International Journal on Recent and Innovation Trends in Computing and Communication
ISSN: 2321-8169 Volume: 11 Issue: 4
***Article Received:** 25 January 2023 **Revised:** 12 February 2023 **Accepted:** 30 March 2023*

Solar Energy in the Renewable Era

Deepak Kumar Goyal[1*], Dr. B. L. Gupta[2] Mahavir Kumar Meghvanshi[3]
[1*]Department of Electrical Engineering, Govt. Engineering College Bharatpur, Rajasthan, India
[2] Department of Mechanical Engineering, Govt. Engineering College Bharatpur, Rajasthan, India
[3]Department of Mechanical Engineering, Govt. Engineering College Baran, Rajasthan, India

Abstract- Today, energy serves as the primary impetus for socioeconomic development. Renewable energy, on the other hand, provides a huge interest due to the progressive rate of concern for the environment. Due to the ongoing depletion of fossil fuels, this alternative energy source is gaining popularity. This is the energy obtained from the sun, wind, and rain, among other sources. Solar energy, as a non-traditional, renewable source, has a significant potential for converting to electric power. It is preferable to maximise the output of a solar system in order to maximise efficiency. To maximise power output, the panels must be positioned with the sun. Additionally, the article discusses the operation of solar energy systems, their management systems, and the possible uses and methodologies for promoting the development of solar energy.
Keywords: Renewable energy, solar power generation, solar management, photovoltaic energy.

I. INTRODUCTION

The growing demand for energy, the consistent depletion of current fossil fuel reserves, and increasing concern about environmental pollution have compelled mankind to develop new technologies for producing electrical energy from clean, renewable energy sources like wind energy, solar energy, and so on [1-4,8]. Among non-traditional, renewable energy, solar energy has the greatest potential for converting to electric power, capable of meeting a significant portion of the planet's electrical energy requirements. Solar energy is completely free, virtually inexhaustible, and produces no environmental pollution residues or greenhouse gases. Among all green technologies, solar photovoltaic (PV) has been a trailblazer for decades. Solar photovoltaic (PV) installed capacity managed to reach 480 GW globally (with the exception of concentrated solar power i.e., CSPs) even by end of 2018, probably the second renewable energy source behind wind. Solar PV once again dominated total renewable and energy capacity additions last year, adding twice the capacity of wind and more than all fossil fuels and nuclear combined, with solar PV inclusions totaling approximately 94 GW [4-6]. Solar photovoltaic (PV) technology has advanced significantly over the years, with the several milestones being reached in contexts of installations (such as off-grid), technical advances, and cost reductions, as well as the formation of key solar energy affiliations. The transformation of solar energy generation is depicted in Table I. Solar energy will undoubtedly remain a critical renewable energy source in the decades ahead. Renewable energy deployment has accelerated in recent years, surpassing previous records and surpassing annual traditional power capacity expansions in several regions. Solar photovoltaic (PV) power configurations have dominated the solar industry for several years. The global capacity of grid-connected and installed solar PV electricity surpassed 480 GW at the end of 2018, up 20% year on year from 2017 (386 GW) and representing a CAGR i.e., compound annual growth rate of approximately 43% since 2000.

Table I: Solar Energy Evolution

Year	Solar energy production
1941	The first monocrystalline silicon cell is constructed.
1954	Inauguration of the International Solar Energy Society
1963	Commencement of mass manufacture of solar cells
1973	Solar One, the world's first solar building, was created using a hybrid solar thermal and solar photovoltaic power source.
1985	The University of South Wales successfully achieves a 20% efficiency rate for silicon cells.
2010	Global average price for solar photovoltaic auctions: 241 USD/MWh

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2012	The cumulative photovoltaic energy capacity of the world exceeds 100 GW.
2015	Solar Power Europe establishes the International Solar Alliance, Solar Power Europe, and the Global Solar Council.
2016	The first solar-powered plane to circle the globe
2017	Solar energy generates 4.5 million employments; Global photovoltaic capacity equals 400 GW.
2018	Solar capacity deployed globally equals 480 GW; the average price of solar PV auctions globally is 85 USD/MWh; and off-grid solar PV capacity approaches 2.94 GW (0.25 GW in 2008)

