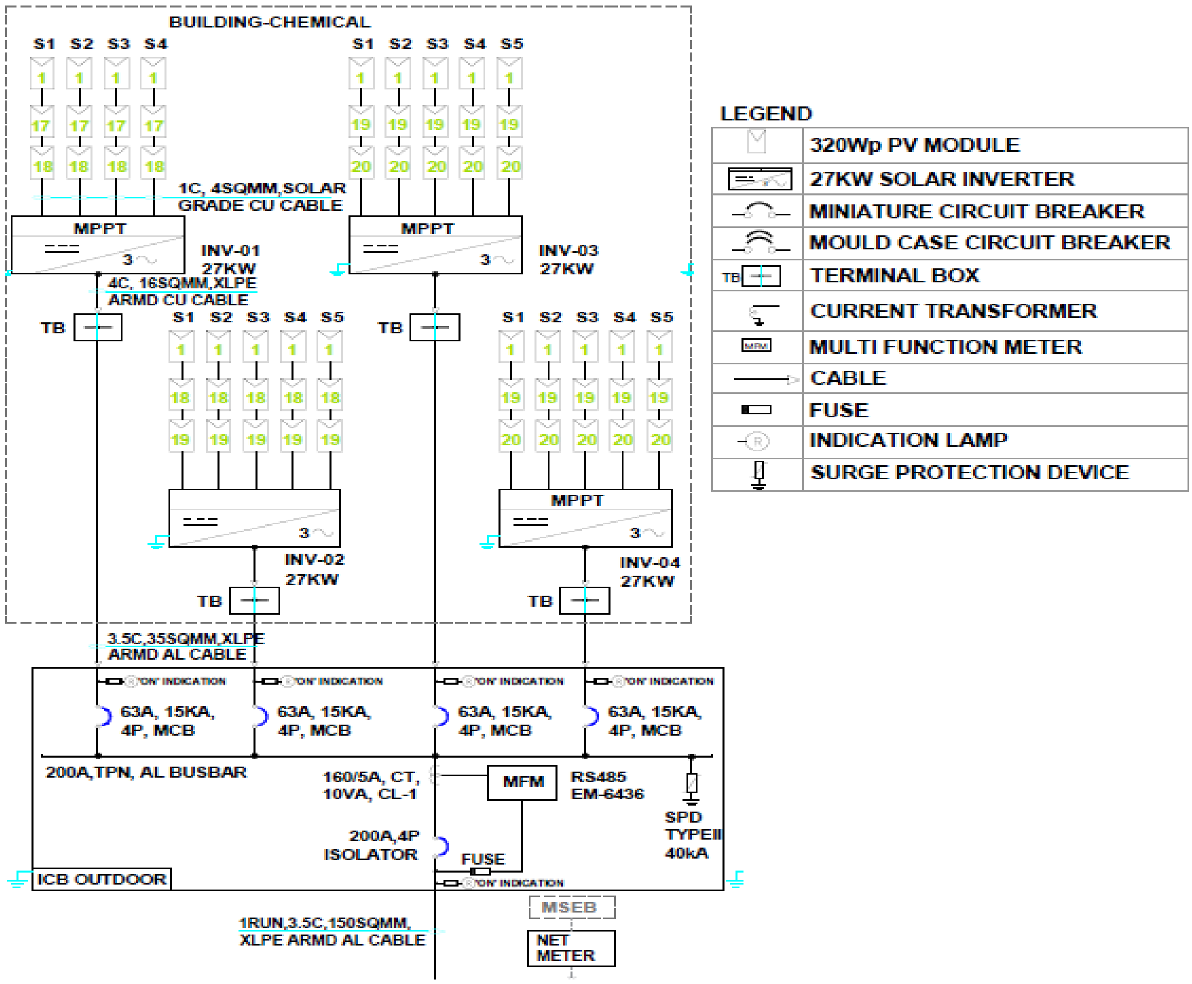


Fig 4.1 SLD of MPPT inverter to Solar Panel array

Chapter 5

5.1 Earthing

To connect the metallic (conductive) Parts of an Electric appliance or installations to the earth (ground) is called Earthing or Grounding.

In other words, to connect the metallic parts of electric machinery and devices to the earth plate or earth electrode (which is buried in the moisture earth) through a thick conductor wire (which has very low resistance) for safety purpose is known as Earthing or grounding.

To earth or earthing rather, means to connect the part of electrical apparatus such as metallic covering of metals, earth terminal of socket cables, stay wires that do not carry current to the earth. Earthing can be said as the connection of the neutral point of a power supply system to the earth so as to avoid or minimize danger during discharge of electrical energy.

In an electrical installation an earthing system or grounding system connects specific parts of that installation with the Earth's conductive surface for safety and functional purposes. The point of reference is the Earth's conductive surface. The choice of earthing system can affect the safety and electromagnetic compatibility of the installation.

In addition to electric power systems, other systems may require grounding for safety or function. Tall structures may have lightning rods as part of a system to protect them from lightning strikes. Telegraph lines may use the Earth as one conductor of a circuit, saving the cost of installation of a return wire over a long circuit. Radio antenna may require particular grounding for operation, as well as to control static electricity and provide lightning protection.

