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Review on Recent Applications and Future Innovations on Photovoltaics

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Abstract:- *The electricity requirements of the world are increasing at an alarming rate and the power demand has been running ahead of supply and as a result of it, the fossil fuels may not be sufficient to keep pace with the ever increasing demand of electrical energy of the world. Also Providing clean, reliable energy is a major goal for policymakers and concerned individuals worldwide. The unfortunate fact is that the cheapest energy sources, with a century of technical and infrastructure development backing them, are polluting fossil fuels. Thus when a technology like solar photovoltaic comes along – converting the sun's rays to electricity with no moving parts, no emissions, and no fuel costs – the excitement is understandable. Our paper elucidates about Photovoltaic Cell, it's applications, economics, growth and scope of Photovoltaic with a view of its current development and the future innovations in the area of solar energy.*

Keywords:- *Renewable Energy Sources, Solar Energy, Photovoltaic cells, Distributed Generation.*

I. INTRODUCTION

Solar energy is radiant light and heat from the sun harnessed using ever-evolving technologies such as solar heating, solar photovoltaic, solar thermal energy, and solar architecture. Its technologies are broadly characterized as either passive solar or active solar depending on the way they captured. Active solar techniques include the use of photovoltaic systems, concentrated solar power and solar water heating to harness the energy. Passive solar techniques include orienting a building to the Sun, selecting materials with favorable thermal mass or light dispersing properties, and designing spaces that naturally circulate air. Among them solar PV(photovoltaic) is a key technology option to realize the shift to a decarbonized energy supply and is projected to emerge as an attractive alternate electricity source in the future. Globally, the solar photovoltaic grid connected capacity has increased from 7.6 GW in 2007 to 21 GW at the end of 2009. The growth trend is continuing and is likely to explode once the grid parity is achieved. Also, India is located in the equatorial sun belt of the earth, thereby receiving abundant radiant energy from the sun [2].

II. HISTORY

In 1897, Frank Shuman, a U.S. inventor, engineer and solar energy pioneer built a small solar engine that worked by reflecting solar energy onto square boxes filled with ether ,and were fitted internally with black pipes which in turn powered a steam engine. In 1908 Shuman formed the Sun Power Company. Shuman then constructed a full-scale steam engine powered by low-pressure water, enabling him to patent the entire solar engine system by 1912.Shuman built the world's first solar thermal power station in Maadi, Egypt. In 1916 Shuman was quoted in the media advocating solar energy's utilization, saying: " We have proved the commercial profit of sun power in the tropics and have more particularly proved that after our stores of oil and coal are exhausted the human race can receive unlimited power from the rays of the sun" [6].

III. PHOTOVOLTAIC METHOD

The term "photovoltaic" comes from the Greek word (phōs) meaning "light", and from "volt" which comes from the last name of the Italian physicist Alessandro Volta, inventor of the battery. When certain semiconducting materials, are exposed to sunlight, they release small amounts of electricity. This process is known as the photoelectric effect. The photoelectric effect refers to the emission, of electrons from the surface of a metal in response to light. Sunlight is made up of photons. Photons contain various amounts of energy, corresponding to the different wavelengths of the solar spectrum. When photons strike a PV cell, they may be reflected or absorbed, or they may pass right through. Only the absorbed photons generate electricity. When this happens, the energy of the photon is transferred to an electron in an atom of the cell. With its newfound energy, the electron escapes from its normal position in an atom of the semiconductor material and becomes part of the current in an electrical circuit. This creates an electron imbalance between in the cell and causes electricity to flow – the greater the intensity of light, the greater the flow of electricity [11].

IV. CELLS TO MODULES TO ARRAYS

Since an individual cell produces only about 0.5 V, it is a rare application for which just a single cell is of any use. Instead, the basic building block for photovoltaic applications is a module, which is a connected assembly of solar cells. It consists of a number of pre-wired cells in series, all encased in tough, weather-resistant packages. A typical module has 36 cells in series and is often designated as a

"12-V module" . An array is a set of solar photovoltaic modules electrically connected and mounted on a supporting structures. The solar arrays can be used as a component of a larger photovoltaic system to generate and supply electricity in commercial and residential applications [1].

