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Optimal Site Selection and Efficiency for Solar PV Power Plant

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ABSTRACT

Solar energy is one form or another is the source of all energy on the earth. Humans, like all other animals and plants, rely on the sun for warmth and food. World widely peoples are also harness the sun's energy in many other different ways. For example, fossil fuels, plant matter from a past geological age, is used for transportation and electricity generation and is essentially just stored solar energy from millions of years ago. Similarly, biomass converts the sun's energy into a fuel, which can then be used for heat, transport or electricity. Wind energy is used for hundreds of years to provide mechanical energy or for transportation, uses air currents that are created by solar heated air and the rotation of the earth. Today wind turbines convert wind power into electricity as well as its traditional uses. Even hydroelectricity is derived from the sun. Hydropower depends on the evaporation of water by the sun, and its subsequent return to the Earth as rain to provide water in dams. Photovoltaics (often abbreviated as PV) is a simple and elegant method of harnessing the sun's energy. PV devices (solar cells) are unique in that they directly convert the incident solar radiation into electricity, with no noise, pollution or moving parts, making them robust, reliable and long lasting as well.

Keywords: *Solar Energy; Photovoltaic, Hydropower; Hydroelectricity.*

1.0 Introduction

Solar energy in one form or another is the source of nearly all energy on the earth. Humans, like all other animals and plants, rely on the sun for warmth and food.

However, people also harness the sun's energy in many other different ways. For example, fossil fuels, plant matter from a past geological age, is used for transportation and electricity generation and is essentially just stored solar energy from millions of years ago. Similarly, biomass converts the sun's energy into a fuel, which can then be used for heat, transport or electricity. Wind energy, used for hundreds of years to provide mechanical energy or for transportation, uses air currents that are created by solar heated air and the rotation of the earth. Today wind turbines convert wind power into electricity as well as its traditional uses. Even hydroelectricity is derived from the sun. Hydropower depends on the evaporation of water by the sun, and its subsequent return to the Earth as rain to provide water in dams. Photovoltaics (often abbreviated as PV) is a simple and elegant method of harnessing the sun's energy. PV devices (solar cells) are unique in that they directly convert the incident solar radiation into electricity, with no noise, pollution or moving parts, making them robust, reliable and long lasting. Solar cells are based on the same principles and materials behind the communications and computer revolutions, and this covers the operation, use and applications of photovoltaic devices and systems.

Solar energy is widely available throughout the world and can contribute to reduced dependence on energy imports. As it entails no fuel price risk or constraints, it also improves security of supply. Solar power enhances energy diversity and hedges against price volatility of fossil fuels, thus stabilizing costs of electricity generation in the long term.

1.1 Solar PV power generation technology

Photovoltaics (PV) is the field of technology and research related to the application of solar cells for energy by converting sun energy (sunlight, including sun ultraviolet radiation) directly into electricity. Due to the growing demand for clean

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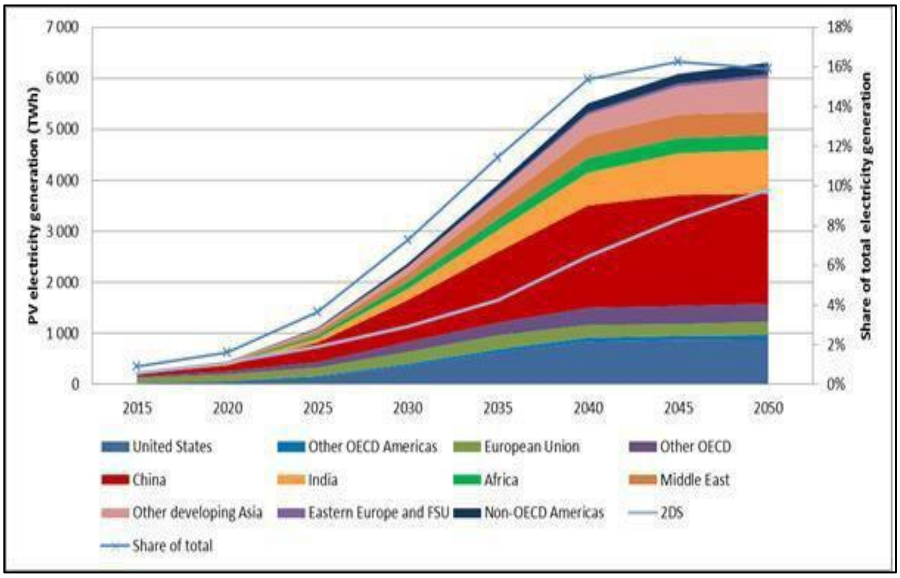
sources of energy, the manufacture of solar cells and photovoltaic arrays has expanded dramatically in recent years. Photovoltaic production has been doubling every 2 years, increasing by an average of 48% each year since 2002, making it the world's fastest-growing energy technology.

At the end of 2008, the cumulative global PV installations reached 15,200 Megawatts. Roughly 90% of this generating capacity consists of grid tied electrical systems. Such installations may be ground-mounted (and sometimes integrated with farming and grazing) or built into the roof or walls of a building, known as Building Integrated Photovoltaic or BIPV for short.

Net metering and financial incentives, such as preferential feed-in tariffs for solar generated electricity; have supported solar PV installations in many countries including Australia, Germany, Israel, Japan, and the United States.

Solar PV entails no greenhouse gas (GHG) emissions during operation and does not emit other pollutants (such as oxides of sulphur and nitrogen); additionally, it consumes no or little water. As local air pollution and extensive use of fresh water for cooling of thermal power plants are becoming serious concerns in hot or dry regions, these benefits of solar PV become increasingly important.

