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Commercial Building Energy Consumption Management with an Optimal Solar Panel Angle

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ABSTRACT: The study examines the use of solar energy in commercial buildings to optimize energy consumption and reduce environmental pollution. The research found that selecting the right angle for solar panels can lead to lower costs and increased energy absorption. The study used DesignBuilder software and Polysun software to calculate energy requirements and solar panel energy, revealing that solar modules could provide a zero-energy system with an annual energy balance.

KEYWORDS: Optimal Angle, Renewable Energy, Photovoltaic Modules, Energy Efficiency, Energy Consumption Management

I. INTRODUCTION

Today, environmental issues have a negative effect on building industries as a result of urbanization and a shortage of energy in the public and professional sectors. Commercial buildings contribute significantly to energy efficiency. According to the Iran Department of Energy (2015), residential, commercial, and office buildings utilize around 40% of the country's total energy [1, 2]. Because this sector accounts for a significant portion of final energy consumption, proper measurement of a building's thermal and cooling loads, as well as measures to limit energy losses, are effective approaches to reducing energy consumption [2]. Architects and engineers must make important judgments in the early phases of building design about the overall implications of building physics.Performance of the building [3]. As previously stated, one of the primary causes of environmental pollution is fuel usage in business and residential structures. This subject has piqued the interest of many scholars and specialists in recent years due to the necessity to optimize energy usage in cities, particularly in the building industry [4].

II. LITERATURE SURVEY

Amani and Reza Soroush (2020) investigated effective energy consumption metrics in buildings. Their studies revealed that each building component played an important part in determining the building's energy performance [2]. Today, the utilization of solar panels is rising.Solar energy generation is important across the world [5]. Solar panels are one of the most effective renewable solutions for powering buildings. Knowing the optimal tilt angle is required to get the maximum potential yearly or seasonal energy production. The ideal tilt angle is determined by a variety of circumstances, including latitude, weather, and surroundings [6, 7]. To improve the effectiveness of solar systems, it is recommended that required precautions be taken from the outset of design to integrate solar panels with the building facade [8]. It is critical to assess the potential thermal or electrical energy output from active solar systems such as solar collectors and PV panels [9]. The availability of worldwide irradiation data measures is one of the most essential elements in determining the solar potential for photovoltaic panel installation [10]. For this reason, using daily data for modeling is critical. In addition, input data for models and validation data should be reviewed at the same station [9]. In some places where it is not practicable, numerical models have been developed for estimating monthly, seasonal, and yearly solar radiation (global diffuse and direct solar radiation), particularly on slanted surfaces [10]. Many solar panels are linked serially. As a result, the panels are frequently exposed to very high potentials compared to the ground, leading to high voltage pressure (HVS). The effect of this pressure was assessed in the long run.NREL assessed the stability of solar panels in 2005 [5]. The utilization of natural energy is one of the most efficient techniques for optimizing fuel use in commercial and residential buildings.energy in the climatic design of buildings based on architectural concepts that are appropriate for each region's environment. As a result, one of the primary planning and design issues in Iran may be the change of construction legislation in response to the energy crisis and the need to

