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Efficiency Improvement Technologies of Solar PV power plant

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Abstract — *Fast growing renewable energy source in India and in the world is the solar Energy. India, in particular, has solar power generation with present installed capacity of over 3743 MW. If the efficiency of solar power panel is improved the difference between the production and demand of electric power can be greatly overcome. It also helps reduce the dependency on fossil fuels. The main reasons of low efficiency are low sunlight absorption, accumulation of dust on the surface of the solar panel and the effect of temperature on the solar panel. We intend to improve efficiency of solar power panel by increasing the absorption of sunlight on the surface of solar panel using epitaxial layer of CdTe and Cds and Carbon nanotubes towers. To avoid accumulation of dust on the surface of solar power panel, we will install a dust removing roller setup which will automatically wipe out the dust. This will improve the efficiency of the setup by almost 2.5%.It is assumed that higher the temp, higher is the efficiency of the solar panel but actually it is not true. Solar panel works most efficiently at a temperature of 25°C.In the project, the temperature of solar panel will be reduced using a water sprinkler system if the temperature exceeds the critical temperature. It will also act as a hybrid water heater implementing the heat energy of sunlight to heat the water. Another main problem surrounding the implementation of solar panels in the rural areas is the problem of theft. Thieves pull out the solar panel out of the setup and then sell it. To overcome this problem, we have installed an anti-theft mechanism in the project which will sound an alarm every time someone tries to forcefully remove the solar panel .The aim of the paper is to review for overcoming the challenges for improvement the efficiency of solar power panel.*

Keywords- *Renewable Energy (RE), Photovoltaic (PV), Mono crystalline, poly crystalline, PV Mounting system, Efficiency*

I. INTRODUCTION

Solar energy has recently become a popular alternative energy source to meet demands around the world due to the fluctuation of oil/coal prices and global warming issues. In a solar farm power generation system, large amounts of current are generated from the heat of the sun. Energy plays a vital role in our daily activities.[1],[2] The degree of development and civilization of a country is measured by the utilization of energy by human beings. Energy demand is increasing day by day due to increase in population, urbanization and industrialization. Hence alternative or renewable sources of energy have to be developed to meet future energy requirement. Due to this reason solar power plant importance is increasing day by day. In this paper section II addresses the types of photovoltaic technology. The section III is related to the photovoltaic mounting systems. The section IV –V discusses the efficiency and methodologies to improve efficiency of solar panels. The section VI expresses the conclusion of research paper.

II. TYPE OF PHOTOVOLTAIC CELL TECHNOLOGY

There are essentially two types of PV technology, crystalline and thin-film. [3] Mono crystalline and thin-film solar panels tend to be more aesthetically pleasing since they have a more uniform look compared to the speckled blue colour of polycrystalline silicon.

2.1 Mono crystalline Cells: These are made using cells cut from a single cylindrical crystal of silicon. While mono crystalline cells offer efficiency approximately 18% conversion of incident sunlight. Complex manufacturing process makes them slightly costlier.

It consists of silicon in which the crystal lattice of the entire solid is continuous, unbroken to its edges, and free of any grain boundaries as shown in figure-1. Mono-Si can be prepared intrinsic, consisting only of exceedingly pure silicon, or doped, containing very small quantities of other elements added to change its semiconducting properties.

Most silicon mono crystals are grown by the Czochralski process [9] into ingots of up to 2 meters in length and weighing several hundred kilogrammes. These cylinders are then sliced into thin wafers of a few hundred microns for further processing.

ADVANTAGES OF MONO CRYSTALLINE CELLS:

(1) Mono crystalline solar panels have the highest efficiency rates since they are made out of the highest-grade silicon. The efficiency rates of mono crystalline solar panels are typically 15-20%. Sun Power produces the highest efficiency solar panels on the U.S. market today. Their E20 series provide panel conversion efficiencies of up to

20.1%. [3] Update (April, 2013): Sun Power has now released the X-series at a record-breaking efficiency of 21.5%. [7]

Fig. 1. Mono crystalline cell
(Source:http://skypoweraz.com/wp/wpcontent/uploads/2010/12/MonoCrystaline.jpg)

(2) Mono crystalline silicon solar panels are space-efficient. Since these solar panels yield the highest power outputs, they also require the least amount of space compared to any other types. Mono crystalline solar panels produce up to four times the amount of electricity as thin-film solar panels.
(3) Mono crystalline solar panels live the longest. Most solar panel manufacturers put a 25-year warranty on their mono crystalline solar panels.
(4) Tend to perform better than similarly rated polycrystalline solar panels at low-light conditions.

DISADVANTAGES OF MONO CRYSTALLINE CELLS:
(1) Mono crystalline solar panels are the most expensive. From a financial standpoint, a solar panel that is made of polycrystalline silicon (and in some cases thin-film) can be a better choice for some homeowners.
(2) If the solar panel is partially covered with shade, dirt or snow, the entire circuit can break down. Consider getting micro-inverters instead of central string inverters if you think coverage will be a problem. Micro-inverters will make sure that not the entire solar array is affected by shading issues with only one of the solar panels.
(3) The Czochralski process is used to produce mono crystalline silicon. It results in large cylindrical ingots. Four sides are cut out of the ingots to make silicon wafers. A significant amount of the original silicon ends up as waste.
(4) Mono crystalline solar panels tend to be more efficient in warm weather. Performance suffers as temperature goes up, but less so than polycrystalline solar panels. For most homeowners temperature is not a concern.