Fig 1: Regional Production of PV Electricity Envisioned in the Roadmap



1.2 Key factors

Since 2010, the world has added more solar photovoltaic (PV) capacity than in the previous four decades. Total global capacity overtook 150 gigawatts (GW) in early 2014 PV system prices have been divided by three in six years in most markets, while module prices have been divided by five

This roadmap envisions PV's share of global electricity reaching 16% by 2050, a significant increase from the 11% goal in the 2010 roadmap

Achieving this roadmap's vision of 4600 GW of installed PV capacity by 2050 would avoid the emission of up to 4 giga tonnes (Gt) of carbon dioxide (CO2) annually

This roadmap assumes that the costs of electricity from PV in different parts of the world will converge as markets develop, with an average cost reduction of 25% by 2020, 45% by 2030, and 65% by 2050, leading to a range of USD 40 to 160/MWh, assuming a cost of capital of 8%

To achieve the vision in this roadmap, the total PV capacity installed each year needs to rise from 36 GW in 2013 to 124 GW per year on average, with a peak of 200 GW per year between 2025 and 2040 The variability of the solar resource is a challenge.

All flexibility options – including interconnections, demand-side response, flexible generation, and storage –need to be developed to meet this challenge

Appropriate regulatory frameworks – and well-designed electricity markets, in particular – will be critical to achieve the vision in this roadmap Levelled cost of electricity from new-built PV systems and generation by sector.

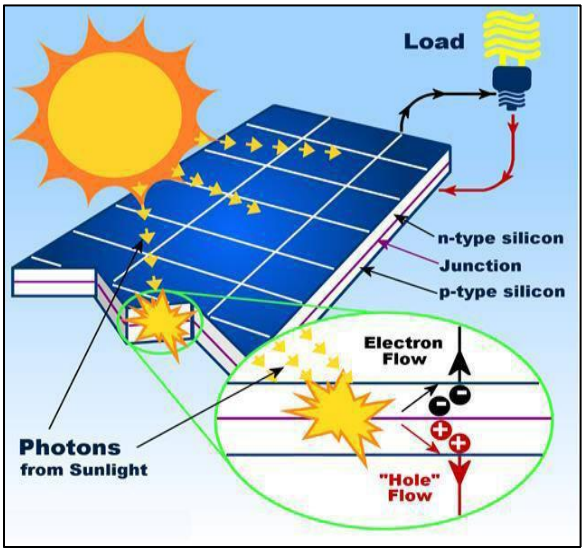
1.3 Solar panels and its types

Solar panel refers to a panel designed to absorb the sun's rays as a source of energy for generating electricity or heating.

A photovoltaic (in short PV) module is a packaged, connected assembly of typically 6×10 solar cells. Solar Photovoltaic panels constitute the solar array of a photovoltaic system that generates and supplies solar electricity in commercial and residential applications. Each module is rated by its DC output power under standard test conditions, and typically ranges from 100 to 365 watts. The efficiency of a module determines the area of a module given the same rated output – an 8% efficient 230watt module will have twice the area of a 16% efficient 230-watt module.

There are a few commercially available solar panels available that exceed 22% efficiency and reportedly also exceeding 24%. A single solar module can produce only a limited amount of power; most installations contain multiple modules. A photovoltaic system typically includes a panel or an array of solar modules, a solar inverter, and sometimes a battery and/or solar tracker and interconnection wiring.

Fig 2: Solar System Model



2.0 Types of Connections

(i) Grid connection

A grid-connected photovoltaic power system or grid-connected PV system is electricity generating solar PV system that is connected to the utility grid. A grid-connected PV system consists of solar panels, one or several inverters, a power conditioning unit and grid connection equipment.

They range from small residential and commercial rooftop systems to large utility-scale solar power stations.

Unlike stand-alone power systems, a grid-connected system rarely includes an integrated battery solution, as they are still very expensive. When conditions are right, the grid-connected PV system supplies the excess power, beyond consumption by the connected load, to the utility grid.

2.1 Advantages of grid connection system

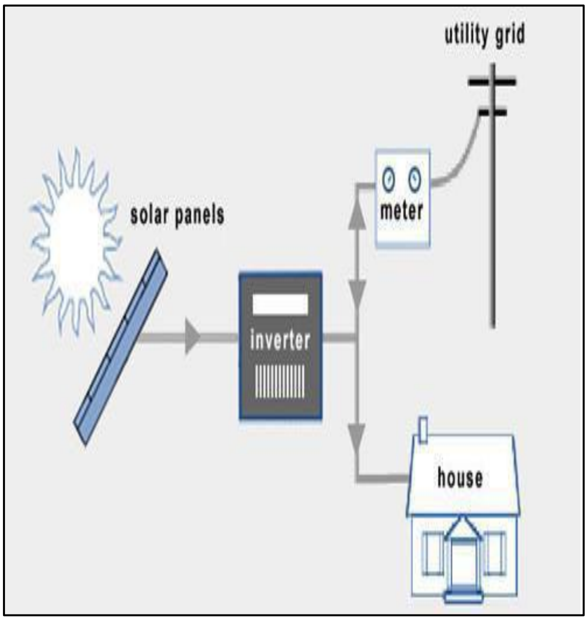
2.1.1 Save more money with net metering

A grid-connection will allow you to save more money with solar panels through better efficiency rates, net metering, plus lower equipment and installation costs:

Batteries, and other stand-alone equipment, are required for a fully functional off-grid solar system and add to costs as well as maintenance. Grid-tied solar systems are therefore generally cheaper and simpler to install.

