Chapter

Energy Return on Investment Analysis of a Solar Photovoltaic System

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Abstract

The consumption of petroleum product assets on an overall premise has required an earnest look for elective vitality sources to get together the present-day request. The world likewise faces the double difficulties of petroleum derivative exhaustion and CO_2 discharges plus the fundamental competitor for confronting these difficulties. However, safe and economic concepts for CCS have not been proven, nuclear suffer from high cost, radioactive waste management, fuel availability, and nuclear weapon proliferation issues, and renewable, other than hydropower, have been limited by resource limits, high cost, and intermittency problems. In any case, the later intense cost decreases in the creation of photovoltaics (PV) which makes ready for empowering sun-based innovations to end up cost focused on petroleum energy generation. The target of present work is to evaluate the capability of sun oriented solar power at Chandigarh University, which lastly built up a framework depending on the potential estimations for a picked region of 1050.1416 m^2. At the end, cost estimation of SPV is determined to indicate whether it is monetarily practical or not.

Keywords: energy, petroleum, sustainable, irregularity, generation, estimation

1. Introduction

Power assumes a critical function in everyday life movements. The level of advancement and progress of the nation is estimated via evaluation of an individual's power use pattern. Power requirement is escalating stepwise with increasing populace, modernization, and commercialization. The global conventional energy source delivery, viz. coal, oil, and gaseous petrol, will consequently be drained in the next 100 years [1]. The speed of energy employment is intensifying; supply is exhausting bringing about inflammation and energy deficiency. It is classified as "power crisis." Hence, possible or inexhaustible wellsprings of vitality have to be created to fulfill future energy necessities. In the previous 200 years, the vitality framework dependent on coal, oil, flammable gas, and other nonrenewable energy sources has extraordinarily advanced the improvement of human culture. However, not only the material life and the spiritual life are increasing, but also serious consequences also brought from the large scale use of fossil fuels are increasing, depleting the resources and deteriorating the environment [2].

It also includes political and economic disputes of a number of nations. Frequently growing anxiety about “global warming” and exhaustion of oil has motivated various nations worldwide to implement novel power techniques to fulfill the power requirement and to conserve our atmosphere [3, 4]. In order to protect the environment and for sustainable growth, the importance of sustainable energy cannot be overemphasized. It leads to speed up the study and progress of sustainable energy techniques particularly PV applications because of its quiet operation, long lifetime, and little repair. PV offer clients the capability to produce electricity in a dirt-free, silent, and trustworthy way. PV systems consist of solar cells, gadgets that convert light energy straight into power [5]. The photovoltaic (PV) system has practiced a rapid growth over the last decade and is expected to accelerate in the next 10–20 years. Recently, a PV system has broadly received a lot of concentration due to many significant advantages such as unlimited accessibility of key energy sources and no polluted emissions [6]. The quantity of PV generation is rising quickly both in size and complexity. As a consequence, the cost of PV systems is constantly declining. It has been noticed that nowadays more and more photovoltaic systems are being installed. Energy classification is shown in **Table 1** [7].

Energy source type	Definition	Example
Primary energy sources	These are the resources which can be legitimately established in nature or put away in nature and can be separated. Accessible in crude from which they should be prepared first for use.	Stored nuclear energy from radioactive material; direct—coal, oil, nature gas, and biomass.
Secondary energy sources	Optional vitality resources are gotten from essential sources in the form of either last fuel or vitality supply. Inclusion of innovative procedures in this change in the middle of makes drop in essential vitality in transit purchasers.	Gasoline, petrol, steam energy from coal, etc.
Waste energy resources	It is possible to reuse waste energy liberated in the process of utilization of primary and secondary energy resources. Practically it is achieved by combined heat and power which is more popular as cogeneration.	Energy extracted from cooling systems in power plants.
Renewable (nonconventional)	This is the energy acquired from never ending sources of energy available in nature. The main feature of this is that it can be extracted without causing pollution.	Solar power, wind energy, geothermal energy, tidal energy, and biomass.
Nonrenewable energy Conventional	Nonrenewable energy is the energy obtained from the conventional fuels which are exhaustible today or tomorrow with time.	Coal, oil, gas, hydropower, diesel power.
Commercial	This is the energy accessible from market at certain price. These are the cardinal source for industrialized countries as its basic need for industries, commercial transport, and agricultural sectors.	Electricity, lignite, coal, oil, natural, gas, etc.
Noncommercial	These sources are not available in the market unlike previous type for a price. Instead, these are traditionally gathered. Also termed as traditional fuel and mostly shrugged off in energy accounting.	Firewood, cattle, dung sugarcane crush, solar and thermal water heating, etc.

Table 1.
Classification of energy sources [7].

1.1 Present energy status

The current energy status is discussed in the form of world, India, and Punjab.

1.1.1 World energy scenario

World energy demand has been growing exponentially in this century as shown in **Figure 1**. By means of fossil fuels like coal, wood, oil, or gas, it was possible for humankind to set up a society for colder climates. Because of the expanding requests for solar energy, a higher portability and a bigger total populace, vitality utilization is immensely raised in the course of the most recent 150 years. The International Energy Agency (IEA) estimates that global main energy between now and 2030 will increase by 1.5% per year [7].

1.1.2 Energy status in India

Before the finish of the year 2019, India had an energy generation limit of around 155 Giga Watt. But still, around 17% (450 million) of towns in India are not electrified [8–10]. With a developing financial system, the interest for energy is developing at 6% consistently and the top burden request is relied upon to achieve 225 GW before the end of the year 2022.

The Indian power division is extremely reliant on coal for energy requirement which is about 53% of the overall capacity. As per the present scenario, coal utilization by power division is probably to arrive at 200 Million Metric Tonnes by 2013. As per the Coal Ministry, the accessible coal resources are predicted to remain for the next 40–45 years. Around 11% of the entire power is received from oil and gas [10–13]. As shown in **Figure 2**, in India, the power division is the major user of oil and gas other than automobiles and industry.

In India, individual energy consumption is extremely lesser as compared to the world level. Indeed, even with such a low individual capita utilization, the power shortfall is around 11% in whole requirement and a shortage of over 12% in crest load request [13]. This obviously means the accessible fuel is not adequate to satisfy the rising need for vitality in India.

1.1.3 Solar energy situation in Punjab

Energy preservation is a standout among the main significant focuses today and Punjab is blessed with tremendous capability of sun powered vitality with more than 300 days of daylight per year and renewable energy source is being adequately developed by PEDA. As the state is endowed with vast potential of solar energy

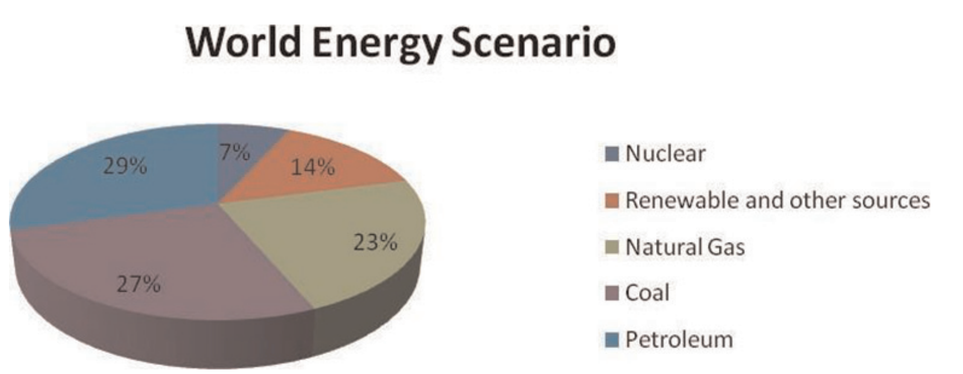

Figure 1.
Energy generation capacity in the world [7].

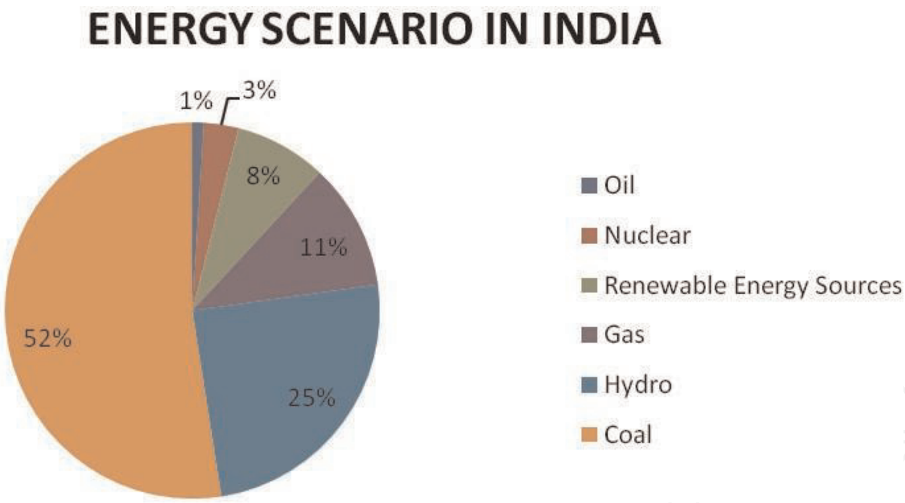

Figure 2.
Power generation capacity in India [7].

estimated at 4 -7 KWH/Sq.mtr of solar insolation levels, the Government is also keen to tap this resource for strengthening power infrastructure in the State by setting up solar energy-based power projects so as to save the depleting resources for our future generation and to control global warming, fast depleting conventional sources of energy and resultant increased environmental pollution. PEDA with its untiring endeavors has effectively charged numerous ventures in various conditions of Punjab [14]. Under the rooftop programme, SPV power projects are being set up at various important Government, Institutional and Religious buildings, namely Punjab Raj Bhawan, Golden Temple, Wagah Border, Punjab Agricultural University, Ludhiana, and Pushpa Gujral Science City, Kapurthala.

1.2 Solar energy in India

India is a region which receives a good amount of solar heat flux. **Table 2** gives mean daily solar radiations at some places in India.

During the last few years, more than 50 small solar power plants have been installed in villages in Uttar Pradesh and other states. The size of these plants varies from 2 to 10 KW. These plants are supplying power to these remote villages where power from grid is not available. In addition, more than 40,000 solar powered street lighting systems have been installed in different states and more than 1000 water pumping systems have also been installed. It is proposed to use more than

Place	Mean daily solar radiations KWH per meter square
Port Blair	4.3
Madras	5.6
Poona	5.7
Jodhpur	6
Delhi	5.4
Shilling	4.4
Western Rajasthan	7.4

Table 2.
Mean daily solar radiations at different places in India [14].

20,000 photovoltaic power packs (each about 70–90 W range) for rural telephone system in the near future. In all, more than 50,000 photovoltaic systems are being used at different places [15–17].

In addition to above, solar water heating system, solar cookers, solar air heaters, solar driers for food grains, etc. are being used on a very large scale [16]. It is expected that the total solar power utilization in India would be around 10,000 MW by the year 2020.

2. Problem formulation

2.1 Motivation

The interest of power has expanded and that much interest cannot be gained by the ordinary power plants, and furthermore, in the creating nations, similar to India, there is a serious issue of lack of intensity [18, 19]. The predominance of the power supply in a couple of spots is described by vast voltage and recurrence variances, arranged and unconstrained power cuts, and burden top limitations. This has prompted quick utilization of sun-oriented capacity to meet the fundamental burden [20]. This framework offers a superior productivity, adaptability of arranging, and ecological advantages contrasted with power frameworks [20, 21]. In this manner, my venture work centers around the independent PV framework joining sun-based PV and battery back-up in the scholastic grounds in light of the fact that a large portion of the activity of scholarly grounds happen in the day time, which is in synchronous with the accessibility of daylight.

2.2 Need and significance of work

Indian power framework is constantly overburdened because of hole between the free market activity, and in this manner, control in the optional conveyance framework is not constantly accessible. Vitality is a critical contribution for monetary improvement [21]. Vitality is required for financial development, for improving the personal satisfaction, and for expanding open doors for advancement. Since expendable vitality sources in the nation are restricted, there is an earnest need to concentrate on the improvement of sustainable power sources and utilization of vitality proficient advances [21, 22]. Notwithstanding nonsolid framework, there is not really a constrained interest of sun-powered photovoltaic frameworks in the business part of a creative nation like India, the primary purpose behind this being the absence of information and inaccessibility of monetarily appealing or reasonable sun-based PV framework [23]. The estimations with regard to the independent power age framework with capacity bank at Chandigarh University, Gharuan, Mohali will be proposed here and there is sufficient energy from the sun that can be provided from the PV-cluster framework. At whatever point there is abundance supply from the sustainable power source, the vitality stockpiling bank stores vitality which will be utilized on the occasion when there are inadequate supplies from the sustainable power source.

2.3 Purpose of the study

- The target of this work is to analyze the specialized achievability and efficient practicality of the PV system with battery reinforcement framework with the available Chandigarh University infrastructure

2.4 Methodology

- Step I: basic load will be determined.
- Step II: total day time energy required will be determined.
- Step III: night time total energy and power required will be determined.
- Step IV: payback period will be calculated

3. Present work

Photovoltaics offer the ability to deliver control in an ideal, calming, and reliable way. Photovoltaic systems contain photovoltaic cells, contraptions that convert light vitality directly into power. Since the wellspring of light is typically the sun, they are consistently called sun powered cells [21, 24]. The word photovoltaic starts from "photo" implying light and "voltaic" which insinuates conveying power. Along these lines, the photovoltaic methodology is "conveying power explicitly from sunlight." Photovoltaics are normally abbreviated as PV.

