22nd International Conference on Renewable Energies and Power Quality (ICREPQ'23)
Bilbao (Spain), 26th to 28th June 2024, Renewable Energy and Power Quality Journal (RE&PQJ),
ISSN 2172-038 X, Volume No.22, September 2024

Grid Connected PV System for an Academic Building of KFUPM Campus in Saudi Arabia.

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Abstract

Rising living standards through smart and sustainable development is crucial to advancing human life and protecting the natural environment. The smart grid is an ideal opportunity to create efficient and sustainable solutions for closed communities. This is to provide them with a robust and resilient infrastructure. Because the smart grid is a large system that can be developed in many forms, such as smart metering, sustainable power generation, demand response automation, and data management, each application can be developed independently and contribute to increasing the value of efficient and sustainable factors. This paper studies alternative power supplies for supplying an academic building in the King Fahd University of Petroleum & Minerals (KFUPM) Campus of Saudi Arabia. The extra power was sold to the electricity company and shared with the grid to reduce consumer bills. A small-scale PV system is modeled and analyzed using HOMER software for community purposes. A simulation-based model has been developed to optimize local power supply and demand for residential communities. Using HOMER, an economic analysis has been conducted and possible alternatives suggested based on the electricity consumption. According to the simulation results, the buildings' electricity supply could be generated most effectively by installing a PV power system on the roof. Though the total net present cost (NPC) and cost of energy (COE) of the system with PV is slightly larger than grid only system, it can be recommended by considering the ongoing increasing energy prices and nonrenewable energy sources. .

Objectives

- Investigate alternative power supply options for an academic building in the King Fahd University of Petroleum & Minerals (KFUPM) Campus in Saudi Arabia, aiming to reduce consumer bills by selling excess power to the electricity company and sharing it with the grid.
- Utilize HOMER software to model and analyze a small-scale PV system for community use.
- Develop a simulation-based model to optimize local power supply and demand for residential communities, with an economic analysis providing suggestions based on electricity consumption.
- Demonstrate through simulation outcomes that installing a PV power system on the roof is the most effective method for generating electricity for the buildings, despite slightly higher total net present cost (NPC) and cost of energy (COE) compared to a grid-only system.
- Support this recommendation with the ongoing rise in energy prices and dependence on nonrenewable energy sources.

Assumption and Model Inputs

A. Solar energy resource potential in the KFUPM

The NASA Surface Meteorology and Solar Energy website was used to automatically calculate the solar resource for the site. A latitude of 26.3071° N and an easterly longitude of 50.1459° E was recorded. This area receives an average solar radiation of

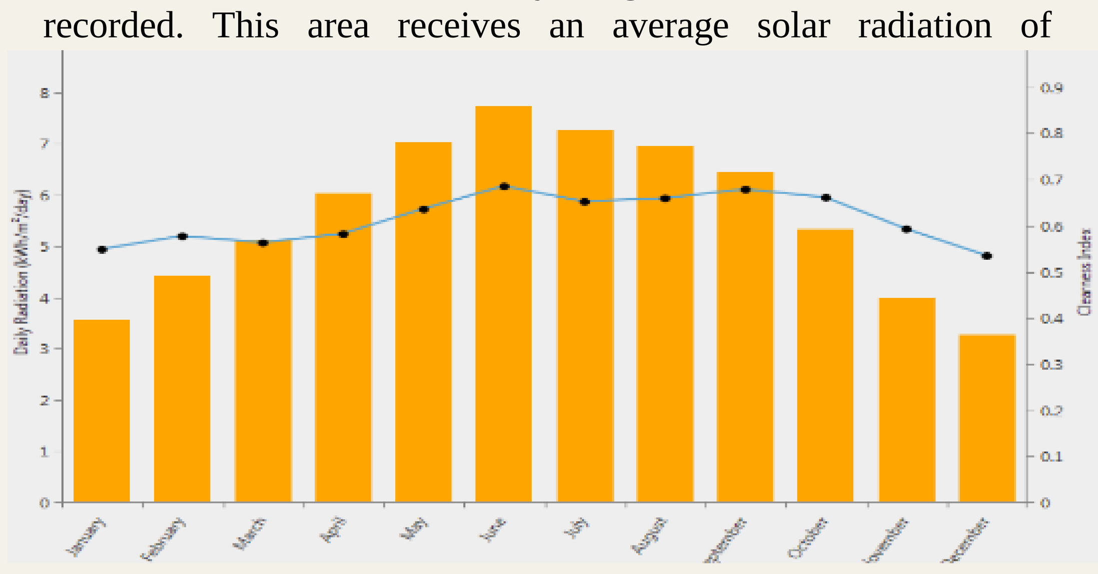

Fig. 1. Solar radiation profile for Al-Dhahran city.

