DESIGN AND SIMULATION OF GRID-CONNECTED SOLAR PROJECT USING PVSYST

Tawsif Hossain Chowdhury[1] and Dr. Md. Tareque Aziz[2]

Abstract**—** Solar energy harnesses sunlight to generate electricity, offering a sustainable and environmentally friendly power source. PVSyst is used for comprehensive analysis and optimization of performance parameters. PVSyst software was utilized in Faridpur, Bangladesh to predict the annual power output of a grid-connected solar energy plant and this paper will be reporting the results and the simulation parameters. The yearly total incident energy on the collector, excluding optical adjustments, and the resultant effective global irradiance after optical losses, stand at 2245.5 kWh/Sq. m and 2084.2 kWh/Sq. m, respectively. Based on this effective irradiance, the PV array generates an annual DC energy output of 1813.7 MWh, while the annual AC energy injected into the grid reaches 1782.0 MWh. The efficiency ratio (PR) stands at 79.3%, with a total annual energy production of 1782 MWh. The peak energy generation occurs in May, while the minimum is observed in January.

Keywords**—** Renewable energy, PV Soalr, PVSyst, global irradiance.

I. INTRODUCTION

Photovoltaic systems are advancing globally as a crucial renewable energy source, despite facing challenges like intermittency, high installation costs, and modest energy conversion efficiency. Optimizing photovoltaic systems for peak efficiency during favorable weather conditions is essential to maximize power output. Bangladesh, grappling with severe energy shortages due to over reliance on conventional sources, urgently needs transition to renewable options. Solar energy emerges as a particularly viable solution for the country. The implementation of environmentally friendly Solar PV (SPV) projects offers a sustainable remedy to Bangladesh's pressing energy woes [1,2,3].

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Renewable energy encompasses sources that naturally replenish over a short period, deriving directly or indirectly from the sun, including wind, hydropower, and other environmental movements [6]. It explicitly excludes energy resources originating from fossil fuels, as well as waste products from fossil and inorganic sources. Renewable energy offers sustainability through inexhaustible sources, emits no greenhouse gases, ensuring a cleaner environment, and is cost-effective by eliminating the need for fuel transportation. Additionally, it can bring economic benefits to remote communities, allows control over power production based on demand, and contributes to waste reduction through biomass energy [6,7].

The solar PV system's technical representation is created through simulation using PVSyst software, with a thorough analysis of each element for plant design. Additionally, a comparison is made between the modeled renewable energy system and real-world solar plant conditions, taking into account economic and environmental factors [7,8]. The section includes the presentation of the PVSyst-based renewable energy system model, featuring proposed system results and a comparative study. The conclusion and future recommendations are also outlined, emphasizing the optimal area for project benefits based on environmental conditions and proximity to the grid station. The detailed presentation covers a comprehensive approximation, power evacuation plan, and the projected structure of the solar PV power park.

II. LITERATURE REVIEW

The growing emphasis on renewable energy sources has led to increased research and development in the field of solar power systems. One crucial aspect of designing efficient solar systems is the utilization of advanced software tools for simulation and analysis. PVSyst stands out as a widely employed software tool for the design, simulation, and performance analysis of solar photovoltaic (PV) systems. This literature review explores the key findings and insights from studies that have utilized PVSyst in the design process of solar power systems.

Anand Mohan et al. [7] focused on the development of a photovoltaic power system in Himachal Pradesh, assessing the economic aspects involved in the installation of the power plant using PVSyst. Understanding the economic viability of solar installations is crucial for decision-makers and investors.

C. P. Kandasamy et al. [8] conducted a solar potential assessment in southern parts of Tamil Nadu state using PVSyst. This study simulated the performance of a 1000 kWp grid-connected photovoltaic system, providing valuable insights into the solar potential of specific geographical regions.

Nallapaneni Manoj Kumar et al. [8] explored the design of a 100 kWp grid-connected system tailored to meet the electrical power needs of an academic institution. This study showcases the versatility of PVSyst in customizing solar power solutions for specific applications. Paras Karki et al. [4] compared the performance aspects of grid-connected systems in Kathmandu and Berlin, employing PVSyst for simulation and analysis. Comparative studies contribute to a better understanding of the performance variations under different environmental conditions.

