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Design and Feasibility Studies of Solar Photovoltaic Power Plant at Jodhpur City

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ABSTRACT

The increasing demand for fossil fuels in the world facing acute shortage of these conventional energy sources. Along with this the developing giants like India and china requires intensive amount of energy for their development. In present scenario solar energy is viable alternative to the conventional energy sources. Intermittent supply of energy from standalone solar photovoltaic and wind power plant cannot satisfy the continuous demand of energy, however grid connected solar energy systems can eliminate the spasmodic supply of energy. Objective of present study is to design 5MW solar photovoltaic power plant and to estimate the potential of grid connected energy systems at Jodhpur city. To perform the technical feasibility an annual energy generation, capacity factor, number of PV modules, inverter sizing, transformer sizing, and land requirement of proposed grid connected solar PV power plant is calculated.

Keywords— Grid connected, Solar Photovoltaic, Techno economic, and Jodhpur.

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I. INTRODUCTION

The rapid depletion of fossil fuels has necessitated the search of renewable energy sources. The current energy scenario clarifies that energy generated by renewables in 2015 is 72,491MW as compared to the 27,897MW in 2002.The motive for the present work based on JNNSM whose objective is generating 20,000MW of grid connected solar power by 2022 in India. The renewable power generating systems are more reliable and environmentally clean. There are three imperatives that necessitate a transition to a sustainable energy system in the 21st century, they are Climate change and its potentially disastrous consequences,Peaking of production, depletion and extinction of fossil fuels and Energy Autonomy and Independence.

Due to this the solar photovoltaic is capturing the market in India. Every year the number of solar PV installations are increasing in Rajasthan. The 5MW solar photovoltaic power plant will be at bhawanising nagar (122.88 acres govt. land available) in tehsil of osian in district of Jodhpur. The IIT Jodhpur spread across more than 800 acres of land is the nearest place to it will require energy. Also demand of nearby villages will also be satisfied.

There is huge solar radiation potential in Rajasthan almost to 5.5 kwh/m^2 to 7 kwh/ m^2. The amount of radiation available makes it the second largest PV energy generation in India.The radiation level for India is shown in fig. 1 Indian solar resource map by NREL.

Allen M. Barnett [1] presented a paper about solar electrical power for a better tomorrow. The promise of solar electricity based on the photovoltaic (PV) effect is well known. Why don't we see these systems all over the world? Consumers in the United States are well-known for their attraction to new technology. Why aren't PV systems appearing on roof-tops in the U.S.? The answer may be that grid-connected roof top systems are Too difficult to acquire, Too difficult to integrate with the grid, Too difficult to measure the energy and Too expensive. It is essential that we make PV systems user friendly, while reducing the component and system costs. Our elegant technology must be reduced to practical systems that can be used by the average person - everywhere.

The techno-economic study of solar photovoltaic plant has been done for the Industrial garment zone at Jaipur city of 2.5 MW capacity. While looking at the cost competitiveness both On site and off site options are considered. The technical design include total 22,230 number of PV modules, 7 inverters, and battery bank size capturing total land of 13.11acres. In the economic part, the levelised cost of electricity of the plant is determined as Rs. 14.74/kwh and Rs. 11.40/kwh for onsite and offsite PV plants respectively. Also simple payback period, net present value, internal rate of return are also calculated [2].

Governments subsidize the deployment of solar photovoltaic (PV) because PV is deployed for societal purposes. About seven thousand megawatts were deployed in 2009 and over 10,000 are expected in 2010. Yet this is too slow to strongly affect energy and environmental challenges. Faster societal deployment is slowed because PV is perceived to be too costly. Classic economic evaluations would put PV electricity in the range of 15–50 c/kWh, depending on local sunlight and system size. But PV has an unusual, overlookedvalue: systems can last for a very long time with almost no operating costs, much like, e.g., the Hoover Dam.
This long life is rarely taken into account. The private sector cannot use it because far-future cash flow does not add to asset value. But we should not be evaluating PV by business metrics. Governments already make up the difference in return on investment needed to deploy PV. PV deployment is government infrastructure development or direct purchases. Thus the question is: Does the usually unevaluated aspect of long life at predictably low operating costs further motivate governments to deploy more PV, sooner [3]

