engineering proceedings

Proceeding Paper

Technical and Economic Evaluation of a 50 MW Solar Power Plant in Quetta †

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† Presented at the 7th International Electrical Engineering Conference, Karachi, Pakistan, 25–26 March 2022.

Abstract: Pakistan is a developing country that is facing its worst energy crisis in two decades. In recent years, the gap between demand and supply has multiplied. With increasing demand, this situation has triggered a complete power shutdown in urban areas for 10–12 h and rural areas for 16–18 h. The prime objective of this study is to evaluate the techno-economic feasibility of a 50 MW solar farm in Quetta, Pakistan. Solar radiation data are collected from radiation devices, i.e., a tier two weather station with a rotating shadow band irradiometer. The devices collected data every 10 min. The data were gathered for one year, and a techno-economic evaluation of the information has been carried out. For the proposed plant's economic feasibility evaluation, the levelized cost of electricity (LCOE) model is used and estimates that the energy produced by the proposed power plant will cost 6 Pkr/kWh. Technical evaluation of the power plant reveals that 91.980 GWh of electricity can be produced per year at the capital cost of 59.689 million USD, with an O and M cost of 0.9 million USD/year and a 10.5498 discount rate (%). An economic evaluation of the proposed PV plant produces electricity at 0.0385 USD/kWh. The results of this study depict that a 50 MW PV plant will be feasible for Quetta.

Keywords: economic feasibility; photovoltaic; solar radiation

Citation: Khan, G.; Hassan, M.; Anwar, M.; Waqas, A.; Shakir, S.; Sajid, J. Technical and Economic Evaluation of a 50 MW Solar Power Plant in Quetta. *Eng. Proc.* **2022**, *20*, 46. https://doi.org/10.3390/engproc2022020046

Academic Editor: Saad Ahmed Qazi

Published: 16 September 2022

1. Introduction

The growth of modern economies is characterized by the availability of energy, mainly electricity. In today's world, in order to carry out activities, the flow of electricity is mandatory because every device is chargeable and needs electricity [1]. The total maximum demand from residential and industrial property is almost 25,001 MW, and the transmission and distribution capacity is about 22,001 MW. The demand peaks lead to a shortage of approximately 3000 MW. This additional 3000 MW is not necessary, even though the country's high demand is far below its installed capacity of 37,402 MW [2].

Baluchistan has been deprived of adequate access to electricity despite being rich in energy sources, like renewable energy, gas, oil, and coal. First, about 91% of villages are non-electrified, and approximately 85.1% of provincial residents live in rural areas [3]. The supply of electricity in Balochistan is limited to 400 to 600 MW, but the current electricity demand is approximately 1650 MW.

Shabbir et al. [4] conducted a study termed "Economic Analysis and Impacted on National Grid by Domestic Photovoltaic System Installations in Pakistan" and concluded that the mainstreaming of solar energy can diversify the energy mix of Pakistan and can reduce the energy dependency on a single source, especially on fossil fuels, which can indirectly reduce the carbon footprint. Shah et al. [5] conducted a techno-economic analysis of solar PV electricity supply to rural areas of Baluchistan and calculated the optimal tilt angle and the potential of sunlight when it encounters the surface of solar panels in a horizontal position. It was concluded that, at an optimal angle of 29.2° in Quetta, a 10.78% increase in solar radiation is possible. Anwar et al. [6] studied renewable energy technologies in Balochistan, including practices, prospects, and challenges, and collected primary data about electricity prices by surveying and concluded that 7% of people are very satisfied with the current electricity prices in Pakistan and that 18% are slightly satisfied. The people who are neither satisfied nor unsatisfied represent 21%, and 19% are somewhat dissatisfied, while 35% of people in the survey are very dissatisfied. Muhammad et al. [7] studied different solar potential coordinates of Pakistan. They stated that to meet the energy demands in Pakistan, we require to generate 2000 MW per year using solar plants while the estimated solar potential is 100,000 MW. Khalid and Junaidi [8] published a study of the economic viability of PV electric power for Quetta, Pakistan, and estimated electric power generation by a simulation-based software (RET screen) and stated that PV power plant generates the highest electricity and has the potential to generate 23.206 GWh of electricity in a year at Quetta, Pakistan.

