CURRENT STATUS OF PHOTOVOLTAIC SOLAR SYSTEM IN INDIA: A Review

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Abstract:

Solar power is defined as the direct conversion of sunlight into form of electricity with the help of Photovoltaic (PV) or by Concentrated Solar Power (CSP).In PV, semiconducting material are used for converting the light into electricity having photovoltaic effect. Solar energy occurs in many forms like a solar photovoltaic, heat thermal and fuels which have a clean climate, protective, abundant and in-exhaustive energy resource for human beings .Many research for development of this energy has been done and many are undergoing because of the advantages that is offered by this technology. In this paper, we are trying to present the current status and future scope of solar photovoltaic energy system that will be helpful for both researchers and scientist in forecasting.

Introduction:

In recent ,conventional energy resources are decreasing continuously and on other side the demand of energy resources are increasing continuously due to vast growth of populations ,re-search ,energy for industrial applications and for other activities which on other side creates environmental issues, so environmental protection concerns are also increased and then such energy sources are investigated and purchased that can fulfill the demand of energy without putting bad impact on the environment. Therefore many renewable energy sources such as wind, micro-hydro, tidal, geothermal, bio-mass and solar are converted into electrical energy. As sun is the biggest source of solar –energy having radiant light and heat.

on the surface of Earth, having reserved fossils fuels such as petroleum and coal that are ultimately be emptied and except this by burning and using these fossils fuels ,creates carbon –dioxide emission that again put bad impact on environment and climate. On other side Solar Power emits no carbon –dioxide which is an effective solution of natural resources and it is eco-friendly. Solar power generating system absorbs sunlight and then converts it into electricity that can be used further in different applications. In every second, sun sends about 42 trillion kilocalories of energy to the earth. If it is possible to converts this entire 100% solar energy into electricity, we can get one year's power for the entire planet in a single hour. Solar energy is the most powerful among all renewable energy resources.

"Solar power is defined as the conversion of sunlight into electricity which may be direct by using PV and indirect by using concentrated solar power (CSP)".

Solar power plants using one of two technologies:

(A) In PV system, panels are mounted either on rooftops or in ground providing direct conversion of sun rays in form of electricity.

(B) In Concentrated Solar Power (CSP) plants, solar thermal energy is used for making steam, which again concentrated into electricity by using a turbine.

In concentrated solar power that is centralized approaches of solar generated electricity ,light and rays are collected and focused with the help of lenses, mirror and tracking system in which large area of sun light are focused into a small beam .Concentrating solar power plants requires direct sunlight. In this system, diffused sunlight is not reflected that becomes ineffective in cloudy conditions. Commercial concentrated solar power plants first developed in 1980s.With power rating of 392MW Ivanpah is the world's biggest concentrated solar power plant, located in Mojave Desert of California. Concentrated solar power system having traditional model of energy distribution and also negligible fuel costs that is counted in its advantages but on other side power generation by concentrated solar system is not constant and having vulnerability that reduce the use of Concentrated Solar Power systems.

In Photovoltaic (PV) system, converting light into electricity by using semiconducting materials has photovoltaic effect. In a Photovoltaic based system, solar panels having a number of solar cells that generate electrical power. In this energy generation process first photoelectric effect has been created with the help of electrochemical process which ionized crystallized atoms in a series and generating electric current. Solar PV panel directly converts sunlight into electricity without moving any parts. Photovoltaic system further is divided into stand-alone photovoltaic system, photovoltaic system used for vehicle applications solar vehicle and grid connected photovoltaic system. After hydro and wind power, PV is the third renewable energy source in secures of globally capacity. The first practical application of photovoltaic was in power orbiting satellite and in space craft but in now days, photovoltaic modules are mainly used for grid connected power generation that requires an inverter also for converting electricity from DC to AC. Solar system in absence of grid, store energy in conventional lead acid battery.