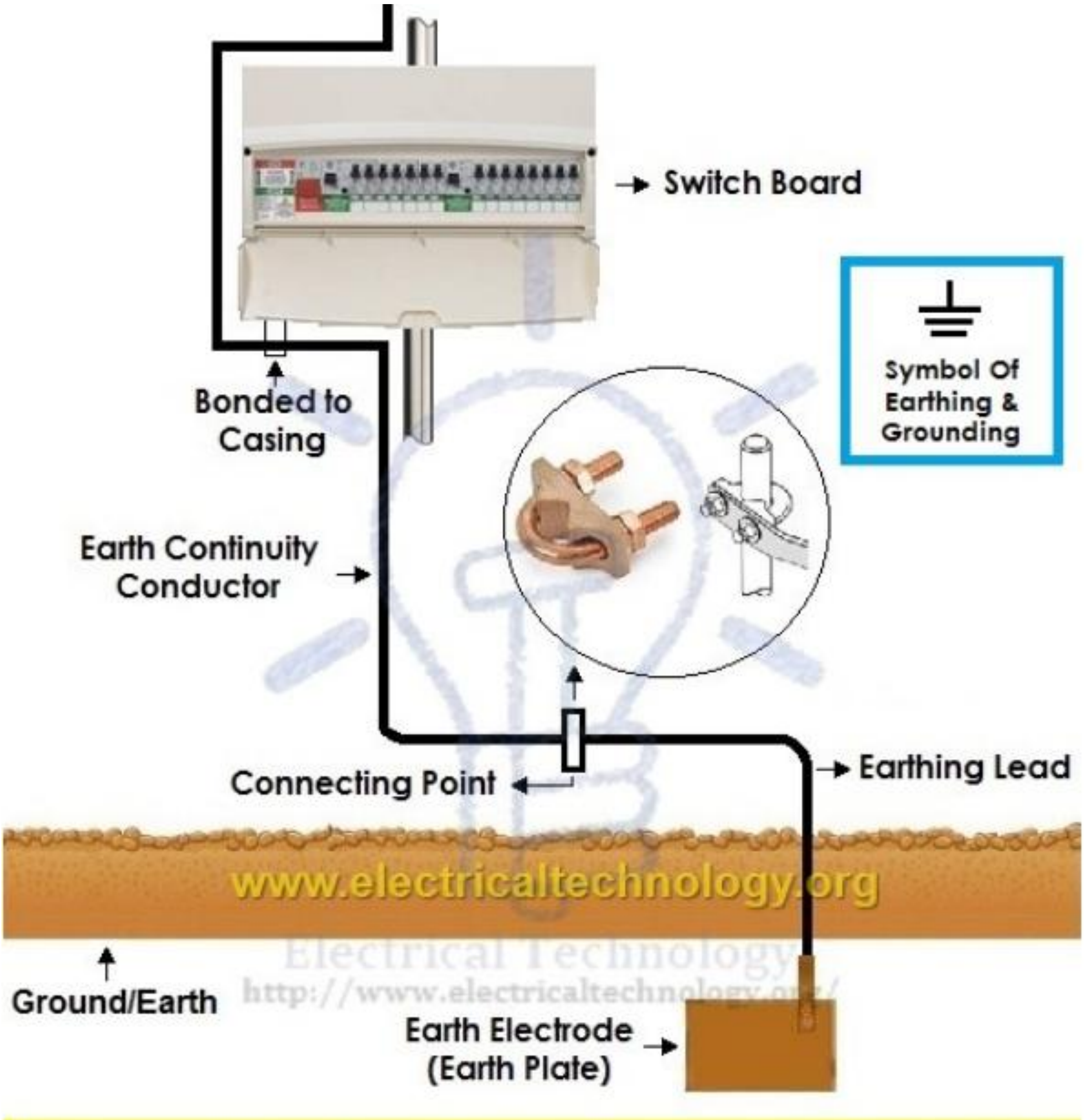


Fig 5.2 Typical earthing system with its components

5.2 Cable Selection

Power Loss and Voltage Drop calculation for selection of cable from String to Inverter

Sr.No	Inputs		
1	Module	320	Wp
2	Inverter-typ-1	27	KVA
3	String Current	8.23	A
4	Resistance of cable	0.0061	Ω/m
5	String Voltage	754	V

XLPE cables are a new range of insulated heavy duty cables introduced to world wide. XLPE compound used have overcome the limitation of PVC Insulated Cables such as thermal degradation, poor moisture resistance and thermoplastic in nature.

Technical Advantages:

- Higher current rating, higher short circuit rating (1.2times of PVC)
- Thermosetting in nature
- Higher resistance to moisture
- Higher insulation resistance (1000 times of PVC)
- Better resistance to surge current
- Low dielectric losses
- Better resistance to chemical
- Longer service life
- Higher cable operation temperature 90°C and short circuit temperature 250°C

The final selection of the cables are done generally by considering the application, but however following factors are important in selection of the same.

- Maximum operating voltage
- Insulation level
- Frequency
- Load to be carried

- Possible overloading duration & magnitude
- Route length and voltage drop
- Ambient temperature chemical & physical properties of soil
- Flame retardant properties

After taking consideration of all this parameters and checking the catalogues of siechem and Polycab cables .

Cable from string to inverter = 4sq.mm, Cu cable.

Cable from inverter to terminal box = 1.1kV 4C, 16sq.mm, Cu cable, Armoured cable.

Cable from terminal box to ICB panel = 1.1kV 3.5C, 35sq.mm, Al Armoured cable.

5.3 Fuse

In electronics and electrical engineering, a fuse is an electrical safety device that operates to provide overcurrent protection of an electrical circuit. Its essential component is a metal wire or strip that melts when too much current flows through it, thereby interrupting the current. It is a sacrificial device; once a fuse has operated it is an open circuit, and it must be replaced or rewired, depending on type.Fuses have been used as essential safety devices from the early days of electrical engineering. Today there are thousands of different fuse designs which have specific current and voltage ratings, breaking capacity and response times, depending on the application. The time and current operating characteristics of fuses are chosen to provide adequate protection without needless interruption. Wiring regulations usually define a maximum fuse current rating for particular circuits. Short circuits, overloading, mismatched loads, or device failure are the prime reasons for fuse operation.

