IJETIE
International Journal of Emerging Technology and Innovative Engineering
Volume 5, Issue 11, November 2019 (ISSN: 2394 – 6598)

A COMPARATIVE ANALYSIS OF ECONOMIC AND COMMERCIAL ASPECTS OF CSP AND PV SOLAR ENERGY GENERATION TECHNOLOGY- A REVIEW

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ABSTRACT

In the quest of meeting the increasing energy demands keeping in mind the environmental safety demand for clean energy is increasing where solar energy is fastest growing technology. There are many ways in which energy electricity is generated by solar energy and they are discussed in this review but CSP and PV technology is the most commonly used technologies are discussed in details. Their commercial and technical aspects are compared which includes the aspect governing its efficiency and financial requirements of both the methods.

Keywords
CSP technology, PV technology.

I. INTRODUCTION

In today's world the demand for energy is at its peak and contradictorily the fossil fuel are getting depleted while the large amount of energy is actually produced using fossil fuel. The higher energy requirements and depleting resources are not the only problems to this generation that has to be taken care of but also measures has to be taken that the environmental damage is no more prolonged beyond sustenance. So it has become important to increases the efficiency of production as well as shift to the use of clean and renewable fuel for energy. The clean and renewable energy sources that are been used for generations are geothermal, wind, tidal, solar, wave, hydro, biomass. The renewable sources of energy comes with a disadvantage of unreliability in terms of their availability. As we have to depend on type of geographical conditions for their feasibility for real-time generation which points out our inability to store energy. We cannot also at once replace the existing grid so we happen to make system compatible with the grid and replacing them system slowly and economically.

A. Solar as a Future Source of Energy

The sun is the ultimate energy source for earth. Also all the other energies like fossil fuel, hydro, wind, biomass origins from sun. Earth receives 120 petawatts energy from the sun which is enough energy to satisfy the world demand for 20 years in a day.

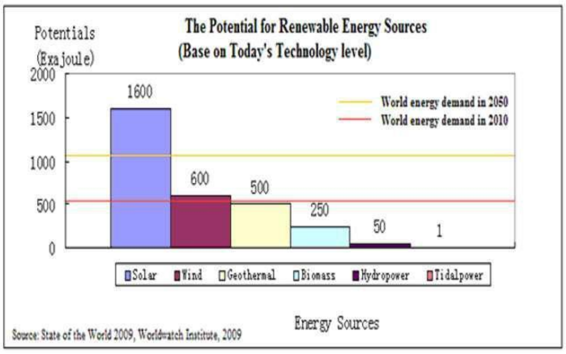

Figure I-A the Potential for Renewable Energy Sources. [1]

Amongst all the existing system solar energy is most growing technology in the market prospective especially in the countries around equator. Globally, the solar PV grid connected capacity has increased.

II. SOLAR POWER GENERATION TECHNIQUES

There are many types of techniques of power generation by solar energy they are broadly classified into two groups concentrating and photovoltaics. All the methods revolve around with their different principles of generation and one of these collecting medium.

1. Concentrating Photovoltaic system
2. (Photo Voltaic) PV technology
3. (Concentrating Solar Power) CSP technology.
4. Dye Synthesized Solar Cell
5. Solar Thermal System

A. PV Technology

In this technology solar radiation is directly converted into electricity by using photovoltaic materials. Photovoltaic material are made up of semiconductors that shows photovoltaic effect. Power is generated by installing number or such PV panels over an area.

6.

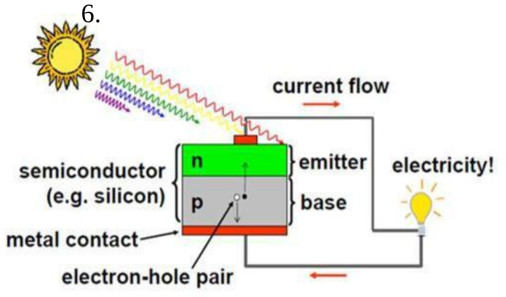

Figure II-A Photo Voltaic Effect

It is a simple concept that electrons are emmited from matter as they absorb energy from electromagnetic radiation of very short wavelength in this case it is sunlight which was first observed by Heinrich Hertz in 1887 and ca,e to known as Hertz effect.

B. Classification

They are broadly classified under two categories:

i. Wafer Based (crystalline silicon)
ii. Thin Films

The classification is done on the basis of the material used for the PV panels. In the present technology the material used include monocrystalline, polycrystalline and amorphous silicon, cadmium telluride, and copper indium gallium selenide/sulphide. There are many variations in cell material, design and methods of manufacture**.**

Wafer based (crystalline silicon)

The manufacturing of c-Si modules typically involves growing ingots of silicon, slicing the ingots into wafers to make solar cells, electrically interconnecting the cells, and encapsulating the strings of cells to form a module..[3]

C-Si modules are subdivided in two main categories:

i. Single crystalline (sc-Si)
ii. Multi-crystalline (mc-Si).