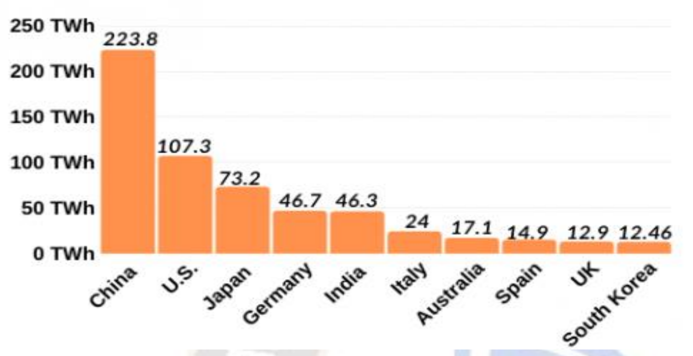

Figure 1: Top ten solar-energy producing countries [3]

Without a doubt, China, the world leader in solar installation, has held the top spot. Following that, the Japan, United States, India, Germany, Australia, Italy, Spain, the South Korea, and United Kingdom joined. Japan came in third position, which is an interesting observation. The cause for this could be Japan's record-breaking yearly sun . Whereas India ranks third in terms of cumulative solar panel system.

II. SOLAR ENERGY

The Sun generates a vast amount of energy in a single day, enough to cover the Earth's energy demands for a entire year, but only about 50% of that energy is absorbed by the Earth and a far smaller quantity is being used to satisfy energy requirements [7,10,19,7]. Solar energy has a wide range of potential applications [5]. Solar energy avoids the emission of 39 billion tons of carbon dioxide per year [16,17,6]. Solar cooking is amongst the most common residential solar energy applications. Solar cookers of many types are readily accessible and extremely cost effective. Solar water heaters are another common application of solar energy for residential uses, and it is predicted that they can greatly reduce carbon dioxide emissions [18]. Solar drying technique is by far the most efficient method for drying fruits and vegetables in a clean and sanitary environment with no electricity expenditures. It also saves energy and time and requires less space. It helps in improving the performance of fruits and veggies and significantly decreases their degradation [12,13,14,19]. Solar energy is the only source of energy that is available all year round in countries like India. Its intrinsic advantage is its widespread availability throughout our country. Due to India's diversified geographical geography, it obtains over 5,000 trillion kWh of solar energy every year, which would be comparable to 600 GW. This is significantly more than the present overall energy usage of the country [5]. Solar energy technology can be classified into two categories:

- Solar thermal power plants are a form of solar thermal system that create energy via the use of sunlight.
- Photovoltaic Energy System (Solar PV)

2.1 Solar Thermal Power plants

Solar thermal power plants generate energy by converting solar radiation to high-temperature heat via reflectors and mirrors. By heating a working fluid, this energy is then converted to steam. The steam would then be utilised to drive the turbine or an engine, which then in turn generates a generator and produce power [6]. Solar collectors are a critical component of a photovoltaic solar thermal system. Solar collectors are a type of heat exchanger unique in that they transform solar radiation to electric power. Furthermore, the upfront cost of this method of generating energy is rather costly in comparison to other methods, but it produces the least amount of carbon. The essential principle of solar thermal generation is illustrated in Figure 2, which would be composed of four major subsystems: the solar receiver, the solar collector field, the energy conversion system, the storage and/or backup system. The solar collector fields is made up of an array of reflectors or mirrors that gather and concentrate solar radiation onto a receiving tube. The receiver tube equipped with a thermal energy carrier collects the concentrated solar energy and converts it to heat that can be utilised directly or indirectly via a secondary circuit to produce electricity. During conversion process, the certain quantity of heat is wasted. Additionally, some solar light is reflected back and therefore does not contact the absorber at all. As a result, selecting an effective solar collector is critical for meeting application requirements and achieving the specified temperature level [11].

