Design, Model and Planning of Prosumer Microgrid for MNSUET Multan Campus

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Abstract

The goal of this study is to provide a model and conceptual design for a 'Prosumer Campus Microgrid' that will help the university campus economically. The proposed model is based on solar Photovoltaic (PV) installation at department rooftop for the campus of Muhammad Nawaz Sharif University of Engineering and Technology (MNSUET) in Multan, Pakistan. This study indicates that a 3,196-kW grid-connected solar photovoltaic system may generate enough electrical power to meet consumption, reducing grid reliance and minimizing energy from grid supply. This study also includes an economic and financial analysis of the proposed system based on various assumptions. 'PVSol' software was used to conduct a solar potential study and design of the site. Our study and analysis revealed that our suggested PV model can create 3,196.53 kWh of PV energy (DC), which is about 81.6 percent of the yearly consumption of our chosen site of 3,784.56 kWh.

Index Terms: Modelling, Campus Microgrid, Optimal Design, Microgrid Planning, Energy Management.

I. INTRODUCTION

For numerous developing countries like Pakistan, electricity self-sufficiency is a social and political concern, has over 70 % of the fuel imports being used for transportation. This significant reliance on fossil fuels has resulted in a slew of unwelcome environmental consequences, with two Pakistani cities ranking among the world's top ten polluting cities [1]. The enormous quantity of CO_2 emitted by internal combustion engines in automobiles and motorcycles is a major contributor to the problem. As a result, there is a pressing need to minimize reliance on fossil fuels and to adopt new environmentally friendly transportation technology [2].

In the current situation, the global energy crisis is the most serious issue. If no preparation is made ahead of time, the scarcity of gasoline, along with its high price, will be impossible to manage. Policymakers should be aware of the impending global energy problem as well as the science underlying it. The utilization of renewable technologies for energy generation is now increasing at a rapid rate [3]. In many respects, Pakistan is a supporter of renewable energy technology. Solar energy is a free source of energy that is nearly always accessible in an endless amount. Given the current state of fossil fuel supply, this type of renewable energy is one of the most reliable energy sources, particularly where maximum solar radiation is accessible across the year. Solar energy is a clean form of energy that aids in the reduction of global warming. It does not affect the environment because it is devoid of carbon and other hazardous greenhouse gases during electricity generation and it can also be implemented in developing clean energy for campus microgrids [4].

The ever-increasing need for energy and depleting fossil resources has necessitated the search for environmentally acceptable, sustainable renewable-energy schemes, taking into account global energy consumption, climate change, and currently accessible technology [5]. The quest for novel techniques to enable clean energy trading among microgrids and to effectively integrate the renewable energy resources for campus microgrids [6]. As per the International Energy Agency's Renewables report 2020, worldwide net installed renewable capacity is anticipated to rise by 4 % in 2020, reaching approximately 200 GW [7]. As a result, the world has great potential to shift to a sustainable, economical, and clean energy system if these sources are properly harnessed and implemented in various sectors like campus microgrids.

Solar energy is one of the most widely employed renewable energy sources used for institutional microgrids, and it provides a variety of advantages over other energy sources. Solar energy helps to minimize the quantity of carbon dioxide, as well as other hazardous pollutants and waste products, that are discharged into the atmosphere [8]. Solar energy also decreases the number of transmission lines that networks require. It is a cheap and clean source of energy and is easily available in both direct and indirect ways. As a result, the Sun's energy may be efficiently utilized during peak load consumption hours of the day, or it can be kept in batteries as storage for later use. As a consequence, solar energy supports us to minimize a significant amount of grid consumption while simultaneously saving a significant amount of money on



power bills, it is an efficient source for campus microgrids [9].

Pakistan is still largely reliant on outdated fossil fuels for energy generation and especially transmission, however owing to finite fossil fuel sources, the country is on the verge of experiencing a power crisis. Due to generating shortfalls or transmission and distribution restrictions, the utility grid in many developing nations is generally intermittent [10]. As a result, many household and business users turn to diesel-based backup systems, which are (a) expensive and (b) emit a significant amount of CO₂.

Our country must move toward the transition to a renewable-energy grid to address the approaching crisis. According to the 'Pakistan Energy Situation', the power industry in these areas has not yet fully transitioned to renewables, with renewables accounting for only 3.3 percent of the country's electricity output and a gridconnected renewable capacity of 439 MW in 2018 [11]. With daily average sun irradiation ranging from 215 W/m² in the north-west to 235 W/m² in the south-west, Pakistan offers tremendous potential and opportunity for solar power [12]. Photovoltaic or (PV) technology may therefore be used to harness solar energy. Solar PV markets have accelerated in recent years, with worldwide PV capacity expansions expected to reach almost 107 GW by 2020 and beyond [13]. As a result, the demand for and use of PV technology has skyrocketed throughout the world. Solar energy offers great potential in a variety of sectors, including campus microgrids, irrigation, minigrids, solar rooftops, etc. Despite its enormous potential, certain obstacles must be overcome, including a shortage of land and suitable technology, insufficient room, and expensive installation costs [14].