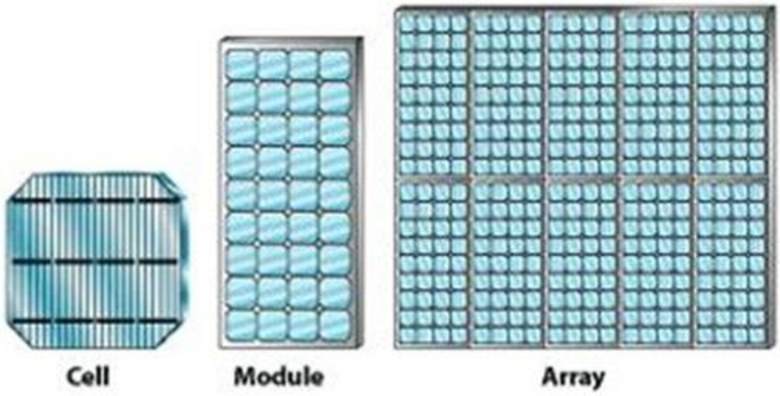
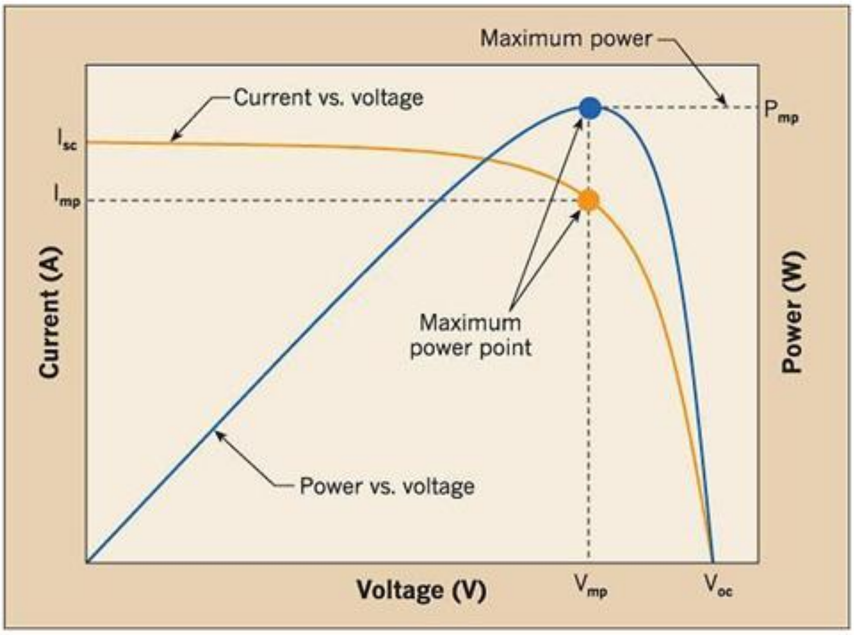


Fig 1. PV Cell, Module and Array

V. PHOTOVOLTAIC MATERIALS

1- Silicon is the most common material used for photovoltaic applications. Mono-crystalline - PV cells that are made from pure mono-crystalline silicon with almost no defects or impurities have efficiency approximately 15%.
2- Polycrystalline material is less expensive to manufacturing due to simpler processes involved in production compared with mono-crystalline and efficiency is approximately 12%.
3- Amorphous Silicon is more effective. It has a lower cost than crystalline cells but have a lower efficiency.
4- Thin-film PV is the most efficient material in poor light conditions, whilst also being an extremely sturdy, vandal-proof photovoltaic. Efficiency is approximately 6% [3].

VI. THE PV I–V CURVE UNDER STANDARD TEST CONDITIONS



Consider, a single PV module to be connected to some load. Before the load is connected, the module sitting in the sun will produce an open-circuit voltage , but no current will flow. If the terminals of the module are shorted together, the short-circuit current will flow, but the output voltage will be zero. In both cases, since power is the product of current and voltage, no power is delivered by the module and no power is received by the load. When the load is actually connected, some combination of current and voltage will result and power will be delivered. To figure out how much power, we consider the I –V characteristic curve of the module as well as the I –V characteristic curve of the load. Figure shows a generic I –V curve for a PV module. Also shown is the product of voltage and current, that is, power delivered by the module. At the two ends of the I –V curve, the output power is zero since either current or voltage is zero at those points. The maximum power point (MPP) is that spot near the knee of the I –V curve at which the product of current and voltage reaches its maximum. Another quantity that is often used to characterize module performance is the fill factor. The fill factor is the ratio of the power at the maximum power point to the product of open circuit voltage and short circuit current [1].