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reduce energy usage [11]. Ifaei et al. (2017) used energy in the climatic design of buildings based on architectural concepts that are appropriate for each region's environment. research on sustainable development in Iran utilizing Technical-Economic-Socio-Environmental Multivariate Analysis (TESEMA) and renewable energy. The findings indicated that Iran's existing centralistic policies should be altered in order to achieve sustainable growth [12]. Furthermore, Karbasi et al. (2007) demonstrated that boosting energy efficiency, particularly combined cycle power production, was the most cost-effective approach for lowering greenhouse gas emissions in Iran. So, pricing reform is the significant policy for boosting energy efficiency and replacing fossil fuels with renewable energy [13]. Climate aspects have historically been the most significant challenges for humans. As a result, one of the factors contributing to architecture's incompatibility with the regional environment is a lack of understanding about detecting climatic conditions and their influence on architecture [11]. Because a large portion of the country experiences hot weather, it is critical to employ appropriate techniques to lower the expense of cooling the structure. Due to Ahvaz's long and hot summers, it is vital to implement energy optimization concepts in the building [14]. Ifaei et al. investigated integrated wind and solar systems al. (2017), Iran is primarily a solar nation, with a solar energy proportion of roughly 74% under optimal circumstances [15]. Furthermore, Karbassi et al. (2008) showed that solar water heating systems as a conventional energy substitute might cut the consumption of electricity or fossil fuels by up to 80% [16]. Because reducing energy consumption is critical for achieving sustainable development and lowering operational expenses [17], efforts should be made to minimize fossil fuel usage. One of the building's energy management options is the employment of innovative technology for energy optimization and sustainability. In other words, the cooling and heating demands of Iranian buildings influence the deployment of innovative energy management systems. A thorough assessment of previous There has been a study on the energy usage of buildings utilizing solar panels. These papers were adapted from well-known databases such as Science Direct, Wiley, and Taylor & Francis. Modeling and simulation have been used to examine issues related to energy conservation and efficiency in buildings using solar panels [18–29]. The energy study was carried out using DesignBuilder software. This is one of the most effective building energy modeling and analysis software tools. The primary arguments for using this program are its high computation accuracy and ability to anticipate air temperature at any time of year. Furthermore, the use of a sophisticated EnergyPlus engine may produce graphs and numerical data for energy analyses. This project modeled a five-story commercial building in Ahvaz.Finally, it was demonstrated that using solar panels to optimize energy usage might minimize expenses and pollution. It should be emphasized that attaining this aim requires the ideal angle of panels. It is a conceptual framework for integrating energy management concepts and application tactics in buildings, with a focus on the construction life cycle, to contribute to sustainable development. This research attempts to reduce the expenses of utilizing a solar panel system optimally. Using Polysun software, transform solar energy into electrical energy by determining the optimal angle for solar panels.

III. MYTHODOLOGY

I. **Software selection:** In this study, the energy model was created using DesignBuilder software. This program can compute cooling and heating loads based on criteria such as material structure, occupants, mechanical and electrical systems, and yearly or hourly climatic data to keep the temperature within a comfortable range. Another feature of this program is the ability to anticipate air temperatures at various locations within the building based on the criteria described above at any time of the year. After constructing the energy model in DesignBuilder software, the building's yearly energy requirements were determined. Polysun software was then utilized to fulfill the building's energy requirements via solar panels. Polysun investigated solar radiation angles based on the project's geographical location.program to determine the best yearly angle. the specifics of the composite roof layers in the DesignBuilder program.

II. **Case study:** The case study building is a 5-story commercial structure in Ahvaz with a total size of 2200 m. It sits on a 30 cm-high integrated concrete surface. To determine the amount of energy necessary to attain the comfort level, which is the supply of temperature and humidity within the prescribed range, the space conditions must be transitory. The analyzed building was simulated using DesignBuilder software. This program allows for energy simulations on an hourly basis throughout the year. three-dimensional image of the building using DesignBuilder software. Each story is 3.5 meters high, and the overall height of the rooftop is 17.5 meters above ground. The building's external walls were 20 cm thick, while its roof was made of composite material. All windows are double-glazed, with a 6 mm-thick intermediate air layer and no blinds. The southern side of the structure had an 8% window-to-wall ratio, whereas the eastern side had 9% on the floors. Additionally, the doors were composed of unbreakable glass. Fluorescent bulbs with a light level of 600 lux were used to provide illumination for the building brightness coefficient of 0.74. The average number of customers was considered 60 people per day.

III. **Climate conditions:** Ahvaz has unique climatic conditions due to its position. One of the characteristics of this climate is the high intensity of sunshine, which, according to Article 19 of Iran's National Building Regulations [30],

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falls into the category of structures with high energy consumption. Extreme heat creates several issues for humans. As a result, the study of climatic conditions is an attempt to mitigate significant issues. Synoptic meteorological data were used to investigate the climatic situation in Ahvaz. **Table 1** [31] shows that Ahvaz has hot and extended summers Short and warm winters. The highest temperature in July and August exceeds 50 °C, while the maximum relative humidity in January is 60%. The greatest rainfall in April is 40.8 mm. Also, the largest number of hours of sunshine in June is 353 hours, while the lowest number of hours of sunshine in January is 167.5.

IV.