A fuse is an automatic means of removing power from a faulty system; often abbreviated to ADS (Automatic Disconnection of Supply). Circuit breakers can be used as an alternative design solution to fuses, but have significantly different characteristics.

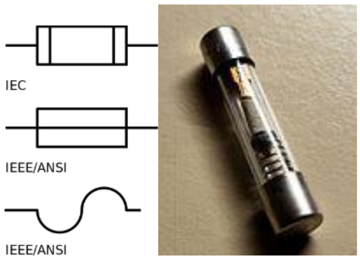


Fig 5.3 Fuse

A fuse consists of a metal strip or wire fuse element, of small cross-section compared to the circuit conductors, mounted between a pair of electrical terminals, and (usually) enclosed by a non-combustible housing. The fuse is arranged in series to carry all the current passing through the protected circuit. The resistance of the element generates heat due to the current flow. The size and construction of the element is (empirically) determined so that the heat produced for a normal current does not cause the element to attain a high temperature. If too high a current flows, the element rises to a higher temperature and either directly melts, or else melts a soldered joint within the fuse, opening the circuit.

The fuse element is made of zinc, copper, silver, aluminum, or alloys to provide stable and predictable characteristics. The fuse ideally would carry its rated current indefinitely, and melt quickly on a small excess. The element must not be damaged by minor harmless surges of current, and must not oxidize or change its behavior after possibly years of service.

The fuse elements may be shaped to increase heating effect. In large fuses, current may be divided between multiple strips of metal. A dual-element fuse may contain a metal strip that melts instantly on a short-circuit, and also contain a low-melting solder joint that responds to long-term overload of low values compared to a short-circuit. Fuse elements may be supported by steel or nichrome wires, so that no strain is placed on the element, but a spring may be included to increase the speed of parting of the element fragments.

The fuse element may be surrounded by air, or by materials intended to speed the quenching of the arc. Silica sand or non-conducting liquids may be used.

1. Rated current IN

A maximum current that the fuse can continuously conduct without interrupting the circuit.

2. Speed

The speed at which a fuse blows depends on how much current flows through it and the material of which the fuse is made. The operating time is not a fixed interval, but decreases as the current increases. Fuses have different characteristics of operating time compared to current. A standard fuse may require twice its rated current to open in one second, a fast-blow fuse may require twice its rated current to blow in 0.1 seconds, and a slow-blow fuse may require twice its rated current for tens of seconds to blow.

Fuse selection depends on the load's characteristics. Semiconductor devices may use a fast or ultrafast fuse as semiconductor devices heat rapidly when excess current flows. The fastest blowing fuses are designed for the most sensitive electrical equipment, where even a short exposure to an overload current could be very damaging. Normal fast-blow fuses are the most general purpose fuses. The time delay fuse (also known as anti-surge, or slow-blow) are designed to allow a current which is above the rated value of the fuse to flow for a short period of time without the fuse blowing. These types of fuse are used on equipment such as motors, which can draw larger than normal currents for up to several seconds while coming up to speed.Manufacturers can provide a plot of current vs time, often plotted on logarithmic scales, to characterize the device and to allow comparison with the characteristics of protective devices upstream and downstream of the fuse.

3. The I^2t value

The I^2t rating is related to the amount of energy let through by the fuse element when it clears the electrical fault. This term is normally used in short circuit conditions and the values are used to perform co-ordination studies in electrical networks. I^2t parameters are provided by charts in manufacturer data sheets for each fuse family. For coordination of fuse operation with upstream or downstream devices, both melting I^2t and clearing I^2t are specified. The melting I^2t is proportional to the amount of energy required to begin melting the fuse element. The clearing I^2t is proportional to the total energy let through by the fuse when clearing a fault. The energy is mainly dependent on current and time for fuses as well as the available fault level and system voltage. Since the I^2t rating of the fuse is proportional to the energy it lets through, it is a measure of the thermal damage from the heat and magnetic forces that will be produced by a fault.

4. Breaking capacity

The breaking capacity is the maximum current that can safely be interrupted by the fuse. This should be higher than the prospective short-circuit current. Miniature fuses may have an interrupting rating only 10 times their rated current. Some fuses are designated High Rupture Capacity (HRC) and are usually filled with sand or a similar material. Fuses for small, low-voltage, usually residential, wiring systems are commonly rated, in North American practice, to interrupt 10,000 amperes. Fuses for commercial or industrial power systems must have higher interrupting ratings, with some low-voltage current-limiting high interrupting fuses rated for 300,000 amperes. Fuses for high-voltage equipment, up to 115,000 volts, are rated by the total apparent power (megavolt-amperes, MVA) of the fault level on the circuit.

5. Rated voltage

The voltage rating of the fuse must be equal to or, greater than, what would become the open-circuit voltage. For example, a glass tube fuse rated at 32 volts would not reliably interrupt current from a voltage source of 120 or 230V. If a 32V fuse attempts to interrupt the 120 or 230 V source, an arc may result. Plasma inside the glass tube may continue to conduct current until the current diminishes to the point where the plasma becomes a non-conducting gas. Rated voltage should be higher than the maximum voltage source it would have to disconnect. Connecting fuses in series does not increase the rated voltage of the combination, nor of any one fuse. Medium-voltage fuses rated for a few thousand volts are never used on low voltage circuits, because of their cost and because they cannot properly clear the circuit when operating at very low voltages.