VI. APPLICATIONS

The first practical application of photovoltaic was to power orbiting satellites and other spacecraft, but today the majority of photovoltaic modules are used for various applications:

A. Standalone devices:

Solar powered remote fixed devices have seen increasing use recently in locations where significant connection cost makes grid power prohibitively expensive. Such applications include solar lamps, water pumps, parking meters, emergency telephones, trash compactors, temporary traffic signs, charging stations, remote guard posts and signals. In May 2008, in Oakville, CA pioneered the world's first "floatovoltaic" system by installing 994 photovoltaic solar panels onto 130 pontoons and floating them on the winery's irrigation pond. The floating system generates about 477 kW of peak output and when combined with an array of cells located adjacent to the pond.

B. Telecommunication and signaling:

Solar PV power is ideally suited for telecommunication applications such as local telephone exchange, radio and TV broadcasting, microwave and other forms of electronic communication links. In hilly and mountainous terrain, radio and TV signals may not reach as they get blocked or reflected back due to undulating terrain. At these locations, low power transmitters are installed to receive and retransmit the signal for local population.

C. Spacecraft applications:

Spacecraft operating in the inner solar system usually rely on the use of solar panels to derive electricity from sunlight. Solar panels on spacecraft supply power for two principal uses: power to run the sensors, active heating and cooling, and telemetry and power for spacecraft propulsion electric propulsion, sometimes called solar-electric propulsion. See also energy needed for propulsion methods.

D. On-Grid Applications

In grid-connected applications, the photovoltaic system feeds electrical energy directly into the electric utility grid. Two application types can be distinguished, distributed and central power plant generation.

For distributed generation, the electric generators are located at or near the site of electrical consumption. This helps reduce both energy (kWh) and capacity (kW) losses in the utility distribution network. An example of a distributed grid-connected application is building integrated photovoltaics for individual residences or commercial buildings. PV manufacturers are also developing PV modules which can be incorporated into buildings as standard building components such as roofing tiles and curtain walls. This helps reduce the relative cost of the PV power system.

Central generation applications are not currently cost-competitive for PV. Several multi megawatt central generation systems have however been installed as demonstration projects, designed to help utilities acquire experience in the management of central PV power plants. Installations of central PV generation represent a long-term strategy by governments and utilities to support the development of PV as a clean energy with a guaranteed fuel supply.

E. Off-Grid Applications

In off-grid applications, PV is frequently used in the charging of batteries, thus storing the electrical energy produced by the modules and providing the user with electrical energy on demand. Off grid has no connection to the electricity grid, so the house or business being powered is relying solely on solar. This is a major advantage for the people who live in isolated and rural areas. Power prices and the cost of installing power lines are often exorbitantly high in these places and many have frequent power-cuts. Off-grid applications include both stand-alone systems and hybrid systems, which are similar to stand-alone systems but also include a fossil fuel generator to meet some of the load requirements and provide higher reliability [6].

VII. EFFICIENCY

Maximum efficiency of a solar photovoltaic cell is given by the following equation:

$$\eta = \frac{P}{E(s,\gamma) \times A}$$

Where,
η = maximum efficiency

P = maximum power output (KW)

E(S,γ) = incident radiation flux (KW/m2)
A = Area of collector (m2)

The most efficient solar cell so far is a multi-junction concentrator solar cell with an efficiency of 43.5% produced by Solar Junction in April 2011. In order to increase the efficiency of solar cells, it is necessary to choose the semiconductor material with appropriate energy gap that matches the solar spectrum. This will enhance their electrical, optical, and structural properties. Ultrahigh-efficiency devices (η>30%) are made by using Gallium Arsenide and Gallium Indium Phosphide semiconductors. High-quality, single-crystal silicon materials are used to achieve high-efficiency cells

(η>20%).Organic photovoltaic cells (OPVs) are also viable alternative that relieves energy pressure and environmental problems from increasing combustion of fossil fuels. Several companies have begun embedding power optimizers into PV modules called smart modules. These modules perform maximum power point tracking (MPPT) for each module individually, measure performance data for monitoring, and provide additional safety. Such modules can also compensate for shading effects, wherein a shadow falling across a section of a module causes the electrical output of one or more strings of cells in the module to fall to zero, but not having the output of the entire module fall to zero.