2.2 Polycrystalline Cells: These are made by cutting micro-fine wafers from ingots of molten and recrystallized silicon. Polycrystalline cells are cheaper to produce, but there is a slight compromise on efficiency (approximately 14% conversion of incident sunlight).

Thin film PV is made by depositing an ultra-thin layer of photovoltaic material onto a substrate. The most common type of thin-film PV is made from the material a-Si (amorphous silicon), but numerous other materials such as CIGS (copper indium/gallium dieseline) CIS (copper indium salanide), CdTe (Cadmium Telluride), dye-sensitized cells and organic solar cells are also possible.

Fig.2. Poly crystalline cell
(Source:http://skypoweraz.com/wp/wpcontent/uploads/2010/12/MonoCrystaline.jpg)

ADVANTAGES OF POLYCRYSTALLINE CELLS:
(1) The process used to make polycrystalline silicon is simpler and cost less. The amount of waste silicon is less compared to mono crystalline.

(2) Polycrystalline solar panels tend to have slightly lower heat tolerance than mono crystalline solar panels. This technically means that they perform slightly worse than mono crystalline solar panels in high temperatures. Heat can affect the performance of solar panels and shorten their lifespans. However, this effect is minor, and most homeowners do not need to take it into account.

DISADVANTAGES OF POLYCRYSTALLINE CELLS:
(1) The efficiency of polycrystalline-based solar panels is typically 13-16%. Because of lower silicon purity, polycrystalline solar panels are not quite as efficient as mono crystalline solar panels.

(2) Lower space-efficiency. You generally need to cover a larger surface to output the same electrical power as you would with a solar panel made of mono crystalline silicon. However, this does not mean every mono crystalline solar panel perform better than those based on polycrystalline silicon.

2.3 STRING RIBBON SOLAR CELL: String Ribbon solar panels are also made out of polycrystalline silicon. String Ribbon is the name of a manufacturing technology that produces a form of polycrystalline silicon. Temperature-resistant wires are pulled through molten silicon, which results in very thin silicon ribbons. Solar panels made with this technology looks similar to traditional polycrystalline solar panels.

Evergreen Solar was the main manufacturer of solar panels using the String Ribbon technology. The company is now bankrupt, rendering the future for String Ribbon solar panels unclear.
The advantage of String Ribbon is the manufacturing of String Ribbon solar panels only uses half the amount silicon as mono crystalline manufacturing. This contributes to lower costs.

DISADVANTAGES OF STRING RIBBON CELL:
(1) The manufacturing of String Ribbon solar panels is significantly more energy extensive and more costly.
(2) Efficiency is at best on par with the low-end polycrystalline solar panels at around 13-14%. In research laboratories, researchers have pushed the efficiency of String Ribbon solar cells as high as 18.3%.[3]
(3) String Ribbon solar panels have the lowest space-efficiency of any of the main types of crystalline-based solar panels.

2.4 THIN-FILM SOLAR CELLS (TFSC) [5]

Technology of TFSC: Depositing one or several thin layers of photovoltaic material onto a substrate is the basic gist of how thin-film solar cells are manufactured. They are also known as thin-film photovoltaic cells (TFPV).The different types of thin-film solar cells can be categorized by which photovoltaic material is deposited onto the substrate:

- Amorphous silicon (a-Si)
- Cadmium telluride (Cd Te)
- Copper indium gallium Selenide (CIS/CIGS)
- Organic photovoltaic cells (OPC)

Depending on the technology, thin-film module prototypes have reached efficiencies between 7–13% and production modules operate at about 9%. Future module efficiencies are expected to climb close to the about 10–16%.
The market for thin-film PV grew at a 60% annual rate from 2002 to 2007.[5] In 2011, close to 5% of U.S. photovoltaic module shipments to the residential sector were based on thin-film.

ADVANTAGES OF THIN-FILM SOLAR CELLS:
(1) Mass-production is simple. This makes them and potentially cheaper to manufacture than crystalline-based solar cells.
(2) Their homogenous appearance makes them look more appealing.
(3) Can be made flexible, which opens up many new potential applications.
(4) High temperatures and shading have less impact on solar panel performance.
(5) In situations where space is not an issue, thin-film solar panels can make sense.

Fig. 3. Thin film solar cell module (Source:http://skypoweraz.com/wp/wpcontent/uploads/2010/12/MonoCrystaline.jpg)

DISADVANTAGES OF THIN-FILM SOLAR CELLS:
(1) Thin-film solar panels are in general not very useful for in most residential situations. They are cheap, but they also require a lot of space. Sun Power`s mono crystalline solar panels produce up to four times the amount of electricity as thin-film solar panels for the same amount of space.[3]
(2) Low space-efficiency also means that the costs of PV-equipment (e.g. support structures and cables) will increase.
(3) Thin-film solar panels tend to degrade faster than mono- and polycrystalline solar panels, which is why they typically come with a shorter warranty.
Solar panels based on amorphous silicon, cadmium telluride and copper indium gallium selenide are currently the only thin-film technologies that are commercially available on the market

III. PHOTOVOTAIC MOUNTING SYSTEM:[9]

Mounting system of solar panels on top of Pacifica's Waste Water treatment plant .Photovoltaic mounting systems are used to fix solar panels on surfaces like roofs, empty plots etc. These mounting systems enable retrofitting of solar panels on roofs or as part of the structure of the building.