3.1 Solar energy

The vitality from the sun is given as radiations. The imperativeness is made in the sun's inside through the mix of hydrogen particles into helium. By and by, in light of greater detachment of sun from the Earth, only a little portion of sun's radiations accomplishes the Earth's surface [21]. The power of daylight-based radiation accomplishing the Earth's surface is around 1369 watts for each square meter [w/m^2]. This is known as the "solar constant". The total solar radiation intercepted by earth's surface can be calculated by multiplying solar constant with cross-sectional area of the earth [26]. In order to calculate the solar radiation received, on average per square meter of earth's surface, we divide the above multiplied result by the surface area of the earth. Thus, the average solar radiations per square meter of earth's surface is given by Eq. (1).

$$R = \frac{S\pi r^2}{4\pi r^2} = \frac{1369}{4} \approx 342\,\frac{\mathrm{W}}{\mathrm{m}^2} \quad (1)$$

where S is the solar constant in W/m^2 and r is the radius of Earth.

3.2 Solar energy realized at the Earth's surface

Till now, the effect of Earth's condition is not thought about. The esteem decided above is for the typical sun-fueled radiation drive at the outer areas of the Earth's atmosphere. So we are charmed to know that the measure of this vitality truly accomplishes the Earth's surface. Nature absorbs around 68 W/m^2 and reflects 77 W/m^2.The radiation achieving the world's surface is 198 W/m^2.The force of sun-oriented radiation additionally relies upon the time and the topographical positions [26]. From **Figure 3**, we can see that each square meter of the upper areas of air gets 342 $\times$ 67 W/m^2 of vitality consumed by the climate and 77 W/m^2 is reflected as shown in **Figure 3**.

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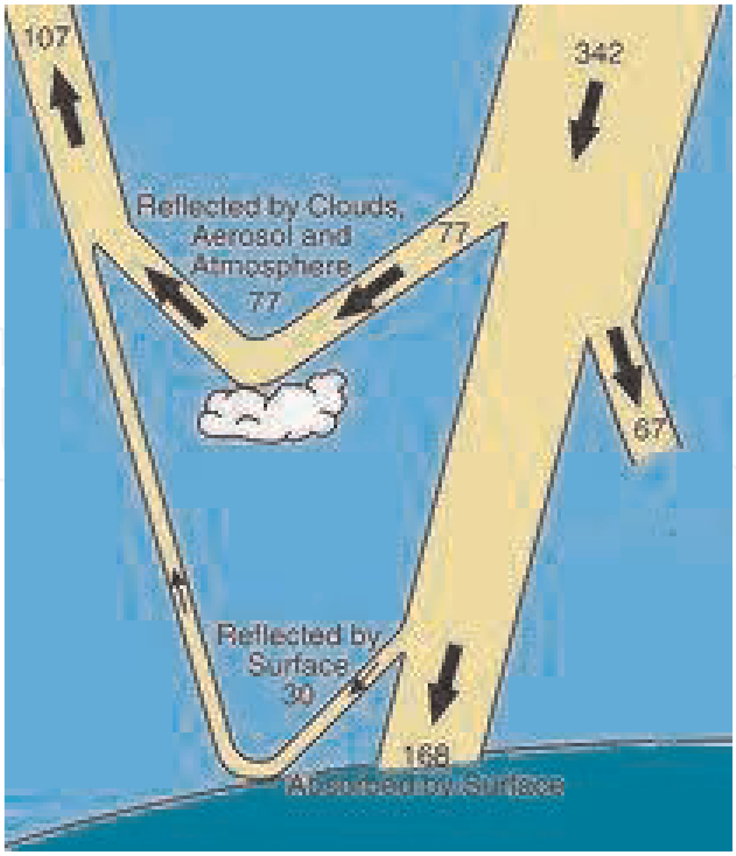

Figure 3.
Distribution of solar radiation [2].

Around 168 W/m^2 vitality lands at the world's surface and 30 W/m^2 is reflected back to space. The energy that reaches the earth surface is around 3.2 EJ/y if we are able to harvest even a small fraction of the available energy at the earth surface we could solve our energy problems. The energy reaching the earth surface is around 7000 times the global energy consumptions [27, 28].

3.3 Solar energy band

The proficiency of a PV gadget is subject to the unearthly appropriation of sun-powered radiation. The assessment of PV gadgets is commonly finished with reference to a standard unearthly circulation. There are two standard earthly appropriations characterized by the American Society for Testing and Materials (ASTM), direct ordinary and worldwide AM 1.5. The immediate typical standard relates to sunlight-based radiation that is opposite to a plane straightforwardly confronting the sun [22, 29]. The worldwide relates to the range of the diffuse radiations. Radiations which are thought about the Earth's surface or affected by climatic conditions are called diffuse radiations. To quantify worldwide radiations, an instrument named pyranometer is utilized [29]. This instrument is planned so that it reacts to each wavelength so that we get an exact incentive for all out power in any occurrence range.

The AM initials in **Figure 4** above represent air mass. The air mass in this setting implies the mass of air between a surface and the sun. The length of the way of sunlight-based radiation from the sun through the environment is shown by the number AMx [19]. The more drawn out the way the more is the divergence of light.

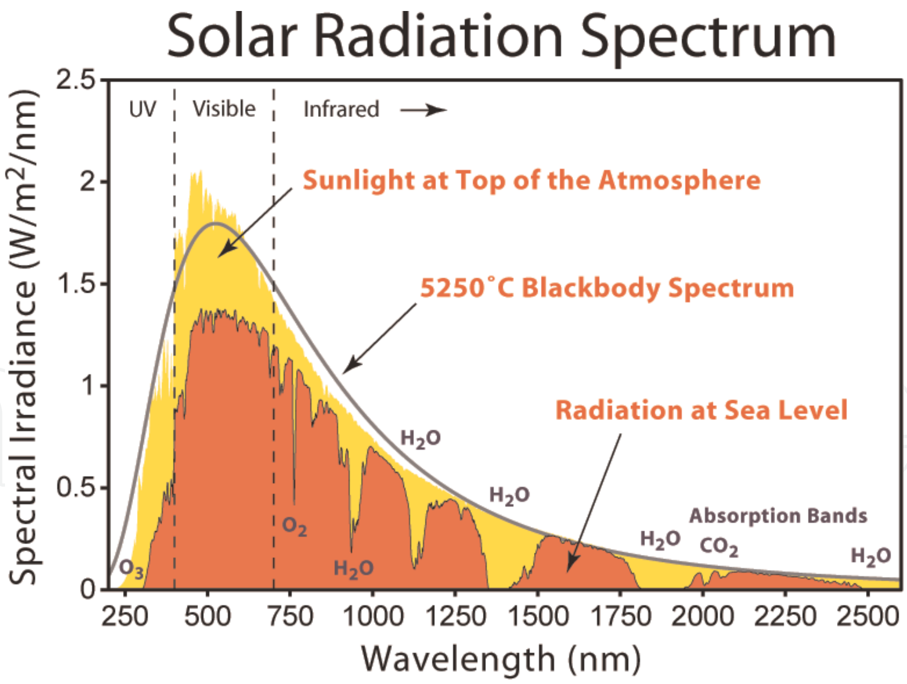

Figure 4.
Solar spectral distribution [29].

3.4 Solar constant

The rate at which solar energy arrives at the top of the atmosphere is called solar constant. This is the amount of energy received in unit area perpendicular to the sun's direction at the mean distance of the Earth from the sun. The rays' focus on the outside of the sun is about 6.33×107 W/m^2. In perspective on the way that radiation spreads out as the separation squared, when it goes to the Earth (1.496×1011 m or 1 AU is the normal Earth-sun remove), the brilliant vitality falling on 1 m^2 of surface zone is diminished to 1367 W as portrayed in **Figure 5**. The intensity of radiation leaving the sun is relatively constant. Therefore, the intensity of solar radiation at a distance of 1 AU is called the solar constant Isc.

3.5 System components

The stand-alone power system, described here, basically includes the following main elements.

1. Renewable energy source: PV system

2. Energy storage bank: battery bank

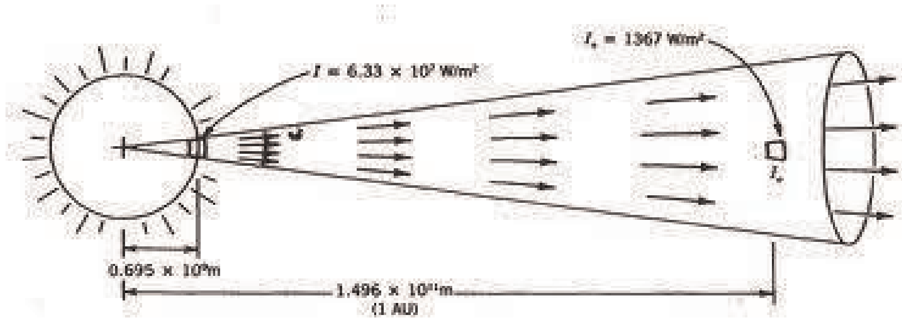

Figure 5.
The distribution of energy from the sun to the Earth [3].

3. AC loads

4. Power electronic devices

The detailed descriptions are given one by one in the following topics.

4. Photovoltaic system

4.1 Description

A photovoltaic structure is a system which uses something like one sun situated sheets to change over sun-arranged imperativeness into power. It contains various parts, including the photovoltaic modules, mechanical and electrical affiliations, and mountings and techniques for coordinating just as modifying the electrical yield. A sun-controlled cell (moreover called a photovoltaic cell) as shown in **Figure 6** is an electrical device that changes over the imperativeness of light (optical essentialness) clearly into power by the photovoltaic effect. It is a sort of photo-electric cell (in that its electrical characteristics—for instance stream, voltage, or deterrent—change when light is incident upon it) which, when introduced to light, can make and support an electric stream without being attached to any external voltage source.

4.2 Semiconductor structure

Semiconductors, for instance, silicon (Si), contain individual atoms fortified together in a conventional, discontinuous structure to outline a game-plan whereby each particle is incorporated by eight electrons. An individual atom contains a center made up of a focal point of protons (determinedly charged particles) and neutrons (particles having no charge) incorporated by electrons. The amount of electrons and protons is comparable, with the true objective that the atom is commonly electrically fair. The electrons enveloping each particle in a semiconductor are a bit of a covalent bond. A covalent bond includes two particles "sharing" a lone electron. Each molecule shapes four covalent bonds with the four incorporating particles. Thus, between each particle and its four including particles, eight electrons are being shared. The structure of a semiconductor is shown in **Figure 7**.

Each line connecting the atoms represents an electron being shared between the two. Two electrons being shared are what form the covalent bond.

Supplanting a silicon particle with an atom that has either three or five valence electrons will along these lines produce either a space with no electron (an opening) or one extra electron that can move more uninhibitedly than the others; this is the

Figure 6.
Solar cell.

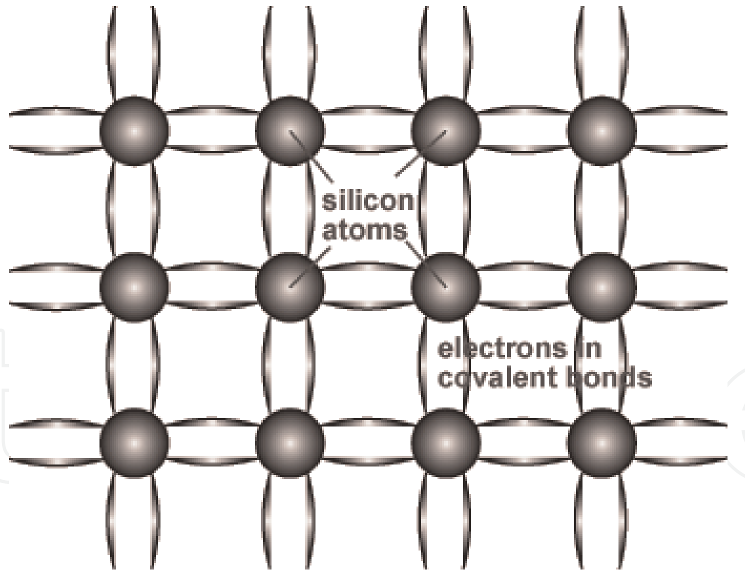

Figure 7.
Schematic representation of covalent bonds in a silicon crystal lattice.

premise of doping. P-type doping, the making of abundance gaps, is accomplished by the consolidation into the silicon of molecules with three valence electrons, regularly boron and n-type doping; the formation of additional electrons is accomplished by fusing a particle with five valence electrons, frequently phosphorus (see **Figure 8**).

When a p-n intersection is made, electrical contacts are made to the front and the back of the cell by vanishing or screen printing metal onto the wafer. The back of the wafer can be totally secured by metal; however, the front just has a network design or slight lines of metal for the occurrence of light photons.