2. Material and Methodology

In this section, light is shed on the materials and methods adopted to estimate energy generation produced by solar panels.

Collection of Radiation Data

Solar radiation data have been collected from authentic sources of the radiation calculation devices that have been installed in Baluchistan University of Information Technology Engineering and Management Sciences (BUITEMS), Quetta, by the World Bank and USAID. The data have been taken from the following website: www.energydata.info.com (accessed on 15 March 2021). The proposed place for installation of solar PV systems is Pakistan, namely, Quetta/Sheikh Mand. The installed device collected data every 10 min for radiation (W/m^2) with the addition of ambient air temperature (°C), wind velocity (m/s), and humidity (%). The solar PV system analysis module was a Canadian Solar CS3U-340P PV module (Poly Crystalline). Table 1 shows the specification that was obtained from the datasheet of the Canadian Solar module manufacturing company. The specification of Huawei Sun2000-90KTL is mentioned in Table 2, with a maximum efficiency of 99% and a power capacity of 90 KW, has been used here. The specification of the inverter is obtained from the datasheet of Huawei Inverters Company.

Table 1. Module specification [9].

Module Classification	Canadian Solar CS3U-340P PV Modules
Classification of Cell	Polycrystalline
Volume of Individual Module	2000 mm × 992 mm × 40 mm
Nominal Operating cell Temperature (NOCT)	43 ± 2 °C
Module Area	1.984 m^2
No. of Panel/ Modules	147,060
Total Module Area	291,768 m^2 (72.1 Acre)
Module Efficiency	17.14%

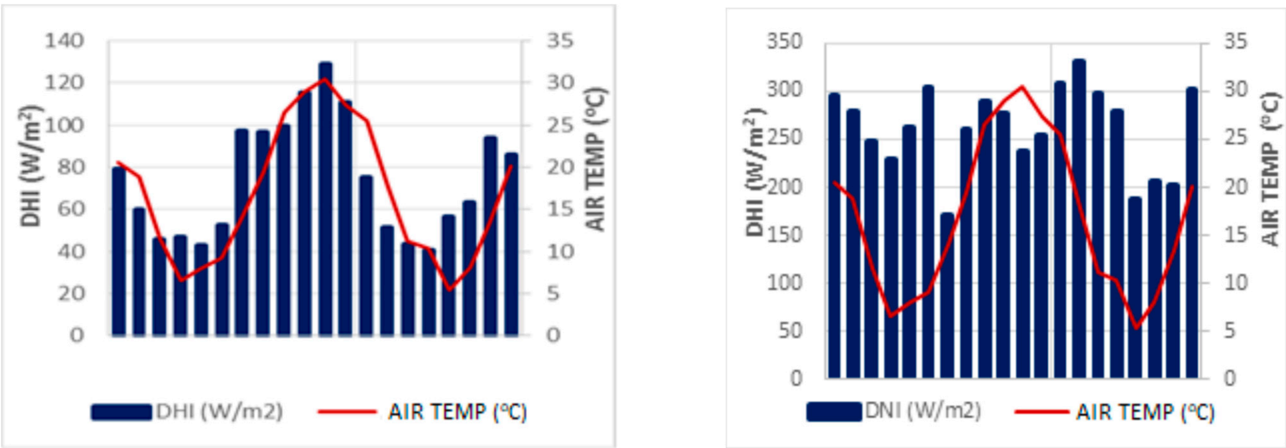
Table 2. Inverter specification [10].

Type of Inverter	Huawei Sun2000-90KTL
Dimensions of each Inverter	1075 × 605 × 310 mm
No. of Inverters used	554
Max. efficiency	99%
Max. Input Voltage	1500 V
Rated AC Active Power	90 KW

3. Results and Discussions

During this study, the radiation data of Quetta city were initially collected to measure the sunlight intensity that reaches the ground. During this study, radiation data were collected for more than 1 year. During May, June, and July, the global horizontal irradiance from a thermopile pyranometer (GHI-PYR) was observed with the highest values, i.e., 322.965, 333.6401, and 320.2997 W/m^2, respectively for each month. It was also observed that the values of the global horizontal irradiance from the rotating shadowband irradiometer (GHI-RSI) also had maximum values of 316.5496, 327.4765, and 314.6698 W/m^2 during May, June, and July, respectively [11].

