International Journal of Scientific Engineering and Technology
Volume No. 6, Special Issue 1, PP : 52-56

ISSN : 2277-1581
22-23 Dec. 2017

Growth, Design Aspects and Applications of Photovoltaic Systems

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Abstract : Solar energy is resource which cannot be used or exhausted completely. The temperature is 15 million ^{0}C at the center of Sun core and at its surface it is approximately reaching 6000^{0}C. Being an effective black body it has temperature of 5777^{0}C and so the sun effectively acts as a continuous fusion reactor, many such fusion reactions takes place and hence there is production of solar energy, one of the important reaction of hydrogen with four protons whichcombines to give helium nucleus. The reaction is here,

4(1H1) 2He4 + 26.7 Me V ⟶

This highly exothermic reaction gives us energy in order of MeV which is collected and converted in the form of heat and further in electricity.This is really an important source of renewable energy and the technologies characterizing is as either passively solar or activelysolar. Theuse of photovoltaic systems is in active solar power systems. In Passive solar system the techniques used are, that they orientatea building towards the Sun in such a way that maximum sunlight falls on PV systems, selection of material with favourable thermal, mass or light-dispersing applicative properties, and designing spaces so that can naturally circulate air.

This paper is made to focus on photovoltaic solar cells, their designing aspects and their applications. This ability of producing electricity directly with the help of the sunlight in the most abundant natural resources, is the heart of this Photovoltaic research, and is explained as becoming one ofthemajorsources of power for ourbetter"greener" future.

Keywords: Worldwide Scenario of Solar Energy, growthof solar PV system, designing of solar PV system and applications of solar PV system.

INTRODUCTION

Contribution of Sun's energy: It merely contributes 94% of energy to Planet, it also warms the surface of our earth and so the atmosphere so that huge forms of life can live.Without the solar energy, our earth will become completely as a rock moving in infinity space with temperature situations extremely low.We humans,consume lot of energy in our day to day life that within couple of years all of our existing fossil fuels which are coal, gas, petroleum, etc will getexhausted.Hence, solar energy has a major responsibility to ensure itself as best sustainable energy for our future generations and also it can minimize the problems of carbon emissions, global warming etc.

Photovoltaic collectors: These photovoltaic collectors are the collectors which convert solar radiation coming from sun directly into electricity, without any kind of use of heat engine in its configurations and with increase in demand and requirement of public integration and their purposes of using energy, the small scale utilization of solar energy for desalination, destination and detoxification of purposes with water has also increased. With the help of these solar collectors which are settled on the rooftops of buildings and with the help of photovoltaic cells of solar panels, the system is made to synchronized with the active as well passive energy systems.

Photovoltaic effect: Abasic theory of solar cell is that, a wide area of semiconductor diode which is having PN junction due to fabrication of pentavalent element (Ph) or trivalent element(B) with tetravalent element (Si, commonly used for solar cells) to provide us charge carriers, either minority or majority depending upon holes or electrons concentration. When light or sun radiation is made to fall on this grouped semiconductor being PN in nature, this generates the electron hole pair giving a force or a kind of tension between the contacts of provided n- sideand p-side of semiconductor and when we apply the load,the current flows within this, making it as completion of circuit as flow of charge is flow of electric current and electric power is dissipated in it.

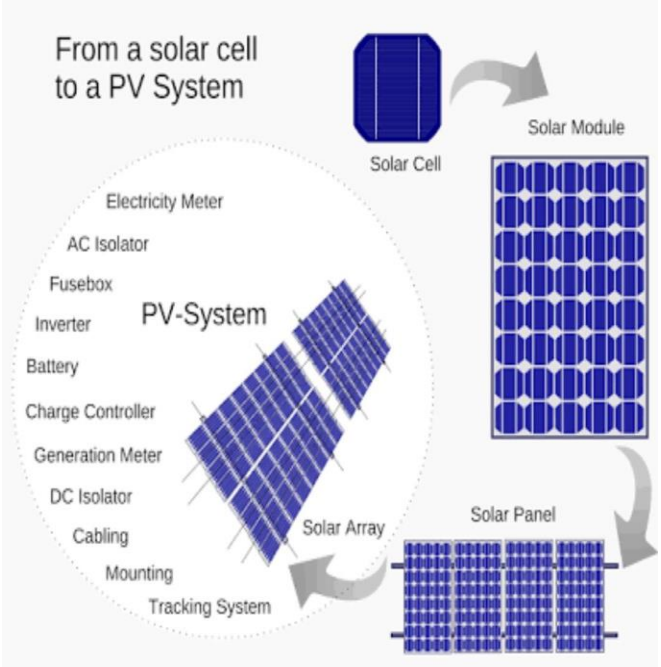

Fig.1: Complete solar PV system
(Source: www.solardirect.com)