In far flung areas, sizes of power panels play a very important role for generating power in reasonable cost. Therefore renewable energy sources are excellent choices in far areas for generating low and medium power level or application due to easy scaling of input power source. As Solar PV generates energy without pollution or without harming the environment that is the main reason of attraction towards PV systems, solar PV system is an inexpensive, low carbon technology to harness renewable energy from the sun. In current technology, using tracking PV system is an optimum selection of enhancing system efficiency and reducing cost PV arrays continuously showing a promising role in generation of solar energy in coming future. In specialized application PV system is used for fifty years ,on other hand stand alone and grid connected systems are in used for more than twenty years. But in grid connected PV system, power output is directly depend on sunlight which is the major disadvantage because if tracking is not used then only for half day, sun light is received and power is generated .Weather condition also effect the amount of generated power especially due to covering of cloud ,which indirectly depends on irradiation level and temperature. In cloud covering conditions, change of PV energy is fast and dramatic. Output power of a PV system is proportional to the insolation levels, calculated from the surface of solar cells.

As solar photovoltaic power generation is a clean energy generation techniques that draws upon the planet's most plentiful and widely distributed renewable energy source that is Sun. This technique is "inherently elegant" due to direct conversion without environmental emissions during operation. For protecting cells, from the environment, cells are packed tightly behind a glass sheet. Materials that are used in fabrication of solar cells in photovoltaic include monocrystalline silicon, polycrystalline silicon, amorphous silicon, and cadmium telluride and copper indium gallium sulfide. Copper is used in form of cable to connect modules, arrays and sub-fields. This technique of power generating is widely used in remote applications with small power requirements in which cost of running distribution lines is not feasible. However large area and high cost of PV modules continue to be obstacles to using PV power for supplement existing electrical utilities and the solution of this problem is the integration photovoltaic's into building materials. Building integrated photovoltaic system is having advantage in form of cost and appearance with in corpora ting photovoltaic's properties including roofing, sizing and glass .In architectural view installation of BIPV is more attractive than roof-mounted PV structure .Most of the application of photovoltaic power generation is based on off-grid i.e. without grid connection that are used in communication satellites, terrestrial communication sites, remote home and villages and water pumps. Sometimes it is also include energy –driven generator that changes batteries when solar power is not sufficient. On the other hand in grid connected applications power from solar cells runs through an inverter and feeds back to the distribution system. Grid –connected systems are capable of providing emergency power in case when utility power is interrupted.

Power capacity of photovoltaic system is measured by calculating maximum power output under standardized test conditions(STC).The actual power output at a particular point may be less or greater than this standardized or "rated" values which may depends on geographical location, time of day, weather conditions and some other factors. In the case of building integrated and ventilated photovoltaic modules that is having high forced air velocity and gives best mathematical and physical performance by which desired improvement in the production of electricity is obtained due to increasing heat transfer and decreasing temperature in PV modules. In BIPV highest D/L ratio i.e. distance between panels D and length of panel ratio gets a highest amount of sunlight that is not proportional to the amount of power generation due to reduction in the area of power generation.

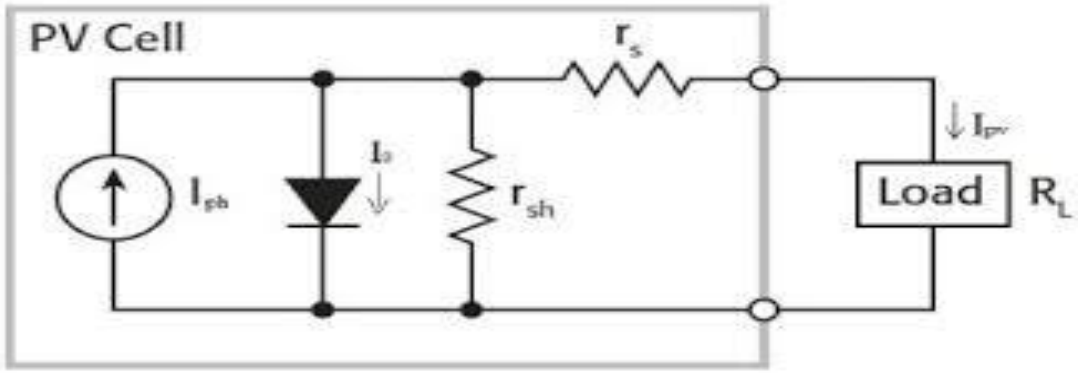

Fig:1 Equivalent circuit of PV cell: one diode (https://www.researchgate.net/figure/284810777_fig 2Single-diode-equivalent-circuit-model-of-solar-cell.)