- Mounting on roofs
- Mounting as a shade structure
- Building-integrated photovoltaic
- Roof-Jack mounting system

3.1 PV Panels Mounted on Roof: PV array can be mounted on rooftops, generally with a few inches gap and parallel to the surface of the roof. If the rooftop is horizontal, the array is mounted with each panel aligned at an angle. If the panels are planned to be mounted before the construction of the roof, the roof can be designed accordingly by installing support brackets for the panels before the materials for the roof are installed. The installation of the solar panels can be undertaken by the crew responsible for installing the roof. If the roof is already constructed, it is most probably designed so that it is capable of bearing only the weight of the roof.

Fig. 4. PV solar cell module mounted on roofs [9]

For installing solar panels in such roofs, the roof structure must be strengthened before-hand with particular consideration to weather sealing or the roof can be converted to composition shingles wherever the panels are planned to be installed. By converting to composition shingles, the weight of the removed roof materials can compensate the additional weight of the panel structure. The general practice for installation of roof mounted solar panels includes having a support bracket per hundred watts of panels.

3.2 Mounting as A Shade Structure: Solar panels can also be mounted as shade structures where the solar panels can provide shade instead of patio covers. The cost of such shading systems are generally different from standard patio covers, especially in cases where the entire shade required is provided by the panels. The support structure for the shading systems can be normal systems as the

Fig.-5. mounting as a shade structure (source: http:www.Wikipedia.org)

weight of a standard PV array is between 3 and 5 pounds/ft2. If the panels are mounted at an angle steeper than normal patio covers, the support structures may require additional strengthening.

Other issues that are considered include:

- Simplified array access for maintenance.
- Module wiring may be concealed to maintain the aesthetics of the shading structure.
- Growing vines around the structure must be avoided as they may come in contact with the wiring.

3.3 Building Integrated Photovoltaic: The CIS Tower in Manchester, England was clad in PV panels. Building-integrated photovoltaic (BIPV) are photovoltaic materials that are used to replace conventional building materials in parts of the building envelope such as the roof, skylights, or facades. They are increasingly being incorporated into the construction of new buildings as a principal or ancillary source of electrical power, although existing buildings may be

Fig.-6. Building Integrated Photovoltaic (source: http:www.Wikipedia.org)

retrofitted with BIPV modules as well. The advantage of integrated photovoltaic over more common non-integrated systems is that the initial cost can be offset by reducing the amount spent on building materials and labor that would normally be used to construct the part of the building that the BIPV modules replace

3.3 Rack-Jack Mounting System: In the mid-1980s Ascension Technology's principals, then working at the Massachusetts Institute of Technology, developed the Roof-Jack mounting system for attaching PV arrays to pitched and shingled residential roofs. The motivation of that effort was to simplify and reduce the cost of residential PV array balance-of-systems.

IV. EFFICIENCY OF SOLAR PANEL:

Efficiency in photovoltaic solar panels is measured by the ability of a panel to convert sunlight into usable energy for human consumption. Knowing the efficiency of a panel is important in order to choose the correct panels for your photovoltaic system. For smaller roofs, more efficient panels are necessary, due to space constraints. How do manufacturers determine the maximum efficiency of a solar photovoltaic panel though? Read below to find out. Let us first start out by saying that the maximum power, also known as P_{max}, of a 200W panel is 200W regardless of the panel efficiency. It is the area the solar panels use up to get those 200W that determines how efficient the panel is. The panel efficiency determines the power output of a panel per unit of area. The maximum efficiency of a solar photovoltaic cell is given by the following equation:

$$\eta_{max} \text{ (Maximum efficiency)} = \{P_{max} \text{ (maximum power o/p)}\} / \{(E_{S\gamma}^{SW} \text{(incident radiation flux)} * A_c \text{ (Area of collector)})\}$$

The incident radiation flux could better be described as the amount of sunlight that hits the earth's surface in W/m2. The assumed incident radiation flux under standard test conditions (STC) that manufacturers use is 1000 W/m2. Keep in mind though, that STC includes several assumptions and depends on your geographic location.[Module performance is generally rated under Standard Test Conditions (STC): irradiance of 1,000 W/m², solar spectrum of AM 1.5 and module temperature at 25°C.]Now, we'll make a sample calculation to determine how manufacturers calculate the maximum solar panel efficiency under STC.
Assume you have a 400W system with an area of 30 ft2 and you want to determine the maximum efficiency of your solar panels under STC. Your first step would be to convert the area of your panels' to units of square meters which is:
Now that you have your P_{max} (400W), ES, γ^{sw} (1000W/m2), and Ac (2.79 m2), you can plug your numbers into the efficiency equation where all units will cancel out and then multiply the value by 100% to give you your efficiency percentage:

$$\eta_{max} = \frac{400\,W}{(1000\frac{W}{m^2} * 2.79m^2)} = 0.143 \text{ x } 100\,\% = 14.3\,\%$$

This would be the *maximum* efficiency of your solar panel, not to be confused with the *minimum* that may be found on the specification sheet. So when you are determining what solar panels are right for you, think about how important the efficiency of panels are in paying a premium price. Perhaps you have a roof with a large area that would be ideal for the placement of solar panels, and therefore, lower cost and less efficient panels would work for you. If your rooftop area is limited though, you may want to determine the efficiency you will need for your panels to achieve the desired power output over a limited area.