International Journal of Scientific Engineering and Technology ISSN : 2277-1581
Volume No. 6, Special Issue 1, PP : 52-56 22-23 Dec. 2017

GROWTH

Humans are capable enough to capture the solar energy from sun directly, and with the help of passive and active solar energy systems intuitively in body. Ancient people in earlier times made their minds so asused to build their shelters and houses of stone or with clay so that the heat absorbed in it can easily be used in night time. Nowadays what builders use to dois somewhat similar to methods for passively capturing the Solar Energy, with the help of photovoltaic cells.

For example, the construction of houses done by them isplanned with large double or triple paned types of windows so that can get a direction to capture the efficient sunlight and can magnify the warmness of sun.

Active solar energy systems work onsomehow the same principles as the passive systems used to do. But the Active solar systems also using the fluid like water to absorb heat or to store heat. Solar collectors which are oriented at the rooftops pumps the heat to the whole system of pipes and then further to the whole building, it is passed on.

The best part of solar energy is, it is renewable energy resource and present in abundant amount in free in nature and the bad part of this is, that the cost of system for the use of consumeris expensive enough at initial stage of while installations. The technology of solar PV was known to us from the last decades and itsutilization was a task to finish, itsminimal cost of bills and efficiency in various other fields of industries can develop the whole system of integration in regards to this PV system. In India, the geographical location isfavorable as Tropic of Cancer passes from middle of India hence for solar energy implementation in India can be done in worth, various companies are taking interest to develop their scope and earn in this field. Considering the socio-economic scenario, India's present situation is fair with it, but many other initiatives areplanned and in a queue for their implementations. And on considering the historical scenario,the first commercial use of new solar cells was done in aspacecraft in the beginning of 1958. So from Small beginning to a Terrestrial, solar cell industry is putting their roots to grow rapidly to fight over Non Renewable sources in the coming years. These companies will increase the International resolves, reduce theCO_2 emissions and produce effective energy for commercial purposes as well as industrial purposes.Some statistical figure shows the growth done in solar PV systems in last decade over the coal and wind power plants in India. The report made by Central Electricity Authority (CEA) of India for the cost effectiveness for various Gol policy instruments for 1MW solar PV installed in 2016-17 in rural and urban areas of India have successful saving in energy and reduced the average electrical cost for nation.

Table.1: Financial cost effectiveness for various Gol policy instruments for 1MWsolar PV installed in 2016-17(source: nitiaayog.com; CEA report on 175 GW RE by 2022)

1 MW Solar PV Installed in 2016-17	Capital Expenditure	Interest Rate	DSCR Min	DSCR Avg	Project IRR post Tax	Equity IRR post Tax	LCOE	Tariff Reduction in LCOE	Absolute Cost reduction for procuer over 25 yrs	Direct incentive payment from GoI	Income Tax Paid by project	Income Tax loss for GoI	Indirect Income Tax loss for GoI due to AD benefit	Total Cost to GoI	Cost Effectiveness
Units	Rs Lakhs	%			%	%	Rs/kWh	Rs/kWh	Rs Lakhs (NPV)	Rs Lakhs (NPV)	Rs Lakhs (NPV)	Rs Lakhs (NPV)	Rs Lakhs (NPV)	Rs Lakhs (NPV)	(1/C0)
Baseline	540	12	1.07	1.45	12.70	14.27	5.81	-		-	87.5	-	-	-	-
Accelerated Depreciation (1)	[illegible]	12	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Generation Based Incentive (2)	[illegible]	12	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Interest Subvention	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Rock loading RE Tariffs with interest subvention (3)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Viability Gap Funding (4)	[illegible]	12	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-	[illegible]	[illegible]

DESIGNING A SOLAR PV SYSTEM

The major components of solar PV system are:

PV Module: It is having PV cells which are wired in parallel so that it can increase the current and in series so that to achieve a higher voltage. Its basic function is to convertsunlight into DC electricity. The module is layered with protective covering of glass material.