Table 1. Meteorological information of Ahwaz station per month

Month	Temperature (°C)				
	Maximum average	Minimum average	Average	Highest maximum	lowest minimum
January	20.5	9.2	14.9	25.9	9.2
February	19.2	7.1	13.2	25.2	7.1
March	25.4	11.3	18.3	30.5	11.3
April	29.5	16.0	22.7	35.6	16.0
May	39.7	23.8	31.8	45.8	23.8
June	42.3	26.4	34.4	47.8	26.4
July	47.3	30.7	39.0	50.4	30.7
August	47.4	29.9	38.6	50.4	29.9
September	45.0	27.4	36.2	49.1	27.4
October	38.2	20.0	29.1	43.5	20.0
November	31.6	15.5	23.6	36.6	15.5
December	20.8	9.0	14.9	25.6	9.0

Month	Rainfall (mm)	Maximum rainfall in one day (mm)	Relative humidity (%)	Frosty day (s)	Dusty day (s)	Sunshine duration (h)	Wind speed (m/s)
January	16.5	16.5	60.0	0.0	3.0	167.5	15.0
February	6.0	2.8	54.0	1.0	8.0	179.1	18.0
March	24.9	15.2	47.0	0.0	3.0	215.8	19.0
April	40.8	23.0	48.0	0.0	3.0	269.4	20.0
May	0.3	0.2	36.0	0.0	5.0	308.9	17.0
June	0.0	0.0	23.0	0.0	8.0	353.0	16.0
July	0.0	0.0	25.0	0.0	6.0	348.0	13.0
August	0.0	0.0	30.0	0.0	1.0	351.7	12.0
September	0.0	0.0	27.0	0.0	3.0	319.3	16.0
October	0.0	0.0	29.0	0.0	5.0	275.5	14.0
November	0.0	0.0	44.0	0.0	3.0	236.4	15.0
December	21.3	11.0	49.0	0.0	2.0	193.3	17.0

V. **Solar radiation analysis:** Solar radiation modeling is a complex process that considers latitude, solar radiation interval, model height, surface orientation, surface reflectivity, and atmospheric conditions. The data reveal that the lowest average monthly sunlight occurs in December, with values ranging from 2.83 to 3.46 kWh. January and November get the least amount of sunlight. The largest amount of sunlight occurs in June, with an average daily value of 8.29 kWh/m. Between April and September, the average daily sunlight exceeds 5.78 kWh/m2 (greater than the average yearly radiation). The average annual intensity of solar radiation is 5.18 kWh/m/day, placing it in a highly acceptable category according to the US National Renewable Energy Laboratory's classification of solar radiation. The maximum quantity of solar energy is generated during the warmer months of the year, which corresponds with the highest power usage in Ahvaz. The high energy obtained during these months allows it to be used to supply a portion of the region's electricity, relieving pressure on power transmission lines and, as a result, reducing power outages. Despite this enormous potential, there is no photovoltaic power plant in Khuzestan Province, and solar energy output is minimal during the experimental and research stages**. Fig. 3** depicts the intensity of solar radiation based on the yearly average [32]. Solar radiation varies depending on the region's environment and the seasons. To make the most use of solar energy, the structure should be oriented so that it gets the most solar radiation during the cold months. In contrast, during the warmer months, the intensity of sunlight on the building's surface should be lowered. However, according to the region's requirements, the building placement was classified to the south. The quantity of solar energy received in different locations varies depending on latitude, height, meteorological conditions, and so on. To obtain information regarding solar radiation, the latitude and altitude of the place must be established. In this instance, you may compute the monthly and yearly averages of solar radiation for the selected region at all levels, with varying orientations and slopes. In this investigation, the latitude is 31.3° and the elevation is 16 meters. Figure 4 depicts the levels of solar radiation in the building on a yearly basis. These values have been extracted to a suitable level of 400 Lux, depending on the quantity of energy received from the translucent walls. In addition, all of the areas were well lit.