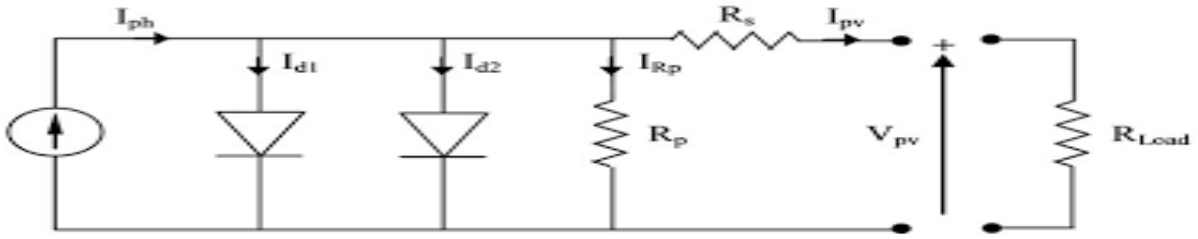

Fig:2 Equivalent circuit of PV cell: Two diodes (http://file.scirp.org/Html/1-6401030_3323.htm.)

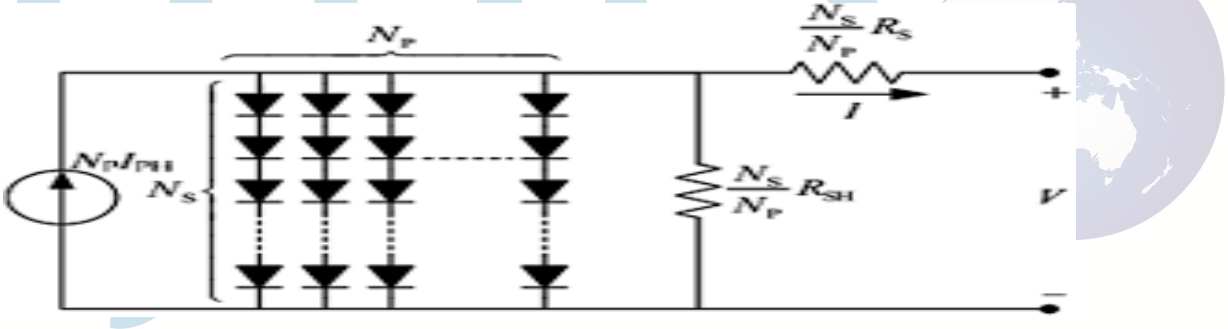

Fig:3 Equivalent circuit of PV cell: Multiple diodes (http://link.springer.com/content/pdf/10.1186%2Fs40068-015-0047-9.pdf.)

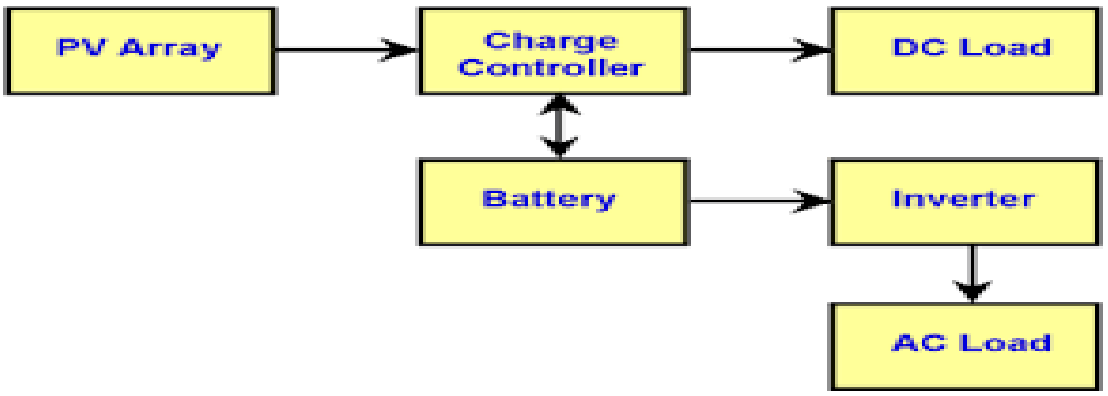

Fig:4 Block diagram of PV system. (http://www.fsec.ucf.edu/en/consumer/solar_electricity/basics/types_of_pv.htm.)

