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Simulation design of Grid Tied Photovoltaic (PV) system of a 1.05 kWp DC for a geographical location of Tandojam, Sindh

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ABSTRACT

Due to rising costs and a lack of conventional sources of power generation, impoverished nations are experiencing an increasing number of energy crises. Pakistan has an abundance of resources for producing renewable energy, particularly solar energy. Although Pakistani markets have a wide variety of solar cells, modeling studies and contemporary technologies may aid the solar power industry in choosing the best site for an efficient power generating system. A photovoltaic (PV) system's performance analysis is largely influenced by its location and the power conversion inverter system's string count. The primary source of solar energy generation for photovoltaic systems is the number of irradiations on collector plane. In places with a lot of incoming direct and indirect sun rays, PV systems are advantageous. Tandojam got an average of 5.1 kWh/m^2 yearly in Sindh province, which is greater than many other Pakistani cities. A grid connected 1.05 kWp DC/ 1 kWp AC Photovoltaic system is now being studied for the Pakistani region of Tandojam Sindh utilizing the PVSyst software version 7.4.0. Current study analyzes the design and performance ratio of PV systems, as the total energy produced by the proposed photovoltaic system and various losses of photovoltaic system. Annually performance ratio (PR) for grid connected photovoltaic system is calculated 75.4% and Minimum PR of 71% is reported in the month of May, while highest PR of 80.4% is recorded in the months of January and December. This demonstrates that using a PV system to generate power is a practical way for Tandojam to meet its growing energy demands.

Keywords:

Grid Tie,
Solar cell power,
Solar radiations,
Silicon-poly 150
Power generation

1. Introduction

Energy demands increasing day by day with the passage of time. Electricity is necessary in almost every industry and home, placing a significant pressure on Pakistan's distribution providers. Growing greenhouse gas emissions from the usage of conventional fossil fuels like coal, natural gas, and oil for energy production have an adverse impact on the environment and contribute to global warming [1,2]. In order to replace conventional sources with modern source of power generation, it is necessary to use cleaner energy sources such as solar, wind, biomass, magneto hydro dynamics (MHD) and hydropower. These resources are renewed on a constant basis by nature, making them renewable [3]. One of the most viable solutions to the world's energy dilemma is solar energy. Since building power lines to isolated and rural locations is not financially feasible, solar photovoltaic (PV) systems have become a reliable source of energy generation throughout the world [4].

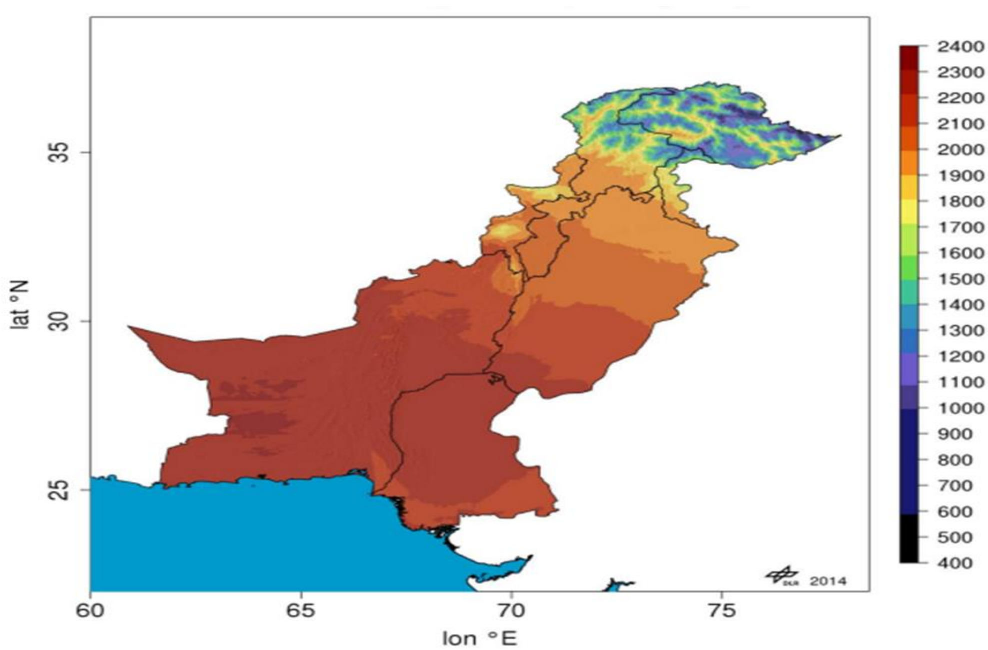

Fig. 1: Annually global horizontal irradiance (GHI) for Pakistan in kWh/m^2 [5].