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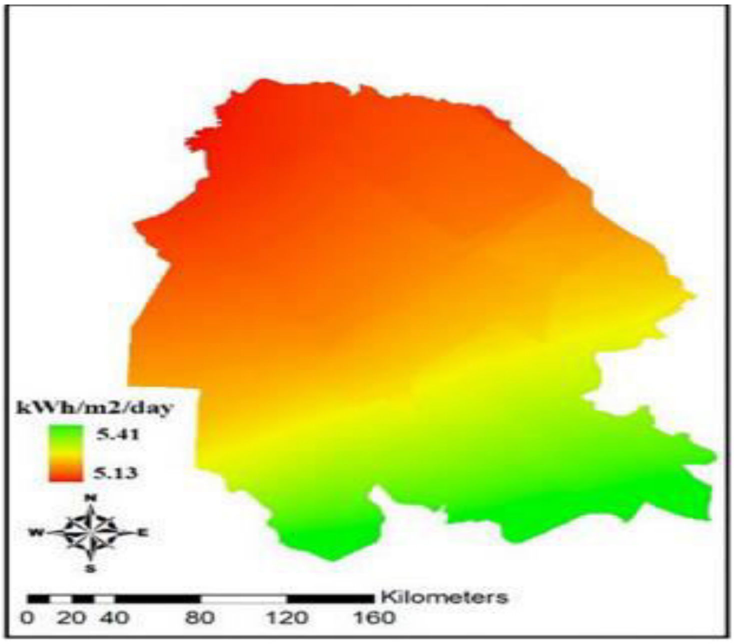

Figure 3. Average annual of daily solar radiation in Khuzestan province

VI. **Evaluation of photovoltaic modules in polysun Software:** Polysun software allows you to simulate solar systems as well as additional facilities such as heat pumps and geothermal energy to meet all or part of the building's energy requirements. In this study, the needed data were collected by Polysun software after defining the project site. Table 2 displays the yearly average energy generated by photovoltaic modules. For example, the value of energy output was computed in both August and February. The results revealed that the average yearly value of energy generated by 61 photovoltaic modules with a power of 350 watts and an angle of 31° was 26978 kWh/year. This figure will be greater than the total building energy usage. Additionally, the value of The energy produced in August by 41 photovoltaic modules with a power of 350 watts and an angle of 5.3° is equivalent to 27572 kWh per year.

VII.

Table 2. Energy generated by photovoltaic modules in Polysun software

Component overview (annual values)				
Photovoltaics roof plan	PV-Modul-350W			
	Unit	Annually	August	February
Number of modules		61	41	80
Total nominal power generator field	kW	21.35	21.35	21.35
Total gross area	M²	99.47	99.47	99.47
Tilt angle (hor.=0°, vert.=90°)	°	31	5.3	42.3
Orientation (E=+90°, S=0°, W=-90°)	°	0	0	0
Inverter 1: Name		Inverter 10500T		
Manufacturer		Anonymous		
Inverter 2: Name		Inverter 4000		
Manufacturer		Anonymous		
Manufacturer		Anonymous		
Energy production AC [Qinv]	kWh	26978	27572	26463

This energy output for February from 80 solar modules with a power of 350 watts and an angle of 42.3° is equivalent to 26463 kWh/year. All panels had a surface covering of 99.5 m. Based on the results of the August and February reviews, energy storage can be utilized to balance energy throughout the year. The angles supplied based on the software analysis correspond to the lowest prices for installing solar panels to convert solar energy into electricity. Figure 5 depicts the amount of energy generated by photovoltaic modules in general mode (year average) using Polysun software. The results reveal that this technology can prevent the emission of 14471 kg of CO_2 per year. Furthermore, by employing the solar water heating system, the The discharge of environmental contaminants can be minimized as much as is feasible. At the national level, this sum may help maintain and sustain the environment while also guiding the country toward sustainable growth.

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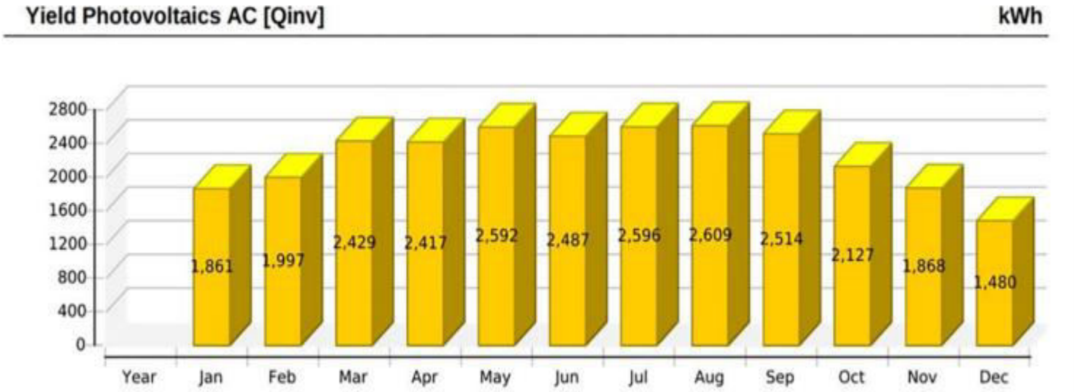