4.3 Conduction in semiconductors

The bond structure of a semiconductor decides the material properties of a semiconductor. One key impact is the vitality level which the electrons can possess

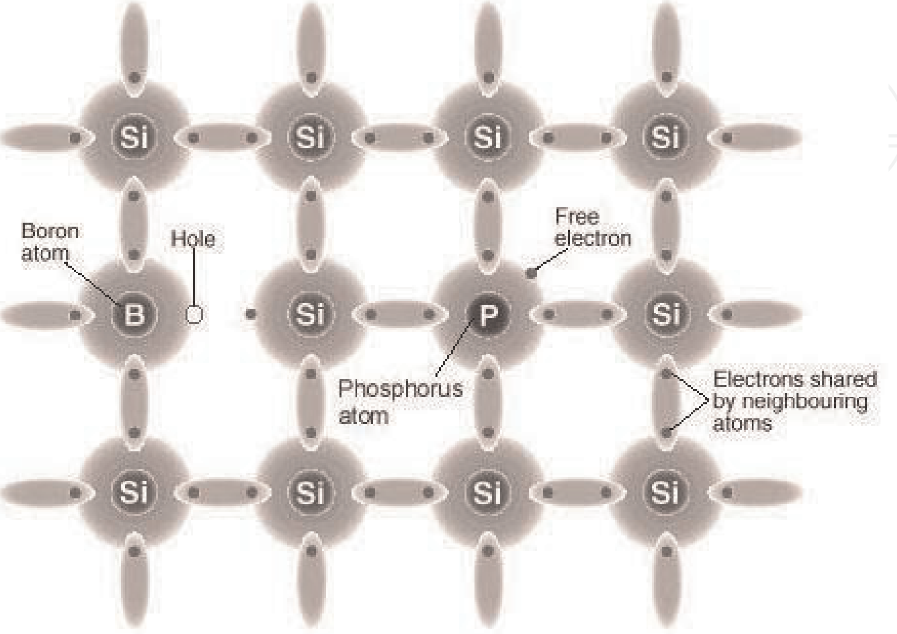

Figure 8.
Si crystal with dopant atoms.

and how they move about the precious stone cross section. The electrons in the covalent bond shaped between every one of the molecules in the cross section structure are held set up by this bond and consequently they are restricted to the locale encompassing the particle. These reinforced electrons cannot move or change vitality, and therefore are not considered "free" and cannot take an interest in current stream, adsorption, or other physical procedures of enthusiasm for sun-based cells. However, only at absolute zero, all electrons are in this "stuck", bonded arrangement. At elevated temperatures, especially at the temperatures where solar cells operate, electrons can gain enough energy to escape from their bonds. At the point when this occurs, the electrons are allowed to move about the gem cross section and partake in conduction. At room temperature, a semiconductor has enough free electrons to enable it to lead to current. At or near supreme zero, a semiconductor carries on like an insulator.

At the point when an electron increases enough vitality to take an interest in conduction (is "free"), it is at a high vitality state. At the point when the electron is bound, and along these lines cannot take an interest in conduction, the electron is at a low vitality state. Along these lines, the nearness of the bond between the two iotas presents two unmistakable vitality states for the electrons. The electron cannot achieve vitality esteems middle of the road to these two dimensions; it is either at a low vitality position in the bond, or it has sufficiently increased vitality to break free and subsequently has a specific least vitality. This base vitality is known as the "band hole" of a semiconductor as shown in **Figure 9**. The band hole of a semiconductor is the base vitality required to energize an electron that is stuck in its bound

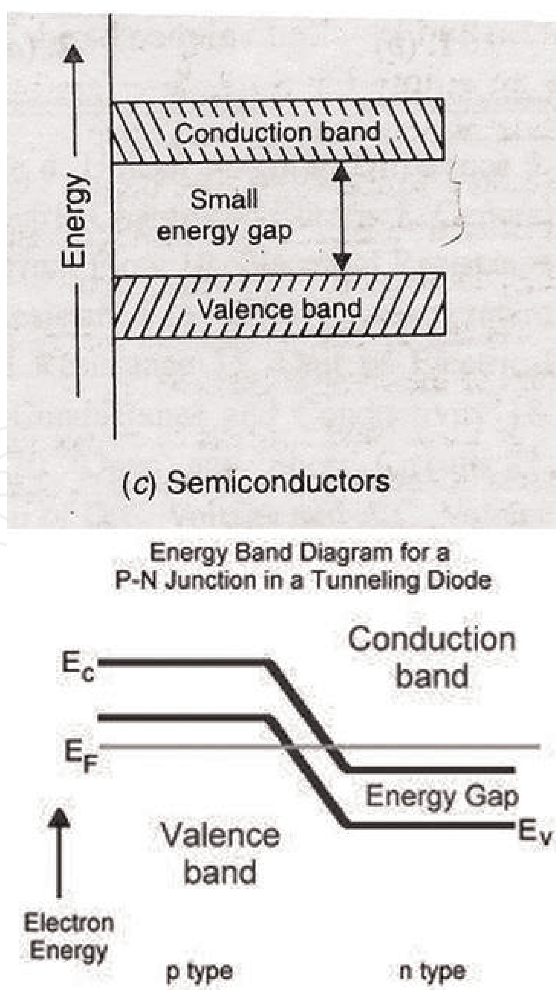

Figure 9.
Energy band diagram.

state into a free state where it can take an interest in conduction. The band structure of a semiconductor gives the vitality of the electrons on the y-pivot and is known as a "band graph." The lower vitality dimension of a semiconductor is known as the "valence band" (EV) and the vitality level at which an electron can be viewed as free is known as the "conduction band" (EC). The band hole (EG) is the hole in vitality between the bound state and the free state, between the valence band and the conduction band. In this manner, the band hole is the base change in vitality required to energize the electron with the goal that it can partake in conduction.

The number and vitality of these free electrons, those electrons taking an interest in conduction, are essential to the task of electronic gadgets. The space deserted by the electrons enables a covalent attach to move starting with one electron then onto the next, in this way giving off an impression of being a positive charge traveling through the precious stone cross section. This vacant space is normally called a "gap," and is like an electron, however with a positive charge. **Figure 10** shows the whole process.

4.4 Types of photovoltaic cells

The use of silicon in the manufacture of photovoltaic cells produces the stereo typical uniform blue-colored PV cell as seen on roof tops and the sides of buildings. Solar cells are made from a wide range of semiconductor materials. Currently, the two main solar technologies are crystalline silicon (silicon wafers) and thin film deposits, which vary from each other in terms of light absorption efficiency, energy conversion efficiency, manufacturing technology, and cost of production. Crystalline silicon is cut from a bulk material. It can be single-crystalline, multicrystalline, and amorphous. These cells are the most common type of photovoltaic cell in use today and are also one of the earliest successful PV devices. There are essentially two types of PV technology, crystalline and thin film. Crystalline can again be broken down into two types.

4.4.1 Crystalline silicon (C-Si)

Crystalline photovoltaic cells are produced using silicon which is first softened, and afterward solidified into throwing of unadulterated silicon. Meager cuts of silicon called wafers are cut from a solitary precious stone of silicon

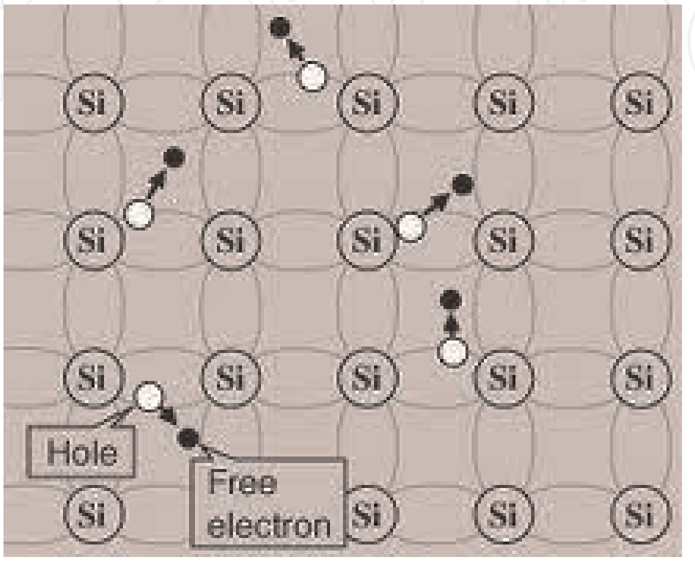

Figure 10.
Generation of holes and electrons.

(monocrystalline) or from a square of silicon gems (poly-crystalline) to make singular cells. The change in productivity for these kinds of photovoltaic cell runs somewhere in the range of 10–20%.

a. **Monocrystalline silicon**: it is a kind of photovoltaic cell material produced from a solitary gem silicon structure which is uniform fit as a fiddle in light of the fact that the whole structure is developed from a similar precious stone. High immaculateness silicon is liquefied in a pot as shown in **Figure 11**. A solitary gem silicon seed is plunged into this liquid silicon and is gradually hauled out from the fluid creating a solitary precious stone ingot. The throwing is then cut into slight wafers or cuts which are then cleaned, doped, covered, interconnected, and collected into modules and exhibits. These kinds of photovoltaic cells are additionally generally utilized in photovoltaic board development. The conversion efficiency for a monocrystalline cell ranges between 15 and 20%. They are highly reliable for outdoor power applications due to their wafer thickness.

b. **Polycrystalline silicon**: these are called multicrystalline silicon and are cast to deliver a silicon ingot. The silicon sub-atomic structure comprises of a few littler gatherings or grains of precious stones, which present limits between them. **Figure 12** demonstrates polycrystalline PV cells. These cells are less vitality effective than monocrystalline silicon PV cells in light of the fact that these limits confine the stream of electrons through them by urging the negative electrons to recombine with the positive openings decreasing the power yield of the cell. The aftereffect of this implies a polycrystalline PV cell which just has a vitality transformation productivity of between 10 and 14%. Nonetheless, these kinds of photovoltaic cells are significantly less costly to create than the proportionate single monocrystalline silicon because of their lower production costs.

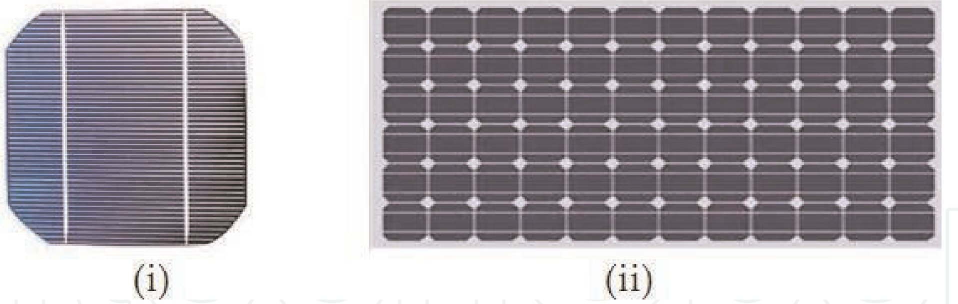

Figure 11.
Monocrystalline cell (i) and panel (ii).

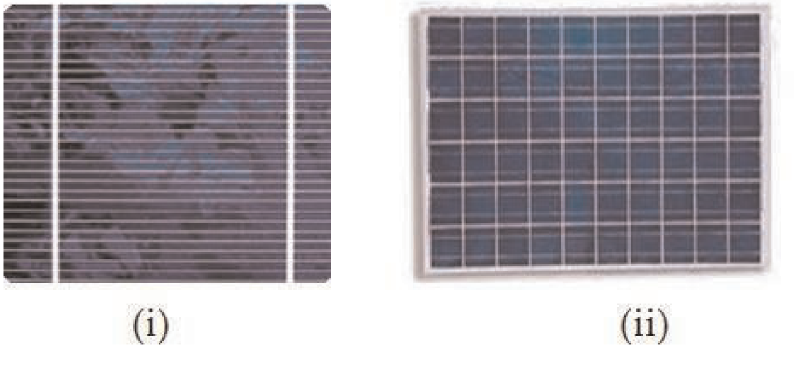

Figure 12.
Polycrystalline cell (i) and panel (ii).

c. **Amorphous silicon**: amorphous silicon is a noncrystalline form of silicon that is widely used in calculators, consumer electronics, and solar garden products that require a small current at a low voltage. Amorphous silicon can be deposited on a variety of low-cost rigid and flexible substrates such as polymers, thin metals, and plastics as well as tinted glass for building integration as shown in **Figure 13**. It has very low conversion efficiency ranging between 7 and 9% when new, degrading down within a few months of exposure to sunlight to less than 5%.

4.4.2 Thin film solar cell

These cells use thin layers of photovoltaic materials deposited onto a substrate as shown in **Figure 14**. This material can be polycrystalline, like cadmium telluride (CdTe), copper indium diselenide (CIS), and thin-film Si, single-crystalline, such as gallium arsenide (GaAs), as well as organic. Crystalline silicon carries on to make up more than 90% of PV panels produced globally. **Table 3** gives comparison of different technologies.

4.5 Photovoltaic array

PV cells are the basic building blocks of PV modules for almost all applications. The one-half volt produced by a single cell is inadequate. Therefore, desired power, voltage, and current can be obtained by connecting individual modules in series and parallel combinations. At the point when modules are fixed together in a solitary mount, they are known as a board and when a few boards are utilized together, they are called an exhibit. At the point when circuits are wired in arrangement, the voltage of each board is included yet the amperage continues as before [11]. When the circuits are wired in parallel, the voltage of each panel remains the same and the

Figure 13.
Amorphous silicon panel.

Figure 14.
Thin film solar cell.