Efficiency: Electrical efficiency that is also known as conversion efficiency is a contributing factor in the selection of a photovoltaic system. It is a physical property which represents how much electrical power can be produced by a cell for a given insolation.

$$\sigma = \frac{P_{max}}{\varepsilon . A_{cell}} = \frac{output\ power}{incident\ solar\ power\ (radiation\ flux\ times\ area)}$$

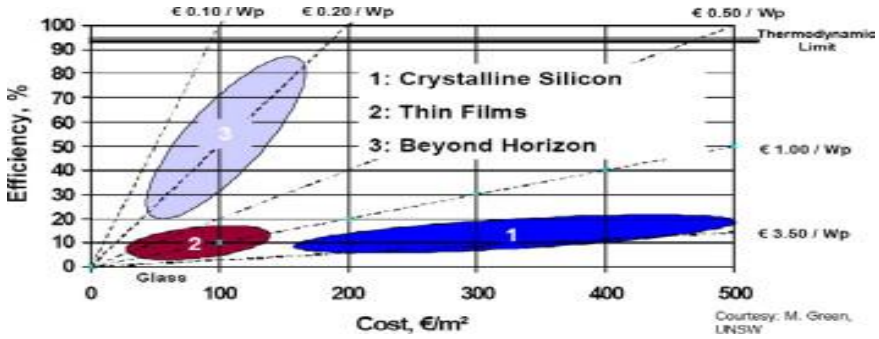

Fig.5: Cost-efficiency analysis for photovoltaic technique- first-generation, second-generation and third-generation (3) photovoltaic technologies. (http://www.sciencedirect.com/science/article/pii/S0038092X1000366X)

Efficiency is affected by the output voltage, current, junction temperature, light intensity and spectrum.

Solar cell: Solar cell is defined as those devices who converts sunlight directly into electricity i.e. convert solar energy into useful energy forms by absorbing solar photons-particles of light which acts as individual units of energy, made of semiconducting materials like computer chip. It is also known as "Photovoltaic Cell" and this phenomenon is known as "Photovoltaic effect "in which cells are assembled in various interconnection according to voltage and current requirement but mostly series –parallel configuration is used for requisite energy. When sun rays are absorbed by these materials, solar energy knocks electrons that are loosed from their atoms and then allowing electrons to flow through the material for producing electricity.

Solar Arrays: Solar cells are very compact and small in size which is capable of generating only few watts of electricity. So these cells are combined into modules of about 18 cells, 32, 56 cells etc.

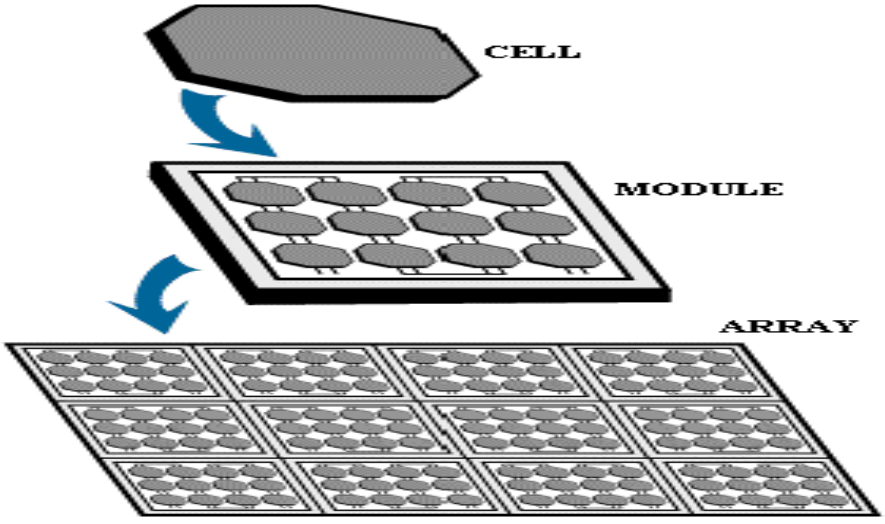

Fig:6 Solar Cells/Modules (http://www.globalspec.com/learnmore/optics_optical_components/optoelectronics/photovoltaic_cells.

