Designing a Photovoltaic System for the New College of Economics at PTUK

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***Abstract*— This study aims to design a grid-connected photovoltaic system (PV) for the Munib Al-Masry building (College of Economics) at Palestine Technical University – Kadoorie (PTUK). The system will be designed to meet the building's electrical energy needs while also minimizing costs. Multiple scenarios will be considered when designing the system to determine the optimal tilt angle for both production and cost. The system will be designed to meet the building's electrical loads, including lighting, air conditioning, elevators, computer labs, cameras, and alarms.**

Keywords*— *Photovoltaic System, PTUK, Solar energy.

I. Introduction

Energy is a crucial component of human advancement. For more than 200 years, fossil fuels (coal, natural gas, and oil derivatives) have been the primary energy sources. However, as society and industry advance, so does the demand for energy supplies. The world's population is expected to increase to more than 11.2 billion by the end of the century. A recent mathematical model that combined world population, wealth, and oil consumption estimated that to support the natural global growth of the gross domestic product, world energy consumption should increase by approximately 1.7 billion tons of oil equivalent per year by 2025. To maintain an oil energy share of around 33% (2015 levels), current oil production would need to increase by more than 11 million barrels per day [1]–[3]

Fossil resources are finite and produce greenhouse gas emissions that contribute to climate change, which can have catastrophic and irreversible effects on the ecosystem. Therefore, the foreseeable increase in energy demand and the depletion of fossil fuels necessitate an accelerated transition to a low-carbon economy, which requires the search for clean and renewable alternative energies. Hydropower, wind, biomass, geothermal, and solar energy are a few examples [4]–[7].

Solar energy is the purest, most plentiful, and most endless source of energy on Earth. According to NASA estimates, the Sun continues to shine for 6.5 billion years, and every hour it sends more energy toward Earth than is needed to power the entire planet for a year. The amount of solar radiation reaching Earth's surface is 120,000 terawatts, which is 20,000 times more energy than Earth needs. In fact, Earth receives enough energy from the Sun in just 18 days to equal the energy stored in all of the world's reserves of coal, oil, and natural gas [8]–[16], [17].

The idea of the project is to design a grid-connected photovoltaic (PV) system. Grid-connected PV systems, also known as grid-tied systems, are connected to the utility grid through a power inverter unit, which allows the system to operate in parallel with the grid and provide electricity to the building or other load.

The main objective of the proposed project is to design and simulate a grid-connected PV system installed on the roof of the Munib al Masri building that can cover the building's energy demand. The goal is to choose the proper design to obtain the best productivity and lower cost, reduce reliance on traditional energy sources, and provide a clean energy source with a short payback period of three to five years. In other words, the project aims to design a cost-effective and environmentally friendly PV system that can meet the building's energy needs. The system is designed to be connected to the grid, so any excess electricity generated can be sent back to the utility company, which helps to reduce the building's reliance on traditional energy sources and reduce its environmental impact. The project is expected to have a short payback period, meaning that the initial investment in the system is expected to be paid back within three to five years, which makes the project a financially attractive investment for the building owners.

II. Methodology

First, the solar cells were distributed on the roof of the building based on the area, in two ways:

- The first method is the usual way of distributing solar cells, in rows.
- The second method is to raise the structure plans two meters from the roof of the building and place the solar cells as landscape.

The aim of these plans is:

- To estimate the area on which solar cells can be placed on the roof of the building.
- To determine the number of panels that can be placed and thus the capacity of the system.

In other words, determining the best way to arrange the solar cells on the roof in order to maximize the amount of sunlight they receive and the amount of electricity they generate. Moreover, the proposed work also tries to determine the total capacity of the system, which is determined by the number of solar panels that can be placed on the roof.

When studying the building and its surrounding parts, where it is noticed that the system is exposed to a lot of shade due to the construction of towers for a Jawwal company, one of which is located on the southern side of the building and the other on the northern side. There is also a roof in the middle of the building with a height of approximately 6 meters.

When the panels are placed transversely and the panel is exposed to shade, about a third of the solar panel could be lost. If the panel is placed longitudinally and the lower part of it is exposed to shade, about a half of the solar panel could be lost. The placement of the solar panels is shown in Fig. 1 below:

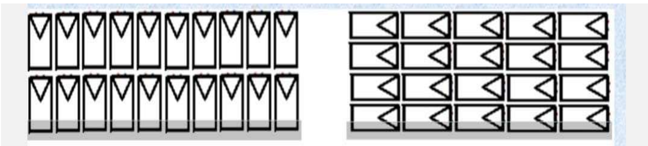

Fig. 1. Placement of the solar panel.