Sr. no	Technology	Efficiency	Cost
1.	Monocrystalline silicon	12.5–15%	High
2.	Polycrystalline silicon	11–14%	Medium
3.	Amorphous silicon (a-Si)	5–7%	Low

Table 3.
Comparison of different solar technologies.

amperage is added. This wiring principle is used to build photovoltaic (PV) modules. Photovoltaic modules can then wired together to create PV arrays.

The PV cells in a module can be wired to any ideal voltage and current. The measure of current created is straightforwardly relative to the cell's size, transformation proficiency, and the force of light. Gatherings of 36 arrangement associated PV cells are bundled together into standard modules that give an ostensible 12 Volt (or 18 Volts @ apex power) as shown in **Figure 15**.

4.6 Basic theory of photovoltaic cell

The PV cell (solar cell) is a light sensitive, two-terminal, semiconducting p-n junction made of a semiconductor material such as silicon. The photovoltaic cells contain one or more p-n junctions. A solar cell has two layers called P-type and N-type and two corresponding electrodes, negative and positive. N-type material is obtained by doping a silicon crystal with N-type impurity. P-type material is obtained by doping a silicon crystal with P-type impurity.

The N-type layer is thin and clear. The P-type layer is wide. At the point when daylight strikes the N-type meager layer, a portion of the light vitality infiltrates up to the P-type layer. The vitality from "photons" in the light waves is bestowed to the particles and iotas in p-n intersection, bringing about freedom of electron-gap sets. Electrons are discharged from the N-type material and holes are made in P-type material. Electrons are negative charges and holes are positive charges. When the external circuit is completed by connecting electrodes to the load, the electrons flow in the closed external circuit from N-type terminal to P-type terminal. Direction of current is from positive terminal to negative terminal in the external circuit. **Figure 3** shows the photovoltaic principle. Within the P-N junction, "electron-hole" pairs are continuously generated during the incidence of the sunlight. Energy from solar rays is captured by the solar cell and is converted directly to electrical energy as shown in **Figure 16**.

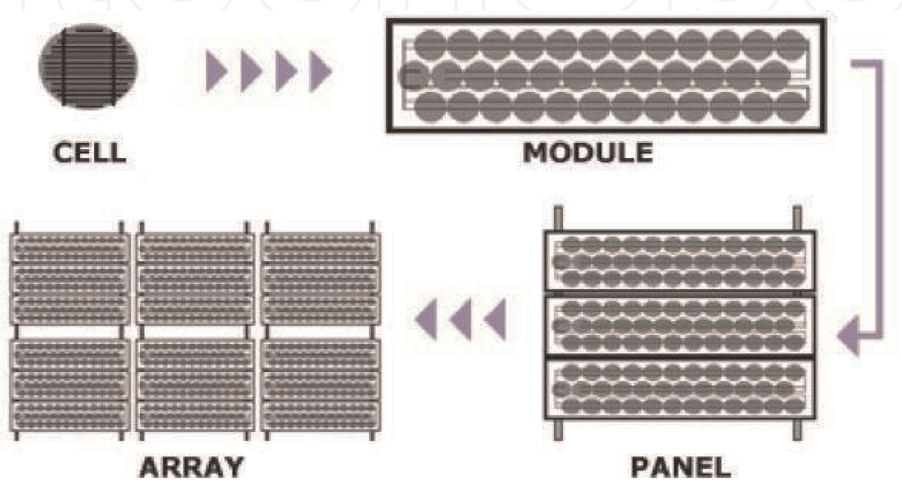

Figure 15.
Photovoltaic hierarchy.

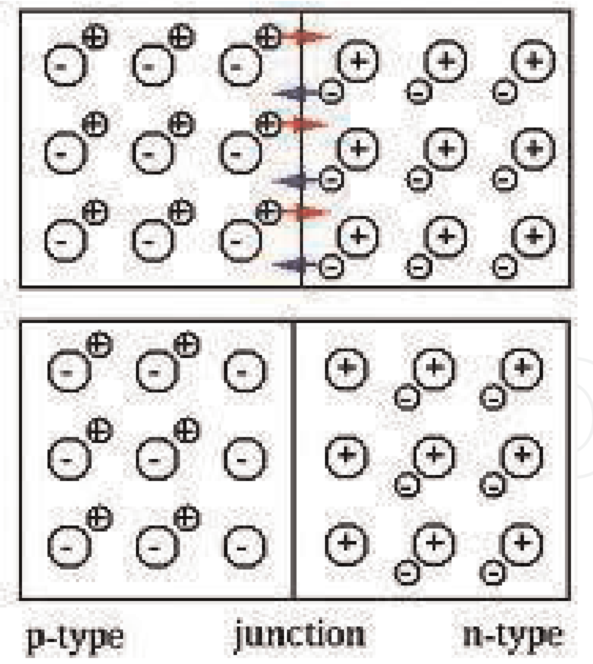

Figure 16.
Structure of P-N junction.

4.6.1 Working of PV cell

Working of a PV cell is based on the basic principle of photovoltaic technology. PV cells contain light engrossing materials (for the most part semiconductors), which are extraordinarily treated to create p-n intersections. A p-n intersection contains two areas of a material with contrasting kinds of conductivity isolated by a semi-conductive intersection. At the point when light falls on the highest point of the cell, it can enter through the intersection and exchange a segment of its vitality to certain electrons, which can cross the intersection into the n-type locale. In the meantime, the integral positive charges called gaps are made in the p-type district where the electrons left. This makes a voltage of 0.5–0.7 Volts over the intersection under open-circuit condition [12]. In the event that an outside circuit is associated with the cell's terminals, the cell will create an immediate current through this circuit. As the outcome, electric power is removed. When the current flows, electrons recombine with holes in the p-type region. As the current increases, the voltage across PV cells drops. **Figure 17** shows the production of electricity directly from sunlight. The maximum current of a PV cell depends on its surface area and intensity of light radiation. In general, the larger the area, the more power can be produced.

The sun-based cell works in three stages:

1. Photons in daylight hit the sun-based board and are consumed by semiconducting materials, for example, silicon.

2. Electrons (contrarily charged) are thumped free from their particles, causing an electric potential contrast. Flow begins coursing through the material to drop the potential and this power is caught. Because of the exceptional organization of sun-powered cells, the electrons are just permitted to move in a solitary bearing.

3. An exhibit of sun-based cells changes over sun-oriented vitality into a usable measure of direct flow (DC) power.

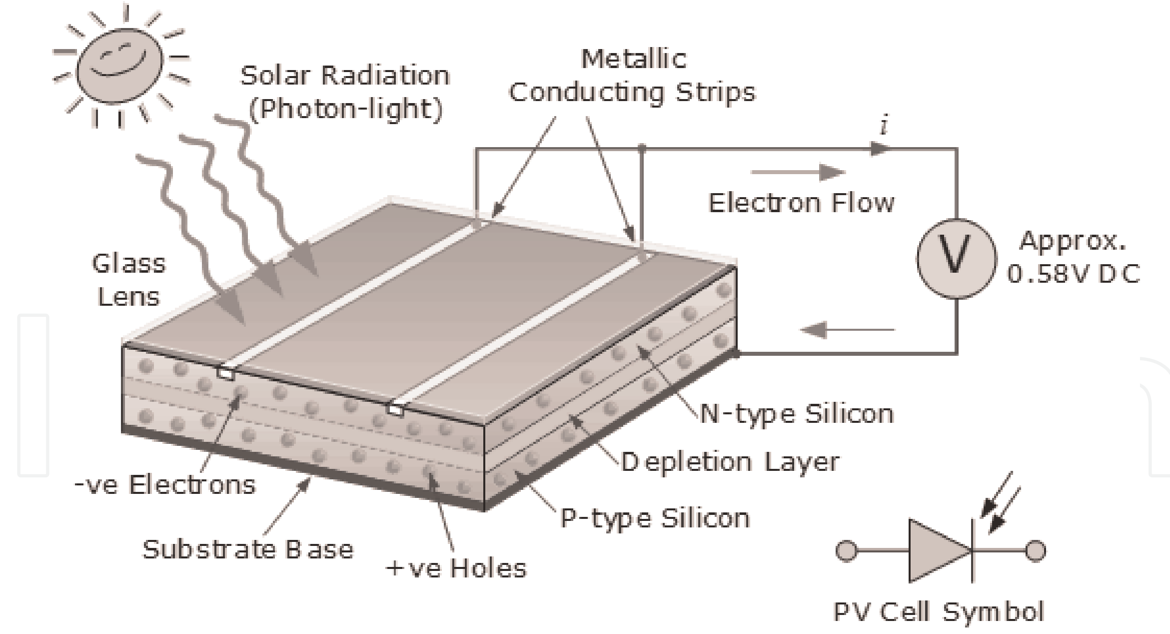

Figure 17.
Production of electricity.

4.6.2 The need for solar cells

The advancement of sun-based cell has been invigorated by:

- The requirement for low upkeep, dependable wellsprings of power appropriate for spots remote from both the principle power network and from individuals; for example, satellites, remote site water siphoning, outback broadcast communications stations, and beacons.

- The requirement for practical power supplies for individuals remote from the principle power matrix; for example, native settlements, outback sheep and steers stations, and some home destinations in framework-associated regions.

- The requirement for nondirtying and quiet wellsprings of power; for example, visitor locales, trains, and campers.

- The requirement for a helpful and adaptable wellspring of little measures of intensity; for example, mini-computers, watches, light meters, and cameras.

- The requirement for inexhaustible and practical power, as a method for decreasing an Earth-wide temperature boost.

4.7 Photovoltaic characteristics

To safeguard similarity with capacity batteries or burdens, it is important to know the electrical qualities of photovoltaic modules. As an update, "I" is the shortening for current, communicated in amps. "V" is utilized for voltage in volts and "R" is utilized for opposition in ohms.

4.7.1 Photovoltaic V-I characteristics

A photovoltaic module will deliver its most extreme current when there is basically no obstruction in the circuit. This would be a short out between its positive and negative terminals. This most extreme current is called hamper, curtailed Isc.

At the point when a module is shortened, the voltage is zero. On the other hand, the most extreme voltage is delivered when there is a break in the circuit. This is called open circuit voltage, condensed Voc. Under this condition, the opposition is interminably high and there is no current, since the circuit is deficient. These two boundaries in burden opposition and the entire scope of conditions in the middle of them are portrayed on a diagram called an I-V (current-voltage) bend. Current, communicated in amps, is on the vertical Y-hub. Voltage, in volts, is on the flat X-pivot as in **Figure 18**.

In the above **Figure 18**, Isc happens on a point on the bend where the voltage is zero. The open circuit voltage happens where the current is zero. The power accessible from a photovoltaic module anytime along the bend is communicated in watts. Watts are determined by duplicating the voltage times the current (Watts = Volts × Amps, or W = VA). At the short out current point, the power yield is zero, since the voltage is zero as shown in **Figure 19**. At the open circuit voltage point, the power yield is likewise zero, yet this time it is on the grounds that the current is zero. There is a point on the "knee" of the bend where the most extreme power yield is found. This point on our model bend is the place the voltage is 17 Volts, and the current is 2.5 Amps. In this manner, the most extreme power in watts is 17 Volts occasions 2.5 Amps, leveling with 42.5. For the maximum output power from a cell, the face of the photovoltaic should be pointed as straight toward the sun as possible. The voltage, current, and power delivered by the solar cell are influenced by

- Conditions of sunlight, intensity, wavelength, angle of incidence, etc. Visible band gives maximum power.

- Conditions of the junction, temperature, termination, etc. It believes there is no shading on the module.

4.7.2 Influence of solar radiation on V-I characteristic of photovoltaic module

Standard daylight conditions on a clear morning are thought to be 1000 Watts of sun powered vitality per square meter (1000 W/m^2). This is now and again called

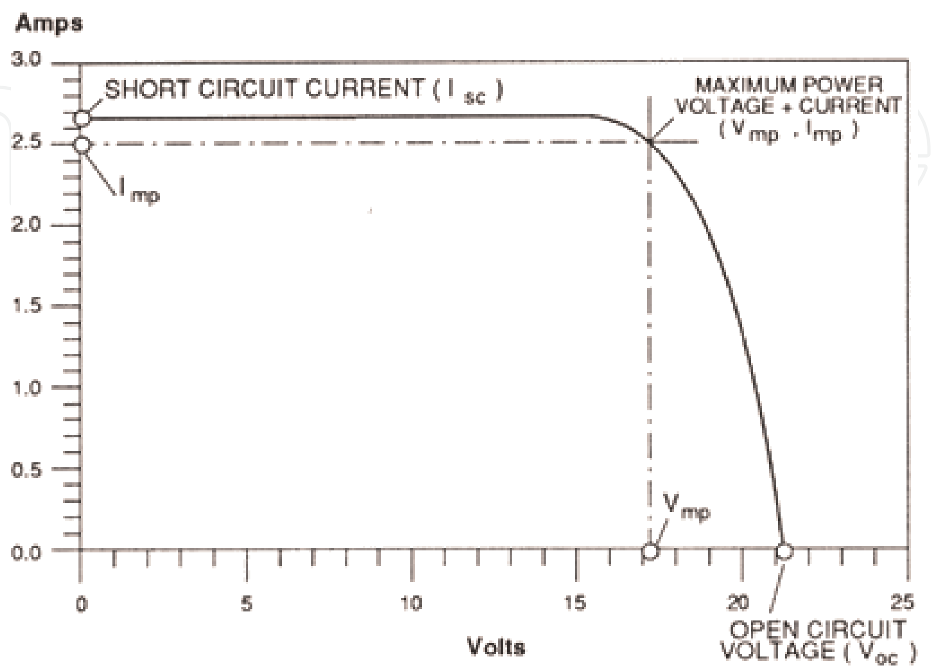

Figure 18.
V-I characteristic curve of photovoltaic module.

