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Improving Electrical Loads and Designing a Solar Energy System for a Government Facility in Hilla City

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Abstract

This research focuses on calculating and improving electrical loads and designing a solar system for a governmental building in Hilla city (Hilla Electricity Training Center). The building operates for 7 hours a day and 22 days a month. The current loads were calculated and were found to be 76% cooling loads, 9% lighting loads, and 15% other loads. Cooling loads are the highest in energy consumption, so the existing traditional cooling devices were replaced with inverter ones. According to the hours of use at the selected location, the percentage improvement in electrical energy consumption for cooling loads is 35%. The lighting load consumption was improved by 55%, as the regular CFL lighting with a capacity of 80 watts was replaced with LED lighting with a capacity of 36 watts. The total improvement in the loads was 31.5%. After the load improvement step, a solar system was calculated and designed to cover the new loads after improvement. The solar system consists of 452 bifacial panels, 580 W, and 150 Lithium batteries, 200 Ah, 48V.

Key words: Solar system design, Energy consumption, Bifacial panels, Load improvement, Solar system sizing, LED & CFL lighting, Inverter air conditioner.

1- Introduction

1-1 What is Solar Energy?

Solar energy is the most available source of energy in nature, and 10,000 terawatts is the total solar energy reaching the Earth daily [1]. It is one of the most renewable energy sources that will be influential in the future [2]. This type of energy is characterized by cleanliness and ease of availability compared to others. Many technologies are used to harness the light and heat of the sun for many purposes, including generating electricity. Photovoltaic (PV) cells are one of these technologies, and the most famous of them [3]. A Photovoltaic cell is the technology used to convert light energy received from the sun into electrical energy for the purpose of human use. Photovoltaic cells are characterized as a renewable, free, safe source without polluting emissions and do not produce noise [4], [5].

Commercially, the efficiency of solar cells in converting into electrical energy is between 5% and 25%, and the remaining energy is converted into heat [6]. There are several problems facing the solar system that affect its efficiency, including temperature, dust, and shade [7]. Dust and bird droppings reduce the surface area absorbing the sun, so they reduce the efficiency of the panel's production [8].

In the Middle East, dust is one of the biggest challenges that affect the efficiency of the PVs [9], [10]. To increase efficiency, the angle of the solar panels is controlled through a sunlight tracking system. Interest in developing this system has increased due to its direct impact on efficiency until it reached the point of using smart systems [11]. There is a clear development in photovoltaic systems that has improved the efficiency and reduced the cost [12], [13].

Globally, one of the problems of supplying the world with energy is the resulting environmental pollution, in addition to the accumulation of carbon dioxide in the atmosphere resulting from the burning of fuel to obtain energy in its various forms. Therefore, the world seeks to develop clean energy sources with little or no negative impact on the environment [14]. The interests in solar energy comes to address the problems of the danger and cost of fossil fuels in the future [15].

1-2- Case Study (Hilla Electricity Training Center)

The climate of Iraq is dominated by temperature changes. Iraq has a distinguished position in the world of solar energy due to its proximity to the solar belt. This makes its lands receive enough radiation. The factors affecting the design of the solar system are wind speed and relative humidity, and as shown in the table below [16].

Table 1: Climate factors in Iraq [16].

Impact	Maximum	Minimum
Temperature	In summer (June, July, and August) (43°C – 50 °C)	In winter (January) (1°C – 8 °C)
solar radiation	(6.5 - 7) KWh/m^2	
actual brightness	In June, 11.4 hours/day,	In January by 6.3 hours/day
Wind speed	4.1 m/s in July	2.5 m/s in December and January
Relative humidity	73.8% in January	25.5% in October