Current Status: Rapid depletion of conventional energy resources, concern about environment and continuous increment in demand of energy have forced the researcher to investigate the PV technology for large scale energy generation and applications both in standalone and grid connect means without storage configuration. Since 2000total growth of photovoltaic in world was calculated as 40% per year and total installation capacity 139MW

where Germany is having most cumulative installations and in Italy generates highest percentage of solar electricity approximate 70%.As PV energy source is one of the best option of future energy requirements of the world .At present PV energy market's demand is increasing vastly with an annual rate of 35-40% with 10.66GW energy production that increased in 2009.. Rapid growth of PV market starts since 1980s when multi-megawatt PV plants started to use for power generation that is similar to telecommunication and computer sector progress. Maximum growth of PV market's mainly founded in European country where the annual production of PV cells or modules 595MW (United State), (1.5GW (Japan) and 5.19GW (China) respectively. During the period of 2010, PV market growth is unprecedented. The cumulative electrical energy production from global PV installations in 2010 is higher than half of the electricity demand in Greece or the entire electricity demand of African countries. In 2014, it increased 40.1GW (28%) which reached 178GW till the end of year and Asia becomes fastest growing region, with more than 60% global installation.

On the other side if we discuss about the current status and growth of PV market's in India similar to other country then Indian government are also supporting in the development of PV technology with renewable energy based electricity production that starts from 31May2016with the capacity of 7,568MW and targeted as 100,000MW till 2022.India is at the first position in solar power production per watt installed with an insolation of 1700 to 1900 KWhour/KWpeak.In because in India ,there are some specific constraints and features that helps in development and production of solar energy: easy availability of sun light maximum time of the year..In January 2015, Indian government significantly expanded its solar plants, with a target of US$100billionof investment and 100GWof solar capacity including 40,000MW from roof top solar by 2022.On 16 May 2011, India's first 5MWcapacity power plant was registered under the clean Development Mechanism. Globally, the solar PV grid connected capacity has increased from 7.6GW in 2007 to 13.5GW in 2008 and 21GW at the end of 2009.India is located in the equatorial sun belt of the earth and thereby receiving maximum radiant energy from the sun. In India, most of parts having cleared sunny weather atleast 250 to 300 days of a year. Now for the development and for increasing the interest of the people towards the development and use of solar energy resources, Indian government launched a solar mission named Jawaharlal Nehru National Solar Mission with a target of achieving 300GW till 2022.According to IEA; India will append 600GW to 1200GW of power generation capacity before 2050.

I. Historical Growth of Solar Energy in India:

India is the first country where a Ministry of non-conventional energy resource was set up before 1980, having several developmental programmes and demonstrating projects for solar techniques. In 2006, Rural Electrification Program was the first step of Indian Government that was helpful in recognizing the importance of solar power guidelines for the implementation of off-grid solar applications. The Ministry of New and Renewable Energy has set up a Solar Energy Centre (SEC) that is dedicated for development of solar energy technologies and to promote its applications through product development. In 2009, MNRE launched "Jawaharlal Nehru National Solar Mission (JNNSM)" with the ambitious goal of making India a global leader in solar energy. JNNSM plans a three-phase approach with specific targets for each phase. The JNNSM is encouraging the production of both PV& CSP technology with equal weight age. This Governmental mission has deployed 20 GW of solar power by 2022 which is shown below in Table 1.