4.1 FACTORS AFFECTING EFFICIENCY OF SOLAR PANELS [2],[9]

1) Temperature

As temperature increases, the band gap of the intrinsic semiconductor shrinks, and the open circuit voltage (V_{oc}) decreases following the p-n junction voltage temperature dependency of seen in the diode factor $^{q}/_{kT}$. Solar cells therefore have a negative temperature coefficient of V_{oc} (β).

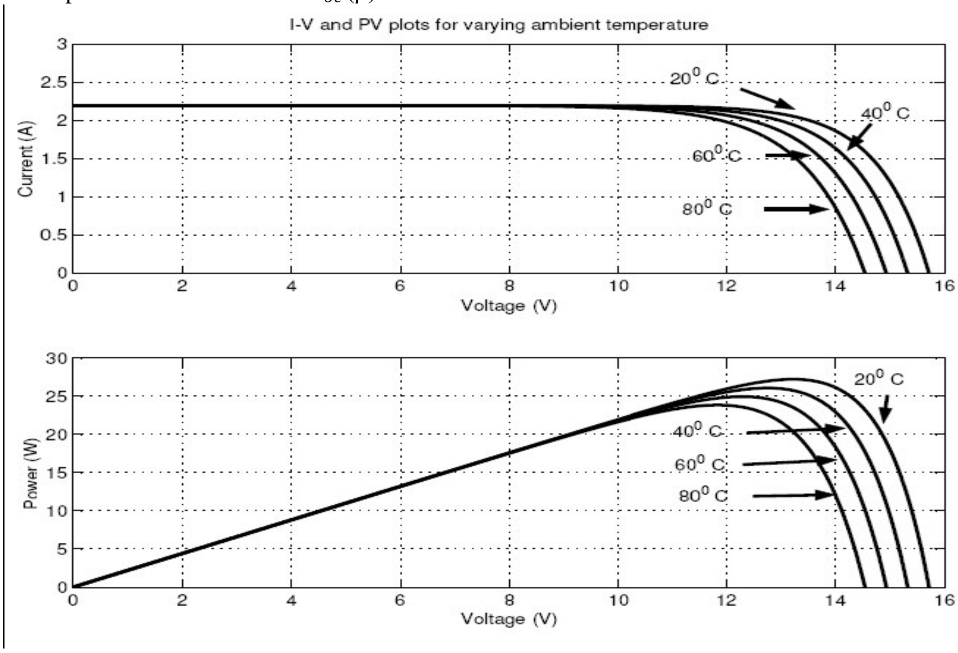

Fig.-7 Temperature coefficient for crystalline cells[9]

Moreover, a lower output power results given the same photocurrent because the charge carriers are liberated at a lower potential. Using the convention introduced with the Fill Factor calculation, a reduction in V_{oc} results in a smaller theoretical maximum power $max\ P = I_{sc} \times V_{oc}$ given the same short-circuit current I_{sc}. As temperature increases, again the band gap of the intrinsic semiconductor shrinks meaning more incident energy is absorbed because a greater percentage of the incident light has enough energy to raise charge carriers from the valence band to the conduction band. A larger photocurrent results; therefore, I_{sc} increases for a given insolation, and solar cells have a positive temperature coefficient of $I_{sc.}$

- **The Effect of High Temperature:**

The energy production efficiency of solar panels drops when the panel reaches hot temperatures. A field experiment in the United Kingdom revealed a drop of 1.1% of peak output for every increase in degrees Celsius of a home photovoltaic solar panel once the panel reached 42 degrees Celsius, or about 107 degrees Fahrenheit. Laboratory experiments at the Rivers State University of Science and Technology at Port Harcourt, Nigeria in 2008 found similar results; solar panel energy production dropped off steadily once the panel temperature reached 44 degrees Celsius, or 111 degrees Fahrenheit. The temperatures of the solar panels tested were, on average, about 20 degrees Celsius higher than the ambient air temperature Accordingly, the drop-off in efficiency begins at about 87 to 91 degrees Fahrenheit - temperatures frequently reached during summer daytime hours in temperate climates, and often exceeded in equatorial nations.