The methodology for designing a grid-connected PV system is as follows:

- First, propose different scenarios for PV system design, which involves considering the following factors: the energy needs of the building, the available roof space, the shading conditions, the budget, and the desired payback period.
- Once the different scenarios have been proposed, the next step is to design the PV system for each scenario, which involves selecting the following components: solar modules, inverters, mounting system, and electrical wiring and connections.
- The design of the PV system varies depending on the specific scenario. For example, a small system might only require a few solar modules and a single inverter, while a larger system might require hundreds of solar modules and multiple inverters.
- Once the PV system has been designed, the next step is to calculate the payback period for each scenario. The payback period is the amount of time takes for the system to generate enough electricity to cover its initial cost.
- Finally, compare the different scenarios to find the best one. The best scenario is the one that provides the best balance of cost, performance, and payback period.

III. Results

Fig. 1 shows the distribution of PV panels. It is considered as the first scenario.

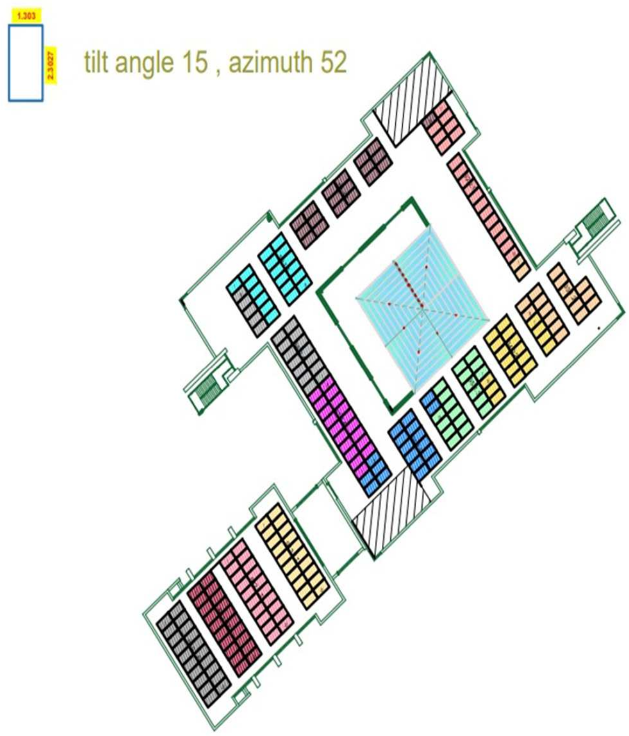

Fig. 2. Distribution of panels for the first scenario.

The single line diagram corresponding the first scenario is shown in the following figure.

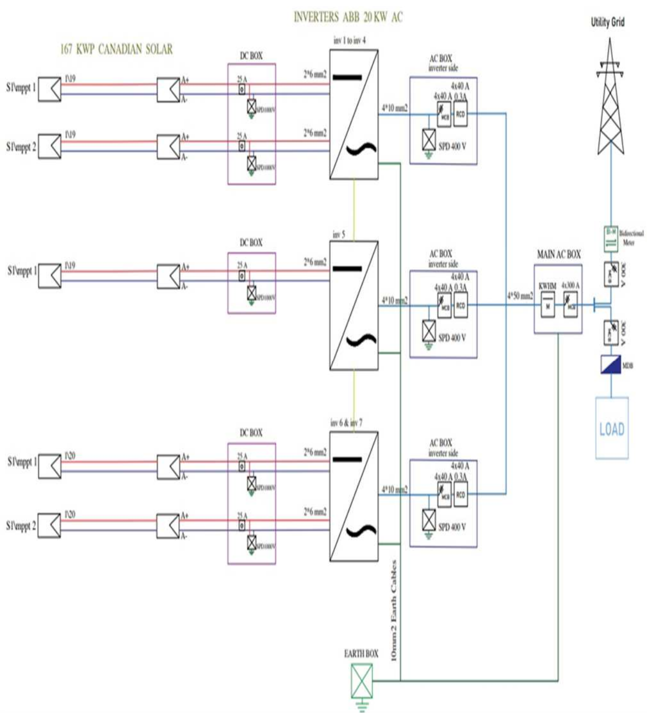

Fig. 3. Single line diagram of the system for the first scenario.

The Sketchup diagram corresponding the first scenario is shown in the following figure.