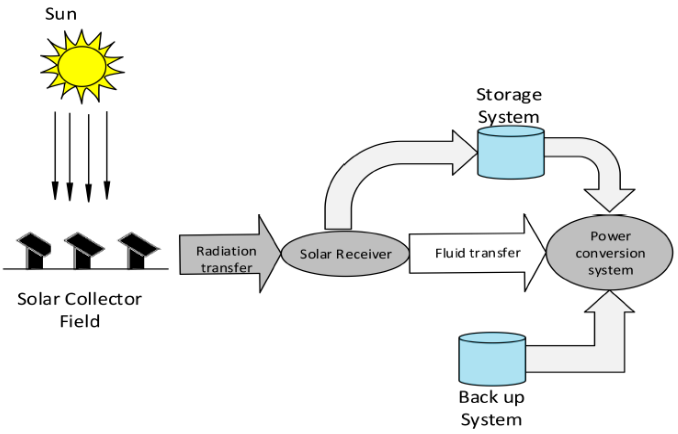

Figure 2: Solar thermal energy production [11]2.1.1 Solar Collectors

Numerous types of solar collectors are available, including the following:

a. Parabolic trough reflectors: This type of reflector utilises a linear parabolic reflector to focus light onto a receiver located along the reflector's focal line. It is composed of a receiver, which is a tube placed exactly above the parabolic mirror's centre, and a working fluid. A working fluid is heated to between 150 and 350 degrees Celsius as it runs through the receiver and is then seen as a source of heat for a power generation.

b. Fresnel: Inside a Fresnel lens, refraction occurs at the surface, whereas the vast material between both the two surfaces exhibits no refraction difficulties.

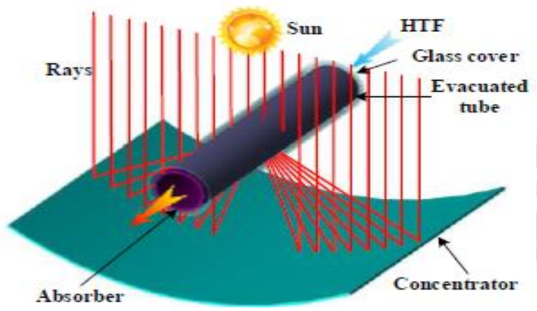

Figure 3: Parabolic trough reflectors [9]

It uses more energy than a typical heater and is also utilised in furnace heating. Its installation has indeed been utilised to modify the surface of metallic materials. This gadget utilises solar energy in areas of extreme heat. This temperature is reached in a matter of seconds. While the Fresnel concentrator reduced the reflective surface by 34.3 percent in comparison to a parabolic of same diameter, the 20 minutes of manual adjustment required to follow the sun proven to be an important drawback of this device[2].

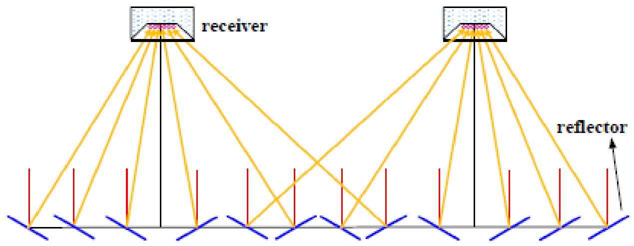

Figure 4: Compact Linear Fresnel Reflector [9]

c. *Parabolic Dish:* It resembles a big satellite dish in appearance, but features mirror-like reflectors and an absorbent as the focal point. It made use of a twin axial sun tracking system. This is a 30% efficiency obtained. This dish generates solar energy at a MW level in a solar power plant. This is the maximum conversion efficiency achievable using concentrated solar power systems[1].

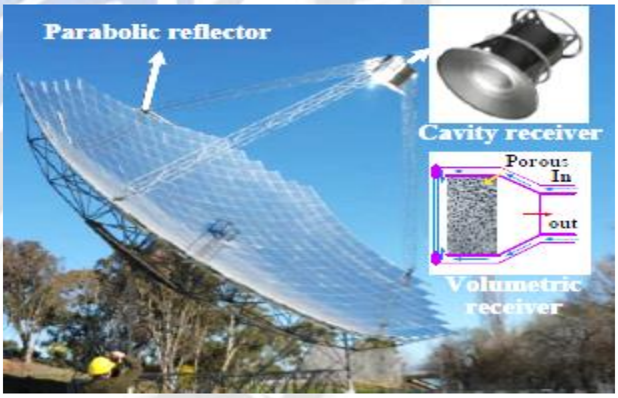

Figure 5: Mini Fresnel Reflector with Linear Reflector [9]2.2 Solar Photovoltaic Power Generation