PV Inverters: Thebatteries used in PV systems can store direct current power which is used for many applications. These inverter are for the purpose to convert the low voltage DC into a higher voltage AC and hence can be used for other various applications.

PV Controllers: Controller word defines its property that the battery life of PV system is in regards with these controllers. If battery is charged beyond its limitations then it will not function and if such happens then the battery life reduces.

PV controllersystem basically helpful in opening the circuit between the PV battery and PV array when voltage rises beyond set

.

PV Batteries: Batteries are for purpose of storing charge andexcess energy which is created by PV system and to use in night when there is no sunlight input is applied.These kinds of batterieshave ability to discharge and are able toyield more current when applied to load appliances.

Load: These are the electrical appliances which will consume the electricity produced or stored and are connected to the solar PV system such as tube lights, refrigerator, fan etc.

Sizing a solar PV system:

1. Determination of power consumption

By the addition of each watt hour required for all the appliancesand get the total watt hoursrequired per day for all of the appliances(load).

Multiply it by the total watt hours per day by a factor of1.3(for the total energy loss in our system, it is assumption) to get the total watt hours per day which we will give to the PV panels of our PV system.

Fig.2: Major components of PV system
(source: www.solardirect.com)

2. Determination of sizing of PV panel

PV modules of different size will produce different amount of power. And to find theactual size of PV module, the total peak watt (Wp) is to be calculated. AndWpis dependent on the size of PV panel as well as on the climatic conditions of that particular location. For India, **'**panel generation factor**'** is4.32**.**

The total watt per day required from the module which is calculated, is then divided by thepanel generation factor(4.32) and hence get the total watt peak rating which is requiredfor PV panels to operate the appliances.

To find the number of PV panels, we havethe total watt peak rating for PV panel and that is to be divided by the rated output watt peak PV of the given module. In our case it is 110 Wp.

3. Determination of sizing of inverter

The total watt of the load is not to be equal to the input rating of the inverter. For our considerations of the standalone system, the inverter must be large enough so that it canhandle the amount of watt power used at a one time. This is why we keep the inverter size 30-35 %bigger than the total watt requirement of the load.

4. Determination of sizing of battery

The type of battery which is recommended for the solar PV system is **'**deep cycle battery**'**. In this type of battery, itgets discharge slowly and get charged comparatively faster. The battery is taken large enough so that it can store the enough amount of power to operate even in cloudy days.

Calculation done for the total watt per day is taken and then divided bythe factor of 0.85 (for the loss of battery), 0.6 (for the depth of discharge made by battery) and by the nominal battery voltage which is 12 volts in our case.

Multiplying the above factor by the number of days of autonomy which is usually from 2 to 3,we consider 3 in our case.

5. Solar charge controller size

The solar charge controller is used for matching the voltage of the PV array and the battery identification is done so that the type of the solar charge controller can also be expected that the which one is correct for our use.

There are two types of controllers. One is series charge controller and other is parallel charge controller. The sizingwhich has to be done for controller that completely depends on the total PV input of current which is delivered to the controller and that too depends on the configuration of the panel (either it is inseries or in parallel).

According to standard practice in India, for expecting the size of controller is done by the taking the short circuit (Isc) of the PV array and again a multiplication factor of 1.3 is multiplied(to incorporate the loss caused by system).

6. Cost Estimation

The total cost of installation of PV system which will reflect the ' pay back calculations ' of solar power PV system.

Example of a household is taken

- 40-Watt two tube lights,used 4 hours per day
- 60 -Watt fan, used 8 hours per day
- One refrigerator, which runs 24 hours per day with compressor or run 12 hours and off 12 hours.

The system is **assumed** to be having power of12 volts dc, 110 Wp PV module,averagely the sunlight available in a day is 8 to 10 hours per day for equivalent in peak radiation., factor of 1.3 is taken for incorporation of system loss and losses due to dust and climatic changes , installation of PV system is done in India hence panel generation factor is 4.32.