Thin Films

Thin films are made by depositing extremely thin layers of photosensitive materials in the micrometer range on a low-cost backing, such as glass, stainless steel or plastic. The oldest of this technology was amorphous (a-si) which was then combined with hybrid silicon cells for better efficiency thus other films were developed. [3]

Thin films are subdivided into five main categories:

i. Amorphous (a-Si)
ii. Micro morph silicon (aSi/μc-Si)
iii. Cadmium-Telluride (CdTe)
iv. Copper-Indium-Diselenide (CIS)
v. Copper-Indium gallium dieselinide (CIGS).

C. Efficiency of different PV technology

Single crystalline silicon technology has the highest efficiency of 23 percent but its manufacturing cost is very high due to which the need of developing the other technologies arrived where CGIS and CdTe are the growing technology due to their moderate efficiency and low lost.

sc-si	mc-si	Thin films	CIGS	CdTe
23%	19%	12%	15%	14%

Table C-I Technical Efficiency of PV technologies [3]

The most popularly used PV technology in the market the silicon technology where CGIS is the new emerging technology with consirately good market contribution other technology like CSPV are installed in roof tops and in house purposes that is they are in experimental level and research is been conducted.

D. Topologies of PV Plant

There are two main topological condition of PV plant:

i. Stand Alone mode
ii. Grid connected

Standalone topology is used for places far away from grids, isolated rural areas or used for small purposes like street lighting. In this mode a battery with a stabiliser is equipped to protect the battery from being over charged and also the charge is not less that the threshold value. It also takes care of the inverter operation so that the dc loads are fed by dc supply and same as for ac. Stand-alone mode is never indulged in high power operations.

The grid connected mode refers to the PV plants directly connected to the electrical grid of the local energy utility company. Here we don't require a battery because all the electricity that is produces by the PV plant is simultaneously used by the loads and when it fails to meet the load requirement the excess is supplied from the grid. A commercial agreement is made for this kind of load exchange.

E. Components for Operation of Grid Connected PV Plant

The components are for plant rated more than 1MW having many inverter for parallel operation in case of fault or maintenance.

The main constitutive components of a grid-connected multi inverter PV plant are the following:

1. PV modules, which collect sun's rays and transform them in DC current.
2. Inverters, which convert the DC waveforms in AC waveforms.
3. Medium Voltage (MV) / Low Voltage (LV) Cabin, which raises the voltage level.
4. High Voltage (HV) / MV cabin which links the PV plant to the electrical grid. This last one is needed only for rated power higher than a prefixed threshold.[4]

F. Losses in PV

These are the probable areas governing the efficiency:

Reflection Losses

The ratings of the panels are decided after testing them perpendicular radiation while when applied in field conditions the incidence angle is more which leads to reflectional losses. These are generally 1% loss.

Soiling

Soiling occurs due to dirt accumulation which reduced the efficiency of the system. Generally the dirt is washed away by heavy rain however the dirt accumulated in the edges and those of the bird dropping remains contributing to losses by 1%.

Miss Match Effects

These losses occurs due to interconnection of solar modules having different condition from one another in series and parallel. This becomes a significant problem as the output of the whole PV array has its Worst case determined by the PV panel giving lowest output. Therefore the selection of PV panels becomes very important for the overall performance of the plant

Maximum Power Point Tracking (MPPT) losses.

This system is responsible to find the angle at which maximum radiation is obtained and keep up the efficiency of the whole system.

Inverter Losses

The efficiency of an inverter has to do with how well it converts the DC voltage into AC. The currently available grid connected inverters have efficiencies of 96 to 98.5%, and hence choosing the correct inverter is crucial to the design process. There are less efficient inverters below 95% also available. Inverters are also much less efficient when used at the low end of their maximum power. Most inverters are most efficient in the 30% to 90% power range. [2]

III. CONCENTRATING SOLAR POWER

In this technology a large area is equipped by mirrors or lenses to concentrate sunlight onto a small section called concentrator where it is converted into heat which is used to drive a heat engine most likely the conventional one which is connected to the generator.

Figure III Basic CSP Plant

A. Types of CSP Plant

CSP plants are classified according to the methods of radiation collectors, they are as follows:

1. Parabolic Trough
2. Solar towers
3. Parabolic Dishes
4. Linear Fresnel Reflectors

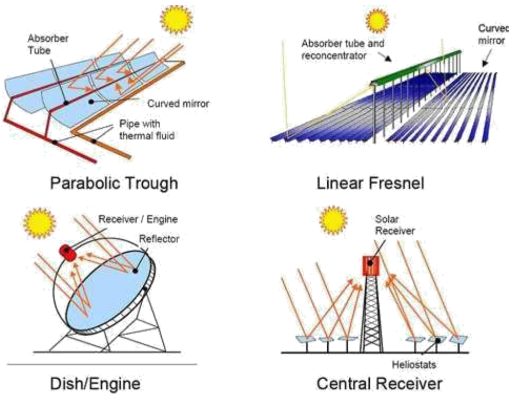

Figure III-A Types of CSP Plant

A. Efficiency of CSP technologies

Amongst all the available technologies LRF is the most popularly used technology where as dish has the highest heating capacity of 750ºC with efficiency of 29.4% but it is yet to be applied.