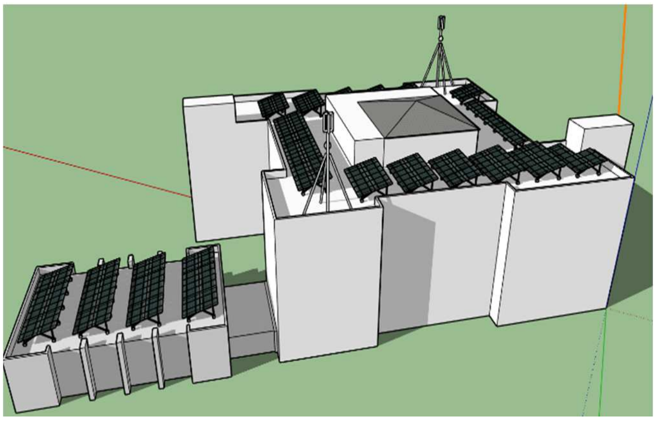

Fig. 4. Sketchup diagram for the first case.

The diagrams represented the other scenarios are shown in the following figures.

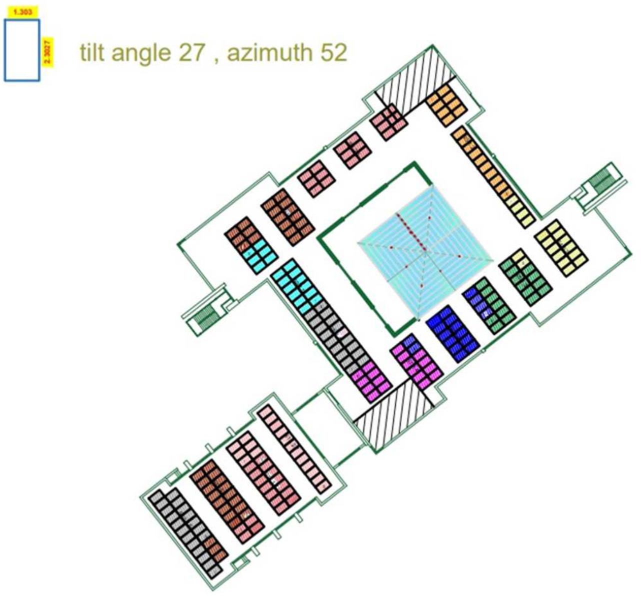

Fig. 5. Distribution of panels for the second scenario.

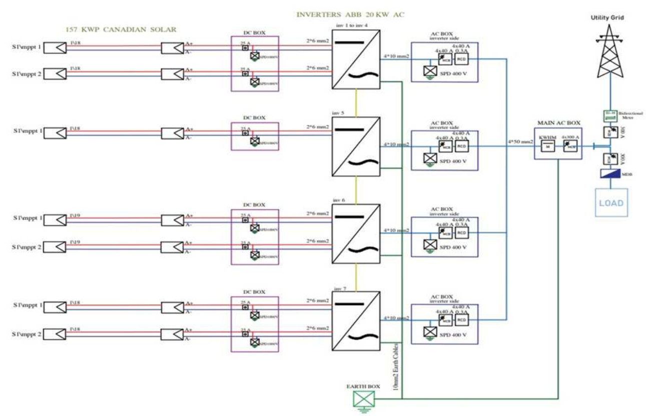

Fig. 6. Single line diagram of the system for the second scenario.

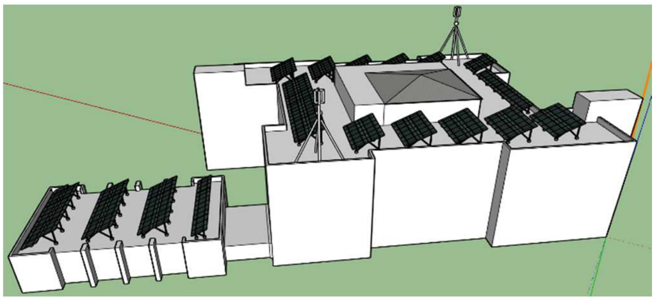

Fig. 7. Sketchup diagram for the second case.