Your solar panels will often generate more electricity than what you are capable of consuming. With net metering, homeowners can put this excess electricity onto the utility grid instead of storing it themselves with batteries.

Fig 3: Solar Panel Grid Connection Layout



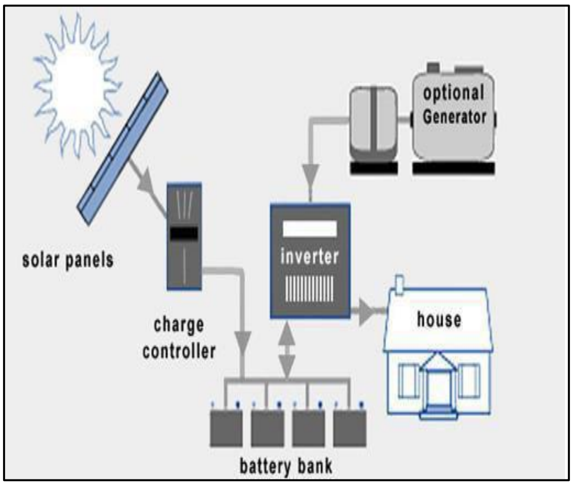
2.2 The utility grid is a virtual battery

Electricity has to be spent in real time. However, it can be temporarily stored as other forms of energy (e.g. chemical energy in batteries). Energy storage typically comes with significant losses. The electric power grid is in many ways also a battery, without the need for maintenance or replacements, and with much better efficiency rates. In other words, more electricity (and more money) goes to waste with conventional battery systems. According to EIA data, national, annual electricity transmission and distribution losses average about 7% of the electricity that is transmitted in the United States. Lead-acid batteries, which are commonly used with solar panels, are only 80-90% efficient at storing energy, and their performance degrades with time. Additional perks of being grid-tied include access to backup power from the utility grid (in case your solar system stops generating electricity for one reason or another). At the same time, you help to mitigate the utility company`s peak load. As a result, the efficiency of our electrical system as a whole goes up.

2.3 Off grid solar system

An off-grid solar system (off-the-grid, standalone) is the obvious alternative to one that is grid-tied. For homeowners that have access to the grid, off-grid solar systems are usually out of question. The reason is To ensure access to electricity at all times, off-grid solar systems require battery storage and a backup generator (if you live off-the-grid). On top of this, a battery bank typically needs to be replaced after 10 years. Batteries are complicated, expensive and decrease overall system efficiency.

Fig 4: Solar Panel Off Grid Connection Layout



2.4 Advantages of off-grid solar systems

2.4.1 No access to the utility grid

Off-grid solar systems can be cheaper than extending power lines in certain remote areas. Consider off-gird if you're more than 100 yards from the grid. The costs of overhead transmission lines range from $174,000 per mile (for rural construction) to $11,000,000 per mile (for urban construction).

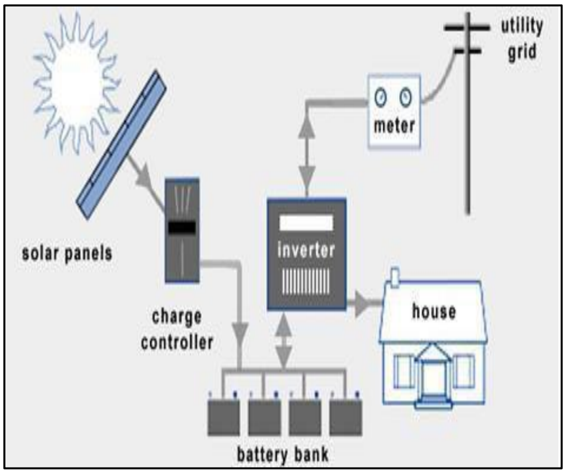
2.4.2 . Become energy self-sufficient

Living off the grid and being self-sufficient feels good. For some people, this feeling feeling is worth more than saving money. Energy self-sufficiency is also a form of security. Power failures on the utility grid do not affect off-grid solar systems. On the flip side, batteries can only store a certain amount of energy, and during cloudy times, being connected to the grid is actually where the security is. You should install a backup generator to be prepared for these kinds of situations.

2.5 Hybrid solar system

Hybrid solar systems combine the best from grid-tied and off-grid solar systems. These systems can either be described as off-grid solar with utility backup power, or grid-tied solar with extra battery storage.

Fig 5: Solar Panel Hybrid Connection Layout



2.6 Advantages of hybrid solar systems

2.6.1 Less expensive than off-gird solar systems

Hybrid solar systems are less expensive than off-grid solar systems. You don`t really need a backup generator, and the capacity of your battery bank can be downsized. Off-peak electricity from the utility company is cheaper than diesel.

2.6.2 Smart solar holds a lot of promise

The introduction of hybrid solar systems has opened up for many interesting innovations. New inverters let homeowners take advantage of changes in the utility electricity rates throughout the day. Solar panels happen to output the most electrical power at noon – not long before the price of electricity peaks. Your home and electrical vehicle can be programmed to consume power during off-peak hours (or from your solar panels). Consequently, you can temporarily store whatever excess electricity your solar panels in batteries, and put it on the utility grid when you are paid the most for every kWh. The concept will become increasingly important as we transition towards the smart grid in the coming years.

3.0 Types of Solar Cells Available

The PV cells are manufactured by hundreds of manufacturers worldwide and there are several different technologies available. There are three main type of commercially available PV cells viz.

