Integrated Electrical Installation and PV System for Qabatya School: Design and Simulation

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***Abstract*—This study presents the design and implementation of an integrated electrical installation and photovoltaic (PV) system for a school. The study aimed to create an energy-efficient and sustainable solution that meets the school's power requirements while reducing its environmental impact. A comprehensive assessment of the school's energy needs was conducted to design a robust electrical distribution system. The PV system design considered available rooftop space, orientation, shading, and climate conditions to maximize efficiency and energy output. High-quality PV modules, inverters, and other components were selected to ensure reliable and long-term performance. An efficient energy management system was implemented to integrate the PV system seamlessly into the electrical installation. This system incorporated a smart monitoring and control system to enable real-time monitoring of energy generation, consumption, and battery storage. It facilitated load management, prioritization of renewable energy utilization, and grid interaction, ensuring optimal utilization of the PV system's output.**

Keywords— Electrical installation, PV, Storage system.

I. INTRODUCTION

The proposed project aims to design electrical installation with integrated PV system for a school, and create an energy-efficient and sustainable solution that meets the power requirements of the school while reducing its environmental impact.

The school is located in Qabatia – Jenin at longitude 35.29580 and latitude 32.4560, Number of students is 400, And it's a building consisting of four floors with 18 classrooms, two teacher room, a headmaster room, a library, a storage, two science labs, and a computer room.

Palestine lies on 30 degrees north of the equator; That's means Palestine has high sunshine hours throughout the year, with the total annual average exceeding 3,000 sunshine hours, and irradiation levels ranging between 5 and 6 kWh/m² per day which make it one of the best areas in the exploitation of solar energy, such conditions are considered excellent for harnessing solar energy in large-scale and stand-alone applications. Furthermore, the global cost of solar power is continually declining, as the cost of installing solar PV has dropped by approximately 80 percent since 2010 – making it more attractive to potential investors [1], [2].

The use of solar energy makes the building environmentally friendly by saving electricity which reduces the air pollution. Beside natural lighting from sunlight, the design of photovoltaic system and solar heaters can be beneficial. The total power of our load is 39kW. Several computers program like AutoCAD, sketch up, Dialux evo, PV syst, and ETAP can be implemented [3]–[5].

The objectives of the project are:

- To design a lighting system for the school that suit with schools criteria.
- To design a power system including sockets and pumps for the school.
- To design a PV system that meets the power requirements of the school while reducing its environmental impact.
- To design a protection system for the school.

II. LIGHTING DESIGN

The lighting design in the buildings depends on providing a comfortable lighting environment for the use of the vacancy and achieving the minimum level of illumination required for the vacancy [6]–[8].

Equation (1) is applied to estimate the number of the required luminaires to achieve a suitable illuminance (lux) [9]:

$$N = \frac{A*E}{n*F*MF*UF} \tag{1}$$

Where, A is the room width. N is the number of Luminaires. F is the luminous flux of each lamp. A is the areal of room or work surface. n is the number of lamps per luminaire. E is the

Lighting level, get from standard table (IEC, EC and NEC). MF is the maintenance factor and UF is the utilization factor.

Though the architectural & structural drawing is usually exported to the lighting design software, carrying out the lighting design knowing the room's dimensions is useful as well. For example, Dialux evo is one of the most commonly used lighting design software. Fig. 1 show the first-floor lighting design using Dialux evo, which is used to design the other floors.

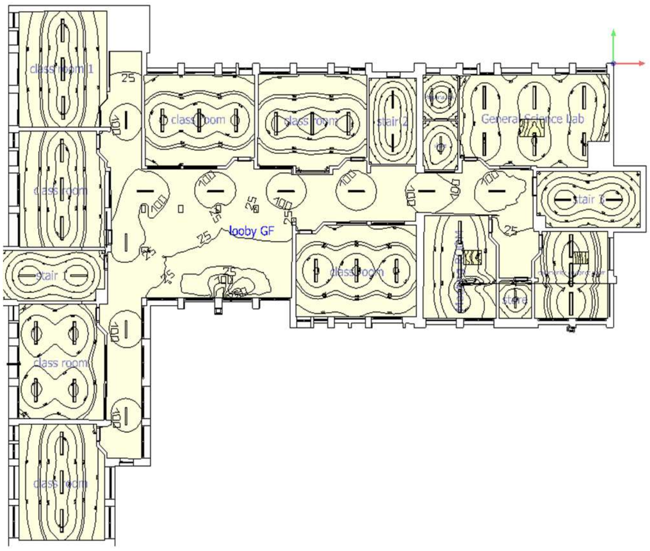

Fig. 1. First floor lighting design using Dialux evo.