The solar PV sector has progressed rapidly in recent years, with numerous significant milestones in terms of installations (particularly off-grid), cost cuts, and technology improvements, and also the formation of major solar energy organizations. Solar energy is abundant on Earth, and it is simple to transform it to electricity using solar cells. A solar cell is indeed an electrical device that converts the energy of light (sun rays) directly into electrical energy (direct current (DC) electricity). This process is called as Photovoltaic (PV) technology, and it may be often used power a variety of devices [8]. The basic solar panel diagram shown in figure 6(a).

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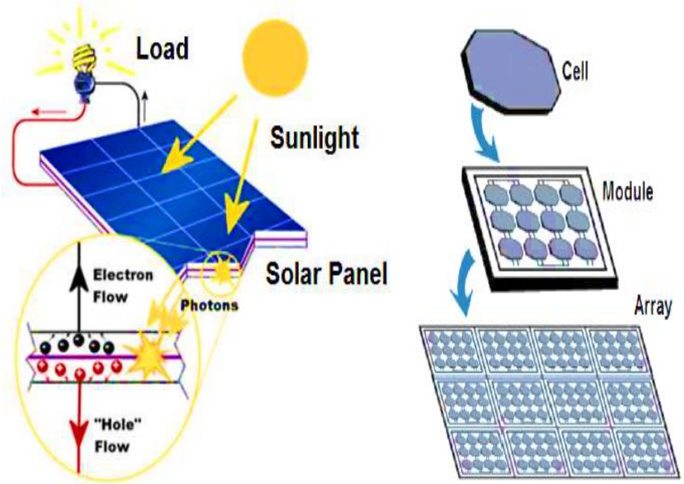

Figure 6: (a) General representation of Solar Panel; (b) Cell, Module and Array [6]

Solar panels, as part of a larger photovoltaic (PV) system, use a photon of light energy from the sun to generate electricity through the PV effect. Solar panels require very little maintenance and can last a life. Copper, silver, or other nonmagnetic conductive transition metals could be used in the conducting wires that take the electricity away from the panels. The cells must be electrically connected to one another and to the entire system[12]. [15,19]. A single PV cell generates very little electricity, which is insufficient for general use. As a result, several single PV cells can be arranged in series to raise voltage, and the cells can indeed be connected in parallel or series to increase current [3]. Cell, module, and array are depicted in Figure 6(b).

2.2 The working principle of solar electricity generating

Simply stated, a solar panel converts sunlight into direct current (DC) electricity via PV cells. The Charge Controller controls the energy from the solar panel, which is then reversed back to the solar panel, causing the panel to be damaged. This system is coupled to an inverter, which converts DC to AC for a variety of loads that are used on a regular basis. Whereas the Battery System is used to store electric power in the event that daylight is not accessible (evening). The electricity stored in a battery is now in the kind of DC, which may be transformed to AC using the inverter in the system. Figure 4 depicts how solar energy works[12].

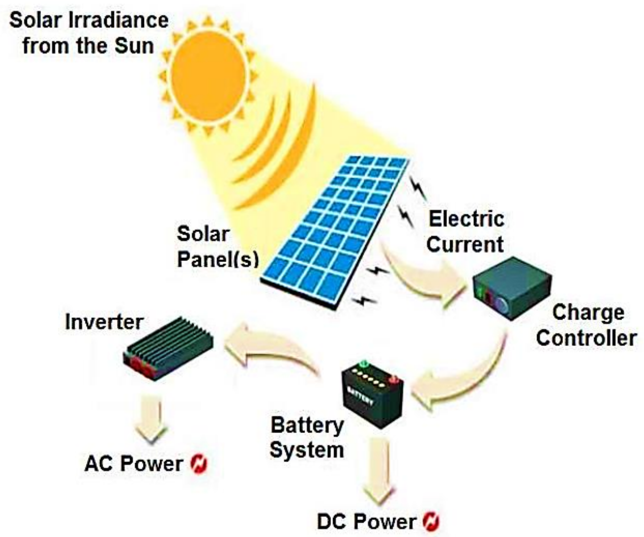

Figure 4: Solar energy's working method [6]

Solar Cell (Photovoltaic Cell): Solar radiation was transformed converted into electricity by the cells (as illustrated in figure 3(b)). It is made up of a variety of semiconductor materials. Figure 3 shows two forms of charge: negative charge (black spheres) and positive charge (red spheres). Such cell technology is utilised to create solar cells that are both inexpensive and efficient. Whenever photons from sun are captured by the cell, electrons are knocked loose from silicon atoms and pulled off by a grid of metal conductors, causing an electric direct current to flow. PV solar cells are made up of a variety of substances[8].