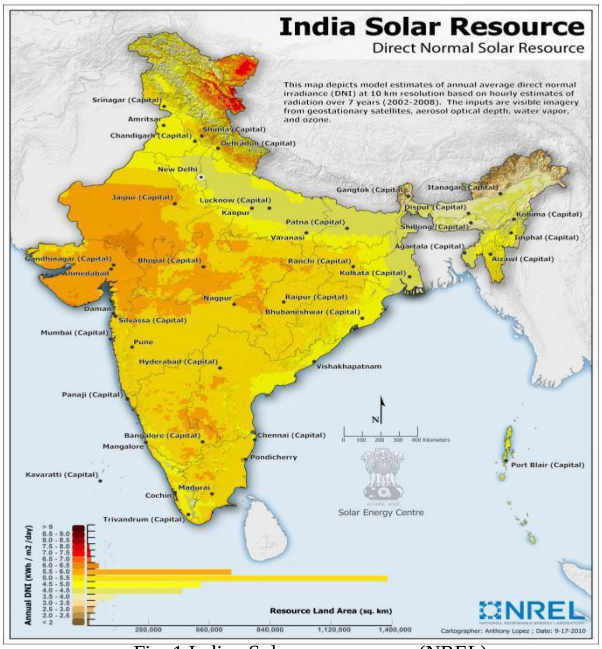

Fig. 1 Indian Solar resource map (NREL)

Phil Bolduc et. al. [4] presented a paper about performance of a grid –connected PV system with energy storage. One kilowatt amorphous photovoltaic system has been operated in a grid-connected mode with energy storage. The purpose of the system development and performance experiment is to investigate the additional value a grid connected system garners with dispatchable battery energy storage. These values are then weighed against the added cost of the system and inefficiencies incurred in the charging and discharging of the battery.

N. Jenkins [5] presented a paper about Photovoltaic systems for small-scale remote power supplies. In his article, he considers the technical aspects of using photovoltaic systems for small power supplies where a connection from a main electricity distribution network is not appropriate. The technology of the various components of a photovoltaic system is discussed and the overall system design considered. Typical applications of photovoltaic systems are described.

R. S. Gupta et. al. [6] presented a paper about Design, Development and Installation of 100 kW utility grid connected solar PV plants for rural application- an Indianexperience. This paper briefly describes tile features of the two power plants, the developmental approach adopted based on "Building Block Philosophy" With 25 KW System as the basic unit with the attendant advantages. It includes the indigenous design and development effort made for grid connected operation and most importantly the special design features incorporated to ensure a very high degree of safety and protection so necessary in the rural areas with predominantly non-literate users.

Masakazu Ito et. al. [7] presented paper about the cost analysis of very large scale PV system on the world desert. a 100 MW very large scale photovoltaic power generation (VLS-PV) system was estimated assuming that it is installed on the would deserts, which are Sahara, Negev, Thar, Sonora, Great Sandy and Gobi desert. PV array was dimensioned in detail in terms of array layout, support,foundation, wiring and so on. Then generation Cost of the system was estimated based on the methodology of Life-Cycle Cost (LCC). As a result of the estimation, the generation cost was calculated.

The environmental impact and total system costs have been investigated for roof-top and ground-based crystalline silicon PV systems by using environmental and cost life cycle assessment. Greenhouse gas emissions and other environmental impacts from Balance-Of-System components are relatively small, in comparison with those of the total PV system. In-roof systems have lower impact due to credit from avoided roof tiles. With proper design of the mounting structure ground-based systems can have low impacts as well.

Although large ground-based systems use larger weights of mounting structure than small roof-top systems and occupy land, they have lower prices than small-scale roof-top systems due to efficient installation and bulk purchasing.[8]

The Indian textile industry is facing shortage of energy since a long time. The main thing is that how one should conserve energy in increasing energy cost scenario. Also modernization of machineries will save energy but eventually it will increase the cost. The other power generation sources are dependent on availability. Therefore the option for renewable energy source taking prime importance, which will satisfy the energy requirement of industries [9]

Various research and many papers have been formed all over the world to evaluate the feasibility criteria and actual performance of various solar photovoltaic power plants. Solar Photovoltaic is the perfect solution to convert non-conventional energy into electricity. It is the most appropriate alternative to the todays energy demanding scenario as well as for future. That is the reason the number of PV plant are increasing year by year. The increasing number of solar photovoltaic power plants in the world states the potential of the source.