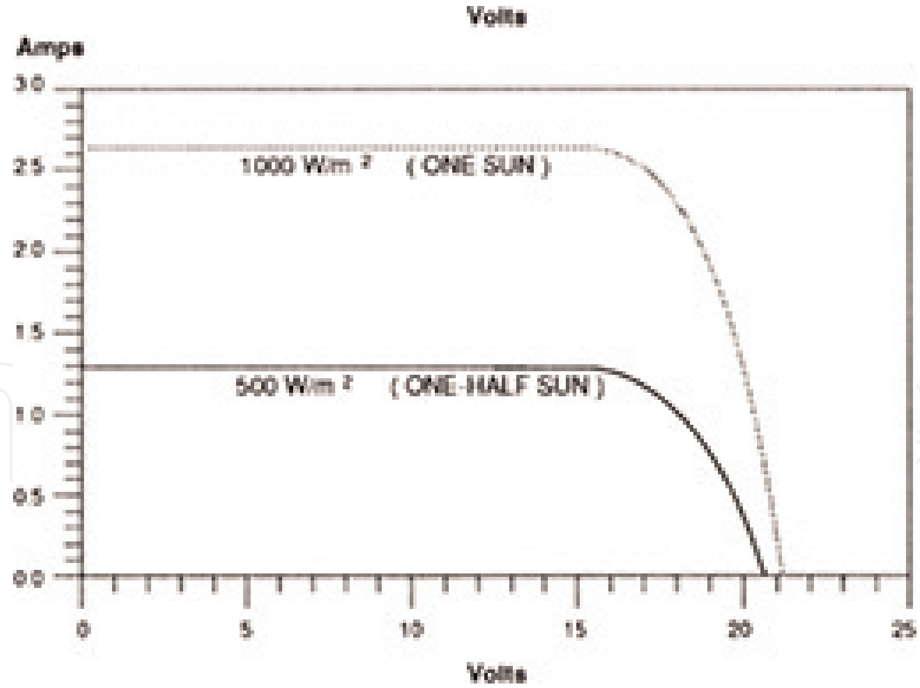

Figure 19.
Change in photovoltaic module voltage and current on change in solar radiation.

"one sun," or a "crest sun" short of what one sun will decrease the present yield of the module by a corresponding sum. For instance, if just one-half sun (500 W/m^2) is accessible, the measure of yield current is generally cut in half for maximum output; the face of the photovoltaic modules should be pointed as straight toward the sun as possible as shown in **Figure 19**.

4.7.3 Influence of temperature on V-I characteristic of photovoltaic module

Module temperature influences the output voltage inversely. High module temperatures will decrease the voltage by 0.04–0.1 Volts for each 1°C increase in temperature (0.04–0.1 V/°C) as shown in **Figure 20**.

That is the reason modules ought to be totally unshaded amid activity. A shadow over a module can nearly stop power generation. Slim film modules are not as influenced by this issue; however, they should in any case be unshaded.

4.8 Photovoltaic system types

PV technology was first applied in space, by providing electricity to satellites. Today, PV systems can be used to power just about anything on Earth. On the basis of working operation PV systems operate in three basic forms.

4.8.1 Standalone PV system

A separate or standalone PV system is comprised of various individual photovoltaic modules (or boards) more often than not of 12 Volts with power yields of somewhere in the range of 50 and 100+ Watts each. These PV modules are then consolidated into a solitary cluster to give the ideal power yield as shown in **Figure 21**. A basic independent PV framework is a programmed close planetary system that produces electrical capacity to charge banks of batteries amid the day for use around evening time when the sun's vitality is inaccessible [11]. An independent little scale PV framework utilizes battery-powered batteries to store the

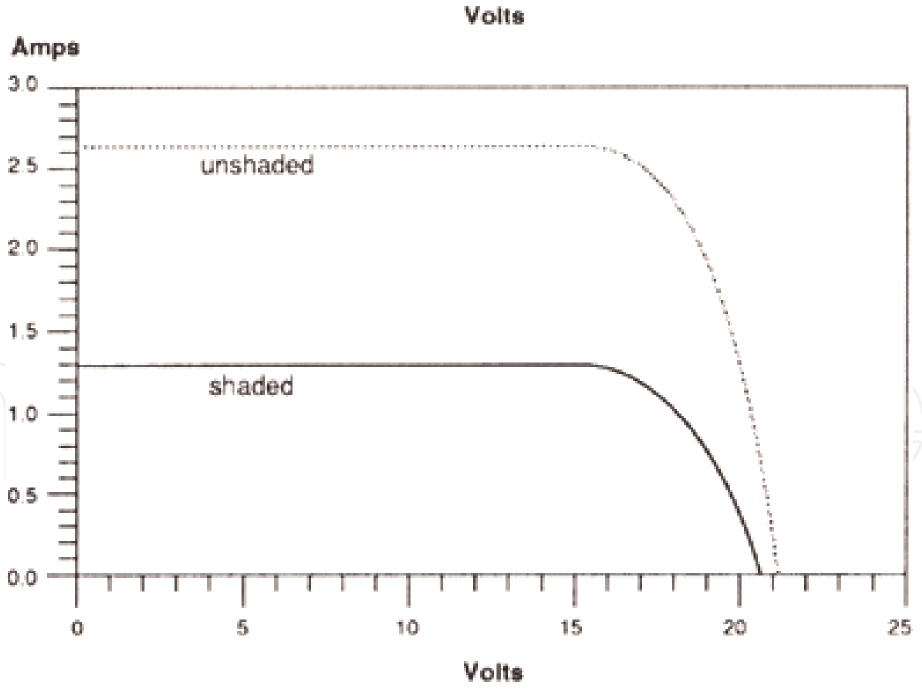

Figure 20.
V-I curve for an unshaded and shaded cell.

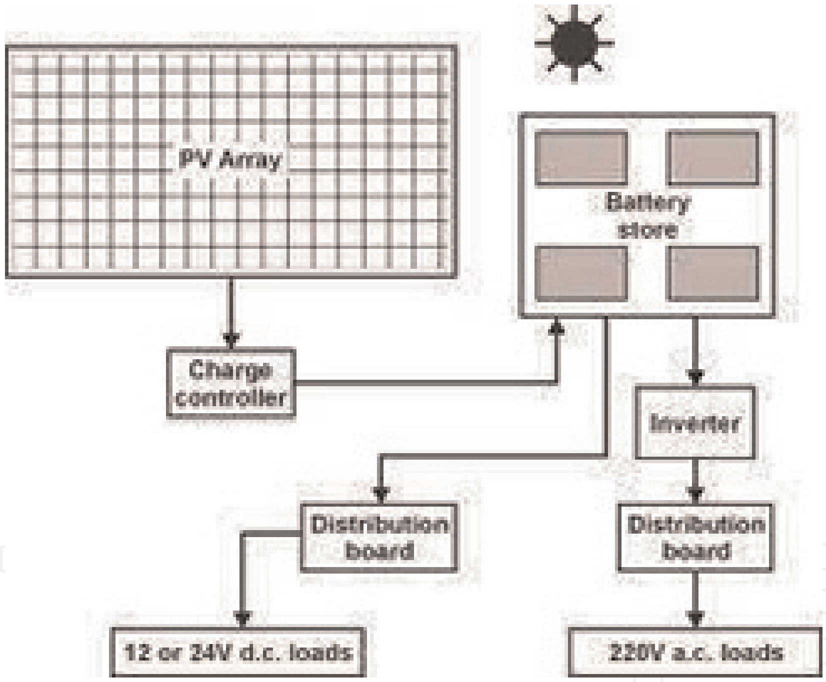

Figure 21.
Standalone system.

electrical vitality provided by a PV board or exhibit. Independent PV frameworks are perfect for remote provincial regions and applications where other power sources are either unreasonable or are inaccessible to give capacity to lighting, apparatus, and different employments. In these cases, it is more savvy to introduce a solitary independent PV framework than to pay the expenses to the neighborhood power organization.

4.8.2 Grid interactive solar PV power system

A grid-connected system is connected to a large independent grid (typically the public electricity grid) and feeds power either directly into a residential or commercial building or back into the grid as shown in **Figure 22**. Grid-associated frameworks differ in size from private (2–10 kWp) to sunlight-based power stations (up to 10 s of MWp). This is a type of decentralized power age [9]. On account of private or building-mounted network-associated PV frameworks, the power created is bolstered into the structure, and any extra power required past what is being created by the framework is conveyed by the matrix. On the off chance that control is delivered in overabundance of what is required by the structure, it is encouraged again into the matrix. The sustaining of power into the network requires the change of DC into AC by an exceptional, framework-controlled sun-based inverter.

4.8.3 Hybrid solar systems

A hybrid sun-powered PV framework consolidates the absolute best attributes of an off-network and a lattice tied framework. These frameworks are associated with the neighborhood utility matrix, yet in addition have a battery back-up framework as shown in **Figure 23**. The battery enables the property holder to store vitality for use amid nondelivering hours (during the evening or amid power outages). These frameworks are perfect for homes where the vitality lattice is questionable on account of harsh climate, a temperamental utility age framework, etc. [8]. This is of specific significance for the individuals who depend on a consistent wellspring of vitality for their home or business.

4.9 We prefer standalone photovoltaic system

Low quality of framework supply (low voltage, fluctuating recurrence, and successive intrusions), high taxes (a lot higher than real expense of supply), uncalled burdens (top hour limitations and impromptu burden shedding), and inert demeanor of State Electricity Boards have constrained numerous ventures to

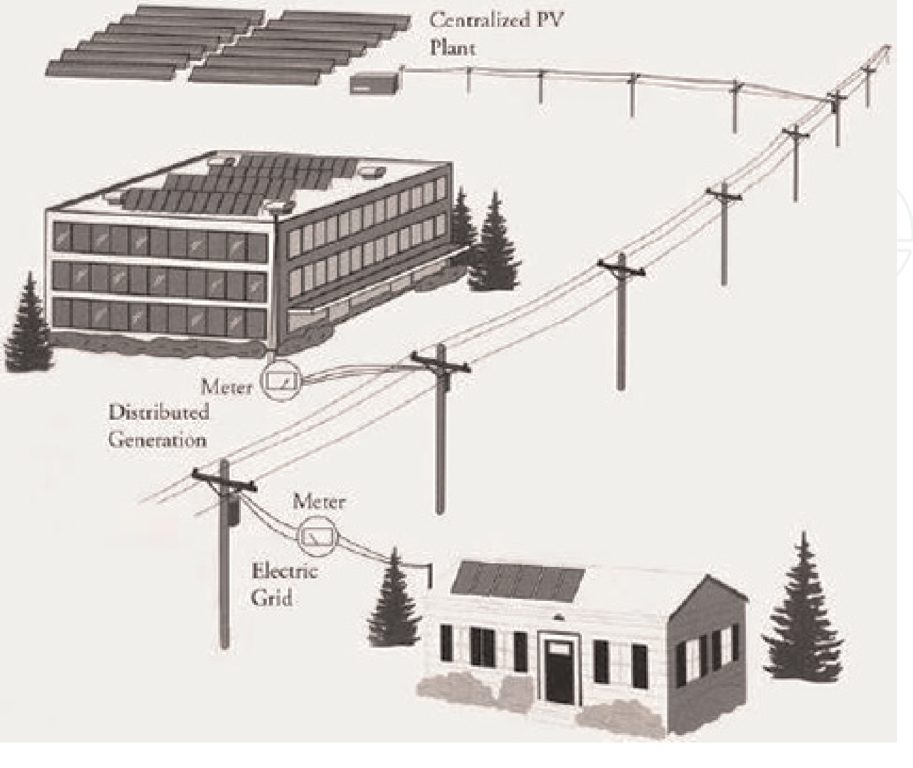

Figure 22.
Grid-connected system.