HRC fuse or high rupturing capacity fuse- In that type of fuse, the fuse wire or element can carry short circuit heavy current for a known time period. During this time if the fault is removed, then it does not blow off otherwise it blows off or melts. The enclosure of HRC fuse is either of glass or some other chemical compound. This enclosure is fully air tight to avoid the effect of atmosphere on the fuse materials. The ceramic enclosure having metal end cap at both heads, to which fusible silver wire is welded. The space within the enclosure, surrounding the fuse wire or fuse element is completely packed with a filling powder. This type of fuse is reliable and has inverse time characteristic, that means if the fault current is high then rupture time is less and if fault current is not so high then rupture time is long.

When the over rated current flows through the fuse element of high rupturing capacity fuse the element is melted and vapourized. The filling powder is of such a quantity that the chemical reaction between the silver vapour and the filling powder forms a high electrical resistance substance which very much help in quenching the arc.

5.4 Circuit Breakers

Nowadays we use more commonly miniature circuit breaker or MCB in low voltage electrical network instead of fuse. The MCB has some advantages compared to fuse.

1. It automatically switches off the electrical circuit during abnormal condition of the network means in over load condition as well as faulty condition. The fuse does not sense but miniature circuit breaker does it in more reliable way. MCB is much more sensitive to over current than fuse.
2. Another advantage is, as the switch operating knob comes at its off position during tripping, the faulty zone of the electrical circuit can easily be identified. But in case of fuse, fuse wire should be checked by opening fuse grip or cutout from fuse base, for confirming the blow of fuse wire.
3. Quick restoration of supply can not be possible in case of fuse as because fuses have to be re-wirable or replaced for restoring the supply. But in the case of MCB, quick restoration is possible by just switching on operation.
4. Handling MCB is more electrically safe than fuse. Because of to many advantages of MCB over fuse units, in modern low voltage electrical network, miniature circuit breaker is mostly used instead of backdated fuse unit.

Only one disadvantage of MCB over fuse is that this system is more costlier than fuse unit system.

- Working Principle Miniature Circuit Breaker

There are two arrangement of operation of miniature circuit breaker. One due to thermal effect of over current and other due to electromagnetic effect of over current. The thermal operation of miniature circuit breaker is achieved with a bimetallic strip whenever continuous over current flows through MCB, the bimetallic strip is heated and deflects by bending. This deflection of bimetallic strip releases mechanical latch. As this mechanical latch is attached with operating mechanism, it causes to open the miniature circuit breaker contacts.

But during short circuit condition, sudden rising of current, causes electromechanical displacement of plunger associated with tripping coil or solenoid of MCB. The plunger strikes the trip lever causing immediate release of latch mechanism consequently open the circuit breaker contacts. This was a simple explanation of miniature circuit breaker working principle.

Miniature circuit breaker construction is very simple, robust and maintenance free. Generally a MCB is not repaired or maintained, it just replaced by new one when required. A miniature circuit breaker has normally three main constructional parts. These are:

- Frame of Miniature Circuit Breaker

The frame of miniature circuit breaker is a molded case. This is a rigid, strong, insulated housing in which the other components are mounted.

- Operating Mechanism of Miniature Circuit Breaker

The operating mechanism of miniature circuit breaker provides the means of manual opening and closing operation of miniature circuit breaker. It has three-positions "ON," "OFF," and "TRIPPED". The external switching latch can be in the "TRIPPED" position, if the MCB is tripped due to over-current. When manually switch off the MCB, the switching latch will be in "OFF" position. In close condition of MCB, the switch is positioned at "ON". By observing the positions of the switching latch one can determine the condition of MCB whether it is closed, tripped or manually switched off.

- Trip Unit of Miniature Circuit Breaker

The trip unit is the main part, responsible for proper working of miniature circuit breaker. Two main types of trip mechanism are provided in MCB. A bimetal provides protection against over load current and an electromagnet provides protection against short-circuit current.

- Operation of Miniature Circuit Breaker

There are three mechanisms provided in a single miniature circuit breaker to make it switched off. If we carefully observe the picture beside, we will find there are mainly one bi - metallic strip, one trip coil and one hand operated on - off lever. Electric current carrying path of a miniature circuit breaker shown in the picture is like follows. First left hand side power terminal - then bimetallic strip - then current coil or trip coil - then moving contact - then fixed contact and - lastly right had side power terminal. All are arranged in series.

