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Solar Photovoltaic Systems – Applications & Configurations

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Abstract – *The energy from the sun can be categorized into two types such as heat energy and light energy. The former has been harnessed since centuries in the form of heating applications. Nowadays the trend is the use of light energy from the sun that has been neglected since ages. With this new era of modern technology, on renewable, non-conventional sources of energy, solar energy in the form of both heat and light has wide range of applications. Photovoltaic cells are those which work on the principle of photovoltaic effect, which states that, when light is incident on photovoltaic cells, light energy is directly converted into electrical energy. So, all that we need to produce electricity anywhere is the light. Here in this context we have reviewed different applications of photovoltaic systems and its different configurations depending on its need and place of its application.*

***Key Words*: Solar energy, photovoltaic, applications of PV, off-grid, BIPV, Hybrid PV Systems.**

1. INTRODUCTION

Energy, as the most important concern of the present and future, has to be discussed, studied, reviewed, and researched in detail. Day by day there is depletion of energy resources that are non-renewable and also causing imbalance in nature. This calls for the need of renewable resources of energy which are also clean and harmless to the environment. Presently, the world energy consumption is 10 terawatts (TW) per year, and by 2050, [1] it is projected to be about 30 TW. With the increasing energy demands, there comes nature to serve its purpose for clean and sustainable environment.

Fig-1: Solar PV Cell

Solar Photovoltaic (PV) cells are those breakthrough for us where we can dream for sustainable future, attaining our energy demands as well. Solar cells work on the principle of photovoltaic effect. These are semiconductor cells where they are doped. When light falls on these cells there is generation of electron-hole pair combinations. Holes are positive and collected at P end, electrons are negative, collected at N end. This creates a potential difference and produces electric current. Rather than simply maximizing the generation, it is always better to work at its consumption and efficacy.

1.1 Solar Energy – as a Renewable Resource

Solar energy is available in abundance anywhere and everywhere from morning till evening, which gives enough time space for us to harness the energy from the sun. PV does not cause any harmful impact on the nature. By replacing fossil fuels, it reduces air pollution which in turn reduces acid rain, soil damage, human respiratory ailments. [3]

It helps reduce emissions as it does not produce any greenhouse gases such as CO_2. [3] Solar electric generation among all other renewable energies has the highest power density. [4] Solar Plants have a life of more than 25 years which is minimized just theoretically but can achieve more than this expected life up to 100 years or more. [5]

Solar Power can be harnessed even from the roof top unlike traditional conventional power systems. [5] It does not need any transmission grid particularly, it can be harnessed at the point of generation directly.

1.2 Solar Photo-Voltaic (PV) System Application

Fossil fuels are still in demand for automobile applications [6] but photovoltaic systems have also found its space of application in the wide range. A photovoltaic cell is a solar cell that is completely dependent on incident light and its intensity. A solar cell or PV cell directly converts incident light energy into electricity. PV cell can produce from few kilowatts (KW) to huge megawatts (MW) of energy, hence it finds its huge area of applications than conventional energy systems. Few of them are discussed here in brief:

- **Water Pumping:** Solar power is commonly used for water pumping facility which has been proved more effective in villages for agricultural purposes. The

energy from the solar panel is used to operate the pump that is used lift the water from lower level to higher level. Following figure shows the diagrammatic representation of it.