Another study delved into the design and installation aspects of a grid-based PV system in Madan Mohan Malaviya University using PVSyst. This research emphasizes the applicability of PVSyst in educational institutions for sustainable energy solutions.

Authors [6] highlighted the importance of HOMER and Solar MAT software in designing hybrid-based PV systems, with a focus on design criteria and CO_2 emission levels. This study underlines the role of PVSyst in conjunction with other tools for comprehensive solar system design [8].

The reviewed literature demonstrates the widespread adoption of PVSyst in various aspects of solar system design, including economic assessments, solar potential analyses, tailored system designs, performance comparisons, and environmental impact evaluations. The use of PVSyst contributes significantly to optimizing the efficiency and sustainability of solar power installations.

III. METHODOLOGY

The PVSyst software is widely utilized for designing and estimating performance parameters in solar PV power plants. Its extensive features yield results close to theoretical values, allowing users to import various data sets, including meteorological and personnel data. This versatile software assesses the performance of PV systems in stand-alone, grid-connected, and pumping configurations. By specifying design requirements, users can evaluate the overall effectiveness of the PV plant. In a case study for Faridpur, the PVSyst software was employed to estimate annual power yields for a grid-connected solar energy plant, with simulation parameters displayed.

PVSyst proves to be a versatile simulation tool, offering options for designing grid-connected and standalone PV systems, as well as small-scale energy production for pumping applications and exclusive DC power generation. Users can select specific design parameters based on their requirements, making it suitable for marketing and promoting PV system installations. The software caters to both preliminary designs for promotional purposes and detailed designs for solar installers, providing simulation results that guide the establishment process for a solar PV plant [9,10,11].

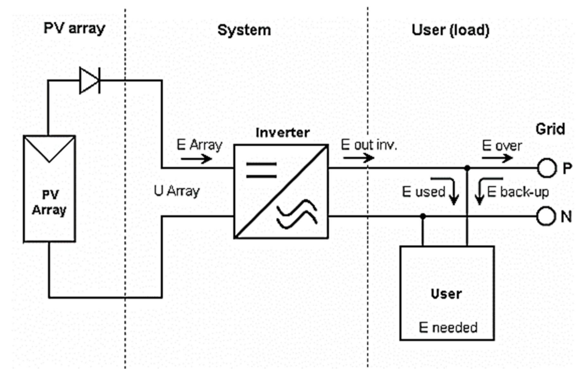

Fig. 1. Block diagram of system

To harness the limited voltage output of individual solar cells, typically around 0.5V each, multiple cells are connected in series during the production of a "laminate." This laminate is then enclosed in a weather-resistant casing to create a photovoltaic module or solar panel. These modules can be connected in series to form a photovoltaic array, allowing for a more efficient utilization of solar energy.

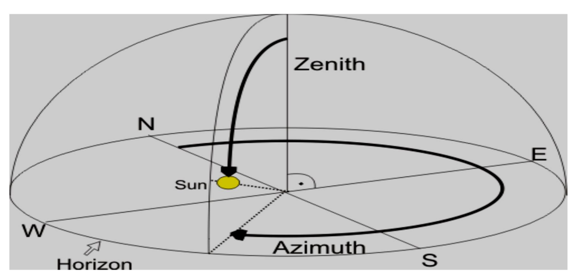

Fig. 2. Explanation of Zenith and Azimuth angles

Zenith and azimuth are terms commonly used in astronomy and navigation to describe the position of celestial objects in the sky. The zenith is the point in the sky directly above an observer. It is the highest point in the celestial sphere that one can see from a specific location. When the sun is at its zenith, it is at its highest point in the sky for a particular location, and shadows are minimal. Azimuth refers to the compass direction from which the sunlight or any celestial object is coming at any specific point. It is measured in degrees from the north in a clockwise direction, with north being 0°, east being 90°, south being 180°, and west being 270°. Azimuth provides information about the horizontal position of an object in the sky [12].