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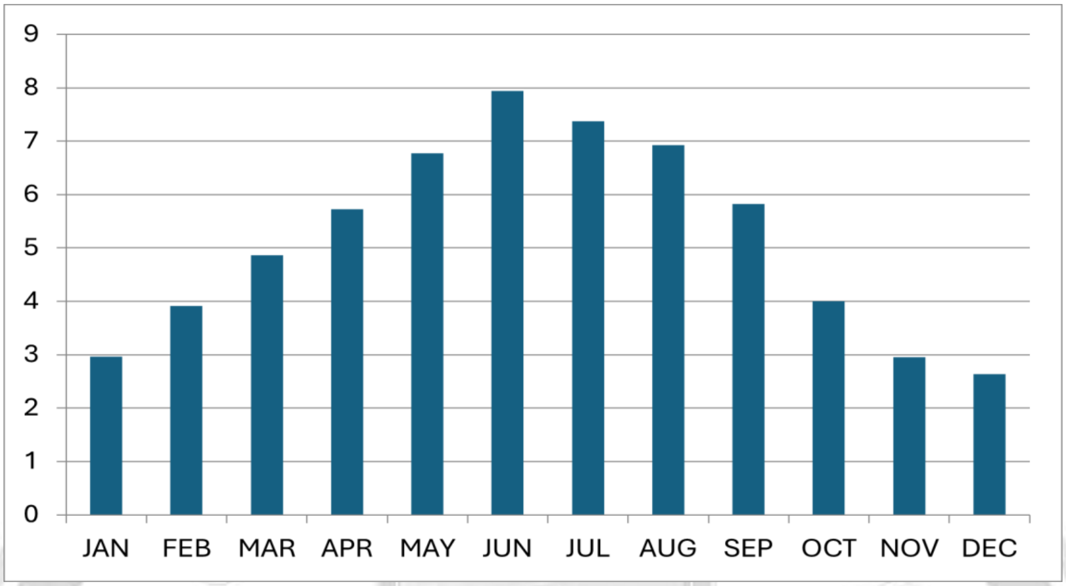

Fig.1. Solar radiation in Hilla city (KWh/m^2 /day) [source: NASA].

The total number of solar energy projects in Iraq can be limited to a capacity of no more than 1395 kilowatts, in addition to small individual projects such as irrigating farms and supplying homes that are far from the national energy source [17], [18], and [19].

Due to the instability of oil prices, Iraq faces major economic challenges that have affected the service reality due to its dependence on oil exports in a basic way [20]. There are also other challenges, such as air pollution that citizens are exposed to as a result of burning fuel and its poor quality [21], [22]. Figures 2 and 3 illustrate the power generation in Iraq by resources and CO2 emissions from the oil and gas, respectively, for the period from 2000 to 2022 according to the IEA.