As a result, a viable solution solar energy plan is adopted that overcomes these obstacles which is necessary. It is also important to guarantee that solar energy infrastructure is socially acceptable so that the general population is ready for unique and creative technologies [15]. Roof-top PV panel installation, for example, is a viable and acceptable application of PV energy that may assist to alleviate the problem of Pakistan's limited land area and congested cities by utilizing the vacant, underutilized space of roofs.

Monofacial PV panels and bifacial PV panels are the two types of solar modules used [16]. Monofacial PV panels are the most widely used conventional solar modules. This type of module is used in the majority of the solar system and design projects. There have been several studies on monofacial solar PV and rooftop solar PV systems. By calculating a numerical analysis of the best design of the plant using real data, an author 'Kazem' and associates published research on the technical-economic feasibility analysis of a (1-MW) grid-connected photovoltaic system based in Adam, Oman [17].

To anticipate solar irradiation and evaluate the performance of an 80-kWp PV power plant in Dhaka, researchers employed Artificial Neural Networks (ANN) and fuzzy logic. They also proposed a fuzzy logic and ANN-based solar irradiation prediction model. An author 'Enol' and colleagues from Cyprus International University refined the design of a self-consumption-based large-scale solar plant and did simulations utilizing

'PVSol' with a capacity ranging from 450 to 1250 kWp i.e., kilowatts peak [18].

A group of researchers looked at the power generation of PV modules, weather dependency, and temperatureinduced deterioration in freestanding PV systems throughout the Jordan Valley [19].

Researchers from India also utilized 'PVSyst' and 'PV-GIS' software to model a 10-MW on-grid solar facility in India, which produced 15798.192 MWh per year [20]. Some researchers performed a simulation-based evaluation of grid-connected roof PV panels for modest dwellings in Ujjain, India, using 'PVSOL', 'Solargis', 'PVGIS', and 'SISIFO', and attained a yearly yield of 1528.12 kWh/kWp [21].

Bifacial PV panels have a lot of potential for capturing solar energy. Unlike monofacial modules, bifacial modules may make use of sunshine coming in from both the front and back [22].

As a result, these modules can boost cell efficiency by up to 35 % by increasing power density, lowering area expenses, and reducing rear side contributions [23].

Furthermore, bifacial modules offer a 50 percent higher power gain than monofacial modules. The bifacial yield is also affected by tilt-angle configurations and albedo factors [24].

If the modules are situated 2 meters above the ground rather than near to the ground as in normal installations, the yearly bifacial energy production can be boosted by 30 % [25].

There have also been important contributions to bifacial modules. The other physical and irradiation properties of bifacial modules, as well as how they perform in the tropics and desert settings, were the major focus of these studies. Work on bifacial panels has also been done on the roof and the roadway. A study of bifacial PV setups in Pakistani roads was undertaken in 2018 [26].

Some researchers focused on conducting a reliability test on the generated data for solar PV bifacial modules by modifying tilt angles and diffuse radiation sharing [27]. Researchers worked on modelling the solar PV microgrid, in view of various irradiance sources as well as the impact of ground shadows [28].

Examiners studied the effectiveness of bifacial modules in tropical urban populations and also investigated the use of vertically mounted bifacial PV panels on campus microgrids with rooftop solar PV irradiance effects [29-31].

In this paper, with the aid of monofacial modules, the primary campus microgrid model was developed on the rooftop of a randomly selected department of the Muhammad Nawaz Sharif University of Engineering and Technology, Multan campus. The yearly consumption coverage of solar PV and the grid were designed by 'PVSol' and monofacial modules mounted at a mounting angle of = 170° and = 20° , respectively. Our study and analysis revealed that our suggested PV model can create 3,196.53 kWh of PV energy (DC), which is about 81.6 percent of the yearly consumption of our chosen site of 3,784.56 kWh. A complete study was carried out in this paper, with an emphasis on economic analysis as well as financial analysis. Prior to physical implementation, a comprehensive software analysis may help us identify

these minute computations and problems, as well as provide us with a good understanding of our system's output capability. As a result, we've built and structured our campus model to consume primarily solar PV energy, reducing our reliance on the utility grid.