Photovoltaic Array: It is made up of a large number of PV cells connected in parallel and series. The parallel connection is capable of raising the current inside the array,

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while the series connection is responsible to increase the voltage of a module. In direct sunlight, it may produce up to 180 watts. The larger the array's total surface area, the more solar energy it will generate.

Photovoltaic Panel: A photovoltaic panel is a pre-wind, field-instable device made up of one or more PV modules. PV cells are connected in series upon the panel. Individual PV cells are joined together to form solar panels[10].

2.3 Advantages and Disadvantages of Solar Energy

Advantages

- No Monthly Bills
- Low running cost
- Eco-friendly
- It is renewable
- Source of Income
- Shared Solar
- Job provision
- Improves the Economy
- Improving Technology
- Value-Added Property
- Low Maintenance Cost

Disadvantages

- It is costly to set up
- It is inefficient
- It takes up more room
- It is dependent on latitude
- It is inconsistent in foggy weather

2.4 Solar Power Applications

A single solar cell can be found in many pocket calculators, however for larger uses, cells will be assembled to form PV modules, which are then grouped into solar arrays. The huge solar arrays systems can generate and supply electricity for household and commercial uses, including but not restricted to:

- Pipeline cathodic protection.
- Supplemental power supply for residential use.
- Power orbiting satellites and other spacecraft.
- Entire generating electricity in areas where it is not available.
- Provides power to roadside emergency telephones in remote areas, as well as orbiting satellites as well as another spacecraft.

Batteries, on the other hand, are used in these applications to store the energy generated during the day and use it at a later time, such as when the sun isn't shining or at night.

2.5 Solar energy generation in India and the rest of the world

India recently surpassed Italy to take fifth place in the world for solar power deployment. In the last five years, solar power capacity has expanded by more than 11 times, from 2.6 GW in March 2014 to 30 GW in July 2018. Solar tariffs in India are currently highly competitive and have reached grid parity. The National Institute of Solar Energy estimated the country's solar capability to be around 748 GW, assuming that solar PV modules occupy 3% of waste land area. Solar energy has been one of the primary missions of India's National Action Plan on Climate Change, with National Solar Mission being one of them. On January 11th, 2010, the National Solar Mission (NSM) was inaugurated. The National Sustainable Growth Mission (NSM) is indeed a significant endeavour of the Indian government, with strong participation from states, to encourage environmentally sustained development while resolving India's energy security issues. It would also be a great contribution by India to international effort to address climate change challenges. The Mission's goal is to make India a worldwide leader in solar energy by establishing regulatory conditions that allow solar technology to spread as quickly as possible all across country. Mission hopes to have installed 100 GW of grid-connected solar power plants. This is in accordance with India's Intended Nationally Determined Contributions (INDCs) goal of achieving roughly 40% aggregate electricity production installed capacity from non-fossil fuel-based energy supplies by 2030, and reducing the emission intensity of its GDP by 33 to 35% from 2005 levels. To meet this goal, the Indian government has implemented a number of policies, including the VGF Schemes, Solar Park Scheme, CPSU Schemes, Canal Bank & Canal Top Schemes, Grid Connected Solar Rooftop Schemes, Defence Schemes, Bundling Schemes, and others[7].

III SOLAR POWER MANAGEMENT

Maintenance [15] is a critical component of the photovoltaic system. Due to the fact that if any element is broken, the system cannot function properly, and the system is rather large, personnel should perform maintenance on a regular basis to guarantee the system operates as designed. If the system is not maintained, when problems happen, repairing it will be prohibitively expensive and may take an inordinate amount of time. Regular maintenance is necessary prevent this.

a. Create an effective technical data management system

- Create a system for storing design and building drawings and technical documentation for power plant technology.