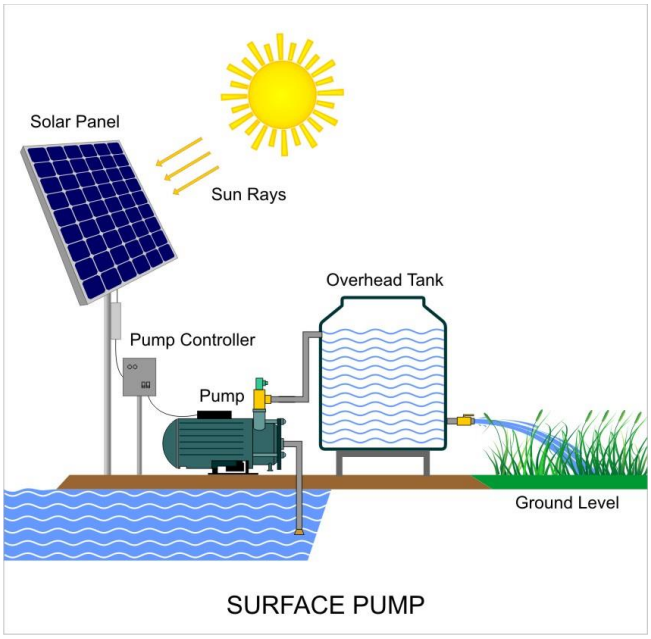

Fig-2: Solar Water Pumping System

- **Cooking:** solar cookers are the most happening in the present market. Solar cookers are commercially available and are easy to operate and maintain. The world's largest solar kitchen has been set up in India at Taleti, near Mount Abu, situated at a height of 1219 m above sea level in Rajasthan. It boasts of a six-module solar steam cooking system and a total of 84 parabolic dish concentrators shell type receivers. [7]

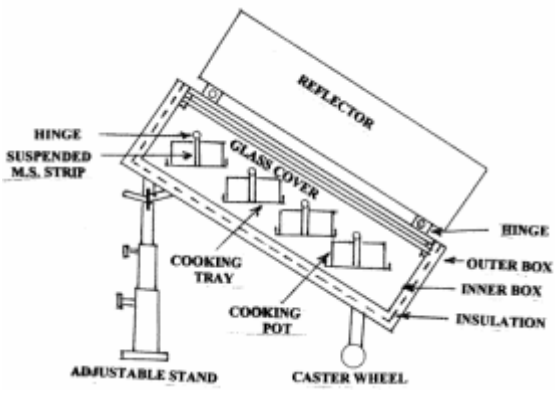

Fig-3: Schematic Representation of Solar Cooker

- **Heating:** solar water heaters and air heaters have been very common since decades even before PV cells could exist. Solar water heaters alone help reduce the consumption of energy to a major extent. These trap the heat energy from the sun, and store hot water in the containers.

- **Lighting:** solar photovoltaic lighting system can be used for street lights, and rural areas. Small sized panels can easily harness enough energy to glow a street light and LEDs.

Fig-4: Solar Lighting

- **Traffic Signals:** Traffic signals at all areas can easily be operated using solar panels. Shadow free area is the only concern for this.

- **Cold Storage:** Solar energy can be used for cold storage as well as air conditioning application. Vapor compressor system using solar photovoltaic panels and vapor absorption system using thermal collectors can be used for these purposes. [2]

- **Solar PV System in Space:** The solar arrays arranged in space station produce more than required power for the space station [8]. When the station is in sunlight, about 60 percent of the electricity that the solar arrays generate is used to charge the station's batteries.

Fig-5: The solar panels in space

Solar panels on spacecraft supply power for two main uses, [9] firstly, power to run the sensors, active heating, cooling and telemetry. Then, power for spacecraft propulsion – electric propulsion, sometimes called solar-electric propulsion.

Solar panels used in space are not as same as ones used in terrestrial applications. They do not require any

glass lamination to prevent from moisture. They must be capable to withstand elevated temperatures and hence the material used is different.

2. SOLAR PV SYSTEM CONFIGURATIONS

SPV system configurations can be of three types for different applications as described below:

1) Stand-alone SPV systems without storage battery and storage battery
2) Grid interactive SPV system.
3) Hybrid systems
4) Building Integrated SPV systems.

2.1 Stand Alone SPV Systems

A] Stand- Alone SPV Systems without Storage Battery:

As the name indicates, these are used for stand-alone applications, which are least expensive and simpler like the water pumps and water sprinkler systems. These do not require any battery storage as it is meant for specific purpose for an abbreviated period of time and hence can be achieved when sun is at its peak with maximum intensity. [2]

Since there is no battery associated with these systems, it eliminates the cost related to it and the charge controller. These are lighter and easily installed and maintained.