1. Mono crystalline silicon PV
2. Polycrystalline silicon PV
3. Thin film amorphous silicon PV

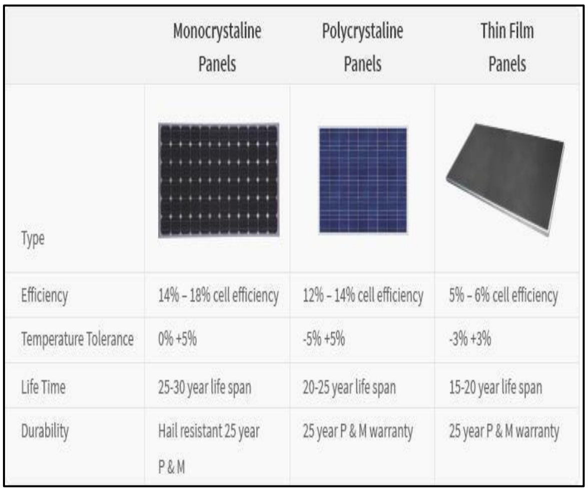
At present the first two categories dominate world markets constituting 93% of it the last one accounts for 4.2% of the market. There are other type of solar cells but are less in use viz. concentrated photovoltaic, hybrid solar cells, multi junction solar cells etc. However, their production is lower because of less usage till now, and thus they are truly not commercial.

The silicon based technologies, crystalline(c)-Silicon, multi-crystalline(mc)-Silicon, amorphous (a)-silicon are the dominant technologies at 18%, 14% and 6% efficiencies at cell levels. The efficiencies at module level are 5-6 % lower due to variety of reasons. Most of the Indian companies are producing at 14-16% efficiencies at cell levels and at about 11-12% at module levels. There is scope of improvement in different technologies. We like to put up state of the art efficient modules. A Thin-Film Solar Cell (TFSC), also called a Thin-Film Photovoltaic Cell (TFPV), is a solar cell that is made by depositing one or more thin layers (thin film) of photovoltaic material on a substrate. The thickness range of such a layer is wide and varies from a few nanometres to tens of micrometres.

Many different photovoltaic materials are deposited with various deposition methods on a variety of substrates. Thin Film Solar Cells are usually categorized according to the photovoltaic material used. The following categories exist:

- Cadmium Telluride (CdTe)
- Copper indium gallium selenide (CIS or CIGS)
- Dye-sensitized solar cell (DSC)
- Organic solar cell
- Amorphous silicon (a-Si)

On an average the efficiency of thin film cells is 5-6% furthermore the thin-film PV market is showing a spectacular annual growth rate of 12.6% in 2007. These thin film solar cells will be suitable for window and facades in Building Integrated PV (BIPV) technologies.



	Monocrystaline Panels	Polycrystaline Panels	Thin Film Panels
Type			
Efficiency	14% – 18% cell efficiency	12% – 14% cell efficiency	5% – 6% cell efficiency
Temperature Tolerance	0% +5%	-5% +5%	-3% +3%
Life Time	25-30 year life span	20-25 year life span	15-20 year life span
Durability	Hail resistant 25 year P & M	25 year P & M warranty	25 year P & M warranty

4.0 Energy Source Technologies

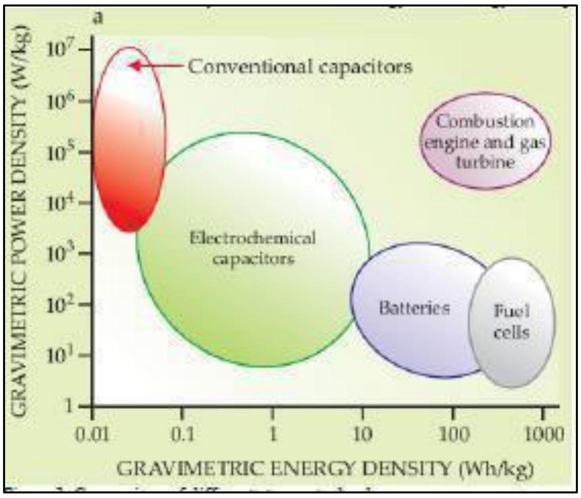
Traditionally, batteries are the storage technology that is considered for backup power. In a battery, the electrical energy is stored using a chemical redox couple whose free energy is increased while the battery is being charged, and the decrease in free energy is used for supplying current during discharge.

The chemical redox couples, which is the fuel for the battery, is usually in the solid form and are enclosed along with an ion conducting electrolyte. The battery life is determined by the number of charge-discharge cycles and the entire unit (redox couple/electrolyte) needs to be replaced after certain number of cycles. In contrast to this approach, it is possible to have electrical storage devices in which the chemical redox couple (i.e. the fuel) are supplied continuously and such devices are called fuel cells (Fig 6). Two central factors that determine the quality of an energy storage device are the power density and the energy density. While these two factors are comparable for batteries and fuel cells, the periodic replacement of the storage unit is not necessary for a fuel cell. Due to this and other factors, there has been a resurgence of interests in fuel cell technology as a potential replacement for batteries, especially when the backup requirement is quite large. Some solar PV farms already have fuel cell technology as the energy back up device Depending on the nature of the fuel and the nature of the ion conducting electrolyte, a variety of fuel cell configuration is possible.

4.1 Proton exchange membrane (PEM)

Fuel cells, also known as Polymer exchange membrane fuel cells typically operate on pure (99.999%) hydrogen fuel. The PEM fuel cell combines the hydrogen fuel with the oxygen from the atmosphere to produce Water, heat (up to 90°C) and electricity.