- **The Effect of Low Temperature:**

Photovoltaic solar panel power production works most efficiently in cold temperatures Cold, sunny environments provide optimal operating conditions for solar panels. Unfortunately, the coldest regions of the globe near the poles are areas with weaker sunshine and for, much of the year, shorter days. Insolation value -- the strength of the sunlight hitting the ground in any particular area -- diminishes closer to the poles as the sun comes in at a lower angle Irradiance, or the brightness of the sun, also diminishes when the sun is at a low angle. Solar tracker systems that adjust the angle of the photovoltaic panel to maximize irradiance and insolation values may improve the ability to take advantage of the positive effects of cold on solar panel efficiency

- **Temperature Coefficient :**

If you look at the manufacturer's data sheet you will see a term called "temperature coefficient P_{max}". For example the temperature coefficient of a 190 W (mono crystalline) solar panel is –0.48%. What this means is that for each degree over 25˚C … the maximum power of the panel is reduced by 0.48%. So on a hot day in the summer where solar panel temperature on the roof might reach 45˚C or so the amount of electricity would be 10% lower. Conversely, on a sunny day in the spring, fall, or even winter when temperatures are lower than 25˚C the amount of electricity produced would actually increase above the maximum rated level. Therefore, in most northern climates the days above and below 25˚C would tend to balance each other out. However, in locations closer to the equator the problems of heat loss could become substantial over the full year and warrant looking at alternatives.
Module performance is generally rated under Standard Test Conditions (STC): irradiance of 1,000 W/m², solar spectrum of AM 1.5 and module temperature at 25°C. All electrical parameters of solar module depend on temperature. The module output decreases with increase in temperature. The loss of power as defined by Temperature coefficients**.** This effect can be seen in the sample V-I characteristics, obtained from the specification sheet for commercially available module

2) DUSTING EFFECT [7], [8]**:** Performance of the PV module is proportional to dirt accumulation. Actually as little of 10% shade on PV module array can result in of 50% lost energy. Even though with an appropriate tilt angle installation still sand particles accumulate on module surface. By performing water washing has no extra operation and maintenance cost, particularly in water pumping application.

Periodically weekly cleaning maintained performance losses between 2 – 2.5%. In framework once a week cleaning intervals and rinse every three days, then follows by once a month cleaning in other months, that help to reduce the dirt's and debris build up. The cleaning intervals is different from site to another, it is important before schedule such agenda to have a fully knowledge of region environment pollution type and it is occur period.

- **Performance Losses in PV modules:**

Humidity, rain, cloud and dust. In a desert environment the operational performance is impeded via sand particles accumulation on surface and higher ambient temperature. An appropriate tilted angle might reduce dust accumulation over PV modules. Furthermore, during installation of solar array to be taken into account the bulk of sunlight through diurnal hours, hence consideration before/after mid-day. The result of earth rotating around the sun, therefore sun passes over the tropic of cancer in the summer, the sun deviates to the north. In winter season the sun lying directly on the tropic of Capricorn the sun deviates to the south, which might need change the tilt angle from season to other. The heavy layer of dust accumulation on module array might cause reduction in output power, so that can recovered by washing process Figure (9) show solar module have heavy dust layer. A major problem facing scientist is sand accumulation, hence numerous researches proved that, more than 50% of solar module performance reduction caused by unclean throughout period of one month. The Polycrystalline photovoltaic modules maximum efficiency averages about 10 to 14%, but it is less cost compared to Mono crystalline photovoltaic modules. The scheduling of cleaning period is required knowledge about environment of the area, which various from country to other. Therefore, before an installation of solar system to be consider the environment and weather of targeted location.

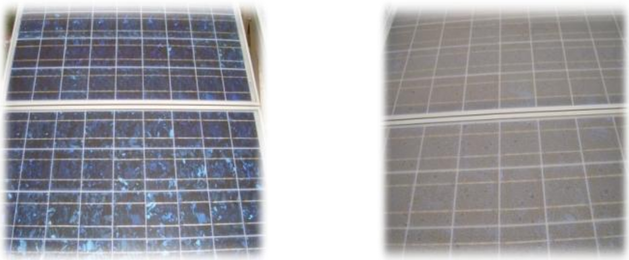

Fig.-8 Dusting effect on surface for crystalline cells: Clean & Dirty surfaces (Source: www.brainright.com)

3) POOR SUNLIGHT ABSORPTION [3]

Major part of sunlight which falls on the panel surface is reflected back and only a dwarf amount is utilized to produce electricity. The maximum power at operating point generated by module, hence the maximum current and voltage is measured at terminal via digital Multi-meter device. In order to determine the amount of maximum operating power by applying in equation as follows:

$$P_{max} = V_{max} \times I_{max}$$

Where, **P max**. Maximum operating Power [**W**]
I max. Maximum operating Current [**A**]
V max. Maximum operating Voltage [**V**]

4) THE EFFECT OF SNOW AND CLOUDS: The positive effects of low temperatures on solar panel power production in colder climates can be countered by clouds and snow that decrease solar panel efficiency. While there is little to be done about cloudy skies, several steps can be taken to help reduce snow accumulation on solar panels.

Fig.-9. Effect of snow and clouds (Source: www.brainright.com)

Tilting solar tracker units or re-mounting fixed ground array units at a steeper angle can encourage snow to slide off faster. A roof rake which looks like a push-broom with a long and thick layer of snow is shown in Fig.–9.