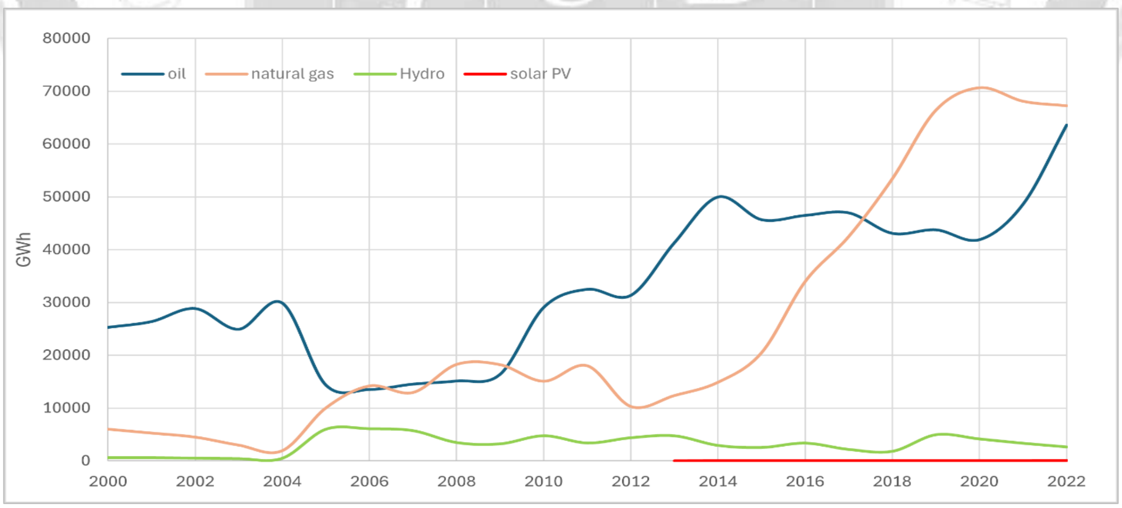

Fig.2. Evolution of electricity generation sources in Iraq since 2000 [Source: IEA Data Services].

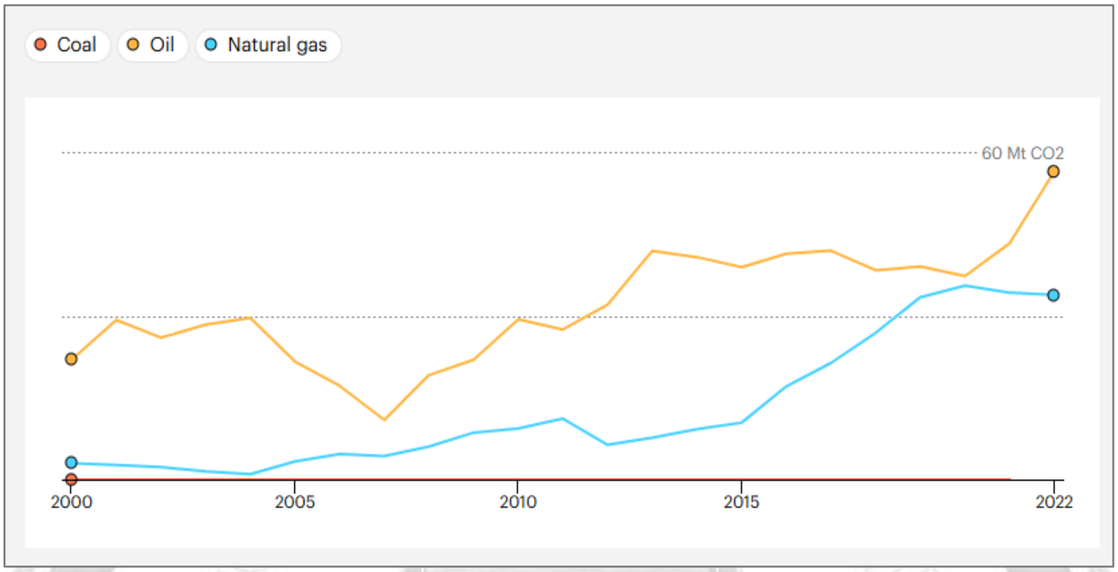

Fig.3. Evolution of emissions from power generation by source in Iraq since 2000 [Source: IEA Data Services]

During the previous years, citizens relied on their personal generators as well as shared regional generators worked by diesel and gasoline to compensate for the shortage in the electrical power supply [23]. The risks of environmental pollution and its impact on human health in Iraq are due to the frequent use of poor fuel in electric generators and vehicles [24]. Pollution problems can be reduced by using renewable energy sources instead of used fuels [25].

Solar energy is one of the most promising renewable energy sources for electricity generation in Iraq [26], [27], [28]. Simply, solar energy can solve many problems in places where it is difficult to provide energy. Farmers need well water for animals and plants, and the energy needed to operate pumps can be provided by photovoltaic cells [29][30]. Communication towers and information transmission can be powered by photovoltaic cells [31]. Street lighting, medical clinics, and garages can rely on photovoltaic cells and reduce national energy consumption [32], [33].