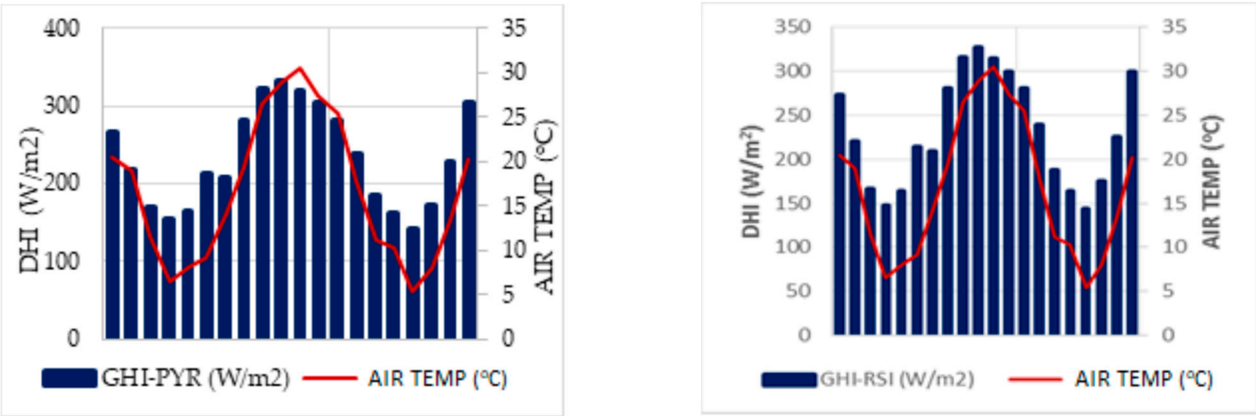
It can be seen from Figure 1a that when the diffused horizontal irradiance was calculated using the thermopile pyranometer, the maximum value of irradiance was recorded during July, followed by June and August. It can be seen from Figure 1b that when the thermopile pyrheliometer calculated the direct normal irradiance, the maximum value of irradiance was recorded during October, followed by September and November. Similarly, the minimum irradiance was documented in March, January, and February.



(**a**) (**b**)

Figure 1. (**a**) Diffused horizontal irradiance (W/m^2); (**b**) direct normal irradiance (W/m^2).

It can be seen from Figure 2a that when the thermopile pyrheliometer calculated the direct normal irradiance, the maximum value of irradiance was recorded during October, followed by September and November. Similarly, the minimum irradiance was recorded during March, January, and February. It can be seen from Figure 2a that when the global horizontal irradiance was calculated using the thermopile pyranometer, the maximum value of irradiance was recorded during June, followed by May and July. Similarly, the minimum irradiance was documented in January, December, and February. It can be seen from Figure 2b that when the direct global horizontal irradiance was calculated using rotating shadow band irradiance, the maximum value of irradiance was recorded during June, followed by May and June. Similarly, minimum irradiance was recorded during January, December, and February.



(**a**) (**b**)

Figure 2. (**a**) Global horizontal irradiance (W/m^2); (**b**) global horizontal irradiance by RSI.

Comparative Analysis

The system simulation was carried out using the RETScreen software package and a 50 MW solar PV system for four distinct locations in Pakistan, including Quetta/Sheikh Mand, Multan, Peshawer, and Islamabad. The best-case scenario, according to the simulations, is Sheikh Mand in Quetta, which has an electrical generation capacity of 4240.3 GWh, followed by Peshawer, which has a capacity of 4001.3 GWh, Multan, which has a capacity of 3756.4 GWh, and Islamabad, which has a capacity of 2978.3 GWh. According to the daily solar radiation (kWh/m^2/d) for the four proposed locations shown in Figure 3, Sheikh Mand is the most suitable site for solar PV-based electricity generation potential, whereas Islamabad is the least advantageous site to be utilized for solar PV-based electricity generation potential.