Fig 6: Comparison of Different Storage Technology



5.0 How it Works

PEM Fuel cells typically utilise platinum based catalyst on the Anode to split the Hydrogen into positive ions (protons) and negative electrons. The ions pass through the membrane to the cathode to combine with oxygen to produce water. The electrons must pass round an external circuit creating a current to re-join the H2 ion on the cathode.

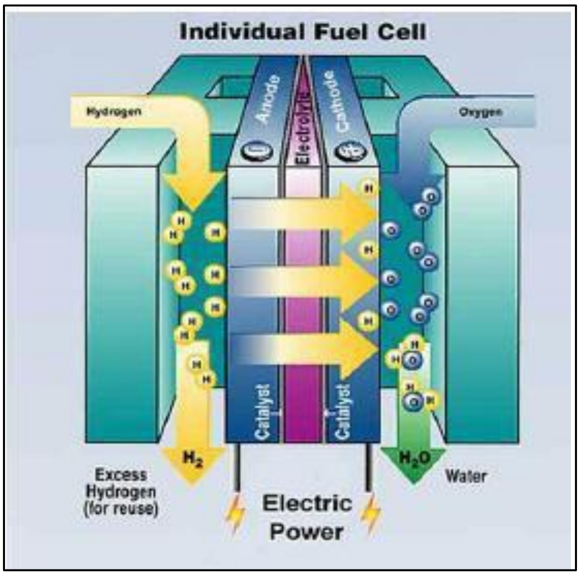
Anode:2H2 »»4H+ +4e-

Cathode:O2 + 4H+ + 4e- »» 2H2O

Each cell produces approximately 1.1 volts, so to reach the required voltage the cells are combined to products stacks. Each cell is divided with bipolar plates which while separating them provide a hydrogen fuel distribution channel, as well as a method of extracting the current.

PEM fuel cells are considered to have the highest energy density of all the fuel cells, and due to the nature of the reaction have the quickest start up time (less than 1 sec) so they have been favoured for applications such as vehicles, portable power and backup power applications.

Fig 7: Working Principle of PEMF



5.1 Optimal Site Selection for Solar PV Power Plant in an Indian State

A criterion is a measurable facet of a judgment, which makes it possible to illustrate and enumerate alternatives in a decision. With the inputs from various works such as, Aran, Adel and Yassine, Alasdair Miller and Ben Lumby, 10 criteria were identified and considered. These include, amount of incident solar radiation, availability of vacant land for its present as well as for its future development, accessibility to site from highways as it affects the transportation cost and thus the initial cost, distance from transmission lines to minimize the losses.

Solar PV panels works efficiently within a range of temperature which is 25oC to 45oC, the degradation of cells happens due to high wind velocity, extreme temperatures, shadow on modules and dusting on arrays, thus variation of local climate is significant criteria for this work. Geotechnical issues like consideration of groundwater resistivity, load bearing properties, soil pH levels and seismic risk are important criteria.

Geotechnical political issues such as Site near to Sensitive military zones and historical places should be avoided. By considering Topography of site, flat or slightly south facing slopes are preferable for projects in the northern hemisphere. Efficiency of plant could be reduced significantly if modules are soiled.

It is, therefore, important to consider local weather, environmental, human and wildlife factors. The criteria should include dust particles from traffic, building activity, agricultural activity or dust storms and module soiling from bird excreta. The criteria are as given in Table 1.

5.2 Identification of GIS software

Software which is used, to create, to manage, to analyze and visualize geographic data, (data with reference to a place on earth) is usually denoted by the umbrella term „GIS software Desktop GIS,

spatial database management system, web map servers, server GIS, web GIS, mobile GIS, software libraries and GIS extensions are some of the types of GIS software.

But the basic requirement for this work is to have one software which can create, edit, and store, mapped, intersect and analyze the data.

Thus, desktop GIS used for this purpose, as it contains GIS viewer, GIS editor, GIS analyst. MapInfo, Autodesk, Bentley systems, Eredas Imagine, ESRI, IGIS, Intergraph, Small world etc. are some of the companies with high market share and providing commercial desktop GIS software's.

Among these software, the ESRI ArcGIS 10 is most suitable because it is highly scalable server architecture. It provides data in both the raster, as well as in vector format and integrates data from multiple sources and serves it on web. ArcGIS 10 is a complete system for designing and managing solutions through the application of geographic knowledge.

ArcGIS 10 has ability to automated the many aspects of cartography, it takes less time as compare to other software for producing any map with better intelligence, therefore ArcGIS 10 is used as software tool in the present work.

Table1: Criteria Considered for Site Selection

S. No.	Criteria
1	Availability of solar radiation
2	Availability of vacant land
3	Accessibility from national highways
4	Distance from existing transmission line
5	Variation in local climate
6	Use of nearby land
7	Topography of site
8	Geotechnical issues
9	Geotechnical political issues
10	Module soiling

5.3 Analysis

The criteria stated in previous section were classified on the basis of their connotation as Analysis criteria and Exclusion criteria. Analysis criteria are those which enhance the suitability of site and have positive connotation and Exclusion criteria are those which restrict the alternatives and have negative connotation as given in Table 2. The maps were generated for the analysis criteria with the help of ESRI ArcGIS 10 software.

The suitable sites obtained from the intersection of all maps. Suitable sites were divided into 3 regions, further exclusion criteria were applied on each region, and the best region for site identified. The detailed discussion of Analysis methodology is taken up in the following sections.