Babylon Governorate is one of the eighteen governorates of Iraq; it's located between latitudes (32°06 and 33°08) north and longitudes (43°57 and 45°12) in the Al-forat Al-awsat region. It is bordered from the north by Baghdad governorate, from the east by Wasit Governorate, from the south by Qadisiyah governorate and Najaf governorate, and from the west by Anbar and Karbala governorates, with a total area estimated at (5333 km2) [34].

Hilla Electricity Training Center is one of the centers of the Iraqi Ministry of Electricity in Babylon Governorate and specializes in training and developing employees of the Ministry of Electricity. It is equipped with electricity from the national grid and is also equipped with 2 generators, each with a capacity of 528 kilowatts. The center works 22 days a month and 7 hours a day. The center's total consumption of electricity for the year 2024 is 246.5 megawatt hours, and the highest load is in June at 32 megawatt hours.

1-3- Research Aims

The research aims to improve the electrical loads of Hilla Electricity Training Center and provide it with sufficient, reliable, and clean electricity, as follows:

1- Calculating the current loads at the relevant facility.

2- Analyzing the loads and knowing the highest consumption as well as the biggest loads.

3- Improving the current loads.

4- Designing a solar energy system that covers the entire facility's needs.

5- Developing recommendations to improve consumption.

2- Related Works

The following related works include improving cooling loads by using an inverter-type motor, and other works include designing and calculating the solar energy system and some of them are similar to our intended facility for different countries and others inside Iraq.

Kumar N. et al. studied the components of a grid-connected solar power system with installation considerations for an educational institution called Karunya Institute of Technology and Sciences. The research consisted of a 95 kW grid-connected system with 312 panels and 4 inverters of 25 kVA each. The simulation results included the amount of energy generated, the amount of emitted CO2 that could be avoided, and recommendations for institutions to adopt photovoltaic energy [35].

Jasim K. designed a solar energy system for a government building, which is a building affiliated with the University of Technology in Baghdad Governorate. The loads were calculated for the entire month of the year, the appropriate system components were sized, and the solar efficiency was calculated in this geographical area. The results consisted of calculating the annual system efficiency and the system cost [36].

Al-Shamani A. et al. designed a stand-alone solar energy system for a residence in Babylon Governorate (Hilla) The house has medium energy consumption. The loads were calculated and analyzed and were 5696.4 watts. The components of the system were sized, and the results were as follows: The number of panels required is 11 panels with a capacity of 180 watts connected in parallel; the number of batteries is 8 AGM batteries of 250 Ah, and the inverter was 3000-W, 24-Vdc, 220-Vac. Considering the loads operating at the same time are 2555 watts [37].

Oleiwi F. et al. designed and simulated a PV system for a house in Baghdad, Iraq, with a capacity of 25 kilowatts using a simulation program called How to Design PV system. The feasibility of the system was studied and compared with both national grid and diesel generators. The results were that the cost of one kilowatt was $ 0.0186 for the national grid, 0.1509$ for diesel generators, and $0.108 for the current PV system. The amount of CO2, that can be avoided for 30 years is about 499,518.2 tons [38].

Almogbel A. et al. compared two types of inverter and non-inverter (conventional) air conditioners, each with a capacity of 18,000 BTU, to evaluate energy consumption and carbon emissions under the same operating conditions for comparison purposes. Energy consumption was measured from July 16 to October 31 (for 108 days). The results showed that the inverter type saves 44% of electricity consumption compared to the conventional type (3471 kWh/year for the inverter type and 6230 kWh/year for the non-inverter type). Also, through the analysis of the World Organization, it was found that the inverter split avoids 49% of carbon emissions [39].

Iriwardhana M. et al. evaluated the electrical energy consumption of a regular split with an inverter split of the same capacity and under the same operating conditions of the office rooms. Consumption was measured for a period of 6 weeks (8 working hours per day). The results showed that the inverter split saves 35% of the energy consumed by the regular split, where consumption was 13.5 kW for the inverter type and 8.7 kWh for the regular type [40].