- Implement a framework for the plants' information management systems.
- Implement a framework for monitoring operation of the plant.
- Devise a process for operational analysis.

Every station must establish a comprehensive technical document file, and the individual accountable for the creation of power plant technological file administration should provide robust technical assistance for the underlying data[6].

b. The component's maintenance: In sandier locations, wiping system components on a regular basis to ensure the system functions properly. Cleanse the elements' surfaces with a soft cloth; avoid using those harsh and abrasive cloths. Additionally, test multiple aspects and wiring on a regular basis and take preventative steps. Make notes following a thorough examination of the system's details. Replace or repair those elements as necessary[4].

c. Train maintenance personnel: Training is primarily focused on two areas of personnel, the first of which is technical and professional personnel development for those significant and tough difficulties, and the second of which is operation maintenance management. And organising those individuals to receive professional training and conduct study on certain issues in order to hone their professional abilities. Second, it is critical to train those system operators, and practically all of those individuals are local. However, because the local personnel will typically lack expert expertise of solar photovoltaic, they must be schooled in the fundamentals[3].

3.1 Various solar energy management applications

a. Utilizing good solar charge controllers: This is essentially a current or voltage controller that is used to charge the battery while preventing overcharging of the electric cells. It is responsible for directing the current and voltage from the solar panels to the electric cell. 12V boards/panels often output 16 to 20V, thus if there is no regulation, the electrical cells will be damaged due to overcharging. Electric storage devices, on average, need 14 to 14.5V to be fully charged. Charge controllers come in a variety of functions, prices, and sizes. These come in a variety of sizes, ranging from 4.5A to 60 to 80A. In today's solar systems, the MPPT charge controller seems to be the shining star. These controllers accurately determine the solar panel's great work voltage and amperage and match it to the electric cell bank. In comparison to a PWM controller, this results in an extra 10-30% greater power from your sun-oriented cluster. Any solar power system with a power output of more than 200 watts is typically worth taking the risk [1].

b. Battery backup systems: Such systems work in tandem with the electric grid and can provide power in the event of a power outage. Grid-tied battery backup systems incorporate batteries and are often designed to only supply power for essential loads. In the case of a power loss, loads are put in a subpanel which will be supported by the battery bank. Battery backup systems fueled by the sun function in tandem with the home's net metre. [2]

c. IoT-Enabled Solar Energy Management: IoT-enabled sensors are used in solar energy management services to gather and process information from solar farms, assess equipment status, and improve energy harvesting and delivery. IoT renewable power management solutions enable management to track and manage hundreds of different solar panels from a single location, allowing them to respond rapidly to problems and develop better-informed management and maintenance decisions [3].

d. QULON HELIOS: This is a solar energy management module that enables remote monitoring and control of the status of a solar-powered stand-alone lighting system. Maintaining crosswalks, bus stations, and safety light systems in good operating order provides more security for pedestrians and motorist. It manages and controls a self-contained lighting system comprised of the following elements: (a) a solar panel; (b) a battery; and (b) an LED lamp. During day, a solar cell transforms solar energy to electric power. During the day, the battery charges electricity, and at night, the battery supplies electricity for lighting[1].

IV. CONCLUSION

Energy is closely tied to long-term prosperity and economic recovery. It incorporates nearly all areas of development, including subsistence, education, health, agriculture, and employment generation. Energy generation and consumption are crucial parts of India's long-term development. All three demand significant amounts of energy: economic expansion, sustainable development, and environmental conservation. Energy generations' policies must always be geared at promoting energy systems derived from energy efficiency, renewable energy, and cleaner fossil fuel techniques that address social, environmental, and economic, concerns concurrently. Increased solar energy consumption can also assist governments in achieving energy security and diversification. Additionally, solar energy is underutilized, despite its huge latent potential. But at the other side, the decreasing expense of solar power generation, technological

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developments, and authorities' involvement in solar energy as a function of its beneficial environmental impact would permit solar energy to increase in India, resulting in prolonged growth. Solar energy is critical in India's view not just to enhance energy production, but also to enhancing energy reliability by bringing social, environmental, and economic factors into account.

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