To design the lighting system, the structure drawing from AutoCAD to Dialux evo is firstly exported, and then, the outside and inside dimensions of each room is selected. Finally, the calculation icon to generate the final lighting design, are checked.

III. Power Design

In this stage, providing a high-quality product and excellent customer service are committed, taking into consideration the expected growth, which makes the energy business decisions based on long-term relationships and commitment, as well as profit margins. Partnering with Power Design means having a team member on board that seeks to create successful, innovative projects, delivered on time and on budget. The standard socket type in Palestine is H, which has three pins in a triangular shape. The supply voltage is 230V and 50Hz, with three-phase sockets also available at 400V.

The goal of electrical load management in schools is to ensure that the electrical infrastructure can safely support all the devices that need power, without compromising the system's safety or functionality. Proper planning and design of the electrical installation can help identify the electrical loads in the school and how much energy is needed to power them. This can lead to the careful selection and installation of the appropriate electrical equipment, including energy-efficient lighting and appliances. Effective load management in schools can help minimize energy consumption, lower operating costs, and reduce environmental impact. A well-designed electrical system in schools must also provide sufficient capacity to accommodate future expansion and upgrades, such as the addition of new classrooms, buildings, and electronic devices. Effective management of electrical loads can help ensure reliable and safe functioning of the electrical infrastructure, ensuring that the school operates smoothly and efficiently. In the proposed study, there are many types of electrical loads, such as pumps, boilers, computers, fans, projectors, and lighting, which makes it possible to estimate the needed power of each room and then the ability to distribute the loads on phases to balance the consumption. Then, the suitable circuit breakers and cable sizes are chosen. Finally, the main distribution board based on the obtained results is designed.

IV. Photovoltaic Solar System Design

Photovoltaic (PV) systems are one of the most important technologies used in renewable energy generation. These systems aim to convert direct sunlight into usable electrical energy. PV systems offer a renewable and sustainable solution for electricity generation. With their components working together, they harness the power of the sun to produce clean and green energy. Understanding the components and operation of PV systems is crucial for harnessing their full potential and maximizing their efficiency [10]–[14].

Software and Simulation design of a solar PV system is a crucial step towards advancing solar energy technology. Through the proposed process, insights into system performance and identify opportunities for optimization is gained. Moreover, by utilizing appropriate tools and software, the system efficiency can be enhanced to reduce the implementation costs, thereby promoting environmental and economic sustainability for buildings and communities.

In the investigated project, the most important steps and programs used to program and simulate a photovoltaic system with a capacity of 50 kW for the "New Qabatiya Girls' Basic School" are presented.

Here's The total Steps:

- Gather Information: Collect detailed information about the building and its electrical requirements, such as monthly energy consumption and load distribution.
- Site Assessment: Evaluate the site's solar resource potential by analyzing factors like solar irradiation levels, shading analysis, and available space for solar panel installation.
- System Sizing: Determine the capacity of the solar PV system required to meet the building's energy needs. Consider factors such as the available roof or ground area for solar panel installation and the local solar radiation levels.
- Component Selection: Select suitable solar panels, inverters, and balance of system components based on the system size, site conditions, and desired performance parameters. Consider factors like efficiency, reliability, and compatibility between components.
- Electrical Design: Design the electrical layout, including the configuration of panels, string sizing, and inverter sizing. Ensure compliance with electrical codes and safety regulations.
- Simulation and Performance Analysis: Utilize solar energy simulation software or tools to model the

performance of the proposed system (use: AutoCAD, sketch up, Dialux evo, PV system, ETAB).

- Analyze factors like energy generation, system losses, and expected performance under different weather conditions.
- Financial Analysis: Perform a financial evaluation of the system, considering factors such as upfront costs, potential energy savings, available incentives or rebates, and the payback period.
- System Integration and Installation: Develop a detailed installation plan, considering the mounting structure, electrical wiring, and interconnection with the building's electrical system. Ensure compliance with local regulations and engage qualified professionals for installation.
- Monitoring and Maintenance: Implement a system monitoring and maintenance plan to ensure optimal performance and identify any issues or inefficiencies. Regularly monitor energy generation, system performance, and address any maintenance or repair needs.