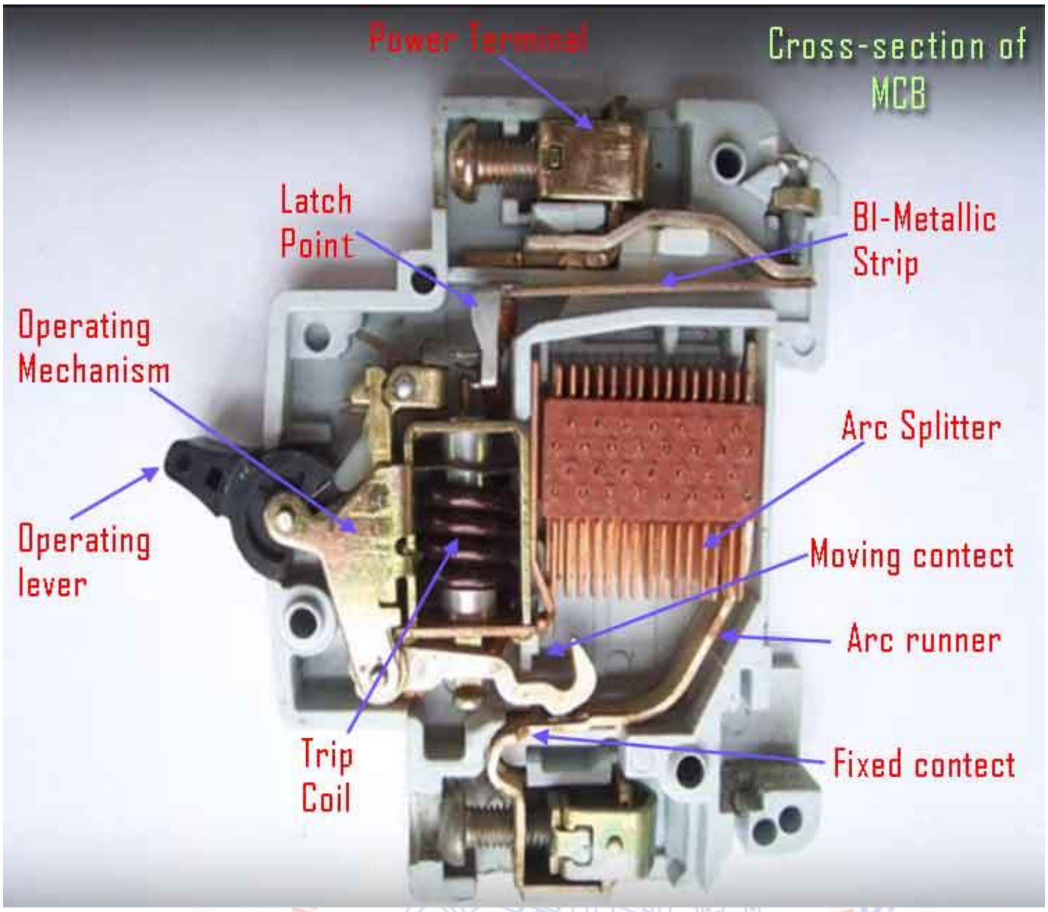


Fig5.4 MCB

If circuit is overloaded for long time, the bi-metallic strip becomes over heated and deformed. This deformation of bi metallic strip causes, displacement of latch point. The moving contact of the MCB is so arranged by means of spring pressure, with this latch point, that a little displacement of latch causes, release of spring and makes the moving contact to move for opening the MCB. The current coil or trip coil is placed such a manner, that during short circuit fault the mmf of that coil causes its plunger to hit the same latch point and make the latch to be displaced. Hence the MCB will open in same manner. Again when operating lever of the miniature circuit breaker is operated by hand, that means when we make the MCB at off position manually, the same latch point is displaced as a result moving contact separated from fixed contact in same manner. So, whatever may be the operating mechanism, that means, may be due to deformation of bi - metallic strip, due to increased mmf of trip coil or may due to manual operation, actually the same latch point is displaced and same deformed spring is released, which ultimately responsible for movement of the moving contact. When the the moving contact separated from fixed contact, there may be a high chance of arc. This arc then goes up through the arc runner and enters into arc splitters and is finally quenched.

When we switch on an MCB, we actually reset the displaced operating latch to its previous on position and make the MCB ready for another switch off or trip operation.

The following are the three factors to be considered for selecting an MCB for specific application.

1. Nominal rating of the circuit breaker

This is the rated ampere current rating of MCB. This value must be lower than the current carrying capacity of wiring system and higher than or equal to the maximum full load current in the wiring system. Generally, this rating should be such that it can handle 125 percent of continuous load plus rating of noncontinuous load. Typically this can be expressed as

Maximum full load current in the system ≤ Current rating of MCB ≤ Cable rating

2. KA rating or breaking capacity

This rating refers to the capability of MCB that can trip or interrupt the circuit under short circuit conditions. It is expressed in Kilo Amps (KA). This rating must not be less than the prospective short-circuit current. The prospective short-circuit current the maximum current that exist in the circuit during short-circuit conditions. In residential installations 6KA MCB is sufficient while 10 KA or above rating MCB is needed for commercial and light industrial applications.

Chapter 6

6.1 Matlab Simulation

MATLAB (matrix laboratory) is a multi-paradigm numerical computing environment. A proprietary programming language developed by MathWorks, MATLAB allows matrix manipulations, plotting offunctions and data, implementation of algorithms, creation of user interfaces, and interfacing with programs written in other languages, including C, C++, C#, Java, Fortran and Python.

Although MATLAB is intended primarily for numerical computing, an optional toolbox uses the MuPADsymbolic engine, allowing access to symbolic computing abilities. An additional package, Simulink, adds graphical multi-domain simulation and model-based design for dynamic and embedded systems.

As of 2017, MATLAB has roughly 1 million users across industry and academia. MATLAB users come from various backgrounds of engineering, science, and economics.