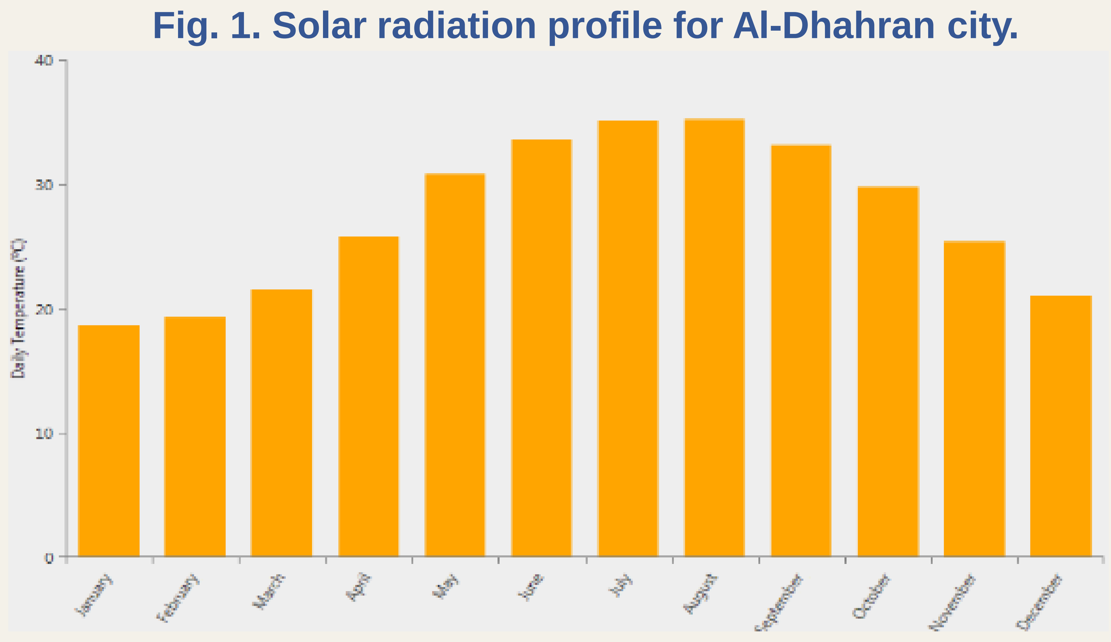

Fig. 2. Temperature profile for Al-Dhahran city.

Assumption and Model Inputs

B. Area and the Isometric view of the proposed buildings

As part of this work, we applied our analysis to a typical academic building in KFUPM. This building has a total area of 6239.62 m2. As shown in Fig. 3,

Fig. 3. Area and overview of the selected Academic building.

C. Load profile of the building

The load profile of the assumed study building is explained in this section. Table I and Table II represent the corresponding load demand for the academic building.

Table I: Electrical Load for Academic Building.

Floor	Number of lights	Total Load (W)
2nd floor	Led spotlight = 54, 15 watts for each	810
	Regular tube light = 367, 36 watts for each light; each box consist of 2	26,424
1st floor	Led spotlight = 54, 15 watts for each	810
	Regular tube light = 367, 36 watts for each light; each box consist of 2	26,424
Ground Floor	Led spotlight = 73 & 15 watts for each	1,095
	Regular tube light = 392 & 36 watts for each light; each box consists of two	28,224
Parking	Regular tube light = 162 & 36 watts for each light; each box consists of two	11,664
External Lights	Regular tube light = 42 & 36 watts for each light; each box consists of two	3,024
	Total	98475

Table II: Overall Interior and External Lighting Load.

Category	Duration (H)	Lighting Load (W)
Interior Lighting	24	95,451
External Lighting	12	3,024
Total		2,327,112Wh/d
		849,545.88kWh/y