In the present current study solar photovoltaic plant design and its feasibility has been carried out, considering the solar radiation energy available at Jodhpur. The government land available at bhawanising nagar of 122 acres will be used for the project.

II. DESIGN OF SOLAR PHOTOVOLTAIC POWER PLANT

The maximum energy requirement is considered 7863 MWh in Jodhpur region of Rajasthan. The energy can beutilized for different institutes, residential as well as commercial places. The complete design will involve Number of PV modules required, Energy required from modules, Total watt peak rating for PV modules, Inverter sizing, Transformer sizing, and land required.

A. Panel Generation factor

Panel Generation factor is the important parameter to decide the size of solar PV cells. It depends upon the climatic conditions available at a particular place. It depends upon solar radiation, sunshine hours of a particular site. [11]

B. Energy required from PV modules

Energy required from PV modules can be determined from peak energy requirement. The peak energy requirement will be multiplied 1.3 (this is the energy lost in the system) to get the total kwh. This amount of energy must be provided by panels.

Peak energy requirement = 7863 MWh / year
Peak energy requirement = 655.25 MWh/ month

= 655250 KWh/ month
= 21841.67 KWh/ day

Energy lost in the system = 30% [11]

Energy required from PV modules = 1.3 × 21841.67 = 28,394.17 KWh/day

C. Total Watt peak rating for PV modules

It is calculated by using the panel generation factor and energy required from PV modules.

Total watt peak rating for PV modules =

Total watt peak rating for PV modules =

D. Photovoltaic Modules

The photovoltaic modules are selected by their efficiency, size, cost. In this power plant SANYO HIT-235S (Hetero-junction with Intrinsic thin layer) PV modules are selected. The cells of this module are made of a thin mono crystalline silicon wafer. This is surrounded by a layer of ultra-thin amorphous silicon.[11]

E. Number of PV modules required

The total number of PV modules are determined by individual PV module maximum output and total watt peak rating.

Number of PV modules required =

Number of PV modules required =

F. Sizing of Inverter

The complete size of the plant is 5 MW therefore the inverter must be large enough to handle the load of the plant. The inverter size should be 25-30% larger than total wattage of plant.
Inverter size = 5 MW × 1.3 = 6.5 MW

Apollo (GTC 500) Inverter of500 KW capacity is considered for the power plant which has inbuilt maximum power point tracking (MPPT) system. [10]

Input characteristics - 550 KWp, 780V
Output characteristics - 500 KW, 400 V, 50Hz

Size & weight - (2440×2640×3600) mm, 5000 Kg.
Number of Inverters required = Inverter size/rating of an Inverter = 13

G. Transformer sizing

G. Transformer sizing

For connecting with the grid, step up transformers is used. The size of the transformer is usually same as that of the output of inverter.

The ABB transformer is chosen which is three phase, grid connected and the required total size of transformers is 6.5 MVA.

H. PV Modules circuit

Maximum open circuit voltage = 780 V_{dc}
Open circuit voltage (V_{oc}) of each PV Mod.= 51.8 V_{dc}
Numbers of modules to be connected in series = 15.05-

16 Maximum power voltage (V_{mp}) of each PV mod=
43 V_{dc} Maximum power voltage (V_{mp}) at inverter input
= 16*43

= 688
V_{dc} Total number of PV arrays to be used for producing
688
V_{dc} =19714/16 = 1233 arrays

Table 1 Characteristics of a SANYO HIT 235S PV module

S. No.	Parameter	units	Values
1	Maximum power (Pmax)	W	235
2	Maximum power voltage (Vpm)	V	43
3	Maximum power current (Ipm)	A	5.48
4	Open circuit voltage (Voc)	V	51.8
5	Short circuit current (Isc)	A	5.84
6	CEC PTC Rating	W	218.7
7	Output power tolerance	%	0%-10%
8	Maximum system voltage	Vdc	600
9	Temperature coefficient of Pmax	%/°C	-0.30%
10	Temperature coefficient of Voc	V/°C	-0.124%
11	Temperature coefficient of Isc	mA/°C	1.75
12	Size of PV module	mm	1580*798*35
13	Module Efficiency	%	18.6