In Sindh and Baluchistan in Pakistan, where global irradiations on horizontal surfaces are highest, the sun's direct irradiance offers a tremendous potential for producing clean, green electrical energy. Global horizontal irradiance in Pakistan's north and north-eastern regions is declining, peaking in the Himalayas. Maximum solar radiation in Sindh and Baluchistan as a whole is just over 2300 kWh/m^2 per year, while other parts of Pakistan also have good solar potential of over 1500 kWh/m^2 per year, covering more than 90% of Pakistan's land area, as shown in Fig. 1 [5]. If this energy is caught effectively, it will be enough to fulfill all of the nation's energy needs. Photovoltaic energy is the only reliable alternative to traditional energy sources due to the exponentially growing population of Pakistan and the quick depletion of conventional energy sources like gas, furnace oil and coal. Numerous steps have already been done in this regard. It becomes vital to size and simulate the system parameters for efficient energy yield in order to make the best use of the solar resource. PVSyst, a simulation program, can be used to evaluate the energy yield and the size of the required PV system [6,7]. PVSyst has been utilized by a variety of researchers to determine the system's performance. Authors examined the effectiveness of a grid-connected, 190kWp solar (PV) power plant [9]. In grid-tied systems in Berlin and Kathmandu, electrical power generated by the photovoltaic system and solar arrays and all conversion losses and losses from the inverter system were studied using PVSyst. For the use of PVSyst simulator Power generation through PV system. In order to assess the feasibility of constructing a 1 MW solar photovoltaic (PV) power plant, authors simulated a grid tie system using PVSyst. They did this by performing simulation of southern region of Tamandua's in India and comparison of performance analysis of different geographical location [8,9]. Due to the best global horizontal irradiance (GHI) in Sindh province, the goal of this research is to use PVSyst simulation to design and simulate a grid-connected photovoltaic (PV) system for geographical location in Sindh, Pakistan. For the design of photovoltaic systems and their performance study for several months and overall, annually, meteorological data is gathered from Meteonorm-8.1.

2. Methodology

Meteonorm-8.1 is used to determine photovoltaic irradiance, wind speed data, and temperature for the Tandojam site at latitude 25.43°N, 68.53°E, and an altitude of 23 meters for the purpose of designing and sizing solar systems. This portion describes how to develop and simulate a 1.05 kWp DC photovoltaic system for the TandoJam site in Sindh using PVsyst Simulator to estimate the design. PVSyst simulation-based software is used to estimate the sizing and performance analysis of proposed photovoltaic system for a specified geographical location. It is used by researchers, architects, and engineers as a basic design and simulator for photovoltaic systems. In the design and development of photovoltaic systems, when choosing an appropriate cell model and inverter for the desired output of the proposed system, PVSyst is more effective. With a huge database that spans the globe, several sites, and its meteorological data, one can manually add data to PVSyst. Results from the softwares are shown in the form of graphs and tables.

Table 1: Input data through metenorm-8.1 of geographic site

Month	Direct irradiation ($kWh/m^2/day$)	Diffuse irradiation ($kWh/m^2/day$)	Direct irradiation ($kWh/m^2/month$)	Diffuse irradiation ($kWh/m^2/month$)	Temperature (°C)	Wind Velocity (m/sec)	Relative Humidity (%)
January	3.76	1.44	116.5	44.5	16.4	1.38	57.7
February	4.73	1.94	132.3	54.3	19.9	1.60	53.1
March	5.44	2.54	168.6	78.7	26.3	1.90	47.7
April	6.25	2.87	187.4	86.2	30.6	2.30	45.8
May	6.58	3.21	204.0	99.5	34.2	3.59	49.3
June	6.42	3.46	192.7	103.9	33.9	3.90	57.3
July	5.31	3.27	164.7	101.4	32.6	3.80	65.0
August	5.12	3.24	158.8	100.3	30.7	3.10	70.6
September	5.41	2.72	162.2	81.5	30.0	2.49	69.3
October	4.75	2.37	147.3	73.5	28.6	1.52	58.1
November	4.02	1.79	120.6	53.7	22.8	1.10	57.2
December	3.55	1.52	110.0	47.2	17.9	1.19	57.2
Yearly	5.11	2.53	1865.1	924.7	27.0	2.3	57.4