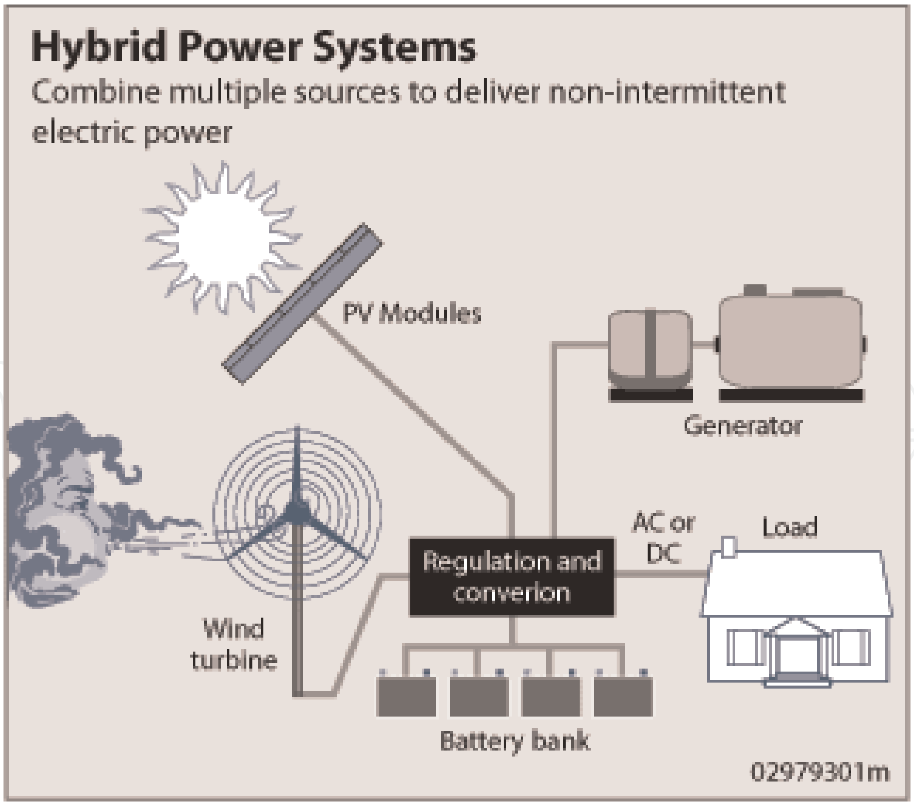

Figure 23.
Hybrid PV system.

segregate themselves absolutely from the state network and be without anyone else. For a solid task of the business, they fundamentally need to utilize hostage age with an excess.

Independent PV frameworks are intended to work autonomous of the electric utility lattice, and are commonly structured and measured to supply certain DC as well as AC electrical burdens. Around the world, independent sun-based establishments are prevalent, while in India, practically all hostage control plants are of the matrix tie. Usually, a smart thought is to begin with little and basic independent sun-oriented PV framework first and afterward to advance from that point. The main benefits of standalone solar electric power systems in remote locations are that they are affordable, reliable, and flexible and their reduced cost [9].

An independent photovoltaic framework does not have the network for reinforcement control. A point by point examination of electric burdens and utilization is required to legitimately structure a framework that will meet the everyday and regular loads and be inside the proprietor/administrators spending plan. It is additionally vital that structures and gear be vitality productive to limit control loads.

There are two kinds of off-network sun-based power frameworks: without batteries and with batteries. Frameworks without battery reinforcement are less difficult to structure and cost less. In any case, they give control just when the sun is sparkling, not during the evening or in awful climate. Frameworks with battery reinforcement give control as long as the battery charge is over a base charge level. These frameworks are progressively intricate to structure due to the day by day and regular variety of illumination (sun-oriented radiation) and the vitality utilization profile (sum and time of day). Another thought is the sort of electrical burden. Direct right (DC) machines can be run specifically from the DC yield from the sun-oriented modules or batteries. Photovoltaic frameworks for rotating current (AC) apparatus utilize an inverter to produce the substituting current. A few frameworks can control both DC and AC apparatus.

Independent frameworks are appropriate as reinforcement or uninterruptible power supplies, particularly for DC hardware or in little networks where matrix control is untrustworthy. Convenient and versatile power frameworks are likewise accessible for remote power circumstances, for example, quick sending, brief burdens, or area evolving loads, for instance, street fix, crisis circumstance, fiasco, salvage, or one-time occasion. Independent sun-based electric frameworks can be planned with a power limit running from 50 Watts to more than 100 KW. The real yield relies upon the insolation (sun-based radiation vitality got on a surface region in a given time) amid the day.

4.9.1 Operational concepts of standalone system

The standalone power system makes use of the solar PV to produce electricity. The configuration of the system is analyzed for various photovoltaic array sizes to operate in tandem with the battery system. The power controller unit will determine the AC conversion of the DC power in relation following the load profile [10, 11]. The charge controller will charge the batteries with energy from solar modules. The main objective of the system is to reduce the cost of operation and maintenance cost by minimizing fuel consumption. A schematic of normal daily operation of a typical solar system can be shown in a series of diagrams in figures below.

4.9.1.1 During day time

In **Figure 24**, solar is the first choice and only source of energy. The inverter converts DC power from the solar PV to AC power for the load. The extra power produced is stored in the battery system.

4.9.1.2 Throughout night

In **Figure 25**, battery is the main wellspring of vitality and sunlight-based PV is off. The inverter changes over DC control from the battery to AC control for the heap. The battery will supply the heap to its most extreme release level.

4.9.2 Elements included in a system of photovoltaic conversion

The main elements that can be included in a system of photovoltaic conversion are the following.

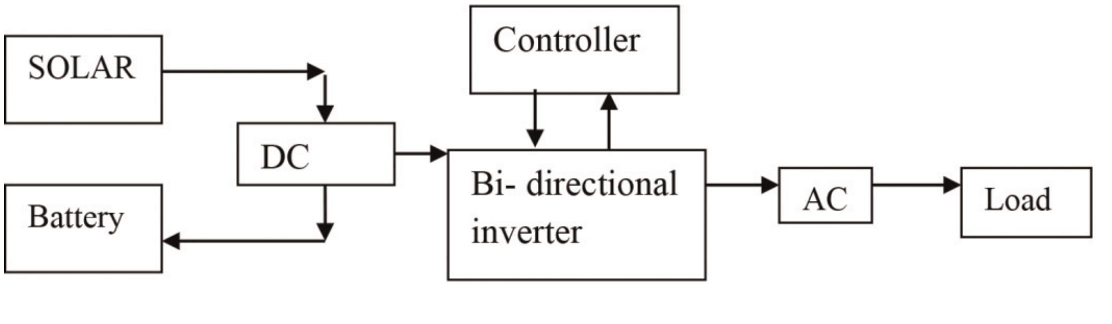

Figure 24.
PV system operation during day time.

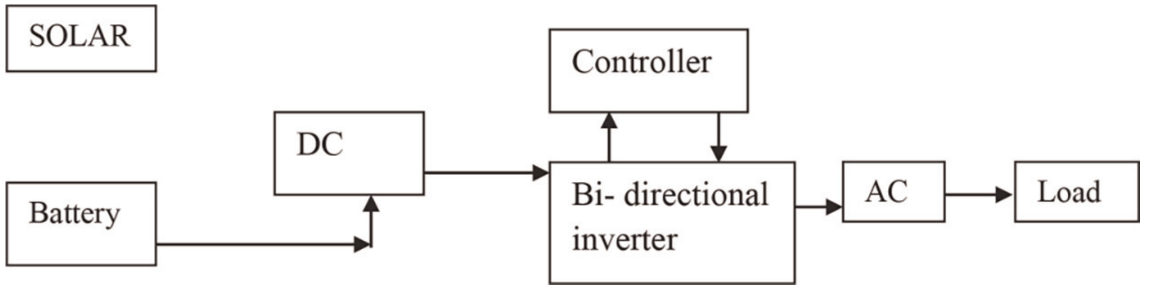

Figure 25.
PV system operation during night time.

4.9.2.1 Batteries

Batteries are a vital component in any independent PV framework; however, they can be discretionary relying on the structure. Batteries are used to store the solar-produced electricity for night time or emergency use during the day. Contingent on the sun-based exhibit setup, battery banks can be of 12, 24, or 48 V and a huge number of amperes altogether. An average battery bank comprises of at least one profound cycle type batteries. The profound cycle batteries are intended to be released and after that energized hundreds or thousands of times. These batteries are appraised in amp hours (AH), which allude to the measure of current that can be provided by the batteries over a particular time of hours. Like sun-oriented boards, batteries can be wired in arrangement and/or parallel to build voltage to the ideal dimension and increment amp hours [11, 12]. The span of the battery bank relies upon the capacity limit required, most extreme release rate, greatest charge rate, and least temperature at which the batteries will be utilized. Batteries can quickly supply huge floods of put away power as expected to begin or run apparatus that the sun powered boards alone could not control.

4.9.2.2 Solar panel

The solar panel is the power source of all photovoltaic installations. It is the result of a set of photovoltaic cells in series and parallel [12]. Solar panel gives power to battery or inverter through charge controller (regulator). The performance of solar PV systems varies with weather conditions due to reduced sunlight exposure on the solar panels, which consequently reduces their output power.

4.9.2.3 Regulator

It is the component to secure the battery against gambling circumstances such as over-burdens and over-releases [13]. The hypothetical definition of the model can be basic, in spite of the fact that it is important to think about the impossibilities to miss discontinuities of the model and the bury the execution with whatever is left of the dissected models.

4.9.2.4 Transformer

A transformer can boost up the ac output voltage from the inverter when needed. Otherwise transformer-less design is also acceptable.

4.9.2.5 Inverter

The inverter allows transforming the DC current to AC. A photovoltaic installation that incorporates an inverter can belong to two different situations, based on the characteristics of the alternating network. An inverter is a gadget that changes DC control from sun-oriented boards or put away in batteries to the standard 120/240 Vac power. Most inverters produce 120 Vac, yet can be outfitted with a stage-up transformer to create 240 Vac. Sun-oriented PV frameworks create direct current, which is put away in batteries. The inverter switches the immediate current forward and backward to create rotating current that is changed into a worthy yield waveform. Inverters come in two fundamental yield plans: sine wave and altered sine wave [14, 15]. The inverter is a noteworthy electronic segment of sun-based PV frameworks and come in evaluations of 50–5500 Watts. It screens control sources and auto chooses among sunlight-based and battery control contingent upon what is accessible.

4.9.2.6 Charge controller

A charge controller anticipates battery over charge and outgassing and is required for charging batteries. A charge controller screens the battery's condition off-charge to protect that when the battery needs charge, the best possible measure of current is given. Interfacing a sunlight-based board to a battery without a charge controller truly chances harming the batteries and makes a potential wellbeing danger. Charge controllers are appraised dependent on the measure of amperage they can process from a sun-oriented board. If a charger controller is rated at 20 amps (A), it means that you can connect a solar panel output of 20 a to the charge controller [16, 17]. A new feature of charge controllers is Maximum Power Point Tracking (MPPT). This is an electronic circuit that improves the effectiveness of sun-oriented boards by augmenting yield control. It enables the charge controller to screen the board's yield and analyzes it to battery bank voltage. At that point, the charge controller changes over the board voltage to the most extreme current for better battery charging. An accuse controller of MPPT improves sun-oriented PV framework execution by around 10%.

4.9.2.7 Metering

A sun-based PV framework meter is like a vehicle measure and is essential for evaluating activity of sun-based PV frameworks. They affirm the battery charging process, show control utilization, battery hold limit, and give chronicled battery information [17]. A meter is normally situated at an advantageous spot in the home. A decent battery meter is a valuable indicative and client administration device.

4.9.2.8 Converter

The situating of a converter between the boards and the batteries will improve the entire photovoltaic establishment, permitting diverse controls from the framework [18]. Contingent upon the connected guideline, the boards will add to the most extreme vitality given to the framework or the ideal vitality for their activity, guaranteeing a productive charge of the battery.

4.9.2.9 Disconnect box

Interfacing sun-oriented PV frameworks to the house and matrix require a distinction box with circuits. Interconnection prerequisites incorporate a utility available box with an obvious primary breaker separate switch, melded between the batteries and other power framework segments to anticipate fires, secure individuals, and gear harm in case of a glitch [18]. The battery banks and sun-powered PV framework additionally need a shared view fixing to the house ground. Having contrasts in ground potential between the house, the batteries and the framework are risky, forcing genuine electrical dangers.

- **Switches and fuses**: these allow the PV system to be protected from accidental shorting of wires and allow power from the PV modules and system to be turned "off" when not required, saving energy and improving battery life.

- **Wiring**: the final component required in PV solar system is the electrical wiring. The cables need to be correctly rated for the voltage and power requirements.

- **Load**: it is the component responsible to absorb this energy and transform it into work.

4.10 Solar radiations

Solar radiation originates at the sun but is measured at the Earth's surface. Before solar radiations had reached the Earth's surface, it must pass through the atmosphere, where it is absorbed, reflected, refracted, and otherwise changed. Together, these components are called the total or global radiation. The sun is a powerful nuclear fusion reactor producing staggering amounts of energy, which is unfortunately dispersed in space and practically all of it is lost. The Earth is 149,596,000 km from the sun, and at this distance, solar flux is relatively small. The energy intercepted by the Earth over 1 year is equal to the energy emitted by the sun in just 14 ms. Energy is radiated by the sun as electromagnetic waves of which 99% have wavelengths in the range of 0.2–0.4 μm [19]. Solar power realization on the crest of the Earth's environment consists of about 8% ultraviolet radiation (short wavelength, less than 0.39 μm), 46% visible light (0.39–0.78 μm), and 46% infrared radiation (long wavelength more than 0.78 μm) as shown in **Figure 26**.