V. METHODS FOR IMPROVEMENT OF EFFICIENCY SOLAR PANELS

5.1 Carbon nanotubes arrays for photovoltaic application: Vertically aligned periodic arrays of carbon nanotubes (CNTs) are used to create topographically enhanced light- trapping photovoltaic cells. The CNTs form the back contact of the device and serve as a scaffold to support the photo active hetero junction. Molecular beam Epitaxy is used to deposit CdTe and CdS as the p/n-type materials and ion-assisted deposition is used to deposit a conformal coating of indium-tin oxide as the trans- parent top contact. X-ray diffraction data shows texture of the CdTe. Photo- current produced "per cm2 of footprint" for the CNT-based device is 63 times that of a commercially available planar single crystal silicon device.

CdTe has been extensively investigated as a material for use in photovoltaic applications. The 1.45 eV band gap is nearly optimal for absorbing sunlight and for integration with a CdS window layer as a complementary hetero junction material. The theoretical efficiency for CdTe-based solar cell is 29%. However, the maximum reported efficiency is 16%. Several studies have focused on improving the efficiency of CdTe-based solar cells by reducing crystal defects and optimizing interface proper ties between CdTe and its complementary cell material. Recently, fullerenes have been pro-posed for materials to be used in photo-voltaic applications. The motivation for photovoltaic applications of fullerenes arises from the high photoconductivity values observed in C60 and the strong acceptor properties of fullerenes. In this study, adherent and conformal hetero junctions between carbon nanotubes (CNTs) and CdTe/CdS/indium-tin oxide (ITO) thin films are formed to create novel photovoltaic cells.

A conformal thin film of CdTe with good adhesion to the multi-walled carbon nanotubes (MWCNT) arrays (Figures 9-11) was generated. The deposition process is not exclusively limited to line-of-sight and significant deposition of CdTe on both normal and orthogonal surfaces of the CNT arrays was observed.

The MWCNTs are not functionalized, treated, or altered in any way prior to CdTe deposition. However, by altering the source and/or substrate temperatures and deposition times during molecular beam epitaxy (MBE), varying morphologies and coating thickness densities can be produced (Figure 12). X-ray diffraction reveals that despite the polycrystalline appearance, the preferred orientation and texture of the CdTe microstructure is predominantly. Coatings of up to 12 Mm in thickness were observed on the MWCNTs, though conformal coatings thinner than 500 nm have also been generated. An ideal thickness for a planar CdTe photovoltaic device is between 2-4 mm. A benefit of the current work is that the light-trapping concept effectively extends the dwell time of the incident photons in the material. Thus, photon absorption increases and as a result the photoactive layer can be made much thinner than what would be considered "ideal" for a planar structure.

With a thinner CdTe layer, the photo generated charge carriers have a shorter diffusion path to travel and thus avoid recombination which is a significant limiting factor for efficiency gains. CdS (E_g = 2.43 eV) serves as a window layer for the photovoltaic device and is necessarily quite thin (150 nm) for optimum performance. Scanning-electron microscopy (SEM) images generally do not reveal significant changes in the microstructure following CdS deposition via MBE, but energy dispersive x-ray spectroscopy (EDS) confirms the presence of both CdTe and CdS as the hetero junction necessary for photocurrent generation. Indium-tin oxide serves as the transparent top contact for the CNT-based device. The adhesion of ITO to the CNT structures is highly conformal, as shown in Figure 12.

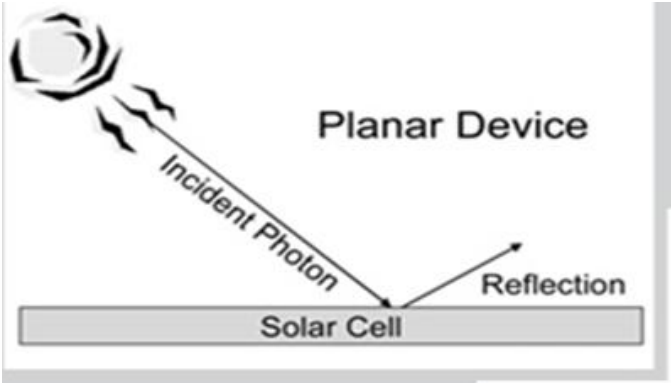

Fig.-10 Characteristics of planar single crystal silicon device

A variety of CNT-based devices were tested via a Filmetrics 205spectrometry system with a Hamamatsu L7893 halogen lamp. For comparison purposes, a commercially available silicon cell was also tested. This test allowed for a measure of the absorb ance of photons of various wavelengths. The various CNT-based devices did not contain an anti-reflection (AR) coating, yet showed. The AR-containing silicon cell absorbed maximally at 560nm,butexhibited significant reflection out of the sample off of this tuned point(as high as 55% which is not shown due to the vertical scale).The CNT-based photovoltaic cells were next compared to the commercially available mono Silicon reference cell using a solar simulator with a D50 fluorescent bulb(Lummi masked to simulate a point source in order to gauge there sponse of the planar cell and CNT-based cells to variations in azimuthally angle.