3- Methodology

The research aims, as previously mentioned, to analyze and improve loads and design a suitable solar energy system. And as follows:

3-1- Load Analysis

The total loads in 2024 are 246.5 MWh, and the maximum load was in summer, in June, at 32 MWh. the workday is 22 days in the month, 7 hours per day.

- Energy consumed per day in June: 32000/22 = 1455 kWh.
- The cooling load ratio is approximately 76% of the total load. Most of the cooling devices used are 2-ton wall-split type from Carrier.
- Lighting loads account for 9% of the total load. Most of the lighting used is the 4*20 watt fluorescent type.
- The remaining 15% of the loads are laptops, printers, water coolers, and other light loads.

3- 2 – Loads Optimization

The improvement may include cooling and lighting loads because they are the largest loads, and these used devices are old and their model is more than 15 years old.

3-2-1 – Cooling Loads Optimization

As mentioned before, the cooling devices are old and consume high power, so they can be replaced with an inverter type of the same capacity, which consumes 35% less energy than the traditional type.

$$\text{The traditional cooling load} = 76\% \times 1455 \text{ kWh} = 1106 \text{ kWh}$$

Since the inverter type consumes 35% less energy than the traditional type, the cooling load capacity after optimization is:

$$1106 - (1106 \times 0.35) = 720 \text{ kWh}$$

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3-2-2 – Lighting Loads Optimization

Lighting loads account for approximately 15% of the world's total electrical loads and contribute 5% of greenhouse gas emissions [41]. The lighting load ratio is 9% of the total load in our building, and then the lighting load will be:

1106 – (1106 x 0.09) = 131 kWh

The lighting used is a fluorescent tube,4 x 20 watts. The 36-watt LED tube can be used; this means saving 55% of electricity consumption because LED lighting can save more than 65% of energy compared to CLF lighting while achieving higher quality and longer life [42]. The lighting loads after optimization will be:

131 – (131 x 0.55) = 59 kWh

The total loads after optimization = not optimized loads + optimized cooling loads + optimized lighting loads.

Not optimized loads = 1455 – (1106 + 131) = 218 kWh

The total loads after optimization = 218 + 720 + 59 = 997 kWh

The total daily loads became 997 kWh, while the loads were 1455 kWh before the optimization. This means that the loads have been optimized by 31.5%.

3-3- Solar System Sizing

In this section, the number of panels, the panel capacity, and the number and capacity of batteries will be calculated.

3-3-1 – Number of Panels

There are many companies and sizes of solar panels in Iraq; the calculations will be for panels measuring 580 watts bifacial PV with dimensions of 2.27m * 1.13m.

The solar radiation hours in Hilla City are more than 5 hours daily; it will be 5 hours per day for design calculations.

One panel production = 580 W x 5 h = 2900 Wh

The total losses in the solar system are 23.8%; therefore, the efficiency of one panel will become 76.2% [43]:

2900 x 0.762 = 2210 Wh

Number of panels required = daily energy required / one panel production = 997000 / 2210

Number of panels required = 452 panels.

The total area of panels is 1160 m2 in addition to 10-20% of the total area to cover the space between the panels, the facility in this research consists of several buildings and contains sufficient surface area to install the panels.

3-3-2 – Number of Batteries

Lithium batteries, compared to other types of batteries, have high performance, higher energy density, light weight, small size, and long life. They are considered the most suitable for solar energy applications [43]. The 48 V, 200Ah capacity lithium type will be used because of its efficiency and availability.

To calculate the number of batteries, the daily Ah needed must be calculated.

Daily Ah = 997 kWh / 48 V = 20770.8 Ah

Batteries needed Ah = Daily Ah x backup days x annual correction factor / D.O.D

If we consider that the depth of discharge (D.O.D) is 80%, the annual correction factor is 1.15, and the backup days are 1 day, then:

Batteries needed Ah = 20770.8 x 1 x 1.15 / 0.8 = 29858 Ah

Number of batteries needed = 29858 / 200 = 150 batteries.