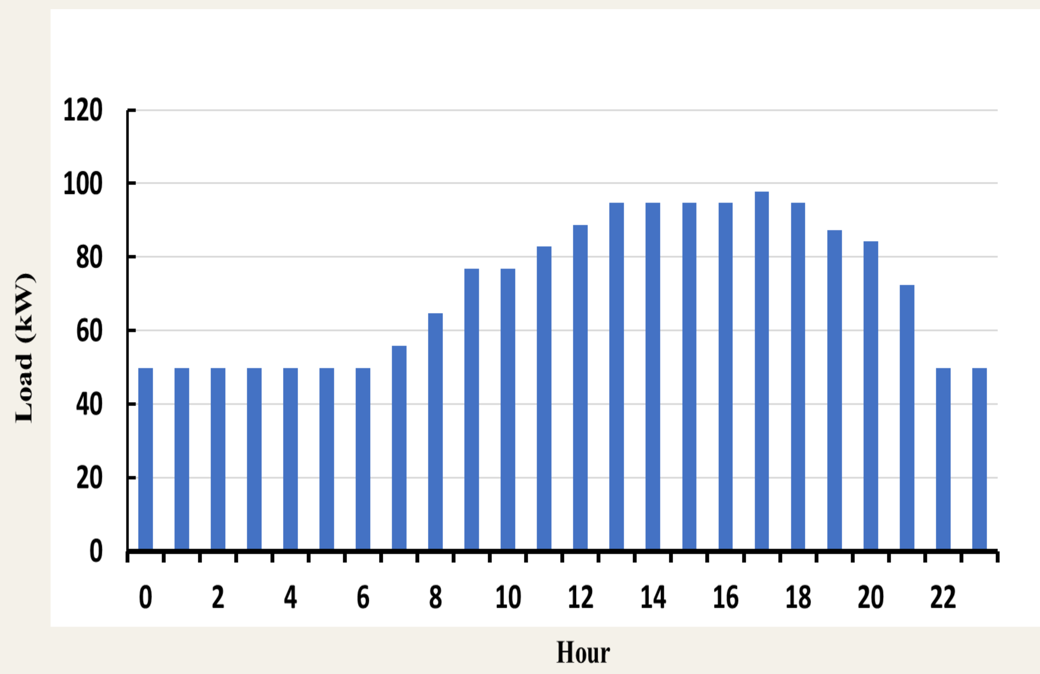

Fig. 4. Daily average load demand for Academic building.

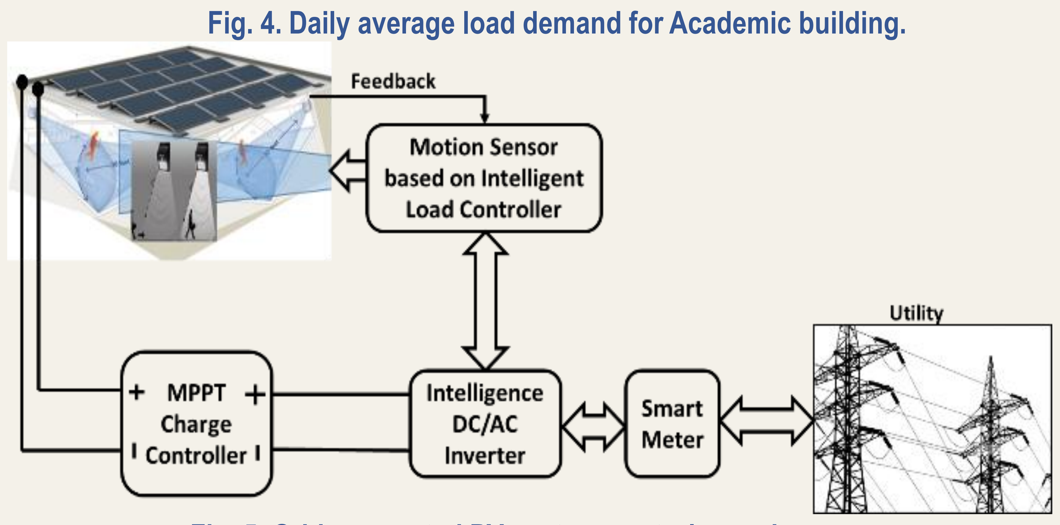

Fig. 5. Grid-connected PV system control overview.

D. Optimum array orientation and Placement

As a result, the tilted angles of the fixed solar arrays for the proposed study building are calculated and presented in Table III for the four different seasons for the proposed study building.

Table III: Solar Tilt Panel Angle Calculation

Season	Tilted angle (Latitude =26.3 degree)
Winter	52.67 degree
Summer	47.17 degree
Spring and Fall	23.8 degree

HOMER Simulation Results and Discussion

A project is created using HOMER software with the following criteria:

- A grid-connected module with a PV system and load.
- The cost of energy from the grid is 0.053$/kW [30].
- PV, Sun power X21-335-BLK Flat plate, price from internet (Most Efficient PV panel with 21% module efficiency guaranteed for 25 years)
- A generic system converter has a lifetime of 15 years and an efficiency of 95%.