By following the above-mentioned steps, the 50kW solar power system for the investigated buildings can be effectively simulate and design.

V. Results

Table I shows the results of the lighting design for each room, including the area, number of luminaires, luminous flux, and load in watts. The load in watts was calculated by multiplying the number of luminaires by the power of each luminaire unit.

TABLE I. LIGHTING LOAD CALCULATION FOR FIRST FLOOR.

Space	Area (m^2)	# of luminaires	luminous flux	load (W)	Luminous efficacy (LM/W)	LPD (W/m^2)	LPD (rec)
class rooms	313.62	35	243005	2310	105.20	7.37	6.9
science lab	56.65	5	34715	330	105.20	5.83	11.2
Stairs	25.08	6	14808	138	107.30	5.50	4.8
Preparation	7.56	2	4936	46	107.30	6.08	9.9
Store	12.78	2	4936	46	107.30	3.60	5.5
meeting room	32.2	3	20829	198	105.20	6.15	6.5
community guidance room	27.4	3	20829	198	105.20	7.23	7.2
Lobby	207.26	9	22212	207	107.30	1.00	8.2

Fig. 2 shows the lighting layout for the first floor, as designed in AutoCAD.

Fig. 2. Lighting distribution for the first floor.

Fig. 3 shows the socket distribution for the first floor, as designed in AutoCAD.

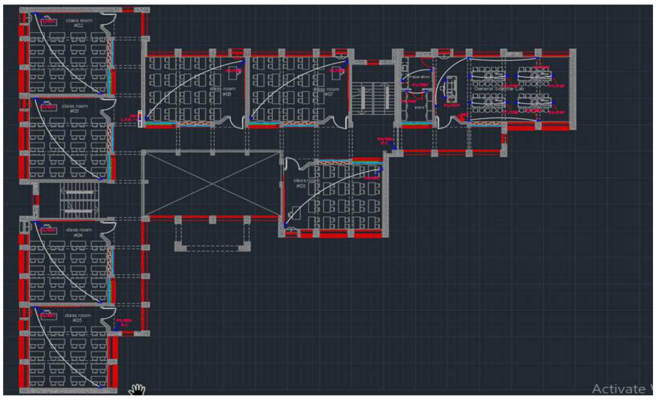

Fig. 3. Socket distribution for the first floor.

After determining the cable size and selection of the circuit breaker rating, Fig. 4 shows the single line diagram for the first floor.

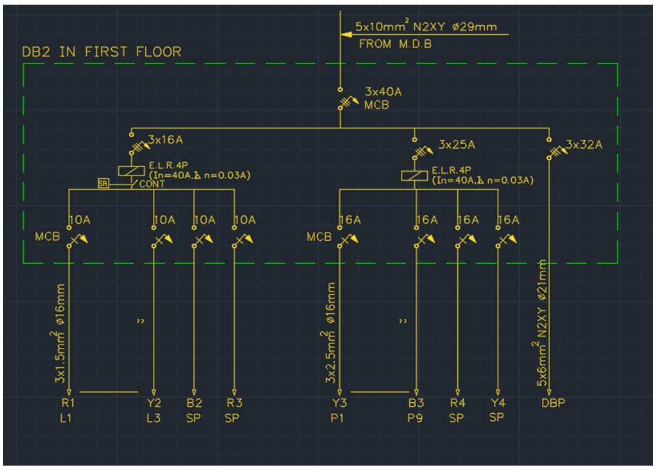

Fig. 4. Single line diagram for the first floor.

VI. Conclusion

This project involved the design and simulation of a 50-kW solar PV system to be installed on the school's rooftop. The project was divided into two parts: The first part involved the design of the electrical installation for the school, including lighting, electrical loads, power distribution, and air conditioning circuits. The second part involved the design and simulation of the solar PV system, including the following steps: Designing a 2D and 3D model of the school building with all rooftop contents. Studying the geographical location of the school. Determining the suitable type of solar panels and inverters. Estimating electrical losses in the system. Simulating the system using software. In addition to the design and simulation work, an economic feasibility study was conducted for the project. The solar PV system helps the school to reduce its environmental impact by generating its own electricity from renewable energy. This is a significant step towards making the school more sustainable and energy-efficient. Finally, the proposed study makes us confident that the solar PV system is a valuable asset to the school for many years to come.

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