C. The CSP is constituted by the following main components

1.Collectors.
2.Receivers.
3.Hydraulic circuit that connects the field of reflectors and the storage system.
4.The control system for controlling the temperature of circulating fluid.
5. Pumping systems.
6.Storage system made of tanks with a circular section.
7.Electrical power station equipped with steam turbines (high and low pressure)
8.A steam generator.A condenser with an appropriate cooling system (water or air) and the feed water preheating system.

D. Losses in CSP

Concentration losses

These losses are concerned with the concentrator efficiency. It is the ratio of sunlight that reaches the receiver divided by the sunlight incident on the concentrator. Due to imperfect reflector materials and challenges associated with varying solar elevation the concentrator efficiency drops below unity in real systems. Thus efficient tracking system is needed.

Heat rejection

These losses take place during the heat exchange which depends on the heat transfer fluid. The other losses are soiling losses and heat engine losses and main challenges are faced in heat storage.

Table III-B Technical Comparison of CSP and PV [3]

Characteristics	PV	CSP
Use	Direct and defused sun light	
Size	From watt to MW	10MW to few hundred MW
Installation	Everywhere	
Capacity	700-200 full load hour	2000-7000 full load hour
Reserve capacity	External	operation)
Proofed time	>20 years	>20 years
Annual production	>25000 GWH	>2500 GWH

Table II-B Characteristic of PV Plant [3]

Number of mono-crystalline PV modules	160.000
PV module Efficiency in Standard Test Conditions (STC)	0,17
Losses of the BOS	0,15
Number of 500-kWp inverters	80
Number of MV/LV cabins	8
Number of HV/MV cabins	1
Area needed for 1 MWp	1,5 x 104 m2
Total area	60 x 104 m2
Total electrical rated power	40
MWp Yearly produced energy	56 GWh/year

Table III-C Characteristics of CSP Plant [3]

Number of the collectors	816
Area of each collector	3.317,76 m2
Total collector area	45 x 104 m2
Distance between collectors	11,5 m
Peak power of the solar field	321
Solar field area	90 ha
Temperature of the hot tank	550
Temperature of the cold tank	290
Storage capacity	3.000 MWh
Rated electrical power	40 MWe
Thermo-electrical efficiency in	0,423
rated electrical	
Produced energy for year	168 GWh/year
Load factor	0,48
Mean collector efficiency for year	0,67
(depending on the annual direct	
radiation)	

Table 4 Initial investment of PV[3]

PV plant				
Rated power	40.000	KWe		
	Costs/unit		Units	Total Cost (€)
PV modules	1,20	€/Wp	40.000.000	48.000.000,00
Inverters	151,00	€/kWp	40.000,00	6.040.000,00
Cabin MV/LV	150.000,00	€/cabin	8,00	1.200.000,00
Cabin HV/LV	180.000,00	€/cabin	1,00	180.000,00
Other electrical components	179,00	€/kWp	40.000,00	7.160.000,00
Other (design cost, purchase of the land)	162,00	€/kWp	40.000,00	6.480.000,00
Taxes (in %)				10.00%
Taxes (in €)				6.906.000,00
TOTAL				75.966.000,00
Cost/unit		€/kWe		1.899,15

Table 5 Initial investment of CSP [3]

CSP plant			
Rated power	40.000	KWe	
	Cost/unit		Total Costs (€)
SCA	97,20	€/m²	47.727.968,26
Hot and cold tanks	8,70	€/kWh$_t$	26.100.000,00
Hp and Lp turbines	650,00	€/KWe	26.000.000,00
Steam generator	124,00	€/kWh$_e$	4.960.000,00
Other (design cost, purchase of the land)	270,00	€/kWh$_e$	10.800.000,00
Other thermal and electrical components	248,76	€/kWh$_e$	9.950.538,66
Taxes (in %)			10.00%
Taxes (in €)			12.553.850,69
TOTAL			138.092.357,61
Cost/unit		€/kWe	3.452,31

Table 6 Economic returns for CSP and PV plants [3]

		PV	CSP
Rated power (MW)		40.000	40.000
Equivalent yearly operation hours (h)		1.400	4.200
Yearly produced Energy (MWh)		56.000	168.000
Feed-in Tariff (€/MWh)		240	270
Total Period of feed-in tariff (years)		20	25
Yearly government incentive (€)	(A)	13.440.000	45.360.000
Yearly selling of the produced Energy (€)	(B)	5.040.000	15.120.000
Yearly total incentive	(A+B)	18.480.000	60.480.000

IV. CONCLUSION

This paper compared CSP and PV the most common technique to produce solar energy. However even though solar energy being the clean and efficient technology it is not at its peak of usage because of the high investment cost although government is giving incentives but it still have to be developed in terms of cost efficiency. PV panels are more used compared to CSP technology only because of the high initial investment also it can be made clear that the returns of CSP is quite higher than that of PV.

CSP as a technology is more preferred to connect to the grid compared to PV and long term returns are better. CSP technology has storage capabilities which allows it to generate even when the sun is low but it fails to use the diffused radiation like PV can. Also the land requirement is more in CSP whereas PV is flexible enough to be installed anywhere even for small application. With these two emerging techniques solar power will be the future of power generation.

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