II. SYSTEM DESIGNING

The model has been developed on 'PVSol' for MNSUET Multan where PVSol is a simulation tool to model, design, and analysis of PV system, it supports the analysis of solar PV installations in a variety of ways:

- The solar PV plant's feasibility can be determined before its execution for practical installation. These tools may be used to size various components in terms of technical specifications.
- The system's efficiency may be evaluated for longterm changes in system parameters.
- Estimates of energy potential can be evaluated.
- The system's financial advantages may be simply determined utilizing software tools that take into account numerous losses causes.
- A few techniques may also be used to estimate Green-House Gas (GHG) emission potentials.
- As a result, the usage of such simulations in academic institutions, research laboratories, enterprises, and consultancies would aid in the analysis of PV plant feasibility, as well as the knowledge of financial advantages.
- With these options, one may determine whether or not to build a PV power plant in a specific area.

A. Simulation Procedure

- The simulation procedure is as follows [32]:
- The user must enter a few parameters such as the location of the PV system installation, the load profile, and yearly energy consumptions into this application.
- Data on PV modules must be provided (this includes rating, number of modules, module tilt angle, the orientation of the module).
- Inverter details have to be given (The user has the flexibility to select an Inverter from the available database).
- This is a hidden process, that 'PVSol's' automatic configuration manager will then optimize the system by arranging the number of modules and the inverter.
- This step would the simulation execution.
- The simulation results of the system are provided. Annual solar energy, performance ratio, independent power usage, and solar percentage are all included.

The simulation procedures are taken out by considering the campus location at location: latitude 30.2° and longitude 71.43° where annual global irradiation 1862 kWh/m^2 and the annual average temperature is 24.4° is shown in Figure 1.

Campus microgrid system is connected with PV system along with utility grid. It exchanges energy with the grid during the non-availability of solar energy. But mostly it is utilizing energy from solar PV during peak hours on regular days. The grid-connected PV system block diagram is shown in Figure 2.



Figure 1: MNSUET Multan Campus Microgrid Top View



Figure 2: Grid-Connected PV System Block Diagram

B. PVSol Premium 2021 (R8)

A high-capacity solar system was required to meet the energy requirement, based on the specified consumption. PVSol Premium 2021 is a system design tool that we used in this aim (R8).

Simulation software is an excellent design tool for creating precise forecasts, visualizing systems, and creating professional reports to provide clients with the best return on their investment. 'PVSol® Premium' is a solar software design tool that simulates the performance of PV systems. It's a full-featured software for people who don't want to model shading and see the environment in 3D.

From this software, the campus microgrid model is designed on the software PVSol by selecting the manufacturer (G-solar) and PV module (GSP 270).



Figure 3: Designing of MNS Microgrid on PVSol

Graphical coverage of the designed model is shown in Figure 3.

Campus microgrid is installed on a random department selected with the PV positioning parameters are shown in Table 1.

Position of PV Area	Position of PV Modules	Mounted Roof Angle	
x = 0 m	x = 3.457 m	α=170°	
y = 15 m	y = 16.396 m	β=20°	

 Table 1: PV Positioning Parameters on Rooftop

III. SIMULATION RESULTS

Our simulation model generates various findings for different sections of our solar PV system after assembling all of the input parameters. As demonstrated in figures i.e., Figure 4 to Figure 8, they are associated with system performance, yearly production forecast, production forecast per inverter, irradiance per module area, and temperature per module area.

A. System Performance

We receive the following findings as to the output of the system of module area 1 by running simulations on PVSol. We obtained a Performance Ratio (PR) of 79.54 percent for the solar system, which is acceptable for the utility site and can produce a particular yearly output of up to 1586.18 kWh/kWp units, which is sufficient for the consumption of all hostels, based on this simulation.

Table 2: Resultant Parameters of Module Area 1					
Module Area Parameters					
PV Generator Surface	191.97	m²			
PV Generator Output	31.86	kWp			
Global Radiation at the Module	1915.25	kWh/m²			
Global Radiation on Module 1993.17 kWh/n					
Performance Ratio (PR)	79.54	%			
Spec. Annual Yield	1586.18	kWh/kWp			
PV Generator Energy (AC grid)	50535.77	kWh/Year			

B. Annual Production Forecast

The yearly production is estimated to be around 4 lacs units. This product is highly dependent on the monthly average utility usage as well as solar radiation for that month. Maximum output, according to our calculations, occurs in the months of May and April.







Figure 5: Annual Performance Ratio (PR) per Inverter (Performance Ratio Vs Months)



Figure 6: Annual Production Forecast per Inverter (Energy kWh Vs Months)



Figure 7: Annual Temperature per Module Area (Temperature ⁰C Vs Months)



C. Financial Analysis

For our PV rooftop installation, a cost estimates analysis was conducted. The installation or capital cost, operation, and maintenance cost, assessment period, and annual savings in the total grid-power price have all been shown, with the cost of solar panels, wiring, inverters, miscellaneous costs, and mounting systems cost being taken into account for our system's installation.

