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Techno-economic analysis of solar photovoltaic power plant for garment zone of Jaipur city

Mevin Chandel, G.D. Agrawal, Sanjay Mathur, Anuj Mathur*

Centre for Energy and Environment, Malaviya National Institute of Technology, Jaipur 302017, India

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ABSTRACT

In this paper, the potential and the cost-effectiveness of a solar photovoltaic power plant for meeting the energy demand of garment zone at Jaipur (India) is analyzed. Also, the energy demand of garment zone for year 2011has been estimated (2.21 MW) and the design of the solar PV power plant of 2.5 MW capacity has been proposed, which requires about 13.14 acres of land area. Looking at the scarcity and cost of the land near the city, an off-site proposal for the power plant has also been considered and compared with the on-site option. For the on-site solar PV power plant internal rate of return (IRR) is 11.88%, NPV @ 10% discount rate is 119.52 million INR, simple payback period is 7.73 years and discounted payback period @10% is 15.53 years, while for the off-site power plant IRR is 15.10%, NPV is 249.78 million INR, simple payback period is 6.29 years and discounted payback period is 10.14 years. Levelized cost of energy is Rs. 14.94 and Rs. 11.40 per kW h for on-site and off-site solar PV plants respectively @ 10% discount rate, which is quite attractive.

1. Introduction

Garment zone of Sitapura industrial area comprises of 44 industries and the main product of the zone is cotton cloth. These industries use sewing machines, interlocking machines, hydro machines, washing machines and drier machines, which utilize electricity while power presses consume steam. Electricity is also needed for lighting gadgets, fans and air conditioners. Here electricity is outsourced from the state electricity grid and steam is produced locally by diesel fired boilers. Industries also have diesel generators as a standby power supply source.

The average energy demand of the garment zone was 1.84 MW_e in 2011 and it varied monthly. These days getting a continuous and uninterrupted supply of energy has become the largest problem for industries, especially for the garment sector, where production gets affected by frequent power cuts. The backup diesel generators have a very high operation cost and are not a clean source of energy either. So there is great need for a sustainable and clean source of energy; solar energy is the largest available carbon-neutral renewable energy source which can meet the energy demand of garment zone.

A 5 MW SPV power plant was designed [1] for 50 cities of Iran, using RETScreen software and the highest capacity factor was found at Bushehr and lower at Anzali, i.e. 26.1% and 16.5% respectively with a mean capacity factor of 22.27%. A computer program was designed [2] for quick evaluation and optimization of fuel saving, battery lifetime, investment costs, and the total annual cost of the project for a 35 kW hybrid PV–diesel power plant along with the feasibility study under climatic conditions of southern Algeria.

* Corresponding author.
E-mail addresses: anujmathur89@yahoo.com, anujmathur15@gmail.com (A. Mathur).

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A viability analysis [3] of a 10 MW PV-grid connected power plant taking 29 metrological sites in Egypt was carried out. Renewable energy production and capacity factor was found to be minimum at Safaga and maximum at Wahat Kharga, i.e. 24.202 GW h/year, 27.6% and 29.493 GW h/year, 33.7%, respectively. Another viability analysis was conducted [4] to find the option of PV power plant in the Gulf Corporation Council (GCC) countries and study showed that the at present PV technology is not a cost-effective option for the GCC countries because of existing lower electricity tariff, higher PV system cost and lower system efficiency. A solar power plant situated in the Kingdom of Bahrain [5] produced 12 MW (32 kW per day) from PV panels installed at the windows and roofs of two buildings along with annual CO_2 reduction of 48,000 t and revenue generation of €4,800,000 annually.

Studies [6] were conducted in Serbia to find out possibilities of generating electrical energy through 1 MW PV power plants by taking different types of solar PV modules available and it was concluded that higher electricity is generated using CdTe solar modules. Researchers [5,6] developed a computer software tool which integrates different types of PV power plants parameters into a single system to verify/compare the performance and dynamic behavior of other researchers' experimental, theoretical and simulation work for PV power plants.

In one study [9] a modular approach was adopted to meet the energy demand of six major cities in India up to year 2025 and solar PV electricity was suggested as the viable solution for meeting future energy demands. Other studies [10,11] also found solar PV system as a reliable substitute to be considered in the Indian process industries, particularly in the garment industry.

Several papers and research have been performed globally in order to evaluate the feasibility and performance of different SPV power plants and it can be concluded that the PV power plant is a viable and feasible option to meet the power requirement at present and in the future. The importance of PV plants is going to increase with the rising electricity tariffs.

In this paper a 2.5 MW on-site and off-site solar photovoltaic power plant was designed along with the land requirement and economic analysis for the garment zone of industrial area, Jaipur. The solar PV power plant has capacity to generate 10.03 GW h electricity in the first year of operation at 35.23% capacity factor for meeting the energy demand of the sector.

2. Energy demand of garment zone

A questionnaire based survey was conducted from July to September, 2011 for energy demand estimation in garment zone of Sitapura industrial area, Jaipur. After the primary survey the questionnaire was modified and used. The questionnaire comprised of the monthly energy demand in terms of heat and power for each individual industry, number of different type of machines, their energy consumption and duration of operation, etc. The estimated average monthly energy requirement for 44 industries is summarized in Table 1 for the seven months of on-season (January–April and October–December) and five months of off-season (May–September) along with the monthly demand on annual basis.

3. Design of solar photovoltaic power plant

The estimated peak power requirement of the zone was 2.21 MW in the month of February 2011 and considering the expected increase in the future, a 2.5 MW solar PV power plant is considered for the garments zone. Design of solar photovoltaic power plant (Fig. 2) consists of PV module sizing, inverter sizing, battery sizing and module circuit design. The design methodology and technical specifications of the PV power plant are discussed in this section.

3.1. Panel generation factor

Panel generation factor (PGF) is a key element in the size determination of solar photovoltaic cells on the basis of total watt peak rating and then for estimating the number of panels required for a particular SPV plant, which varies with the solar intensity and sunshine period of the site. [12]

$$\text{Panel generation factor} = \frac{\text{Solar irradiance} \times \text{sunshine hours}}{\text{Standard test conditions irradiance}} = \frac{617 \times 9.32}{1000} = 5.75$$

Table 1
Monthly average electricity requirement of the industries.

Average on-season demand (kW h/month)	Average off-season demand (kW h/month)	Average annual demand (kW h/month)
634,175.07	439,643.5	553,120.3