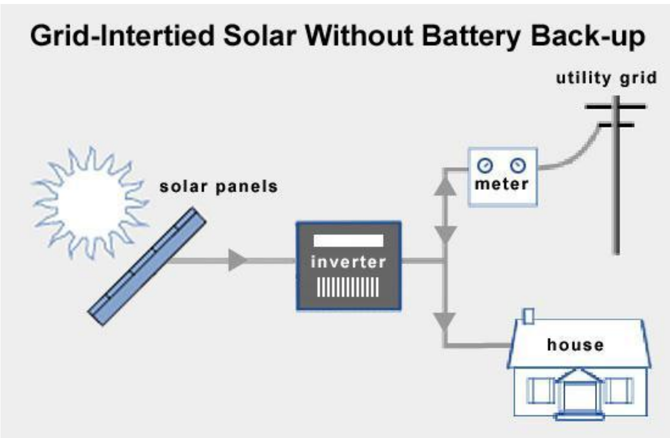

Fig. 2 Solar photovoltaic power plant

I. Land required

Number of PV module required = 19,714
Dimension of one PV module = 1.58m × 0.798m

Number of modules in an array connected in series = 16 Total width of each PV array = 16 × 0.798 = 12.77m Length of one PV module = 1.58m

Number of arrays in PV field = 1233 Number of arrays in a row = 16

Width of the solar field = 16 × 12.77 = 205m Number of rows in solar field = 77
Pitch distance between two arrays = 3m

Length of the solar field = 77 × 3 + 1.58 = 232.58m
Land required for PV field = 205 × 232.58 = 47678.9 m^2

= 11.78 acres (1 acre = 4047 m^2)

III. PROJECT COST

A. Module and Inverter cost

Cost of each PV module = \$590 = 37768 Rs [11]

Total cost of 19,714 modules used for 5 MW = \$11,631,260 = 744.40 Million INR

Cost of each Inverter of 500 KW capacity= 5.75 Mil. INR Total cost of 13 Inverters = 74.75 Million INR [10]

Cost of each transformer of 1250 KVA capacity = 0.832 Million INR

Total cost of 5 Inverters = 4.16 Million INR

B. Design engineering and management cost

Labour cost for design, engineering and project management = Rs. 200 / Man-hour

Design, engineering and project management hours per kw = 2 hours [12]

Total design, engineering and project management cost for 5MW = 2 million INR

Table 2 Project cost of PV Power plant of 5 MW capacity

Sr. No.	Particular for PV power plant	Million INR
1	Module cost	744.40
2	Array structure	20.50

3	Electrical items	34.00
4	Inverters	74.75
5	Transformer	4.16
6	Design, Engg, & P.M. cost	2.00
7	Total labour cost for Installation	3.00
8	Installation hardware- civil,shade,fencing	5.00
9	Packing and Freight	0.50
	Total cost of the plant	888.31

C. Installation labour cost

Labour cost for installation = Rs. 50/man-hour
Installation man hour required per kw = 12 hours

Total Labour cost for installation of 5MW PV power plant = 3 Million INR

D. Operation and Maintenance cost

Fixed O and M cost= 5.48 Million INR/ MWh [13]
Variable O and M cost = 4.95Million INR/ MWh [13]

E. Levelised cost of energy

Levelised cost of electricity is mostly used for evaluating the cost of energy delivered by the projects for different technologies. It used to determine the most cost effective energy source. It is the average cost consumer has to pay to the investor for capital cost, maintenance cost, fuel cost of the plant considering rate of return.

F. Capacity factor

Capacity factor is the main economical parameter of the solar photovoltaic power plant. Most of the cost parameters are fixed in nature in solar PV power plant. [14] Capacity factor is CF = {Annual KW hours generated for each kw AC peak capacity (kwh/kwp)} / {8760 h in ayear}

Energy required to be generated from the plant = 21,841.67 KWh/day

Annual energy to be generated from the plan=21,841.67 × 365 = 7.97×10^6 KWh

Peak capacity requirement of the PV plant = 5×10^3 KWp CF = $\{7.97\times 10^6 / 5 \times 10^3\}/\{8760\}$ = 18.20%

IV. COMPUTATIONAL WORK

The design study has been carried out to assess the technical feasibility and economic viability of a 5 MW capacity solar photovoltaic power plant for meeting the energy demand of industrial, commercial, institute of Jodhpur. For this power generation total 19,714 PV modules are required with 16 modules in each row. Thirteen inverters with MPPT controller of 6.5 MW capacity and transformers are required to supply the power to the grid and the total land area required is 11.78 acres. All the power generated is supplied to the grid simultaneously and a centralized inverter is used with a step-up transformer.

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