Solar Application	Target-Phase I 2010-2013	Target- Phase II 2014-2017	Target Phase III 2018-2022
Grid Solar Power includes roof top and small solar projects	1100MW	4000MW	20,000MW
Off Grid Solar applications includes rural solar lights	200MW	1000MW	2000MW
Solar Collector	7Million sq.meter	157Million sq.meter	207Million sq.meter

Table: 1. Target of installed solar systems from the year 2012-2022.

II. Challenges and Future Scope of Solar Energy Development in India:

Solar energy will becomes as a crucial component of India's energy portfolio in coming decades, perhaps more compare to other countries. National Action Plan (NAPIC) based on climate change in India identifies eight critical missions for promoting climate mitigations and adaption. It is doing efforts for increasing the use of solar technologies in urban areas, industry and for commercial establishment. There are various factors and challenges that can put their effect on the growth of solar energy: industry demand, supply cost of solar power generation and disparity in solar potential across states. India suffers from persistent energy shortage with average demand-

supply gap revolving around 12% of total power supply and also solar industries are still in nascent stage that are facing challenges of high cost of solar power generation. In India, cost of solar electricity produced on-grid is Rs. 18.44/unit. This high cost is mainly due to dependence on imports for silicon and solar wafers used for the manufacture of solar cells – about 80% of which comes through imports. Another major factor restricting the growth of this sector is the lack of standards, resulting in the fragmentation of the market among manufacturers and suppliers. On the other side, current power generation in India is heavily dependent on non-renewable natural resources such as coal and diesel, whose fast depletion has forced the government and the power generation companies to look into renewable energy sources, especially solar power.

III. Indian Power Sector:

Thermal	Hydro	Nuclear	Renewable	Total
1,53847MW	39,623MW	4780MW	28454MW	2,26,704MW

Table: 2. Installed Power Capacity: India: 226.704GW and World: 995GW

Year	Cumulative Capacity (in MW)
2010	161
2011	461
2012	1205
2013	2319
2014	2632
2015	3743
2016	6763

Country	Solar PV Capacity
Germany	35.5GW
China	18.3GW
Italy	17.6GW
Japan	13.6GW
United State	12GW
Spain	5.6GW
France	4.6GW
Australia	3.3GW

IV. Solar Projects in India till 2013:

Commissioned	
Solar PV	**1801**
Solar Thermal	**56**
Total	**1857**
Under Development	
Solar PV	**2339**
Solar Thermal	**445**
Total	**2784**

Benefits and Applications: Solar energy sources are seen as an alternative source of energy because of the advantages offered by this technology and its simplicity, abundance, pollution free and renewable, direct use of heat and direct conversion of light into electricity through a simple solid-state device, absence of moving parts, nature of modular, voltages and power levels can be calculated by simple integration, minimum manufacturing cost, long effective life and high reliability, rapid response of output with respect of input radiation changes, high power handling capabilities and power distribution problems are also solved by using solar cells. It can be used with or without tracking system but having major disadvantage that is it is having cyclic time dependency, Thatswhy solar system requires an energy storage devices for providing energy in absence of insolation.

PV Applications:

1. As PV panels providing clean, green energy i.e. during electricity generation does not generates any harmful green house gas, so it is environment friendly.

2. Solar energy is received by sun –a natural source ,so it is free and abundant and available almost everywhere easily that's allow the direct conversion of electricity and using Solar PV ,electricity bills are also reduced.
3. On recent time Solar Panels cost is continuously on reducing track and in future also expected, Thatswhy Solar PV Panel has a highly promising future both in economical viability and environmental sustainability.
4. Electricity is generated by using solar panel for more than 25 years without using any traditional fuels, so also reduce the cost of fuels.
5. One of the other important advantage of PV panels are its operating cost and maintenance charge that is low ,almost negligible compared to other renewable energy resources. It also has no mechanically moving parts except sun tracking system, so having fewer breakages or requires less maintenance. It is also totally silent without producing any kind of noise. So it is a perfect solution for urban areas and for residential applications.
   (a) Agriculture field: Used in water-pumping installations for providing automatic irrigation technique without waiting for electricity and wasting water.
   (b) Health: This technology also beneficial in health department especially for freezing and conversion of vaccines and blood.
   (c) Commercial Lighting**:** PV powered lighting systems are reliable and low cost alternative. Security, billboard sign, area, and outdoor lighting are all viable applications for PV.
   (d) Consumer electronics**:** Solar powered watches, calculators, and cameras are all everyday applications for PV technologies.
   (e) Residential Power: A residence located more than a mile from the electric grid can install a PV system more inexpensively than extending the electric grid.