Pv Module that has been used from jinkosolar with 385 Wp. Total 2600 solar modules of each 385 W have been considered in 100 strings x 26 in series.

IV. RESULTS AND DISCUSSIONS

DC power systems encompass the infrastructure responsible for processing and managing the generation of direct current, with the photovoltaic (PV) module playing a crucial role in converting solar energy into electrical energy within a solar power plant. Additionally, the alternating current generated by the inverter is consolidated by the AC combiner box. In instances where the chosen inverter incorporates an integrated AC combiner function, a separate combiner is unnecessary. The efficacy of the solar power system is significantly influenced by environmental factors. While increased irradiance augments output power, it's essential to note that elevated panel temperatures can diminish system efficiency, highlighting the intricate relationship between environmental conditions and solar system performance.

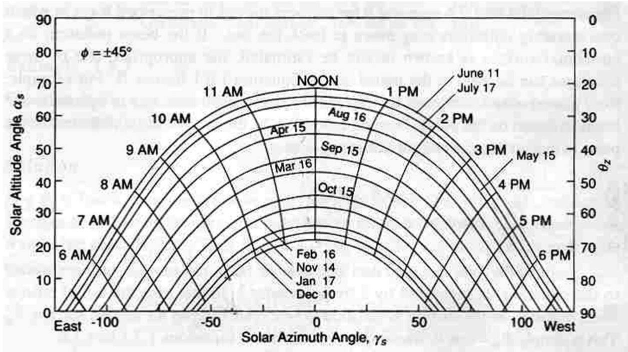

Fig. 3. Sun path plot & solar azimuth angle

This diagram serves as a valuable tool for gaining insights into the solar potential within a specific region. It includes a functionality that allows users to approximate a shading profile for the analyzed site. Through the manipulation of the shading area, users can ascertain a Diffuse Factor, representing the percentage of total power achievable after factoring in losses attributed to shading.

Table 1. The incident energy data from Meteo database.

Month	Glob_Hor kWh/m2	Diff_Hor kWh/m2	T_Amb ·c	GlobInc kWh/m2	GlobEff kWh/m2	EArray MWh	E_Grid MWh	PR ratio
January	125.6	53.7	17.17	165.5	151.4	138.2	135.9	0.820
February	132.3	61.9	20.98	166.5	155.3	138.2	135.7	0.815
March	173.7	76.8	25.66	223.8	207.4	178.4	175.3	0.782
April	183.4	87.8	27.88	230.6	214.6	181.9	178.8	0.776
May	185.4	1,048	28.80	219.5	207.4	176.9	173.9	0.792
June	1,497	93.5	28.22	171.0	161.1	139.2	136.8	0.799
July	151.7	90.6	28.49	179.0	167.9	144.40	1,418	0.791
August	148.7	87.1	28.61	178.7	166.3	142.6	140.6	0.783
September	146.1	71.2	27.73	189.1	173.1	180	145.6	0.768
October	138.2	73.1	26.86	170.9	1581	137.8	135.3	0.791
November	135.9	48.1	22.98	183.6	1,685	149.2	149.2	0.798
December	126.4	49.5	18.88	167.3	153.0	138.7	136.4	0.814
Yearly Total	1797.1	898.0	25.21	2245.5	2084.2	1813.7	1782.0	0.793

The diagram illustrates various balances and significant outcomes, incorporating factors like overall sunlight exposure on a flat surface, average ambient temperature, unadjusted sunlight exposure on the collector's surface, and effective sunlight exposure accounting for dirt and shading impacts. Furthermore, the computations encompass the electricity generated by the silicon-polymer photovoltaic panel, electricity fed into the grid considering losses in electrical components, and the efficiencies of both the photovoltaic panel and the system as a whole. These computed values for each parameter, as outlined in the balances and primary results, are provided on a monthly and yearly basis.