Cartographic maps had been generated with the help of ArcMap 10.0 using public maps. These inputs which were in vector format were converted into raster format and reclassified, in order to get discrete values from 1 to 9. 1 is the best of all. Thus, mapping was completely normalized. The cartographic maps produced are as follows:

Table 2: Classification of Criteria

ANALYSIS CRITERIA	EXCLUSION CRITERIA
Availability of solar radiation	Variation in local climate
Availability of vacant land	Use of nearby land
Accessibility from national highways	Consideration of Geopolitical sites
Distance from existing transmission line	Module soiling

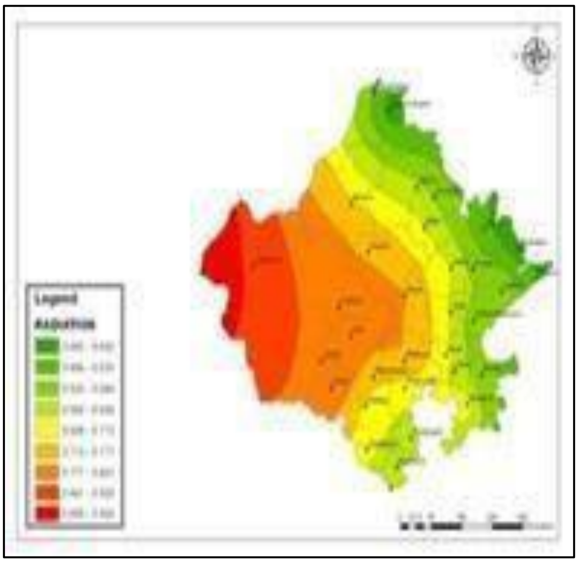
Table 3: Discretization Value

Continuous Value (in kWh/m2/day)	Discretized Value
5.392-5.456	9
5.456-5.520	8
5.520-5.584	7
5.584-5.648	6
5.648-5.713	5
5.713-5.777	4
5.777-5.841	3
5.841-5.905	2
>5.905-5.969	1

5.4 Cartographic map of solarradiation

The data of average annual solar irradiation which is available for 32 districts of Rajasthan has been taken. The discretized value is given in Table 3.

Fig 8: Cartographic Map of Solar Radiation



6.0 Power Plant Efficiency – Utilisation Factor

Power Plant life span can be calculated using Capacity Factor. Plant Capacity Factor is the key factor to estimate costing structure for the whole plant. This gives clarity on the Capacity Factor for the different power plant segments.

To calculate the capacity factor, take the total amount of energy the plant produced during a period of time and divide by the amount of energy the plant would have produced at full capacity.

Capacity factors vary greatly depending on the type of fuel that is used and the design of the plant. The capacity factor should not be confused with the availability factor, capacity credit (firm capacity) or with efficiency.

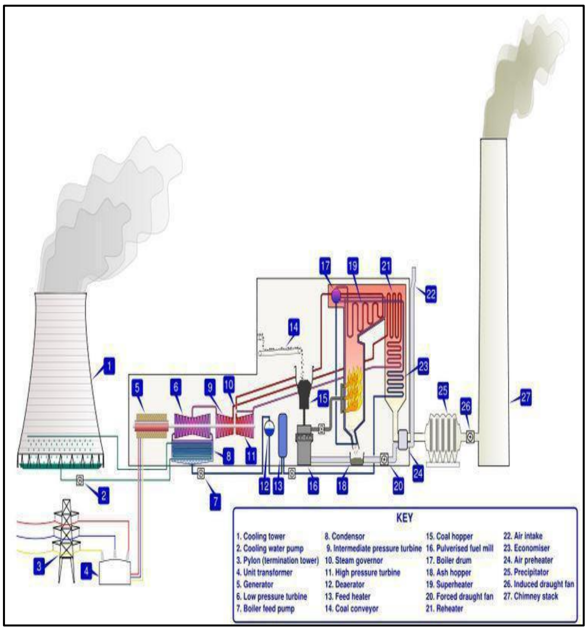
6.1 Conventional power plants

6.1.1 Thermal power plant

Thermal Power Plant Efficiency normally 60 - 65% [i.e. Capacity Factor].

Thermal Power Plant capacity 4000MW [4 x 1000MW Units] produces energy yield as 2,17,24,800 MWh units [As an annual average generation], Now Calculate Plant Capacity Factor?

Fig 12: Block Diagram of Thermal Power Plant



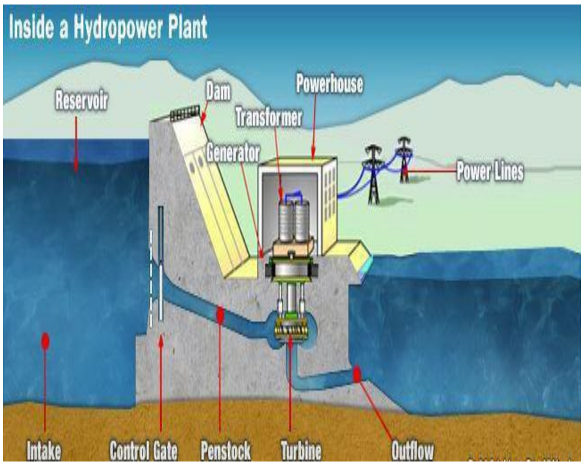
Energy Estimated= Plant Generator Name plate capacity x 24 Hours x 365 Days

For the above Project Capacity Factor, as:

- 2,17,24,800 MW-h
- (4000 MW x 24 Hours x 365 Days)
- 2,17,24,800 MW-h x 100
- 3,50,40,000 MW-h
- Capacity Factor = 62 %.