The following inputs are provided to the PVSyst software: Data from Meteonorm-8.1, Radiations on photovoltaic plane, Suitable Photovoltaic (PV) cell and array design, Photovoltaic field orientation, Inverter system and losses, Operating conditions, Energy use and efficiency, Normalized performance index. Because locations around the world get varying amounts of solar irradiance on solar cells, photovoltaic (PV) system placement is important for the production of solar energy. This positional difference can be seen as a distinct set of location-specific metrics like latitude, longitude, and altitude. Southern Pakistan's Tandojam city is located in latitude 25.43°N (25°25'41.2"N), longitude 68.53° E (68°31'50.5"E), and an elevation of 23 meters. Solar System Size 1.05 kWp DC, Solar cell model Goldi Green Poly 150 Wp, 36 cells, Inverter Model Sunway R5-1K-S1, 1 kWp. To capture the most solar radiation in the sun's path, tilt angle is crucial. In order to capture more and more solar energy, particularly at the beginning and end of the day, photovoltaic cells are installed at a specified angle. The total performance and efficiency of a photovoltaic system can be improved by choosing a precise angle at which solar cells are mounted to face the sun the most. In most cases, the tilt angle taken into account is equal to or close to the latitude value of the geographic point at which global irradiance on the collector plane is at its highest and loss with respect to the ideal condition is zero. Current research for the proposed system is selection of transpose factor (FT) is kept 1.08, loss with respect to optimum is 0.0% for global on collector plane and tilt angle is 25 deg and other input parameters shown in table 01. Azimuth angle basically related to sun direction around the earth and taken as zero to face the sun, and solar cell mounted at facing south for maximum radiation collection. Seven solar paths are identified that alter the principal sun direction depicted for the suggested location given the azimuth angle of 0°. Albedo is a measurement of the earth's surface's refractive index. The texture of the ground at the place is a factor. The range of its values is 0.1 to 0.9. In locations with snow, or grass it is higher. Due to the plane landscape, we chose an albedo value of 0.2 for Tandojam. Goldi green polycrystalline silicon modules with 150 Wp each and a sunway Inverter with a capacity of 1 kWp were taken into consideration for the size of the 1.05 kWp DC system for proposed location. 5.11 kWh/m^2 of average global horizontal irradiance on a yearly basis in Tandojam indicates a strong potential for solar power generation. Table 1 for the proposed site shows the monthly diffuse irradiance, temperature, wind speed, and global horizontal irradiance. The monthly average for worldwide horizontal irradiation is 6.58 kWh/m^2 in May and 3.55 kWh/m^2 in December.

Table 2: performance ratio and injected energy into grid

Months	GlobHor (kWh/m²)	DiffHor (kWh/m²)	TAmb (°C)	GlobInc (kWh/m²)	GlobEff (kWh/m²)	E-Array (kWh)	E-Grid (kWh)	Performance Ratio (%)
January	116.5	44.5	16.38	154.5	151.2	135.7	131.3	0.809
February	132.3	54.3	19.94	162.6	159.2	138.7	134.4	0.787
March	168.6	78.7	26.29	186.7	182.7	151.8	147.1	0.750
April	187.4	86.2	30.55	190.1	185.8	148.9	144.1	0.722
May	204.0	99.5	34.23	192.5	187.5	148.3	143.6	0.710
June	192.7	103.9	33.95	176.9	172.2	138.7	134.2	0.722
July	164.7	101.4	32.56	153.0	148.7	123.2	119.0	0.741
August	158.8	100.3	30.74	155.7	151.8	126.7	122.5	0.749
September	162.2	81.5	29.99	172.0	168.0	138.4	134.0	0.742
October	147.3	73.5	28.59	171.3	167.6	139.1	134.7	0.749
November	120.6	53.7	22.75	155.2	151.8	131.8	127.7	0.784
December	110.0	47.2	17.94	148.1	144.9	129.9	125.7	0.809
Year	1865.1	924.7	27.03	2018.7	1971.3	1651.0	1598.2	0.754

3. Results & Discussion

This part presents a thorough detail made up of numerous graphs of performance analysis and data of energy tables that were obtained using PVSyst simulation software for proposed system. For the proposed system, which has a Pnom ratio of 1.05, one 1 kWp inverter and seven 150 Wp modules are needed. Following the application of all essential efficiency modifications, the output power is achieved. Table 2 displays the outcomes of the system simulation. At a tilt angle of 25° of the solar plate installed with optimal incident irradiation received on the plane, the annual incident global horizontal radiations on the collector plane of the solar cell are 1865.1 kWh/m^2.