1. Determination of power consumption

=(2 tube lights×40 watt × 4hours per day)+(60 watt × 8 hours per day) +(75 watt ×24×0.5 hours per day)

=1700 watts hour per day

Required PV panel

=1700× 1.3
= 2210 watt hour per day

2. Determination of sizing of PV panel

Total peak watt of PV panel as per its capacity= 2210/4.3
= 513.95Wp
=550 Wp (on rounding off)
Number ofPV panels required=550/110
Required number of modules =5 modules
This system if have at least 5 modules of 110 Wp PV module then work properly.

3. Determination of sizing of Inverter

Total watt power of appliances is =2×40+60+75
=215 watt
Due to safety purposes, considering size of inverter to be 30-35%bigger
Hence inverter should beat least of **290 watt**.

4. Determination of sizing of battery

Appliance use of watt is =1700-watt hour per day
Nominal voltage of the battery is =12 volts
Days of autonomy considered is =3days
Battery capacity will be
=(1700×3)÷(0.85×0.6×12)
The total ampere hours required for our module is =833.33Ah
Hence the battery should be rated,**12 volts 900Ah** of for 3 days autonomy.

5. Determination of Solar charge controller

The specifications of PV module at nominal operatingcell temperature**(NOCT**) are as follows:

P=110 Wp
V =16.7 V
I=6.6A
Voc=21.3 V
(Voc is open circuit voltage)
Isc=7.5A
(Isc is short circuit current)
Rating of solar is given by
=(5 strings×7.5A)×1.3
=48.75A
Hence the solar charge controller on making it round off should be of at least **50 ampere**.

6. Cost estimation

Cost of arrays is =number of PV modules× cost per module
=5×12000=Rs.60000
Cost of batteries is =number of batteries× cost per battery
=1×15000=Rs.15000
Cost of inverter is =number of inverters× cost per inverter
=1×10000
=Rs.10000
The total cost of system is 60000+15000+10000=Rs 85000
(Additional cost of wiring may also be taken consideration)

Payback calculations of solar PV system

In normal electricity bills Rs per unit or kWh is 6.5 is assumed and on monthly basis if average rupees 1000 bill comes then per year Rs is 12000 required to pay bill which includes some fix money which also has to be paid to power grid companies. In **7.08 years** the amount of Rs 85000 will be paid in normal electricity bills.

Benefits of solar PV system are

- Solar PV panels can give us clean, green energy. As there are no harmful emission of gases from solar PV system.
- Solar energy is free in nature and in abundant amount and can be utilized at great extent.
- PV panels give us the direct electricity generated with the help of photoelectric phenomenon.
- Residential solar panels are of not so large size and are easy to install
- PV modules does not contain any moving parts so they degrade very slowly and average life of PV is boosted.

Limitations of solar PV system

- Efficiency of solar panels are comparably low from other electric power systems.
- These solar panels are less reliable as many persons are unaware of its benefits.
- Installation of such PV system is quite costly.
- When a continuous supply of electric poweris required,these solar panels are less efficient in storing and giving energy.

APPLICATIONS OF SOLAR PV SYSTEM

- Thermoelectric refrigeration driven by solar.
- Solar nanowires working with infrared spectrum.
- Microcomputer based control of a residential photovoltaic power system
- Imagine a future in which we are having solar cells all around us, on windows, walls, laptops. Such transparent photovoltaic cells are already being developed by MIT scientists, giving us advance solar technologies.

CONCLUSION

Thegeographical location of India country can stand for the tremendous scope in generation of solar energy and its utilization so as to achieve its maximum benefits and to provide nationwide development in power and reducing costs of power expenditure of India. With the advancement and development of India, implementations of several new plans will establish solar grids. And in that, this renewable energy is playing promising role not only in India but in world. As the example coated of household where solar PV panel system gives us the idea of money saving when compared to normal bills paid in power grid systems of nonrenewable sources. We saw 85000 rupees were required to install a solar panel and it will become our own power generation system in 7.08 years whereas in other case family is expected to pay bill for lifetime. If such huge step of using solar energy is taken for world then this will be the actual advancement in the field of power systems in respect to generation, transmission, and distribution.

- Table 1: Financial cost effectiveness for various GoI policy instruments for 1MWsolar PV installed in 2016-17
- Fig.1: Complete PV system
- Fig.2: Major components of PV system

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