The sun is a big ball of extremely scorching gases, the heat being generated by a variety of fusion reactions. Its diameter is 1.39 × 106 km as that of the Earth is 1.27 × 104 km. The average distance between the two is 1.50 × 108 km. Though the sun is big, it subtends an angle of merely 32 min at the Earth's exterior. This is because it is also at a very large distance [21]. Thus, the beam radiation received from the sun on the Earth is almost parallel. The brightness of the sun varies from

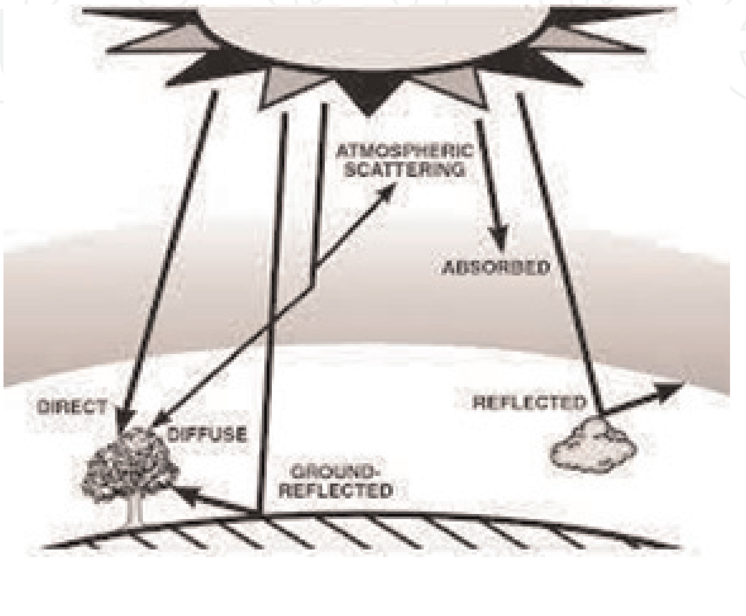

Figure 26.
The distribution of solar radiation.

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its center to its edge. The quantity of solar energy falling per instant on unit area, held 90° to the solar radiation outside the Earth's atmosphere when the Earth is at the average distance from the sun is known as the "solar constant." As per the latest measurements, the solar constant has a value of 1.36 KW/m^2 or 1.95 $calories/cm^2$ per minute.

4.10.1 Earth-sun relationship and insolation

Earth's seasons are constrained by changes in the length and the power of sun-powered radiation or insolation. Both of these variables are thus administered by the yearly change in the situation of the world's hub with respect to the sun. Yearly changes in the situation of the world's hub cause the area of the sun to meander 47° over our skies. Changes in the area of the sun directly affect the power of sun-based radiation. The power of sun-based radiation is to a great extent a component of the edge of occurrence, the edge at which the sun's beams strike the world's surface [22]. In the event that the sun is situated straightforwardly overhead or 90° from the skyline, the approaching insolation strikes the outside of the Earth at right edges and is generally serious. In the event that the sun is 45° over the skyline, the approaching insolation strikes the world's surface at an edge as shown in **Figure 27**. This causes the beams to be spread out over a bigger surface zone of frequency from 90 to 45°. As illustrated, the lower sun angle (45°) causes the radiations to be received over a much larger surface area. This surface area is approximately 40% greater than the area covered by an angle of 90°. The lower angle also reduces the intensity of the incoming rays by 30%.

4.11 Measurement of solar radiations

4.11.1 Universal solar irradiance: pyranometers

The essential instrument used to quantify worldwide sun-powered irradiance is the pyranometer, which estimates the sun's vitality originating from all headings in the half of the globe over the plane of the instrument. The estimation is of the aggregate of the direct and the diffuse sun-oriented irradiance and is known as the worldwide sun-powered irradiance. The most well-known pyranometer configuration utilizes a thermopile (different thermocouples associated in arrangement) connected to a slight darkened retaining surface protected from convective misfortune and protected against conductive misfortunes as shown in **Figure 28**. At the point when put in the sun, the surface accomplishes a temperature corresponding to the measure of brilliant vitality falling on it. The temperature is estimated and changed over through exact adjustment into readout of the worldwide sun-based irradiance falling on the engrossing surface [21, 23, 24]. A legitimately structured

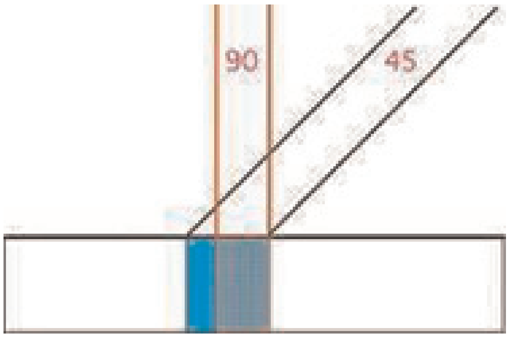

Figure 27.
Effect of angle on the area that intercepts an incoming beam of radiation.

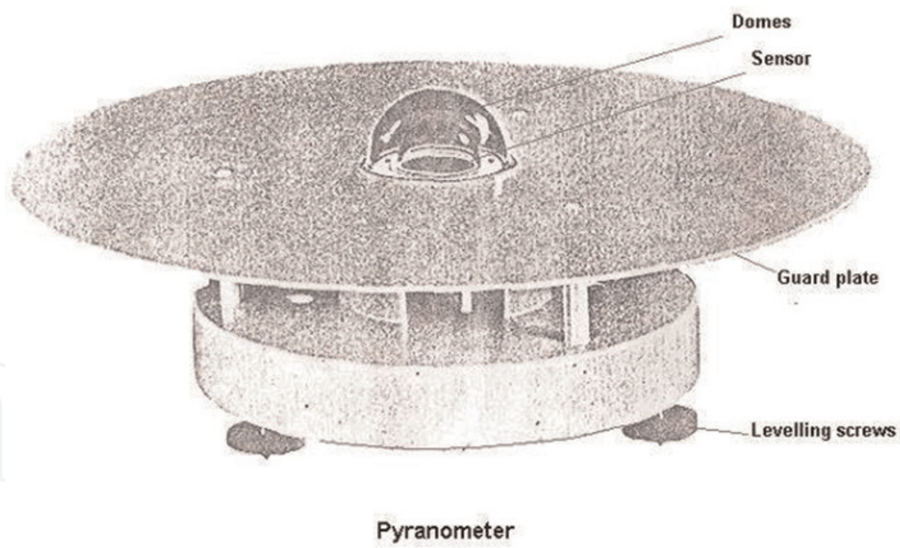

Figure 28.
Pyranometer diagram.

instrument estimates radiation in all the sun-powered wavelengths and its reaction to radiation ought to be relative to the cosine of the edge between the sun and a line typical to the pyranometer safeguard surface.

The common utilization of a pyranometer is for estimation of the worldwide flat sun-oriented irradiance. For this reason, it is set in a level introduction and adequately high over the environment so it has an unmistakable, hemispheric perspective on the whole sky with no shading or reflecting trees or structures inside this field of view [24].

To gauge the immediate typical part of the sunlight-based irradiance, just an instrument called an ordinary rate pyrheliometer (NIP) is utilized. This gadget, shown in **Figure 29**, is basically a thermopile pyranometer put toward the finish of a long cylinder which is gone for the sun [21]. The viewpoint proportion of the cylinder is generally intended to acknowledge radiation from a cone of around 5 degrees. A two-pivot following system is consolidated to keep up the sun's circle inside the acknowledgment cone of the instrument.

Notwithstanding the pyranometer and the ordinary occurrence pyrheliometer, which measures the worldwide and direct sun-oriented irradiance separately, there

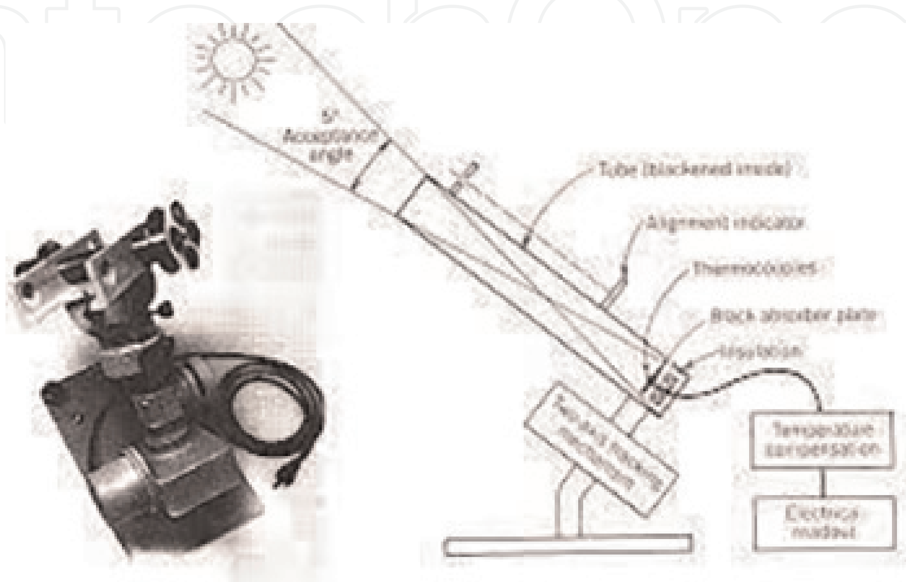

Figure 29.
Pyrheliometer.

is a customary estimation frequently—detailed in meteorological perceptions. This is the "length of daylight." The conventional standard instrument used to quantify this parameter is the Campbell-Stokes daylight recorder. This instrument comprises a glass circle that centers the direct sun-based radiation and consumes a follow on an extraordinary pasteboard card [25, 26]. These recorders have been supplanted in many establishments by photograph indicator enacted "daylight switches".

4.12 Design of a photovoltaic electric power system

Regular strategies for bringing power to the heap focus through long separation voltage transmission/dissemination framework are not in every case financially practical, if the heap focus is situated far from the focal transmission network. In this circumstance, direct transformation and capacity of sun-oriented vitality to power using sun-based cell boards and the batteries offer an option and alluring strategy for giving electrical vitality to such loads. Aside from the sunlight-based boards, the photovoltaic electric power system (PEPS) is made out of various different parts, for example, exhibit structure, mounting outlines, control circuits, wiring and interconnections, stockpiling batteries, and extras. Expenses are likewise acquired for the framework estimating and structure establishment and checkout and testing and upkeep, and so forth, all these can be lumped together as balance of system (BOS). The plan of PEPS for any heap focus needs watchful thought of both sun-powered cell boards and BOS segments [26, 27]. Now we design PEPS for necessary load in Chandigarh University, Gharuan, Mohali.

4.12.1 Electrical energy needs and load pattern

The electrical energy needs of the Chandigarh University (CU), Gharuan for which we have to design PEPS are given below. The load is calculated for Boy's Hostel-2 as shown in **Table 4**.

Calculation of load:

Light points = 5607 × 60 = 336.42 KW

Fan points = 5328 × 80 = 426.24 KW

Plug (5 Amp) = (6921/3) × 60 = 138.42 KW

Plug (15 Amp) = (940/3) × 1000 = 313.33 KW

AC's = 82 × 2500 = 205.00 KW

Motive load = 94.815 KW.

Total campus

load = 336.42 + 426.24 + 138.42 + 313.33 + 205 + 94.815 = 1514.225 KW

We consider just the fundamental heap of Boys' Hostel-2 for count for summer season.

The thought of day time load is from 8 am to 4:30 pm while the thought of night load is from 5 pm to 7 pm. To plan a PEPS for the above burdens, most importantly, we build up a strategy to break down everyday electrical vitality needs and burden example of the Boys' Hostel-2 at C.U. Gharuan. The all out size of sun-based cell boards and capacity batteries is resolved from the vitality balance contemplations.

4.12.2 Energy balance considerations

So as to choose the correct size sun-oriented cell boards and capacity batteries for meeting the day and evening time loads, we characterize a vitality balance condition where the absolute vitality accessible from sun powered exhibit (ESA) is adequate to energize the battery (EB) and vitality required by the framework

Sr. No	Name of building	Light points	Fan points	Plug 5 Amp	Plug 15 Amp	AC's
1	Main building	1144	1415	1400	204	30
2	HMCT	400	460	460	100	15
3	Polytechnic	402	468	455	70	10
4	Engineering Block	398	442	450	100	15
5	CBS	405	504	465	112	12
6	Boys' Hostel-1	1413	536	1593	22	Nil
7	Boys' Hostel-2	595	483	1148	Nil	nil
8	Girls' Hostel	700	805	750	264	Nil
9	Workshop	150	215	200	68	Nil
Total		5607	5328	6921	940	82

Table 4.
Total load of C.U. campus.

electrical burden including framework misfortunes (EL), for example, without any reinforcement control supply.

$$ESA = Eb + EL \tag{2}$$

Assuming that the night time load is solely provided by the storage batteries with an overall efficiency factor K1:

$$EB = EN/K1 \text{ where } K1 = \eta D.FU.\eta R.\eta L.\eta B \tag{3}$$

ηD being the solar array diode efficiency, FU the solar array utilization factor, ηR the regulator efficiency, ηL the line loss factor, and ηB the battery Whr efficiency.

Similarly assuming that most of the day time load is directly fed by the solar array except when PD > PSA, the solar array output is given as

$$EL = ED.\alpha/K2 + (1 - \alpha)\ ED/K1 \tag{4}$$

where α is the fraction of day time when PD < PSA and K2 = K1 /ηB is the overall efficiency factor by which the solar array directly drives the load.

The solar array size is expressed in terms of its peak output PSAMP which is obtained from:

$$ESA = PSAMP\sum(f(t)\ dt)I; \text{where I is from } i = 1 \text{ to } P \tag{5}$$

where f(t) = ESA/PSAMP over the ith segment (dt)I during the day time load. z is the number of time segments in the day.