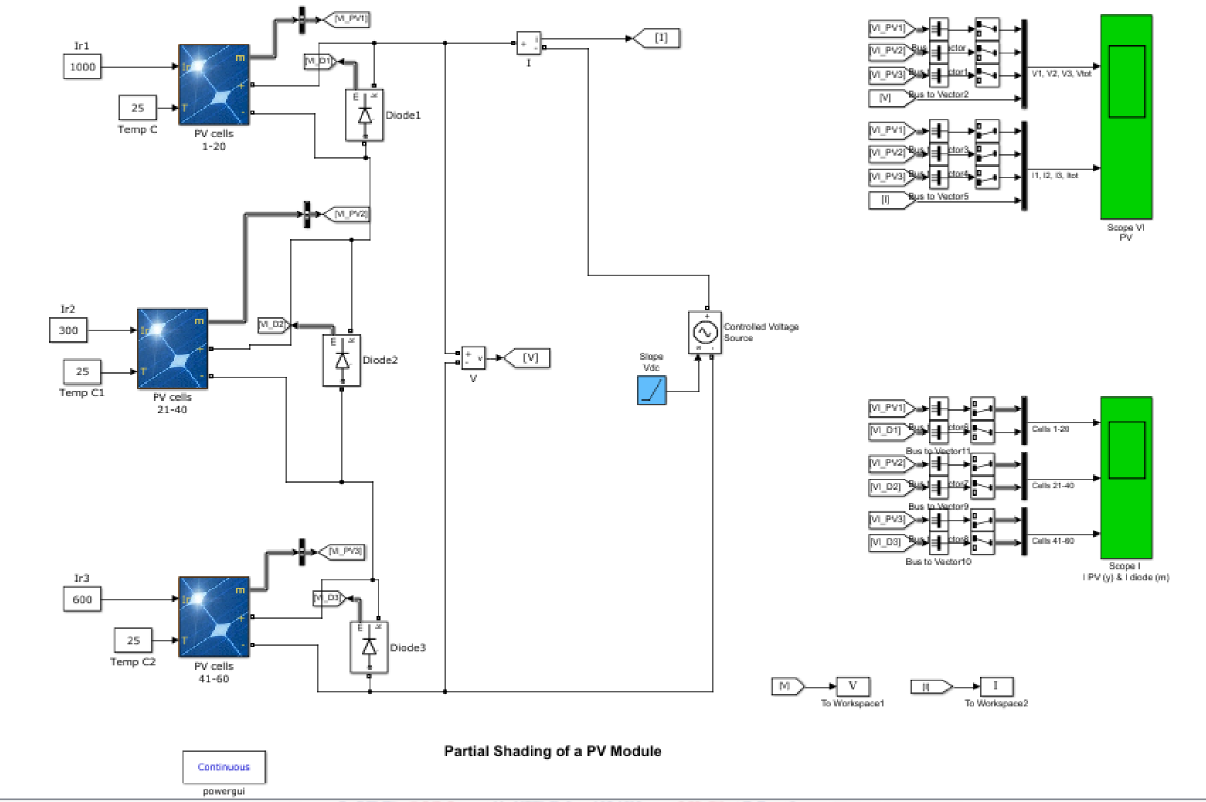


Fig 6.1 Simulation of partial shading of PV module

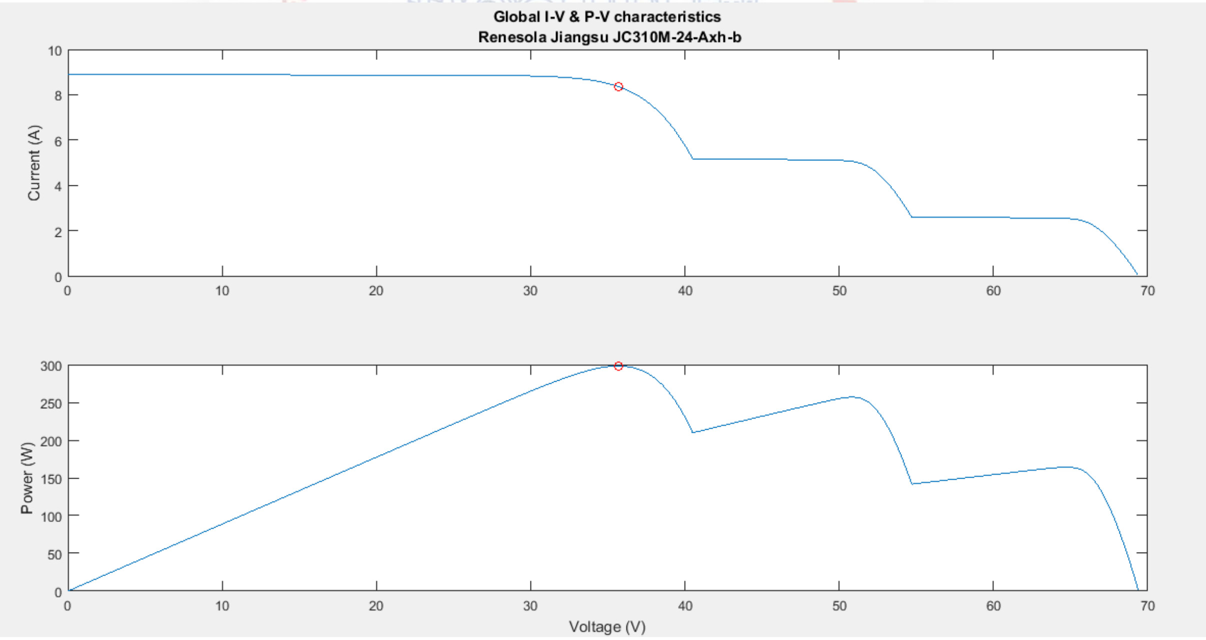


Fig 6.2 I-V & P-V characteristics of partial shading

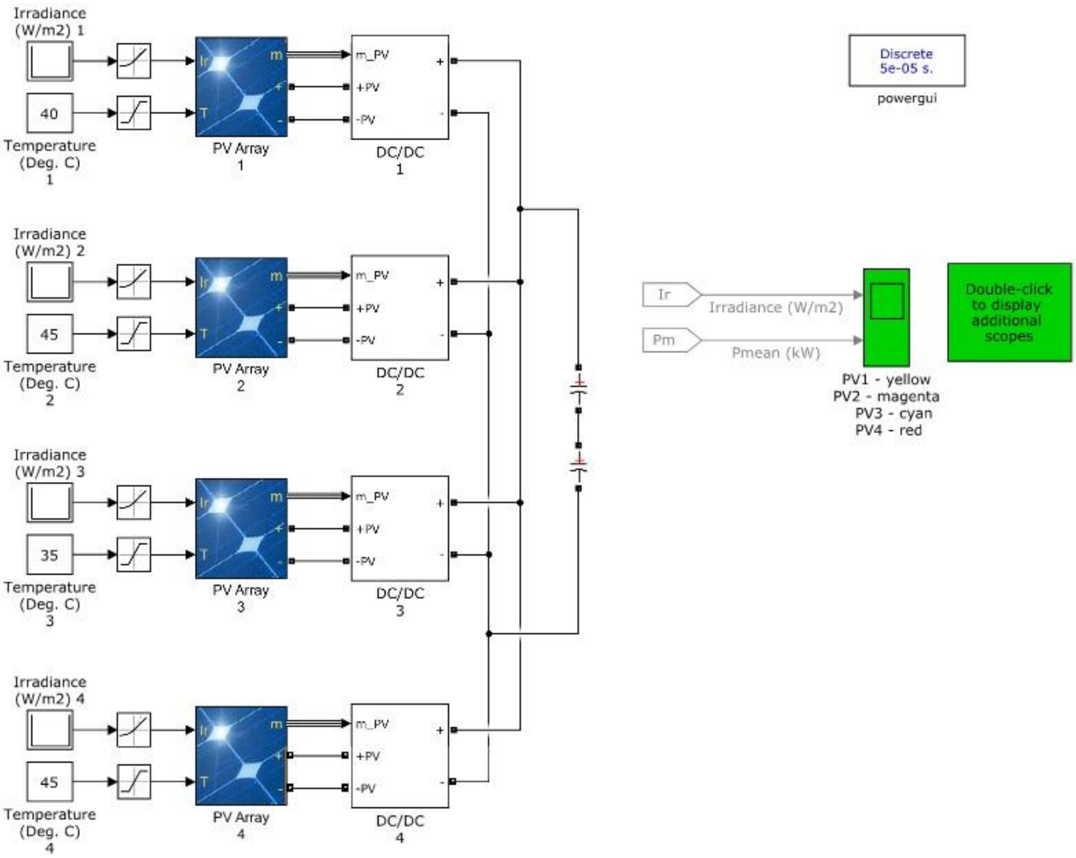


Fig 6.3 PV array

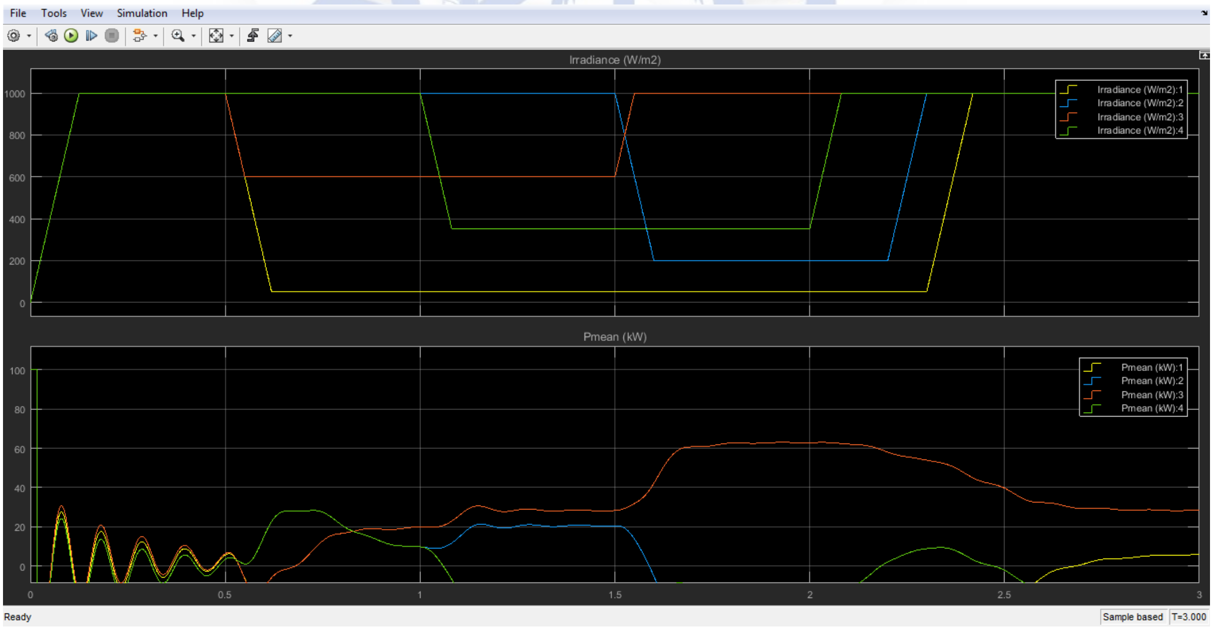


Fig 6.4 Irradance & power output

Chapter 7

7.1 Payback Period

Payback period in capital budgeting refers to the period of time required to recoup the funds expended in an investment, or to reach the break-even point. For example, a $1000 investment made at the start of year 1 which returned $500 at the end of year 1 and year 2 respectively would have a two-year payback period. Payback period is usually expressed in years. Starting from investment year by calculating Net Cash Flow for each year: Net Cash Flow Year 1 = Cash Inflow Year 1 - Cash Outflow Year 1. Then Cumulative Cash Flow = (Net Cash Flow Year 1 + Net Cash Flow Year 2 + Net Cash Flow Year 3, etc.) Accumulate by year until Cumulative Cash Flow is a positive number: that year is the payback year.