For the specific location under study, the annual overall sunlight exposure on a horizontal plane is 1797.1 kWh per square meter. The annual sunlight energy incident on the collector, before optical adjustments, and the effective overall sunlight exposure post-optical losses, are 2245.5 kWh per square meter and 2084.2 kWh per square meter, respectively. With this effective sunlight exposure, the annual electricity produced by the photovoltaic panel and the annual electricity supplied to the grid amount to 1813.7 MWh and 1782.0 MWh, respectively.

Table 2: hourly grid generation (MWh)

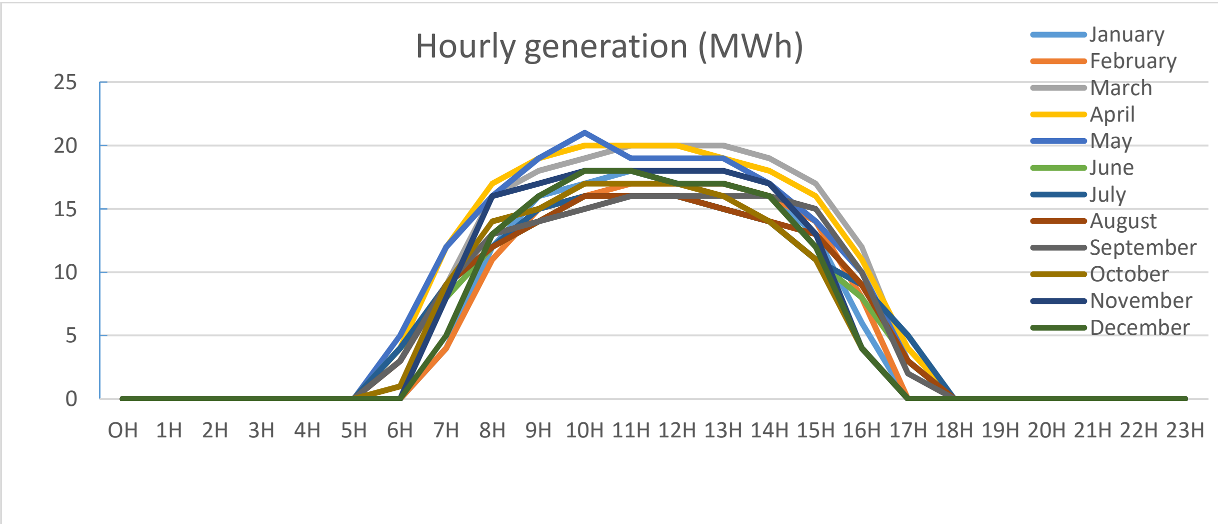

Table 3: Annual generation of the project.

Month	Eout_Inv MWh	Eff_InvR %	Inv_Loss MWh	IL_Oper MWh	IL_Pmin MWh	IL_Pmax MWh	IL_Vmin MWh	IL_Vmax MWh	IL_Imax MWh
January	135.9	98.3	2.321	2.278	0.000	0.000	0.000	0.000	0.000
February	135.7	98.2	2.437	2.310	0.090	0.000	0.000	0.000	0.000
March	175.3	98.3	3.353	3.023	0.031	0.000	0.261	0.000	0.000
April	178.8	98.3	3.809	3.055	0.000	0.000	0.718	0.000	0.000
May	173.9	98.3	3.504	2.961	0.003	0.000	0.503	0.000	0.000
June	138.8	98.2	2.685	2.424	0.017	0.000	0208	0.000	0.000
July	141.8	98.2	3.022	2.55	0.051	0.000	0.384	0.000	0.000
August	140.1	98.2	3.027	2.492	0.038	0.000	0.460	0.000	0.000
September	145.4	98.2	3.222	2.629	0.058	0.000	0.498	0.000	0.000
October	135.3	98.2	2.539	2.381	0.071	0.000	0.046	0.000	0.000
November	146.7	98.3	2.505	2.439	0.024	0.000	0.000	0.000	0.000
December	138.4	98.3	2.327	2284	0.000	0.000	0.000	0.000	0.000
Yearly Total	1782.0	98.3	34.753	30.825	0.383	0.000	3.078	0.000	0.000

The depicted diagram showcases the hourly and monthly output of the system. Predictably, generation is significantly reduced during the winter months. The performance ratio (PR) stands at 79.3%. The system generates a total of 1782 MWh per year. May records the highest energy generation, while January experiences the lowest. Other noteworthy findings include the yearly global horizontal irradiation, energy outputs, power generation, and system efficiency. The solar photovoltaic array achieves its peak power production, generating a total of 1782 MWh. The overall efficiency of the system is commendable.