Table	3:	Financial	and	Economic	Parameters	of th	ne System	Data

System Data					
First-year Grid Feed-in (incl.	50.536	kWh/Year			
Module Degradation)	20,220	n on rou			
Solar PV Generator Output	31.9	kWp			
Start of System Operation	9/1/2021				
Assessment Period	20	Years			
Capital Interest	1	%			
Economic Parameters					

Return on Assets (ROA)	11.38	%
(Cash Balance) Accrued Cash Flow	65,009.07	\$
Amortization Period	8.1	Years
Energy Production Costs	0.05	\$/kWh
Payment O	verview	
Exact Investment Costs	1,500.00	\$/kWp
Specific Investment Costs	47,790.00	\$
Incoming Subsidies	0	\$
One-off Payments	0	\$
Annual Costs	0	\$/Year
Savings	0	\$/Year
Remuneration	and Savings	
Utility Total Payment in 1st Year	6,163.70	\$/Year
Validity	9/12/2021 -	12/31/2041
Specific feed-in	0.122	\$/kWh
Export Tariff / Feed-in	6.163.70	\$/Year

The G-solar and PV module GSP 270, which costs \$261.57, is the solar-panel model we've chosen. As a result, the total cost of 118 panels is (\$41,687.32).

A single SUN2000L-5KTL type inverter costs \$1495.41. As a result, the total cost of 11 inverters is projected to be \$15449.51.

The capital cost of mounting will be around \$2480.2, assuming a roof mounting cost of \$0.057 per watt of power produced. In conclusion, wiring and other expenditures such as switchgear, fuses, relay, and other miscellaneous charges will cost about \$3439.66 to install. As a result, the total cost of installation, including incidental expenses, is \$47,790.00.

We estimated that Operating and Maintenance (O&M) expenses would be 5 % of the initial cost. As a result, the O&M cost is 3414.09.

The price of grid power was estimated to be 0.072 \$/kWh. The yearly PV yield is 50535.77 kWh/Year on average. As a result, yearly savings of \$4483.56 will be attainable. However, a 10-year comparison analysis was carried out to examine the project's outcome and to determine how much it will generate and provide advantages.

	Table 4:	Financial	Analysis for	or the Upcoming 10-years
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Years	(Year-1)	(Year-2)	(Year-3)	(Year-4)	(Year-5)		
Investments	\$47,790	\$0	\$0	\$	\$0		
Feed-in / Export Tariff	\$6,102	\$6,042	\$5,982	\$5,923	\$5,864		
Annual Cash Flow	\$41,687	\$6,042	\$5,982	\$5,923	\$5,864		
Accrued Cash low (Cash Balance)	\$41,687	\$35,645	\$29,662	\$23,739	\$17,874		
Years	(Year-6)	(Year-7)	(Year-8)	(Year-9)	(Year-10)		
Investments	\$0	\$0	\$0	\$0	\$0		
Feed-in / Export Tariff	\$5,806	\$5,749	\$5,692	\$5,635	\$5,579		
Annual Cash Flow	\$5,806	\$5,749	\$5,692.08	\$5,635	\$5,579		
Accrued Cash low (Cash Balance)	\$12,068	\$6,319	\$627	\$5,008	\$10,588		



Figure 9: Annual Cash Flow-Cash Balance (Cash Flow in \$ Vs Years)

An analysis has been provided above that includes a thorough explanation of the installation's technical characteristics and accumulated cash flow. Once the solar assessment has been completed, the expected Global PV radiation, rated PV energy in 'W' is also been estimated annually from PVSol as shown in Figure 10 and Figure 11.



Figure 10: Global PV Radiation in 'W' Vs Months

Haseeb Javed et al,



Figure 11: Annual PV Energy with Outside Temperature (Temperature ⁰C Vs Months)

IV. CONCLUSION

In this research paper, with the support of monofacial modules, a main investigative investigation was done on the rooftop of a randomly selected department of the Muhammad Nawaz Sharif University of Engineering and Technology, Multan campus. The yearly consumption coverage of solar PV and the grid were given using PVSol and monofacial modules mounted at a mounting angle of = 170° and = 20° , respectively. Our study and analysis revealed that our suggested PV model can create 3,196.53 kWh of PV energy (DC), which is about 18.4 percent of the yearly consumption of our chosen site of 3,784.56 kWh. As a result, yearly savings of \$4483.56 will be attainable. A complete study was carried out in this paper, with an emphasis on economic analysis as well as financial analysis.

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Author Contributions

Both authors Haseeb Javed and Hafiz Abdul Muqeet contributed to the investigation, project administration, supervision, visualization, data collection, pre-processing of the input data, writing, review, and editing. Both authors have read and agreed to the published version of the manuscript.

Conflict of Interest

The authors declare no conflict of interest.

Data Availability Statement

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

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