The capacity (CB) in Ahr of the storage battery at the rated load is determined by the daily night load and a part of day time load for which sufficient storage is to be provided as protection against cloudy weather, thus leading to

$$CB = xPN + yPD/[\eta LVD\ (CD/100)] \tag{6}$$

where x and y are the periods for which storage are to be provided for different loads, VD is the average voltage of discharge of batteries, and CD is the maximum permissible depth of discharge in percentage.

4.12.3 Balance of system components

As referenced before, separated from the sun-based cell boards, the PEPS includes various parities of framework parts, for example, (a) cluster module mounting outlines, outline backings, and establishments; (b) electrical control circuits, load executives and power molding hardware, wiring interconnections, and so on; and (c) stockpiling batteries, racks, and venting types of gear, and so on [22].

Further expenses are likewise caused for the establishment and checkout of module test and investigation, framework estimation, and structure bundling upkeep, and so on; the whole of all these expenses, lumped as BOS cost, should be considered for plan of PEPS. An important factor contributing to the highly nonlinear behavior of BOS cost /peak W with the PEPS size is the nature of variation of the storage batteries cost/Ahr with the capacity in Ahr of battery.

4.13 Design requirements

A module can be made by attaching one cell to another with metal shaped from solid wire or solid ribbons. The interconnections can be rigid or flexible to contend with movement within the array produced by thermal expansions and other forces. All connections should provide for the lowest possible resistance and least possible interference with PV performance. Thus designers attempt to keep such connection short, reducing cross sectional area against increasing resistance. The output from an array is tied to a collecting conductor called a bus.

4.13.1 Placing of cells

Placements of cells in the array and cell's shape are important. Overall panel efficiency as measured by voltage per unit area drops as the space between cell increases. Large cells are not often to boost packing efficiency (i.e., the need for a maximum cell to panel area ratio). Cell sizing is an important aspect in creating a module with desired electrical properties. The current available from a cell varies with the size of the cell and voltage remains constant. For large voltage, many small cells should be connected in series [19]. Round cells are used that have been cut in half and then placed into an array in an offset pattern to get more of them into a unit area. This increases the packing density of the cell. It can also be increased by square or hexagonal cells. Cells are placed as closely or as possible and cannot be allowed to touch as they will short out electricity [30]. Extra space must be allowed between the cells to accommodate thermal expansion.

4.14 Array support

There is more to array building that resourcing electrical need individual solar cells are fragile groups of them can be equally fragile. Each module must be able to hold up to the rigour of assembly and disassembly. An array must be able to withstand mild loads, mechanical movements, and stresses induced by temperature changes. Part of a module's support is the form of the transparent cover applied to it [31]. The primary application of the cover is to protect the PV module against conditions with oxygen, humidity, dust, and precipitation.

4.14.1 Size of array

Size of solar cells may be ranging from about 1 mm to over 100 mm in diameter. The thickness range for the most common silicon cells is 0.2–0.4 mm.

We developed a very simple semi-empirical rule for the selection of the size of array.

$$Pph = (LH + LHd/Cr\ Bb \times 100)/X \tag{7}$$

where Pph is the array size in peak watts. X is the annual average equipment peak hours per day that is the annual average watt-hours received per weak hour of flat plate photovoltaic module per day. L is load rating in watts. H is the hours of operation per day. d is the number of days of storage required. Cr is the charge recovery period of the period and Bb is the watt-hour efficiency of the battery.

The value of X is directly dependent on the total insolation received by the panel at the site of installation. The value of X can be estimated as

$$X = EXm/12; \quad \text{With } Xm = \eta ov\ Im/\eta m \tag{8}$$

where ηov is the overall efficiency of the system, Im is the average insolation on a horizontal surface of the location, and ηm is the module efficiency. The overall efficiency is the product of the module efficiency and the balance of system efficiency, including the power conditioning efficiency, temperature coefficients of efficiency, and so on.

4.14.2 Solar panels

Most of the silicon solar cells employed for terrestrial applications are round of 5 cm diameter and a thickness of 0.3–0.5 mm. the tendency is toward large diameters. A cell of 5 cm diameter with a surface area of about 20 square cm delivers in full sun and at room temperature a power of 0.2 W at 0.45 Volts. For higher power or higher voltage, a number of cells must be assembled into a panel [31, 32]. For instance, to double power at constant voltage, two cells are connected in parallel. By connecting a number of cells in parallel and series, it is possible to provide any amount of power at a desired voltage.

4.14.3 Battery storage

The simplest means of storage on a smaller moderate scale is in electric storage battery. Solar cells produce the direct current required for battery charging. The stored energy can then be delivered as electricity to the local load when needed. A battery is a combination of individual cells. A cell is the elemental combination of materials and electrolyte constituting the basic electromechanical energy storer. A battery can also be thought as a block-box into which electrical energy is put, stored as electromechanical energy, and later regained as electrical energy. Primary batteries are nonrechargeable while secondary batteries can be recharged again and again. So secondary batteries are of chief interest for solar electrics. Examples of secondary batteries are lead-acid, nickel-cadmium, iron-air, nickel-hydrogen, zinc-air, sodium-sulfur, sodium-chlorine, etc.

Energy efficiency of a battery is defined as

$$\eta energy = \int I1\ E1\ dt / \int I2\ E2\ dt \tag{9}$$

where I1 = battery discharging current for a period of 0 to t1. I2 = battery charging current for a period of 0 to t2. E1 = Battery discharging terminal voltage. E2 = Battery discharging terminal voltage.

Cycle life is the number of times the battery can be charged and discharged under specified conditions and this may vary greatly with the depth of the discharge. Deep discharge tends to result in short cycle life.

4.15 Design calculations

Site information:
Proposal site for the solar plant is Chandigarh University, Gharuan, Mohali, Punjab. Its coordinates are
Latitude: 30°46′5″ N
Longitude: 75°34′36″ E

Now by using the above relations, we can design the PEPS as below.

Type of load	Quantity	Wattage	Total wattage	Hours of operation	Total KWhr
Light points	593	60	35,580	17	656.880
Fan points	483	80	38,640	7	249.060
Total					905.940

- Total roof area = 1050.1416 m^2

During summer, solar energy is available for 8 h per day. Therefore, array size can be calculated using a natural energy loss factor of 0.85 [9].

- Array size = (0.85 × 905.94)/8
  = 96.256 KW
  = 97 KW (approximately)

- We use 150 W panel of 1.5 m^2. Therefore, the number of solar panels (Ns) required is calculated as

Ns = total load in watts/rating of single panel in watts

= 97 x 103/150

= 646.67

Ns = 647 (approximately).

(Based on the roof area we need: 1050.1416 m^2/1.5 m^2 = 700. Therefore, we have enough space for the accommodation of 647 panels.)

- We use 12 Volts, 17 Ahr lead acid battery. The capacity of storage batteries CB in Ahr is determined as

CB = total KWhr/voltage of single battery

= 905.94 KWhr/12 Volts

= 75.495 KAhr

- The number NB of lead acid batteries required can be calculated as

NB = CB/Ahr rating of single battery.

= 75.495 KAhr/17 Ahr

= 4440.88

= 4441 (approximately)

- We use 12 V, 20 Ampere charge controller. The rating of the charge controller is in amperes and can be calculated as

= Total load in W/12 Volt

= 97 × 103 W/12 Volts

= 8.0833 × 103 Amp

= 8083.333 Amp

= 8083 Amp

- Number of 12 V, 20 Amp charge controllers (NC) required can be calculated as

NC = 8083/20

= 404.15

= 404 (approx.)

For 97 KW load we need 97 KW inverter.

Now the total BOS cost can be calculated as

Cost per watt is $0.70 or Rs 37.667 [14].

Cost of solar panels C = total load in watts × cost per watt

= 97 × 103 W × Rs 37.667

C = Rs 3,653,699

Cost of battery can be calculated as:

= NB × cost of one battery

= 4441 × $34

= 4441 × 1982.54

= Rs 8804460.14

Cost of charge controller can be calculated as

= NC × cost of one charge controller

= 440 x Rs 1899

= Rs 835,560

Cost of 97 KW inverter can be calculated as

= total load in KW × cost per KW

= 97 × $2000

= 97 × Rs 107,620

= Rs 10,439,140.

Total cost = cost of solar panel + cost of battery + cost of charge controller + cost of inverter.

= 3,653,699 + 8804460.14 + 835,560 + 10,439,140

= Rs 23732859.14

To take into account the cost of wiring, junction box, etc., 20% of the total cost is added to get the total cost of the project.

= 20% Rs 23732859.14

= Rs 4746571.828

Therefore, the total cost of the project C = Rs 23732859.14 + 4746571.828

C = Rs 28479430.83

If we purchase the energy from the utility, we have to pay

= total demand in KWhr × price of one unit

= 905.94 KWhr × Rs 7/unit

= Rs 6341.58

Total cost per year is

D = Rs 6341.58 × 365

D = Rs 2314676.7/year

Payback period

It is the period of time required to recoup the expense of a venture. The recompense time of a given speculation or venture is a critical determinant of whether to embrace the position or undertaking, as longer compensation periods are regularly not attractive for speculation positions.

Payback period = cost of project/annual cash inflows

The payback period can be calculated using the following equation:

C – ND = 0

Or N = C/D

where C = Rs 28479430.83

D = Rs 2314676.7/year

Therefore,

N = Rs 28479430.83/Rs 2314676.7

N = 12.3

Therefore, the cost of the project installation can be paid back or recovered in 12 or 13 months.

5. Results

From the structure system, roof top methodology has accommodated the establishment of the sun powered boards at Boys' Hostel-2 C.U. This methodology is the coordination of the boards to the top of the structure. This methodology is given as it replaces the regular rooftop while enabling the normal daylight to channel through. As a rooftop, it servers as auxiliary and climate condition prerequisites by giving basic quality and solidness; it secures against harms like substance and mechanical harm, averting against flames, and ensuring against downpour, sun, wind, and dampness; it permits heat assimilation and warmth stockpiling; it controls the dissemination of light and so on; notwithstanding these highlights, it fills in as a power generator through gathering some portion of the electrical burden necessities of the structure.

In view of the very particular nature of both sunlight-based cells and capacity cells, indicated burdens can be controlled independently by individual rooftop-top PEPS for meeting similar vitality needs of the diverse loads as referenced previously.

6. Conclusion and future scope of the work

It is normal that with present increasing speed in the endeavors with respect to makers, creators, organizers, and utilities with satisfactory governmental support, PV frameworks will within the following two decades involve a position of pride in the nation's capacity part, guaranteeing ideal usage of the vitality specifically from the sun around the year. Plainly, the SPV framework can give some help toward future vitality requests. This PV framework comprises PV exhibit with vitality putting away gadgets and power electronic gadgets that have been talked about in this undertaking work to accomplish an effective and cost focused framework design so that sun-based power sources could improve the life of individuals particularly in provincial regions where power from primary lattice has not come yet [33]. The procedure received appears to be tasteful for deciding the conceivable required vitality from the sun-based board for a self-assertively picked zone. The complete BOS cost determined appears to be palatable for the proposed structure. The surplus vitality produced can be utilized when sun is not accessible.

6.1 Future scope of the work

Later on, we will figure out the quantity of PV exhibits and cost of the framework which can satisfy the heap need of all grounds. In the beginning, we have not considered the climate control system load. In future, we will incorporate the heap of forced air systems. A point by point cost investigation can be made considering carbon credit to demonstrate whether it is monetarily feasible or not since the execution of PV framework is firmly reliant on misfortune factors, for example, shading, PCS misfortunes, bungle, PV exhibit temperature rise, and so on. There is a need for checking on these misfortune elements to assess and investigate precisely the execution of PV framework. This framework can be structured with additionally some other electrical machines like channel for stifling the swells. A point by point execution examination of the present framework can be done to demonstrate its unwavering quality as a future study. Sun-based PV is an innovation that offers an answer for various issues related with nonrenewable energy sources. It is spotless decentralized, indigenous, and does not require consistent import of an asset. What's more, India has among the most noteworthy sun-oriented irradiance on the planet which makes sun-based PV even more appealing for India. The territories of Orissa and Andhra Pradesh likewise house probably the best quality stores of silica. India has a substantial number of cell and module producers. Despite every single above preferred standpoint, Indian Photovoltaic Program is still in the earliest stages. One reason could be nonappearance of basic, activity arranged, and forceful PV approach of the nation both in state and focal dimension. All the more rapidly we do it with the experts, the more we ensure our future vitality security.

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A. APPENDIX

Specification of solar panel used

EPCOM polycrystalline solar panel

Wattage of single solar panel = 150 Watt

Cells per module = 36

Maximum power voltage = 18.28 V

Maximum power current = 8.21 Amp

Open circuit voltage = 21.9 V

Short circuit current ISC = 8.93 Amp

Cell efficiency = 17%

Module efficiency = 14.9%

Cell size (mm) =156 × 156

Dimensions = 1480 × 680 × 35

Weight = 11.6 kg

Price of single panel = $ 0.70

Specification of sealed lead acid battery

Nominal voltage = 12 V

Nominal capacity = 17 Ahr, 204 Whr

Maximum charging current = 5.1 Amp

Maximum discharging current = 255 Amp

Dimension = 181 mm × 76 mm × 167 mm

Weight = 6150 g

Energy density = 3 Whr/Kg

Price = $34.00

Others

Maximum number of panels in series = V inverter/V panel

Maximum number of panels in parallel = I inverter/I panel

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