For the planar cell, maximum performance was achieved with an orthogonal "high noon" position. This performance degraded as the azimuthal angle was adjusted away from the normal (Figures 10 and 11). Contrast this with the performance of the light-trapping CNT-based device that has a maximum efficiency when the photons impinge the surface at 45°. Performance doubles from ~3.5% to ~7%whengoing from the "high noon" orthogonal incidence to a45°arrangement (Figures 12 and 13)

This effort demonstrated for the first time that a hetero junction photovoltaic cell can be created using CNTs as a conductive scaffolding coated with semiconducting materials. The p/n-type materials formed a coating that is adherent and conformal. Due to the light-trapping nature of the CNT-based device, thinner than "optimal" (for a planar device) CdTe layers can be used to reduce undesirable carrier recombination. Molecular beam epitaxy was used to grow CdTe and CdS thin films, while ion-assisted deposition was used to deposit a conformal coating of ITO as the transparent top contact. X-ray diffraction data showed a strong (111) structure of CdTe. Electrical testing via a solar simulator shows significant series resistance losses are present in the structure. Efficiency is shown to double from 3.5% at an orthogonal "high noon" azimuthal angle to 7% at a 45° solar incidence. In addition, the cells are very compact (~1 cm^2) due to the light-trapping topographic surface. This study was successful in demonstrating conditions required for CdTe/CdS/ITO thin film growth on CNT arrays for photovoltaic applications

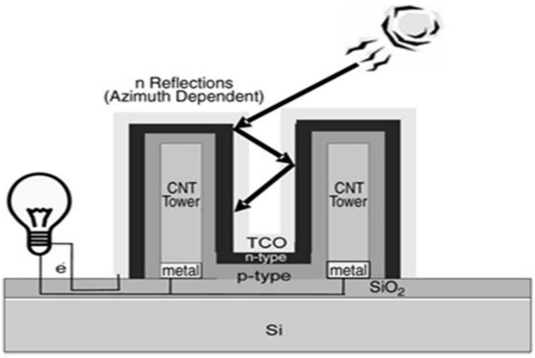

Fig.-11 CNT-based cells to variations in azimuthally angle

. **5.2 ALUMINIUM STUDS:** Rows of aluminum studs help solar panels extract more energy from sunlight than those with flat surfaces. This picture shows a solar panel with rows of aluminum studs and large electrical connections. The studs have been enlarged here but would normally be so small that they are invisible to the naked eye.

At the heart of the blooming solar power industry is the semiconductor material, like silicon or gallium arsenide, which absorbs sunlight and forms the basis of solar panels. It converts electromagnetic energy in the form of sunlight to electrical energy. Now, researchers from London have demonstrated a technique to increase the amount of electrical current produced by a solar panel simply by augmenting its light-facing surface with aluminium nanostructures .When photons, particles of light, are absorbed by the semiconductor, they knock out electrons, which are passed through a circuit and then to a battery for storage as electricity. However, scientists now want to find ways of increasing the absorption of light in thin layers of semiconductors, so that solar panels can be made using less raw-material and at a lower cost.

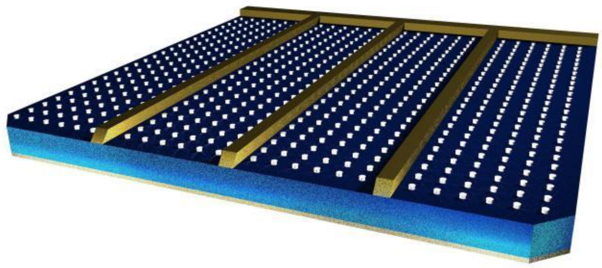

Fig.-12. Aluminum Studs (Source:http://www.thehindu.com/sci-tech/science/improving-the-efficiency-of-solar-panels/article5265330.ece)

Recent research from the Imperial College, London (ICL), has demonstrated one way to increase the electrical current produced by devices in the lab by 22 per cent. By studding the light-receiving surface of gallium-arsenide (Ga-As) devices with aluminium nano cylinders, like the ridges on Lego blocks, the researchers were able to promote the scattering of light in the visible part of the spectrum, which dominates the energy in sunlight.

The scattered light then travels a longer path inside the semiconductor, meaning that more photons can be absorbed and converted into current. It is important that the metal nano cylinders do not absorb the light themselves, as that would prevent it from reaching the panel.

"The advantage of aluminium structures is that their absorption occurs in the ultraviolet part of the spectrum. That means that the absorption losses are limited to the ultraviolet and scattering from the aluminium particle dominates in both the visible and near infrared," said Dr. Nicholas Hylton, a Research Associate at the Blackett Laboratory, ICL, in an email. Dr. Hylton was lead author of the research group's paper, published in Scientific Reports on October 18.