4- Results

The system's component selected as shown in table 2 was chosen because it is modern and available in local markets and from good companies in this field.

Table 2: Solar system items and their specifications

No.	Item	Specification
1	Panels	Bifacial, 580 w, 2.27m x 1.13m
2	Battery	Lithium, 200 Ah, 48V, 90 kg
3	Inverter	According to panel groups (taking into account future expansion)
4	Panel location	On the roofs of buildings and garage roofs

By analyzing the existing loads and improving them, a clear change occurred in the percentage of improvement of the total loads after the process of improving the cooling and lighting loads. This in turn led to a clear reduction in the number of system components and their capacities while ensuring the quality and continuity of energy supply in addition to the environmental and economic impact. Table 3 and Figure 4 show the improvements in the system.

The standard working hours in Iraq are 8:00 a.m. to 3:00 p.m. This is the optimal period for solar radiation in Iraq, as Iraq is one of the sunniest countries. Therefore, most of the energy demand periods can be met by solar cells without the need for a large number of batteries used in the storage system. therefore, the number of batteries can be reduced to much less than this number to meet only the most necessary needs.

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Table 3: System items before and after improvement.

Item	Before improvement	After improvement
Cooling loads	1106 kWh	720 kWh
Lighting loads	131 kWh	59 kWh
Total loads	1455 kWh	997 kWh
Number of panels	659 panel	452 panel
Number of batteries	218 batteries	150 batteries
Optimization %	31.5 %	

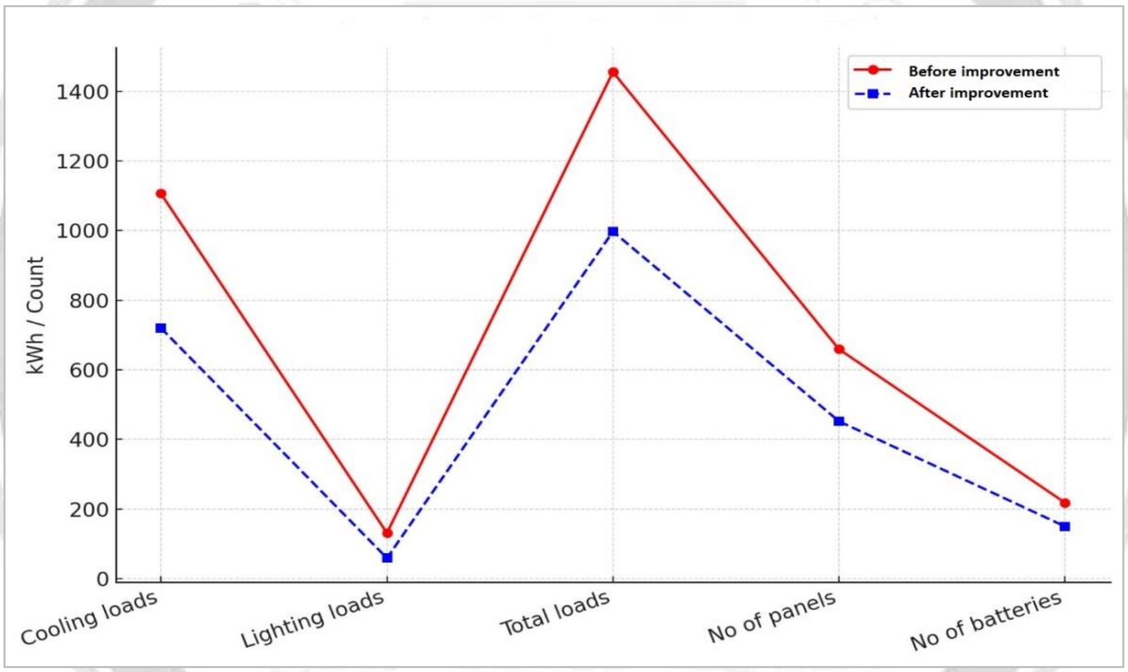

Figure 4: system components before and after improvement.