6.2 Hydro electric power plant

Fig 13: Block Diagram of Hydro Electric Power Plant



Hydro Electric Power Plant Efficiency normally 38 - 50% [i.e. Capacity Factor]. Hydro Electric Power Plant capacity as 200MW [4 x 50MW Units] produces energy yield as 7,00,800 MWh units [As an annual average generation], Now Calculate Plant Capacity Factor? Energy Estimated= (Plant Generator Name plate capacity x 24 Hours x 365 Days) For the above Project Capacity Factor, as: 7,00,800 MW-h=200 MW x 24 Hours x 365 Days

7,00,800 MW-h x 100	
17,52,000 MW-h	
Capacity Factor	= 40 %.

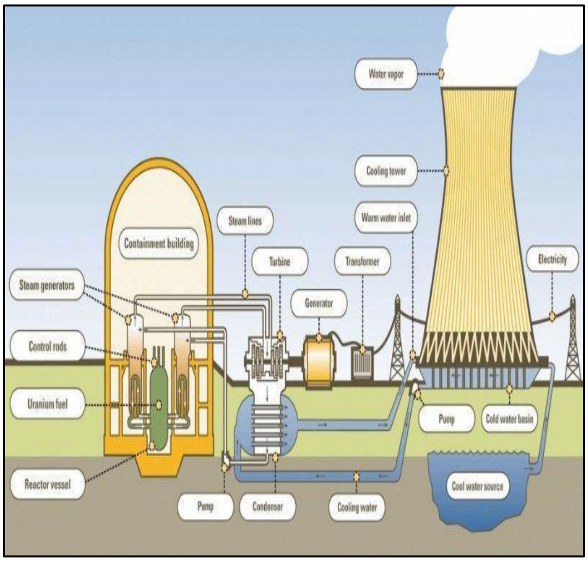
3.0 Nuclear Power Plant

Nuclear Power Plant Efficiency normally 80 - 93% [i.e. Capacity Factor].

Solar PV Power Plant Efficiency normally 13 - 19% [i.e. Capacity Factor].

Solar Power Plant capacity as 4MW produces energy yield as 5326.08 MWh units [As an annual average generation], Now Calculate Plant Capacity Factor?

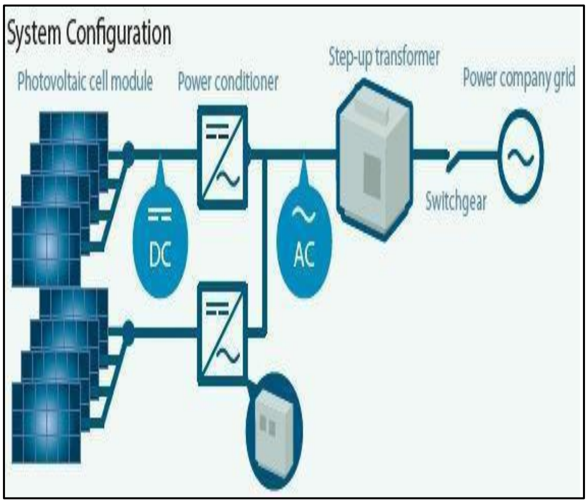
Fig 14: Block Diagram of Nuclear Power Plant



6.3 Non- conventional power plants:

6.3.1 Solar PV plant

Fig 15: Block Diagram of Solar PV Power Plant



Energy Estimated=Plant Generator Name plate capacity x 24 Hours x 365 Days

For the above Project Capacity Factor, as:

5326.08 MW-h=(4 MW x 24 Hours x 365 Days)

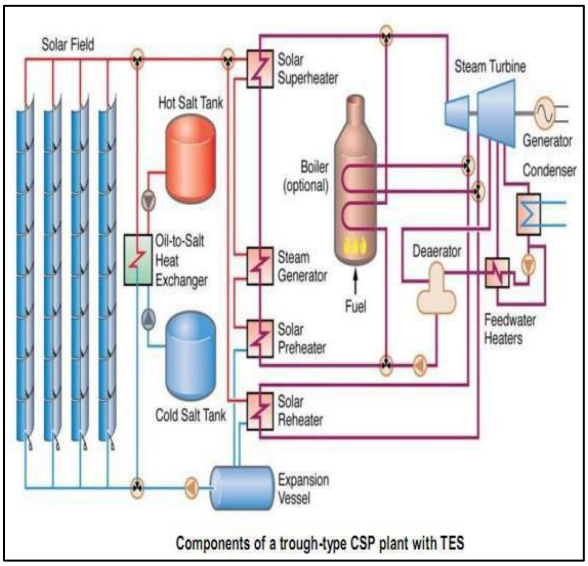
5326.08 MW-h x 100

35,040 MW-h

Capacity Factor = 15.2 %.

6.3.2 Concentrated Solar Power Plant & Solar Thermal Power Plant

Fig 16: Block Diagram of Concentrate Solar Power Plant



Solar Thermal Power Plant Efficiency normally 25 - 35% [i.e. Capacity Factor].

Solar thermal Power Plant capacity as 400MW produces energy yield as 10,51,200 MWh units [As an annual average generation], Now Calculate Plant Capacity Factor?

Energy Estimated=(Plant Generator Name plate capacity x 24 Hours x 365 Days)

For the above Project Capacity Factor, as:

10,51,200 MW-h=400 MW x 24 Hours x 365 Days

10,51,200 MW-h x 100

35,04,000 MW-h

Capacity Factor = 30 %.

6.3 Wind power plant

6.3.1 Wind power plant efficiency normally 20 - 40% [i.e. Capacity Factor].

Wind Farm capacity as 50MW [50 x 1MW] produces energy yield as 1,10,595 MWh units [As an annual average generation], Now Calculate Plant Capacity Factor?