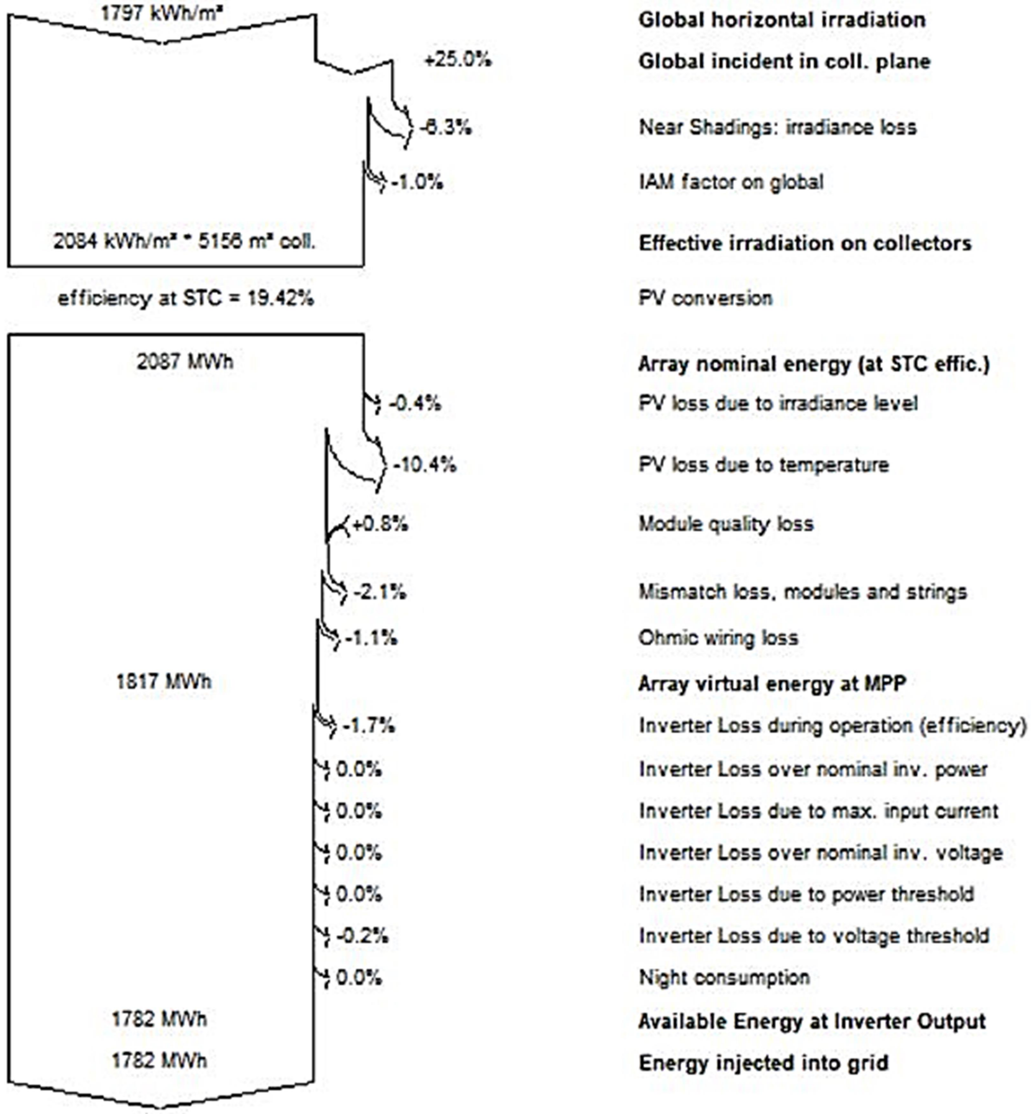

Fig. 4. Detailed information of system loss

The diagram above is derived from simulated studies, aiding in the analysis of various losses encountered during the installation of a PV plant or factors to be considered. The global irradiance on the horizontal plane measures 1797 kWh per square meter, while the effective irradiance on the collector is noted at 2087 kWh per square meter. This disparity results in an energy loss of 0.4%, attributed to variations in irradiance levels. When absorbed by the surface of a photovoltaic module or array, effective irradiance leads to the production of electrical energy. Following the photovoltaic conversion, the nominal energy output of the array under standard testing conditions (STC) is set at 2087 MWh. The efficiency of the PV array at STC is documented at 19.42%.

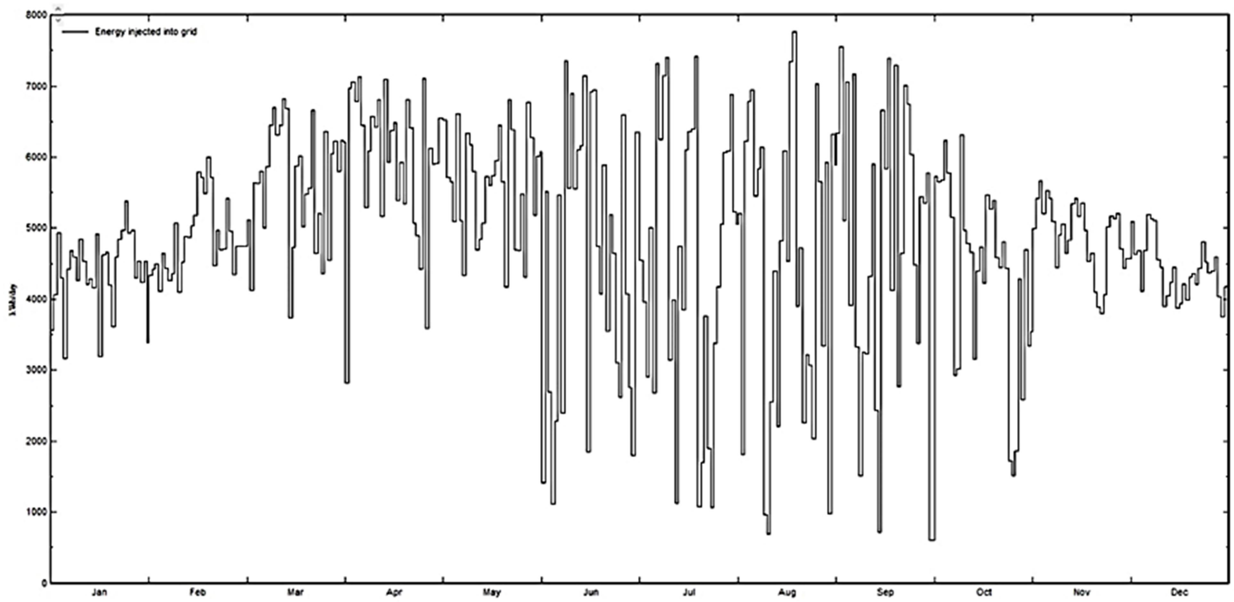

Fig. 5. Daily generation graph.

In Figure 5, the daily generation graph illustrates the highest power production exceeding 19000 kilowatt-hours per day in March, with a module temperature of 21.49°C and a plant efficiency of approximately 83.8%. The total global incident energy (GHI) falling on the collector area plane annually is measured at 1854.3 kWh per square meter.

V. CONCLUSION

This research provides a comprehensive overview of the solar energy power plant situated in Faridpur, offering detailed insights into annual production, power losses within the system, and future implications related to the energy crisis. The system achieves a maximum energy output of 185.5 kWh in May and a minimum of 125.6 kWh in January. The cumulative energy extracted from the photovoltaic system array amounts to 1782 MWh. The average yearly Performance Ratio (PR) for the PV plants is determined to be 79.3%, with May showing the lowest PR at 79.3% based on simulation results. This study's findings have significant implications for the installation of efficient solar parks in industries.

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