Although incident sun irradiance is reduced in the months of December and January around 110.0–116.5 kWh/m^2 the system still performs at its best over 80% of the time due to low temperatures 17.94° and 16.38° respectively, because high temperature that also affect solar cell efficiency and produce higher conversion losses. Solar cell modules and PV arrays experience a variety of losses. The following losses are included: 1.17% for wiring loss, 1.50% for module quality loss, and 2.00% for module array mismatch loss, photovoltaic loss due to incident irradiance is 0.36%, inverter loss during operation 3.03%. After deducting all energy losses, the energy that is left over at the inverter's output is 1598 kWh, which is sent to the grid system's limitless load. Feed the grid-connected photovoltaic system with losses and any residual energy. The proposed system's illustrates the total energy produced by solar cells, energy loss from photovoltaic conversion, mismatched and wire losses, and total energy available at the inverter output for grid feeding. The PV plant's performance is assessed using the performance ratio (PR). The system's performance ratio measures the relationship between energy output and radiation incidence on a certain region. It is acceptable for a system this size because it hovers around 0.75 for the majority of the months in a year.

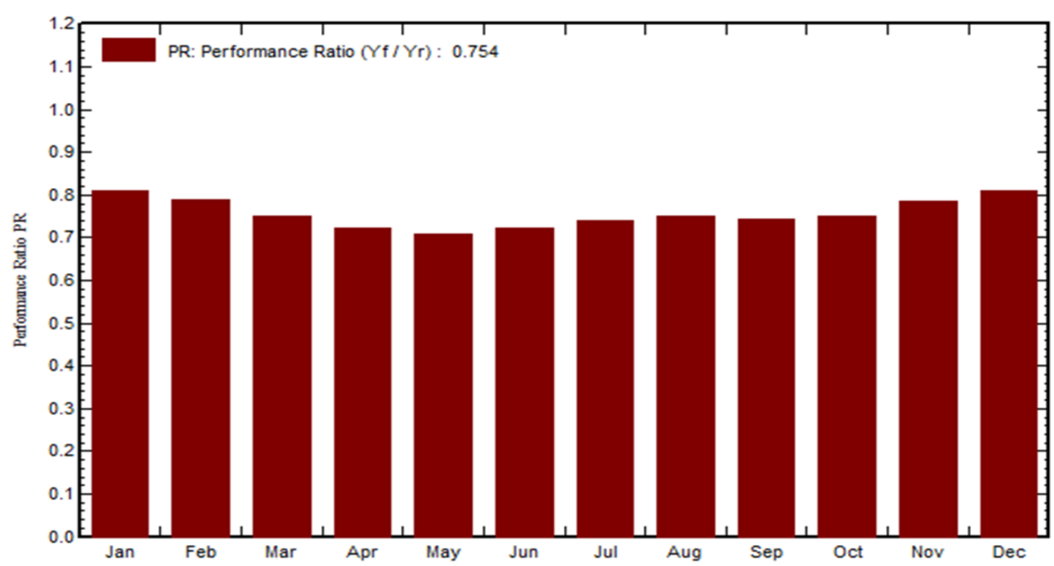

Fig. 2: Performance Ratio (PR) for grid-connected PV system fluctuation on a monthly basis

4. Conclusion

In this current research, a complete design and simulation technique for solar systems utilizing PVsyst simulation is described. The globally horizontal irradiation data of the suggested location for Sindh's Tandojam metropolis is used to get more accurate results. It is found that a Photovoltaic

(PV) system's design is totally reliant on its geographical location. Performance ratio is a crucial factor to consider when assessing system performance. The system's performance ratio for the entire year is calculated to be 0.754, which is highest in Pakistan's Sindh province and exhibits a strong potential for solar energy production. It demonstrates that Tandojam should consider using a Photovoltaic system to generate electrical power and fulfil the load demand in local level. Large capacity systems can be created for this site based on this analysis.

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