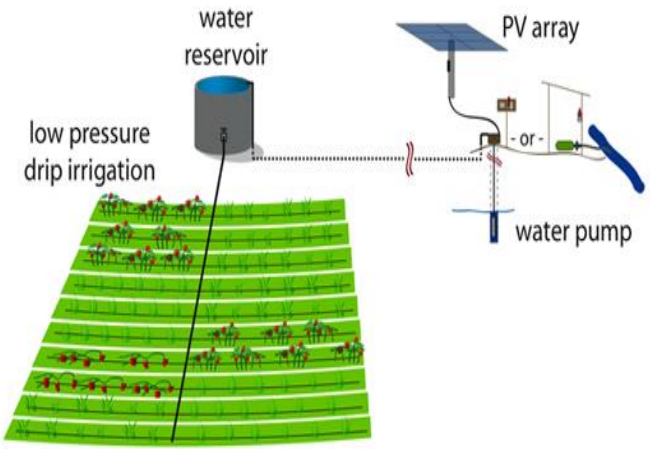

Fig-6: Solar water sprinkler- drip irrigation

B] Stand- Alone SPV Systems with Battery Storage:

A simple stand-alone PV system harness the solar energy and store it in battery banks that could be used even at night times when there is no sunlight. A stand-alone small-scale PV system employs rechargeable [10] batteries.

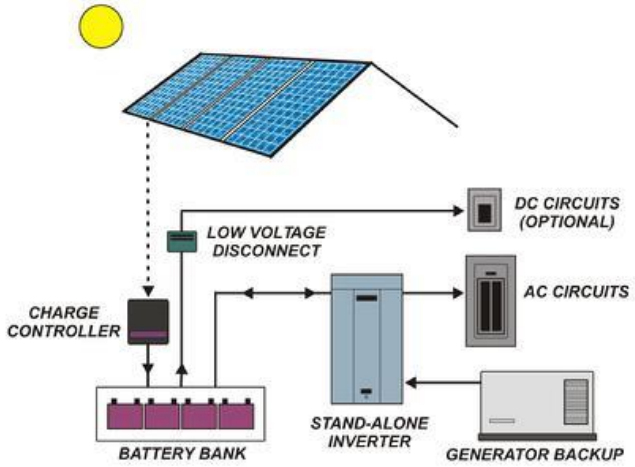

Fig-7: Stand-alone roof top system with battery storage

Roof top systems are best suited example for these systems. In the roof top system as shown in fig-4 it consists of solar modules which produces electricity are connected to the battery via charge controller. Further it is connected to the stand-alone inverter to convert direct current (DC) to alternating current (AC), making it available to connect to AC loads. Deep cycle lead acid batteries are generally used to store the solar power generated by the PV panels, and then discharge the power when energy is required. Deep cycle batteries are not only rechargeable, but they are designed to be repeatedly discharged almost all the way down to a very low charge. [10]

2.2 Grid interactive SPV system

A grid-connected photovoltaic power system, is an electricity generating system that is connected to the utility grid. A grid-connected PV system consists of solar panels, one or more inverters, a power conditioning unit (PCU) and grid connection equipment. When conditions are right, the grid-connected PV system supplies the excess power, beyond consumption by the connected load, to the utility grid. [11]

A grid connected system is connected to a large public electrical grid (owned by utility company) and feeds power into the grid. Grid connected systems vary in size from residential (2-10kW) to solar power stations (1-10MW). In the case of residential or building mounted grid connected PV systems, the electricity demand of the building is met by the PV system. Only the excess is fed into the grid when there is an excess.