Simulation Results and Discussion

HOMER software defines the levelized cost of energy (COE) as the average cost per kWh of usable electrical energy produced by the system.

$$COE = \frac{C_{Tot.Ann} - c_{boiler} H_{Served}}{E_{Served}} \quad (1)$$

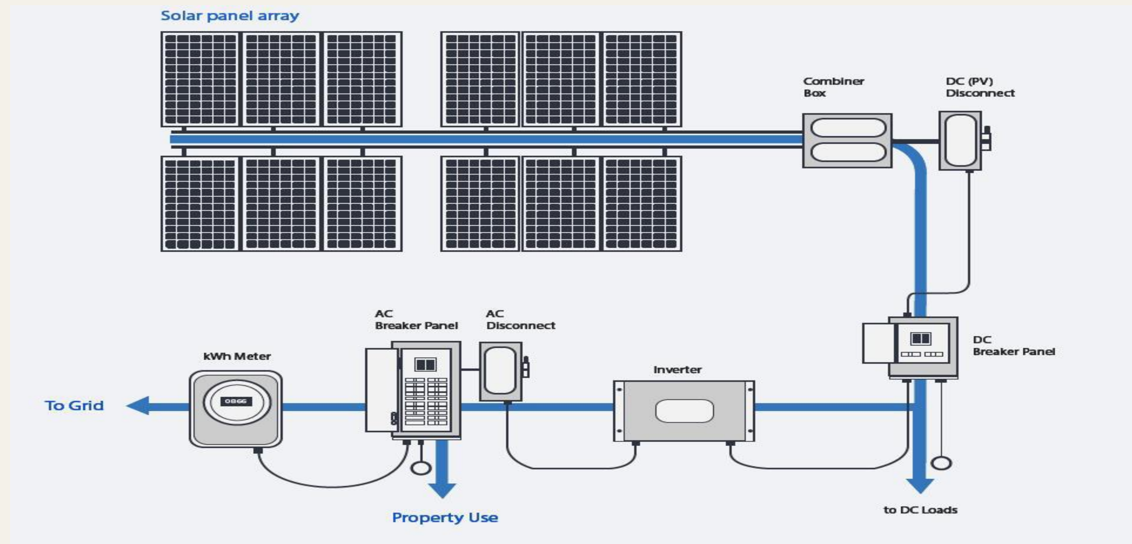

Fig. 6. Grid Schematic for the building

- The proposed system's energy production covers 73% of the overall load, amounting to approximately 965,351 kWh per year.
- Energy sharing between the PV and grid systems to meet the building load is detailed in Table IV.
- Table V summarizes monthly purchased and sold energy, resulting in net purchased energy in kWh.
- The optimized system allows the building to use all available resources more efficiently, yielding higher production values than other non-optimized systems.
- This optimization reduces the building's energy bills and allows for greater energy independence.
- The net present costs (NPCs) of the proposed system are $87,121, with capital expenditures of $117,660, contrasting with the grid's only NPCs of $581,971.
- Additionally, the Levelized Cost of Energy (COE) is 0.00532 ($/kWh), while the grid-only COE is 0.053 ($/kWh).
- This significant discrepancy indicates that the proposed system has significantly lower NPC and COE than the grid-only system, making it a more economically viable option.

Table IV: Overall Electrical Production for the System.

Production	kWh/yr	Percentage of total production
PV system	965,351	72.4
Grid	367,638	27.6
Total	1,332,989	100

Table V: Monthly Net Energy Purchased and Sold.

Month	Energy purchased (kWh)	Energy sold (kWh)	Net Energy purchased (kWh)
January	21,466	40,145	-18,679
February	16,124	40,940	-24,816
March	21,905	42,566	-20,661
April	21,510	37,322	-15,812
May	44,322	26,637	17,685
June	51,879	23,831	28,048
July	48506	26,432	22,074
August	43,081	29,053	14,028
September	37,370	30,281	7,089
October	25,076	38,701	-13,625
November	18,673	41,208	-22,535
December	17,726	40,175	-22,449
Annual	367,638	417,291	-49,653

Conclusion

- An economic feasibility study of a PV system has been conducted using HOMER software for a building situated at KFUPM in Saudi Arabia.
- The study offers insights into the potential of PV systems in the region, aiming to develop a more efficient and cost-effective energy solution for the building.
- Simulation results suggest that installing a PV power system on the rooftop is the most effective way to generate the building's electricity supply.
- The PV system is demonstrated to provide a reliable energy supply to the building while reducing electricity bills and carbon footprint.
- Despite higher net present costs (NPC) and cost of energy (COE) compared to the grid-only system, the study recommends considering ongoing increases in energy prices and reliance on nonrenewable energy sources.
- The benefits of the PV system make it an attractive option, offering cost savings, reduced environmental impact, and enhanced energy security.

Acknowledgements

The authors would like to acknowledge the support and funding provided by Applied Research Center for Metrology, Standards and Testing (ARC-MST) through Grant NO. CMST2488, Research and Innovation at the King Fahd University of Petroleum & Minerals (KFUPM).