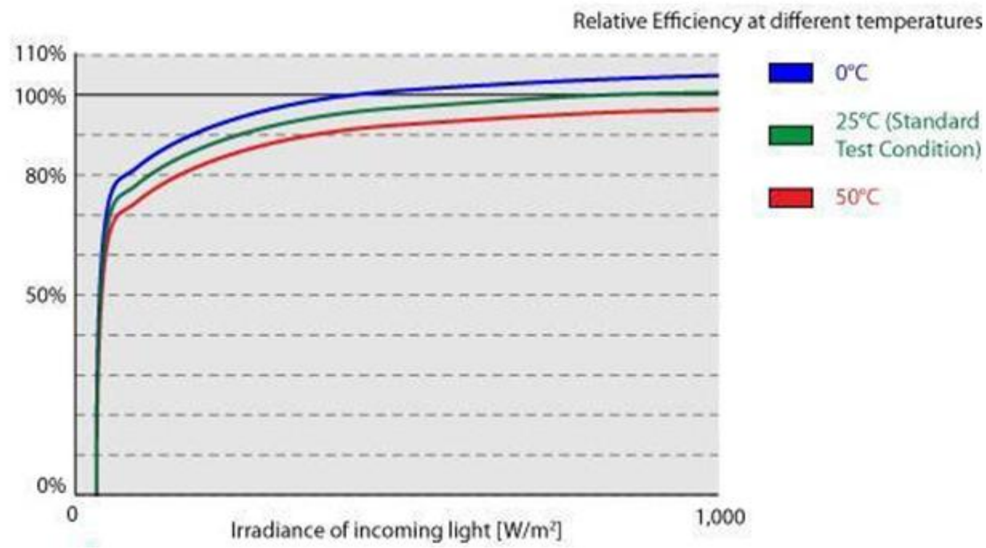


Fig 3. Relative Efficiency at different temperatures

Here is a typical curve for relative efficiency over the intensity of the incoming light for different temperatures. Naturally, at 25°C and 1,000W/m2 the relative efficiency is 1.0, as these are the standard test conditions. Changes in temperature cause the curve to shift upwards (if colder) or downwards (if warmer). Silicon is more sensitive to temperature changes than many of the thin-film materials

VIII. IX. ECONOMICS

There have been major changes in the underlying costs, industry structure and market prices of solar photovoltaic technology, over the years, and gaining a coherent picture of the shifts occurring across the industry value chain globally is a challenge. The PV industry has seen dramatic drops in module prices since 2008. In late 2011, factory-gate prices for crystalline-silicon photovoltaic modules dropped below the $1.00/W mark. The $1.00/W installed cost, is often regarded in the PV industry as marking the achievement of grid parity for PV. Technological advancements, manufacturing process improvements, and industry re-structuring, mean that further price reductions are likely in coming years. Financial incentives for photovoltaic such as feed-in tariffs, have often been offered to electricity consumers to install and operate solar-electric generating systems. Government has sometimes also offered incentives in order to encourage the PV industry to achieve the economies of scale needed to compete where the cost of PV-generated electricity is above the cost from the existing grid. Such policies are implemented to promote national or territorial energy independence, high tech job creation and reduction of carbon dioxide emissions which cause global warming. Due to economies of scale solar panels get less costly as people use and buy more—as manufacturers increase production to meet demand, the cost and price is expected to drop in the years to come.

IX. GROWTH AND SCOPE OF PHOTOVOLTAIC

Solar photovoltaic is growing rapidly from a small base, to a total global capacity of 139 Giga watts at the end of 2013. The total power output of the world's PV capacity in a calendar year is equal to some 160 billion kWh of electricity. This is sufficient to cover the annual power supply needs of 40 million households in the world, and represents 0.85 percent of worldwide electricity demand. More than 100 countries use solar PV. China, followed by Japan and the United States is now the fastest growing market, while Germany remains the world's largest producer, contributing almost 6 percent to its national electricity demands. For best performance, terrestrial PV systems aim to maximize the time they face the sun. Solar trackers achieve this by moving PV panels to follow the sun. Panels are often set to latitude tilt, an angle equal to the latitude.

X. GOVERNMENT INVOLVEMENT

The Jawaharlal Nehru National Solar Mission, also known as National Solar Mission, was launched on 30th June 2008. The immediate aim of the Mission is to focus on setting up an enabling environment for solar technology penetration in the country both at a centralized and decentralized level. Also it anticipates achieving grid parity by 2022 and parity with coal-based thermal power by 2030. The Mission recommends the implementation in 3 stages leading up to an installed capacity of 20,000 MW by the end of the 13th Five Year Plan in 2022.

The Mission will adopt a 3-phase approach:
1. spanning the remaining period of the 11th Plan and first year of the 12th Plan (up to 2012-13) – Phase 1,
2. the remaining 4 years of the 12th Plan (2013-17) – Phase 2 and the 13th Plan (2017-22) – Phase 3

Mission Targets:
1. To achieve the above mentioned target of 20,000 MW by 2022 .
2. . To promote programmes for off grid applications, reaching 1000 MW by 2017 and 2000 MW by 2022
3. . To achieve 15 million sq. meters solar thermal collector area by 2017 and 20 million by 2022.
4. . To deploy 20 solar lighting systems for rural areas by 2022.