The feeding of PV generated electricity into the grid requires the transformation of DC into AC by a grid-controlled inverter. On the AC side, the function of grid-connected inverter is to supply electricity in sinusoidal form, synchronized to the grid frequency, limit feed in voltage to no higher than the grid voltage including disconnecting from the grid if the grid voltage is turned off. On the DC side,

because the power output of a module varies as a function of the voltage that power generation can only be optimized by varying the system voltage to find the 'maximum power point'. Most inverters therefore incorporate 'maximum power point tracking' (MPPT). [12]

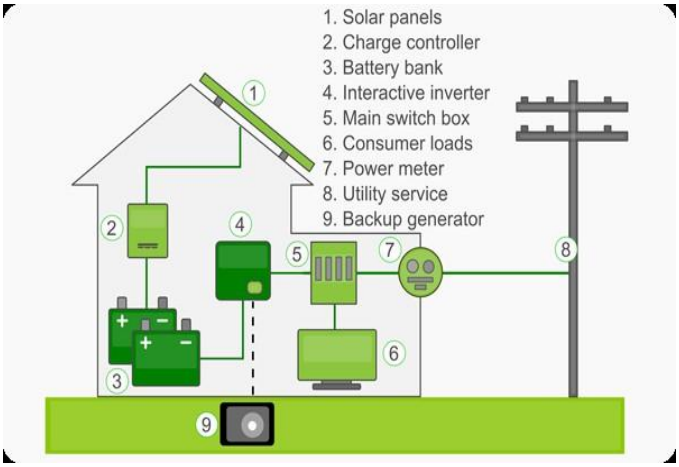

Fig-5: Solar grid connected system

2.3 Hybrid systems:

Hybrid energy systems combine two or more forms of energy generation, storage or end-use technologies, and they can deliver a boatload of benefits compared with sole source systems.

Variety is the spice of life, so why limit ourselves to just one energy source or storage option? In these cases, hybrid energy systems are an ideal solution since they can offer substantial improvements in performance and cost reduction, and can be tailored to varying end user requirements. [13] They have the potential to dramatically reduce cost and emissions from energy generation and distribution for households.

The best business case can be observed for hybrid power plants. In mining, these are solar or wind systems that are combined with or integrated into existing diesel power plants. Wind and solar energy are often up to 70% less expensive than electricity from diesel, especially in remote areas where transport makes up a large share of the total diesel cost. Hybrid power plants combine at least two different energy types. Rather common is the combination of diesel gensets and renewable energy systems with or without storage. [14] Solar and wind prices have reduced considerably in recent years. Solar module prices have come down by 30% during a period of just two years. Wind turbine towers have become taller, which allows for an efficient power generation in many locations where the wind is not strong enough at lower altitudes. This makes solar-wind hybrid systems more happening in the present scenario.

The combination of wind and solar has the advantage that the two sources complement each other because the peak operating times for each system occur at various times of the day and year. The power generation of such a hybrid system is more constant and fluctuates less than each of the two component subsystems. [15]

Fig-6: Solar-Wind hybrid systems

Mini solar-wind hybrid systems are also in use in residential and small commercial places.

2.4 Building Integrated PV systems (BIPV):

A Building Integrated Photovoltaics (BIPV) system consists of integrating photovoltaics modules into the building envelope, such as the roof or the facade. By simultaneously serving as building envelope material and power generator, BIPV systems can provide savings in materials and electricity costs, reduce use of fossil fuels and emission of ozone depleting gases, and add architectural interest to the building. [16]

While the majority of BIPV systems are interfaced with the available utility grid, BIPV may also be used in stand-alone, off-grid systems. One of the benefits of grid-tied BIPV systems is that, with a cooperative utility policy, the storage system is essentially free. It is also 100% efficient and unlimited in capacity. Both the building owner and the utility benefit with grid-tied BIPV.

Fig-7: Photovoltaic wall, BIPV

4. CONCLUSION

- Solar Photovoltaic system have wide range of applications. This could be expanded to whatever level of research expected.
- From the above few discussed applications, it is clear that be it any part of its application, PV systems stands on for its output that is preferred.
- Costs are reduced and efficiency is improved with every step of its usage.
- Incorporating solar PV technology not only saves fuel, but also helps in contributing for a safer environment and protecting our ecology.
- Emissions, greenhouse gases and all oxides of carbon and nitrogen would be reduced due to use of these renewable energy systems.
- Further, it has a broad scope in future, with renewable energy replacing the non- renewables in every energy sector.
- There is lot of research work going on floating solar panels, CPVT technology, where you have both light and heat energy harnessed at same time in same equipment.

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