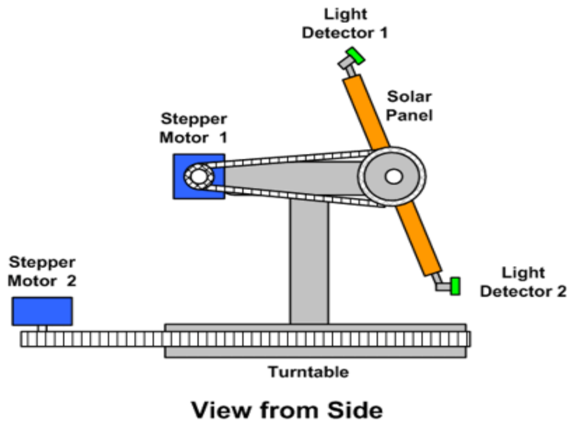

Fig.-13 **Sun tracking solar system**
(Source: www.pc-control.co.uk)

This isn't the first time such nanostructures have been deployed to enhance the performance of solar panels. Earlier, silver and gold nanoparticles have been used because they improved the performance of the devices in the near-infrared part of the electromagnetic spectrum. "We were able to demonstrate that gold and silver scatter light in the near infrared part of the spectrum but absorb visible light strongly," Dr. Hylton wrote. The significance of Dr.Hylton's work lies in demonstrating aluminium's better performance over silver and gold nanostructures. For one, aluminium is more abundant and less costly than silver and gold. For another, the 22 per cent spike that aluminium provides, as their paper notes, makes thinner-film solar panels technically feasible without "compromising power conversion efficiencies, thus reducing material consumption."

Higher efficiency devices could play a significant role in realizing energy goals even in India, making them more cost-effective. Already, according to industry trackers, the price of solar power in India has come from Rs. 18/kWh in 2011 to Rs. 7/kWh in 2013, while the price of thermal power is pushing Rs. 4/kWh with subsidies.

5.3 CLEANINNING AND WASHING OF PANEL: Periodically weekly cleaning maintained performance losses between 2 – 2.5%. In framework once a week cleaning intervals and rinse every three days, then follows by once a month cleaning in other months, that help to reduce the dirt's and debris build up. The cleaning intervals is different from site to another, it is important before schedule such agenda to have a fully knowledge of region environment pollution type and it is occur period

5.4 SUN TRACKING SOLAR PANEL PRINCIPLE: [10]

Sun tracking solar panel consists of two LDRs, solar panel and two stepper motors and ATMEGA8 Micro controller. Two light dependent resistors (LDR) are arranged on the edges of the solar panel. The principle on which these work is that their resistance decreases as the light intensity increases. Typically it is about 1M ohm in darkness, 10K ohm in moderate light and 2K ohm or less in bright sunlight. Light dependent resistors produce low resistance when more bright light falls on them. The stepper motor connected to the panel rotates the panel in the direction of Sun. Panel is arranged in such a way that light on two LDRs is compared and panel is rotated towards LDR which have high intensity i.e. low resistance compared to other. Stepper motor rotates the panel at certain angle. The mechanical arrangement of the stepper motors and the solar panel must be such that one stepper motor can control the vertical angle of the panel whilst the other can rotate a platform on which it is sits.

When the intensity of the light falling on right LDR is more, panel slowly moves towards right and if intensity on the left LDR is more, panel slowly moves towards left. In the noon time, Sun is ahead and intensity of light on both the panels is same. In such cases, panel is constant and there is no rotation. The function of the control system is to move the solar panel in such a way as to keep the received light on each LDR in a pair about the same.

VI. CONCLUSION

Though solar energy is a green , clean , environment friendly renewable energy. It faces many challenges as stated above. Hence efforts are needed to search new materials and sophisticated manufacturing techniques to improve the overall performance of PV solar systems. There are two types of PV cells: crystalline and thin-film. Each of them sub divided into many varieties. These cells are mounted in module in different ways depending upon availability of space.The efficiency of solar cells is quite low. When we mount it in module it further decreases. Further due to factors described above efficiency will decrease further. So to make it cost effective and commercially viable efficiency must be improved as much as possible. Efficiency of different types of solar cells are shown in figure – 14.

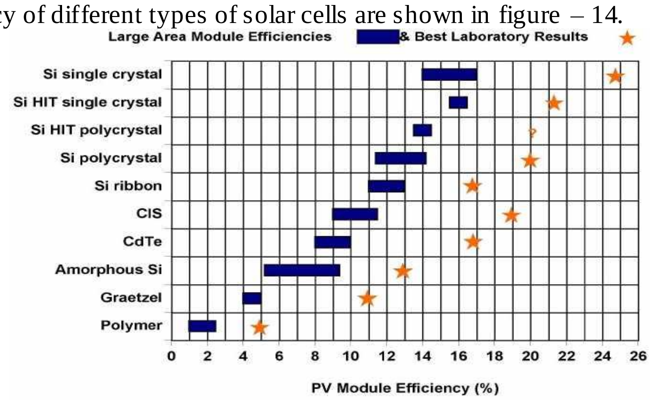

Fig.14 Efficiency of different types of solar cells (source:www.pipkinelectric.com)

The performance of the solar power panel has been analyzed for the duration of project. It was found that the efficiency of solar panel was maintained at an efficiency of 20%. The impact of dust collection and temperature variation on the performance of photovoltaic solar power panels was studied both on daily and yearly basis. It is observed that the efficiency is varied due to temperature variation and dust settlement on solar panels. It was found out that the output is highest during morning hours but low during the middle of the day and again starts increasing from late afternoon.

On this basis, we can conclude that the efficiency of solar panels is improved by if dust is removed periodically and if temp is regulated. Thus this practice must be adopted at all solar power stations to improve the utilization of solar energy and produce more power.

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