Energy Estimated=(Plant Generator Name plate capacity x 24 Hours x 365 Days)

For the above Project Capacity Factor, as:

1,10,595 MW-h=(50 MW x 24 Hours x 365 Days)

1,10,595 MW-h x 100

4,38,000 MW-h

Capacity Factor = 25.25 %.

6.3.2 Annual solar energy output of a photovoltaic system

The global formula to Aestimate the electricity generated in output of a photovoltaic system is:

E = A * r * H * PR

E = Energy (kWh)

A = Total solar panel Area (m²)

r = solar panel yield or efficiency (%)

H = Annual average solar radiation on tilted panels (shadings not included)

PR = Performance ratio, coefficient for losses (range between 0.5 and 0.9, default value = 0.75)

r is the yield of the solar panel given by the ratio: electrical power (in kWp) of one solar panel divided by the area of one panel.

The solar panel yield of a PV module of 250 Wp with an area of 1.6 m² is 15.6%.

Be aware that this nominal ratio is given for standard test conditions (STC): radiation=1000 W/m², cell temperature=25 °C, Wind speed=1 m/s, AM=1.5. The unit of the nominal power of the photovoltaic panel in these conditions is called "Watt-peak" (Wp or kWp=1000 Wp or MWp=1000000 Wp).

H is the annual average solar radiation on tilted panels. Between 200 kWh/m² y (Norway) and 2600 kWh/m² y (Saudi Arabia).

PR: PR (Performance Ratio) is a very important value to evaluate the quality of a photovoltaic installation because it gives the performance of the installation independently of the orientation, inclination of the panel.

It includes all losses.

Example of detailed losses that gives the PR value (depend on the site, the technology, and sizing of the system):

- Inverter losses (4% to 10 %)
- Temperature losses (5% to 18%)
- DC cables losses (1 to 3 %)
- AC cables losses (1 to 3 %)
- Shadings 0 % to 80% !!! (specific to each site)
- Losses at weak radiation 3% to 7%
- Losses due to dust, snow... (2%)

7.0 Environmental Protection Planes

Before implementation of any new technology, we need to look at its impact on environment. In case of Solar PV Technology, we need to worry about impact on environment during production, installation and disposal of PV panels.

Since our solar sub-station does not involve production of PV panels, our primary concern is environmental impact during installation and disposal. There is no issue of air or water pollution during installation and operation. We will develop the mechanism of disposal of PV panels after their (15-20 years) in the project. Additional concerns are from energy storage technologies and some mechanisms will be developed for their safe disposal as well.

8.0 Conclusions

]The main task was to verify and understand the optimal site selection and efficiency for photovoltaic system of solar laboratory and find the utilization possibilities of this system. Solar cells are based on the same principles and materials behind the communications and computer revolutions, and this covers the operation, use and applications of photovoltaic devices and systems.

References

[1] Solar Energy Perspectives: Executive Summary. International Energy Agency. 2011.

[2] Powering the Planet: Chemical challenges in solar energy utilization. August 2008.

[3] Darmstadt University of Technology solar decathlon home design. Darmstadt University of Technology, 2007.

[4] Werner Weiss, Irene Bergmann, Gerhard Feininger Solar Heat Worldwide, edition 2008

[5] Markets and Contribution to the Energy Supply 2006

[6] International Energy Agency Solar Heating & Cooling Programme, May 2008.

[7] The World Solar Challenge - The Background. Australian and New Zealand Solar Energy Society.19 July 2008.

[8] North American Solar Challenge. New Resources Group.3 July 2008.

[9] South African Solar Challenge. Advanced Energy Foundation. Archived from the original on 12 June 2008

[10] Photovoltaic System Pricing Trends – Historical, Recent, and Near-Term Projections, 2014 Edition

[11] Shockley, William; Queisser, Hans J. (1961). Detailed Balance Limit of Efficiency of p-n Junction Solar Cells

[12] Guidelines for Generation Based Incentive Grid Interactive Solar PV

[13] Power Generation Projects by MNRE guidelines for plant to come after Dec. 2009.

[14] http://mnre.gov.in/pdf/guidelines_spg.pdf

[15] Solar Cell Research, The Prashant Kamat lab at the University of Notre Dame

[16] Energy Sources: Solar. Department of Energy.19 April 2011.

[17] An Assessment of Solar Energy Conversion Technologies and Research Opportunities. July 2008.

[18] Hybrid Wind and Solar Electric Systems. United States Department of Energy. 2 July 2012.

[19] Solar: photovoltaic: Lighting Up the World 19 May 2009

[20] Solar: photovoltaic: Lighting Up the World 19 May 2009

[21] Running Out of Precious Land? Floating Solar PV Systems May Be a Solution. EnergyWorld.com. 7 November 2013.

[22] The Combined Power Plant: the first stage in providing 100% power from renewable energy. Solar Server. January 2008.

[23] Editorial (19 October 2007). Solar power edges towards boom time.

[24] Life Cycle Greenhouse Gas Emissions of Crystalline Silicon Photovoltaic Electricity Generation: Systematic Review and Harmonization, 2011.

[25] Data and sources in articles Growth of photovoltaics and Concentrated solar power #Deployment around the world.

[26] PV Systems and Net Metering. Department of Energy. July 2008

[27] Levelized Cost and Levelized Avoided Cost of New Generation Resources in the Annual Energy Outlook 2014

[28] BP Statistical Review of World Energy June 2015, Renewables section, June 2015.

[29] The Solar Energy Book-Once More. Mother Earth News, Jan. 1975