5- System Efficiency Improvement

Efficiency can be increased through several important points.

1- Using natural lighting instead of lamps due to working hours during the day and the presence of the sun, which will save electrical energy.

2- Insulating the rooms well and preventing the entry of temperature from outside and reducing the use of heat generation sources inside air-conditioned rooms.

3- Utilizing the rooms well to suit the number of employees to reduce the number of rooms used and thus reduce electrical loads

4- The backup days in the designed system were 1 day; the loads can be reduced to what is necessary only during the period of absence of the sun, and thus energy can be supplied from the batteries for more than a day.

5- The efficiency of the system ranges from 76.2% to 90%. 76.2% was considered in the design, which is the minimum, but in reality, the efficiency will be higher than this percentage.

6- Conclusions and Recommendations

By working in this research on calculating and improving loads and designing a solar system suitable for loads after improving them for a government institution in Babylon Governorate. The following conclusions were reached.

1- The total loads during the year 2024 are 246.5 MWh, and the maximum load was in summer in June at 32 MWh for 22 days per month, which means that the highest energy consumed per day is 1455 kWh.

2- The percentage of cooling loads is 76% of the total loads, and lighting loads are 9%, while the rest of the loads are 15%.

3- After improving the cooling and lighting loads, the total load became 997 kWh instead of 1455 kWh; it was improved by 31%.

4- After improving the loads, the solar system was designed and consisted of 452 bifacial panels (580 w) and 150 batteries with a capacity of 200 Ah, 48 v, and lithium type.

5- The system is designed for the worst conditions and the highest loss value, which is 23.8%, so the system will provide higher energy than the design calculations in all conditions, including the worst.

6- We recommend focusing on improving cooling efficiency through good insulation and use. We also recommend studying the economic feasibility of the system and calculating losses accurately.

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تحسين الأحمال الكهربائية وتصميم منظومة الطاقة الشمسية لمنشأة حكومية في مدينة الحلة

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الخلاصة :-

يركز هذا البحث على حساب الاحمال الكهربائية وتحسينها وتصميم منظومة شمسية لبناية حكومية في محافظة بابل (مركز تدريب كهرباء الحلة). المبنى يعمل ٧ ساعات في اليوم ولمدة ٢٢ يوم في الشهر وتم حساب الاحمال الحالية وكانت عبارة عن احمال تبريد بنسبة 76 % واحمال انارة 9 % وبقية الاحمال بنسبة 15 %. احمال التبريد هي الاعلى في استهلاك الطاقة لذلك تم استبدال اجهزة التبريد التقليدية الموجودة بأخرى حديثة نوع عاكس وبلغت نسبة تحسين احمال التبريد حوالي 35 %. كذلك تم تحسين استهلاك احمال الانارة بنسبة 55 % حيث ان الانارة الحالية الموجودة نوع CFL سعة 80 واط تم استبدالها بانارة نوع لد سعة 36 واط وكان التحسن الكلي للأحمال هو ٣١.٥ %. بعد خطوة تحسين الاحمال تم حساب وتصميم منظومة شمسية تغطي الاحمال الجديدة بعد التحسن وكانت المنظومة الشمسية تتكون من الواح Bifacial, 580 w عدد 452 لوح وبطاريات عدد 150 نوع 48V , 200 Ah ,Lithium .

كلمات الدالة: تصميم النظام الشمسي، استهلاك الطاقة، الألواح ثنائية الوجه، تحسين الحمل، تحديد حجم النظام الشمسي، إضاءة LED و CFL، مكيف الهواء العاكس.