The time value of money is not taken into account. Payback period intuitively measures how long something takes to "pay for itself." All else being equal, shorter payback periods are preferable to longer payback periods. Payback period is popular due to its ease of use despite the recognized limitations described below.

The term is also widely used in other types of investment areas, often with respect to energy efficiency technologies, maintenance, upgrades, or other changes. For example, a compact fluorescent light bulb may be described as having a payback period of a certain number of years or operating hours, assuming certain costs. Here, the return to the investment consists of reduced operating costs. Although primarily a financial term, the concept of a payback period is occasionally extended to other uses, such as energy payback period (the period of time over which the energy savings of a project equal the amount of energy expended since project inception); these other terms may not be standardized or widely used.

Plant	Solar System Size	400	KW
	Rate of Interest	0.12	Flat Rate
	Plant Cost	2.6 Cr.	INR
	IRR	18.53 %	
Annual Generation	Annual Generation per KW	600,000	Units
	Generation to reduce	2.50%	First Year
	Generation to reduce	0.70%	Per year
Warranty	Panels	25	Years
	Inverters	5	Years
Accelerated Depreciation	Year 1	40	Percentage per FY
	Year 2	40	Percentage per FY
	Year 3	20	Percentage per FY
Operating Costs	Plant maintenance etc Inverter Replacement and allied spares in year 12	14,952,671	Annual cost per year towards Asset Replacement, Repairs and Maintenance over 25 Years
	Plant Capital Cost	2,579,144	
Cost computation	Maintance+spares	26,000,000	
		17,531,816	
	Total Costs of D + M		
	Total Generation in 25 Years	43,531,816	
		13,565,724	kWh
Unit cost	Average Per unit costs	2.58	

For payback period MSEDCL rate is assumed as Rs 7.5. Payback period will be varied accordingly to MSEDCL tariff rate. Assumption is made that it is a 400KW capacity plant.

Annual Generation	Year	Depreciation Benefit	State Utility Board Charges Rs/KWh	Annual Cost Saving from Solar (in Rs)	Total Earnings	Maintenance	Spares	Interest (12%)	Net Savings	Reduction in Capital
600,000	1	3,432,000	7.5	4,500,000	7,932,000	320,000		2,184,000	5,428,000	20572000
585,000	2	3,432,000	7.7	4,519,125	7,951,125	336,000		1,728,048	5,887,077	14684923
580,905	3	1,716,000	8.0	4,622,116	6,338,116	352,800		1,233,534	4,751,782	9933141
576,839	4		8.2	4,727,454	4,727,454	370,440	0	834,384	3,522,630	6410511
572,801	5		8.4	4,835,193	4,835,193	388,962	0	538,483	3,907,748	2502763
568,791	6		8.7	4,945,387	4,945,387	408,410	78,000	0	4,458,976	-1956214
564,810	7		9.0	5,058,092	5,058,092	428,831	81,900	0	4,547,361	-6503575
560,856	8		9.2	5,173,366	5,173,366	450,272	85,995	0	4,637,099	-11140674
556,930	9		9.5	5,291,267	5,291,267	472,786	90,295	0	4,728,186	-15868860
553,031	10		9.8	5,411,855	5,411,855	496,425	94,809	0	4,820,620	
549,160	11		10.1	5,535,191	5,535,191	521,246	99,550	0	4,914,395	
545,316	12		10.4	5,661,338	5,661,338	547,309	104,527	0	5,009,502	
541,499	13		10.7	5,790,360	5,790,360	574,674	109,754	0	5,105,932	
537,708	14		11.0	5,922,322	5,922,322	603,408	115,242	0	5,203,673	
533,944	15		11.3	6,057,292	6,057,292	633,578	121,004	0	5,302,710	
530,207	16		11.7	6,195,338	6,195,338	665,257	127,054	0	5,403,027	
526,495	17		12.0	6,336,529	6,336,529	698,520	133,406	0	5,504,603	
522,810	18		12.4	6,480,939	6,480,939	733,446	140,077	0	5,607,416	
519,150	19		12.8	6,628,639	6,628,639	770,118	147,081	0	5,711,441	
515,516	20		13.2	6,779,706	6,779,706	808,624	154,435	0	5,816,647	
511,908	21		13.5	6,934,216	6,934,216	849,055	162,156	0	5,923,004	
508,324	22		14.0	7,092,246	7,092,246	891,508	170,264	0	6,030,474	
504,766	23		14.4	7,253,879	7,253,879	936,083	178,777	0	6,139,018	
501,233	24		14.8	7,419,195	7,419,195	982,888	187,716	0	6,248,591	
497,724	25		15.5	7,735,623	7,735,623	1,032,032	197,102	0	6,506,489	
13,565,724	Total	8,580,000				14,952,672			111,526,913.16	

Conclusion

In this project we have shown the factors required for the installation of solar PV plant. With an approx simulation of the yeld which is provided by it to the user. In this project Simulink based model of solar cell and solar array is developed . Modelling of solar array is much easier than its modelling in real environment and testing it. Boost converter is used to boost and regulate the output voltage of solar array . Duty cycle of boost converter is controlled through MPPT controller to track the maximum power from solar array. Simulink based models and their outputs of solar cell and array are shown clearly for different stages to understand the use of physical modelling using Simulink. Payback period and commercial gain and benefit is also measured by this method of management and potential time for investment return and profit thereafter for a predefined period of 25 years solar life time of operation is also given.

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