XI. ADVANTAGES

1. Photovoltaic systems provide green, energy. Consequently, the more we use PV panels to cover for our energy needs, the more we help reduce our impact to the environment by reducing CO2 emissions into the atmosphere.
2. Photovoltaic panels operate autonomous without any noise generation as they do not incorporate any moving mechanical parts. Even in this adjustable PV systems, the movements are very moderate, almost negligible, and do not generate any disturbances.

3. With respect to operating costs and maintenance costs, PV panels, require minimum operating or maintenance costs.

XII. LATEST INNOVATIONS

A. Micro inverters

This device which takes the DC power produced by solar panels and transforms it into AC power. The price of an inverter to handle the power you could produce on your rooftop used to be quite high, but with the advent of micro inverters, it's possible to have just one panel to start your solar power generating station

B. Infrared Solar Energy

Only about 60% of the light that hits the earth's surface is visible light. The rest lies in the infrared and ultraviolet spectrums. Our traditional silicon-based photovoltaics can only convert visible light into energy, leaving huge amounts of potential energy untapped. A group of MIT researchers have pioneered a new carbon-based solar panel that can harness the light in the infrared range. Luckily, the new carbon cells are transparent, hence they transposed on top of silicon-based cells to gather both infrared and visible sunlight.

C. Building Integrated Photovoltaic

Building Integrated Photovoltaic (BIPVs) are thin-film solar panels built smoothly into building materials like roof shingles, curtain walls, facades, or windows .BIPVs are an enticing alternative because they cut out many installation costs (they don't require racking, laborers don't necessarily need to be trained in solar installations) especially on new buildings.

Fig 4. Building Integrated PV

D. Solar leaf

Daniel Nocera and his research team at MIT have developed the first "artificial leaf." Made from a thin silicon solar cell, the leaf is dropped into water where it separates hydrogen and oxygen molecules that are collected and connected to fuel cells that produce electricity. Nocera and his team believe the leaf could bring electricity cost effectively, especially in developing countries, to households that aren't connected to energy grids.

E. New Solar Manufacturing Processes

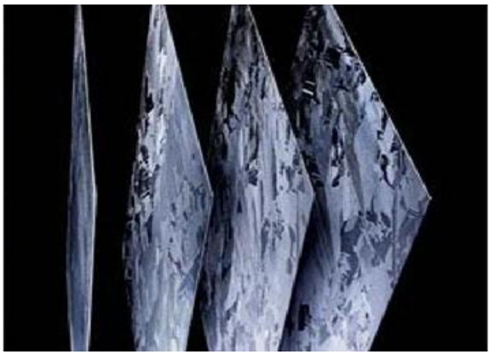


Fig 5. Silicon Wafers

The process of creating the silicon in a solar panel involves sawing a block of crystalline silicon into what are called "wafers" that are 180 mm thick. Unfortunately, about half of the original block is wasted as sawdust during this process. A few companies are working on ways to reduce the amount of waste by creating thinner, but equivalently efficient, slices of silicon. 1366 Technologies has developed a machine that creates wafers straight from molten silicon, removing some manufacturing processes to cut costs.

F. The Lotus Position

Partly an electric-vehicle charging station, partly an LED street lamp, the "Lotus" is a solar kiosk-like structure in the shape of a giant lotus leaf. Italian architect Giancarlo Zema, teamed up with Luminexence to create the multi-faceted design. A single small Lotus generates 500 watts of electricity Larger leaves generate 2.8 kilowatts, and can be used as covered parking structures for multiple vehicles. The Lotus may find its way into parks as self-operating information kiosks [5].

XIII. CONCLUSION

In this paper, a short review on the existing materials, new innovations and trends in photovoltaic systems has been performed. Here, the direct conversion of sunlight to electricity occurs without any moving parts or environmental emissions during operation, this will increase countries' energy security through reliance on an indigenous, inexhaustible and mostly import-independent resource and reduce pollution. Solar PV is now, after hydro and wind power, the third most important renewable energy source in terms of globally installed capacity. But it is still more costly than conventional systems. However, large variations in cost of conventional electrical power, and other factors, such as cost of distribution, create situations in which the use of PV power is economically sound. Also the amount of solar energy reaching the surface of the planet is so vast that in one year it is about twice as much as will ever be obtained from all of the Earth's non-renewable resources. And as technological advances narrow the cost gap, more applications are becoming economically and feasible at an accelerating rate

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