Figure 5. The energy produced by photovoltaic modules monthly

IV. DISCUSSION

For years, academics have been thinking about how to make a beneficial contribution to the future by developing new energy in response to rising global temperatures and pollution. Solar energy is one of the cleanest and most readily available energy sources. Solar panels are very important in this industry since they convert solar energy directly into electrical energy. The tilt angle of a solar energy system is an important component for maximizing solar radiation falling on solar panels. This angle is site-specific and determined by the sun's daily, monthly, and annual journey. To accurately determine the optimal tilt angle, Essential for the system's maximum energy generation. Yadav and Chandel (2013) investigated the importance of the optimal tilt angle in energy production and lowering the cost of solar energy systems. Their studies revealed that for best energy gain, the optimal tilt angle for solar systems must be precisely established for each site. Various anisotropic models and optimization strategies might be utilized to achieve this goal. Furthermore, for metropolitan regions, barriers impacting solar radiation should be addressed when calculating optimum tilt angles [38]. In addition, Yadav and Chandel (2014) investigated several isotropic and anisotropic diffused solar radiation models for calculating the best tilt angle in India. They discovered that the Liu and Jordan models demonstrated The lowest error among other models. Accordingly, the yearly optimal tilt angle was calculated to be 27.1° [39]. Chandel and Aggarwal (2008) evaluated the thermal performance of a passive solar commercial building in India's Himachal Pradesh. The results revealed that the solar passive system features saved on the power required for space heating and decreased heat losses in the building by approximately 35% [40]. Ben Othman et al. (2018) studied global solar radiation on tilted surfaces in Tunisia and discovered that the best yearly angle in the north was 37.5°, while the northeast and south were 36.6° [10]. The study emulated a commercial building in Ahvaz. Ahvaz is known for its great intensity of sunshine amid a collection of buildings with significant energy usage. This environment offers great potential for maximizing the use of sunshine to generate energy. Solar radiation research revealed that the lowest average monthly solar radiation was in December, with values ranging from 2.83 to 3.46 kWh. Furthermore, the highest value of sunlight occurred in June, with an average daily rate of 8.29 kWh/m. From April to September, the average daily sunlight is more than 5.78 kWh/m, above the average yearly radiation (22). The optimum tilt angle of solar photovoltaic panels is critical in determining the optimal size of solar photovoltaic systems for a given site. As a result, a solar module's capacity to maximize incident radiation is dependent on. To improve the power generation of solar photovoltaic systems, monthly, seasonal, and yearly optimum tilt angles should be determined for the considered site. In this study, the optimal tilt angle of photovoltaic panels was determined to be 31°. The evaluation of photovoltaic modules showed that the angle of placement of panels affected the amount of energy produced and the number of modules. As a result, selecting the optimal angle of placement for panels will have In addition to minimizing energy use, economic and socio-cultural factors should be considered. The tremendous potential of solar energy in Iran to diversify the energy basket and build a platform for the development and promotion of renewable energy offers the opportunity to use this limitless resource.

V. CONCLUSION

The Ministry of Energy's Rule No. 667 established the ideal yearly angle for Ahvaz as 23.7°. However, this study found that establishing the ideal angle of solar panels based on the building's energy requirements was the most essential component of cost reduction for effective energy management. These findings might reduce the cost of employing solar panels to convert solar energy into electrical energy. The energy modeling findings revealed that the total building energy usage was 26604 kWh/year. As a result, the building energy use was 69.10 kWh/m/year, which

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was reduced to zero using solar panels. Furthermore, the findings of the photovoltaic module evaluation in Polysun software revealed that the energy generated by 61 photovoltaic modules with a power of 350 watts and a surface area of 99.5 meters, the annual energy consumption was 26978 kWh. This number was higher than the total building energy usage. This system allows for the release of 14471 kg of carbon dioxide being prevented on a yearly basis. Finally, a comparison of several techniques of energy consumption revealed that the optimal approach for achieving a zero-energy system was 61 photovoltaic modules with a power of 350 watts, an angle of 31°, and a surface coverage of 99.5 m.

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