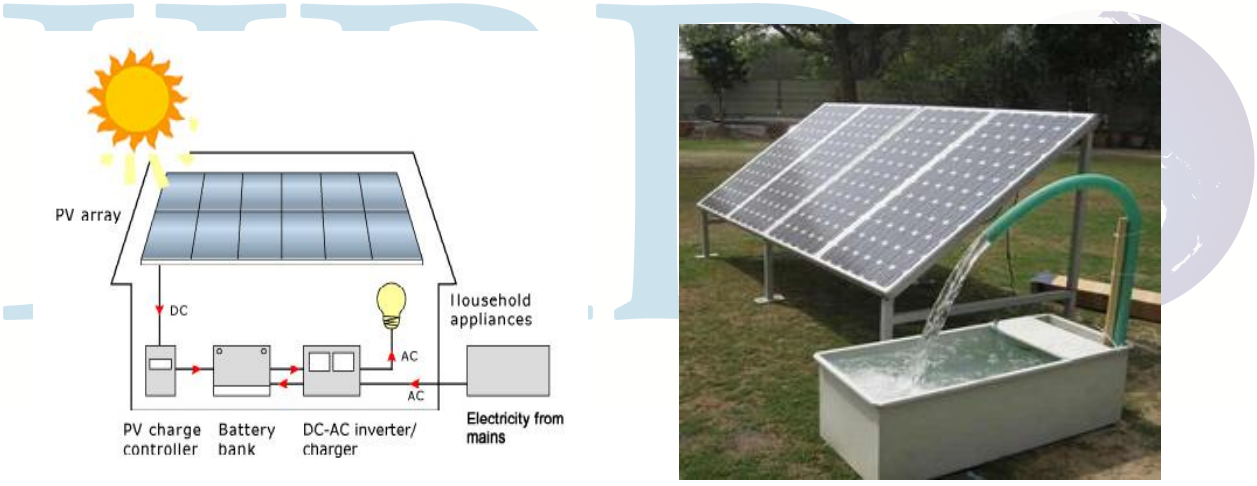

Fig: 7 (a) Agricultural Field (http://dir.indiamart.com/hyderabad/solar-water-pump.html)

Fig: 7 (b) Health Field (http://www.enerpoint.de/photovoltaic_systems.php.)

Fig: 7 (C) Commercial Lighting (http://www.solarlighting.com/.)

By using PV arrays, solar energy is converted into DC power depending insolation. Blocking diode is used to allow the array to flow the generated power towards power conditioner. In the absence of blocking diode ,battery discharge back through the solar array during low insolation where power conditioner have a maximum power point tracker(MPPT),a battery charger and a discharge controller .MPPT is used for ensuring the amount of extracted maximum power that is generated by the solar PV at all instants and charge discharge controller is used to prevent the overcharging and over discharging that is required to store electricity generated by the solar energy during sunless time.

Increasing the output power: Power that is generated by solar arrays depends mainly on insolation, temperature and array voltage. As the power is the function of voltage and current, so to maximized power one of these parameters can be varied .Except this ,it can be used by tracking system such as fixed, single, double that tracks the direction of sun. So maximum power point tracker(MPPT) is an electronic instrument such as dc to dc converters that ensures that the PV arrays gives the correct amount of current for the operation and then load always gets the maximum power under all atmospheric condition following maximum power theorem.

Conclusion:

Solar energy resources play an important role in future in fulfilling the energy demand where dependency on fossil fuels are reduced and put the environmental issues at the priority. Model of solar panel that is used is more accurate, having enough degree of precision and can be used for solar cell based analysis to study the large scale PV arrays without increasing computational time. As the energy generation by using photovoltaic technology is simple, reliable, in-exhaustive, maintenance almost minimum, clean and suitable for off grid applications.

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