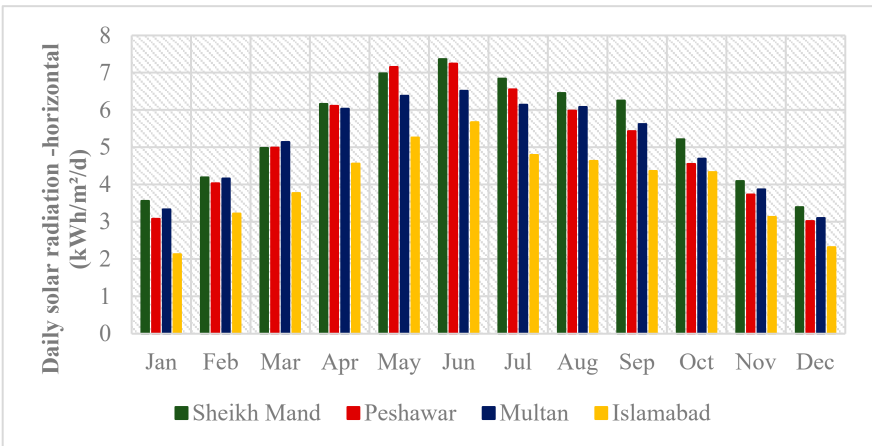


Figure 3. Comparative analysis of 50 MW solar PV systems.

4. Technical Analysis Results

The Canadian Solar CS3U-340P PV module was proposed here because it has already been used in other countries and has delivered excellent results. The size of each PV solar module will be 3.1 m^{2,} as calculated from the datasheet. Almost 250 acres of land is required for the installation of solar modules. The lifespan of the PV solar plant is up to 25 years, but, due to rural electrification, it is proposed that this plant will be used for 20 years; after that, it will be sold out at half cost to tribal areas. With the installation of such a mega project, there will be a significant decrease in the use of fossil fuel for energy generation by QESCO. Within May, the energy generation can reach 47.73 MW, followed by June, which will give 44.62 MW as mentioned in Table 3.

Table 3. Estimated monthly power output.

Months	Power Output (MW)
January	31.13
February	34.78
March	34.86
April	34.27
May	47.74
June	44.62
July	38.35
August	34.11
September	30.61
October	27.59
November	24.09
December	28.20

Similarly, during the winter season and in cold weather, it is difficult for solar radiation to reach the ground. The lowest energy will be produced during November, i.e., 24.09 MW, followed by October, during which only 27.58 MW will be produced. The average daily output of the plant is calculated to be 36 MW, which can be obtained by taking a three-point estimation of the calculated power in various months.

The cost of electricity for a 50 MW Photovoltaic power plant for Quetta, which receives the most sunlight in Pakistan, is 0.0385 USD/kWh or 6.09 PKR/KWh. The per-unit electricity generated using fossil fuel has an average cost of 12.76 PKR/kWh. This is twice the price of electricity units that solar power plants will develop. On the other hand, the energy produced by such a solar power plant is environmentally friendly and does not harm the surrounding areas. The levelized tariff calculated in this study is 3–6 PKR cheaper than the lowest power purchasing price during 2019–2020 in Quetta.

5. Conclusions

Technical assessment of a PV power plant shows that 91.980 GWh of electricity can be produced per year. The economic assessment of the proposed PV plant shows that it could produce electricity at a cost of 0.0385 USD/kWh or 6.09 PKR/kWh for 25 years. The results of this study show that a 50 MW PV plant will be feasible for Quetta as the levelized cost of electricity for this evaluation was three rupees less than the minimum quotation of the Quetta Electric Supply Company (QESCO).

Author Contributions: G.K. developed the main idea of the current study. M.H. worked on research conduction and wrote the manuscript. M.A., A.W. and S.S. reviewed and updated the manuscript. J.S. reviewed, edited, and formatted the manuscript. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Acknowledgments: The author significantly acknowledges the support of staff, lab engineers, and utilization of facilities at US-Pakistan Center for Advanced Studies in Energy, NUST for the completion of this research.

Conflicts of Interest: The authors declare no conflict of interest.

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