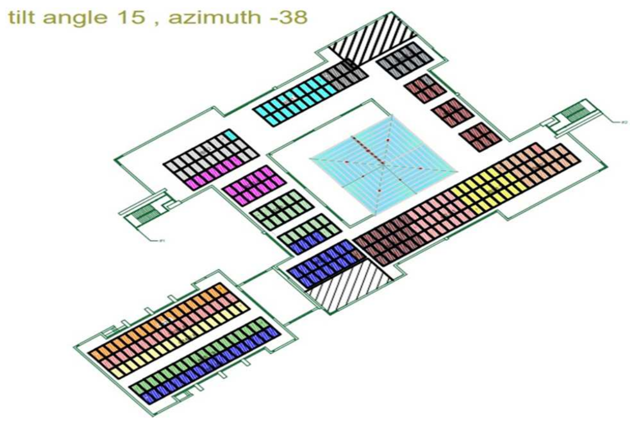

Fig. 8. Distribution of panels for the third scenario.

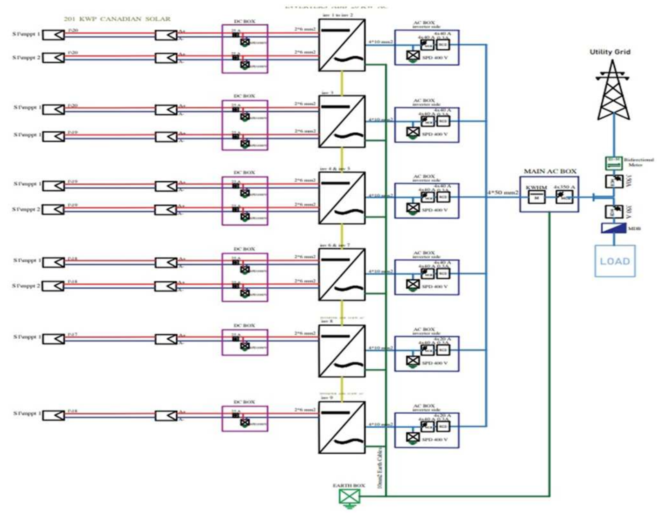

Fig. 9. Single line diagram of the system for the third scenario.

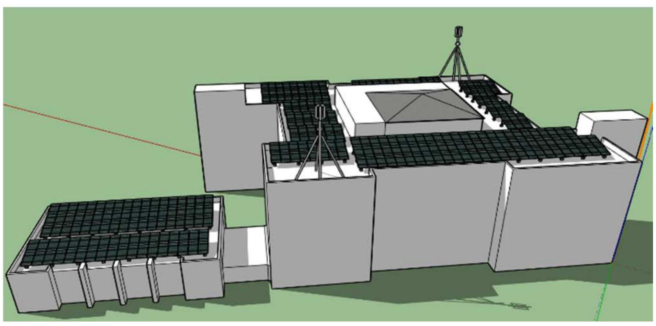

Fig. 10. Sketchup diagram for the third case.

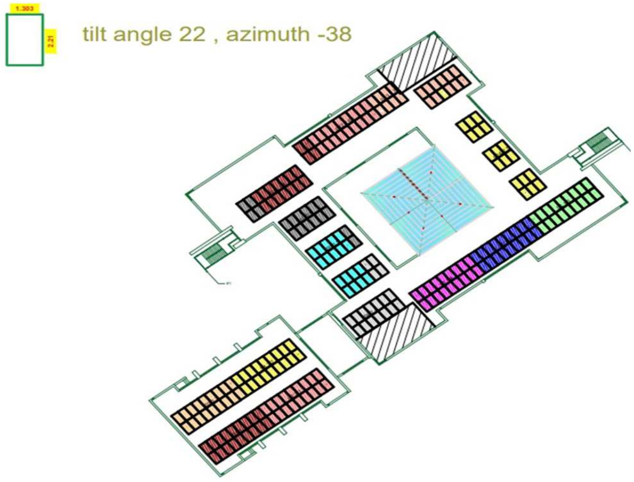

Fig. 11. Distribution of panels for the forth scenario.

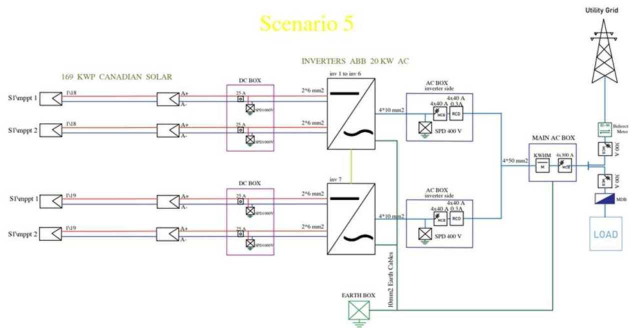

Fig. 12. Single line diagram of the system for the forth scenario.

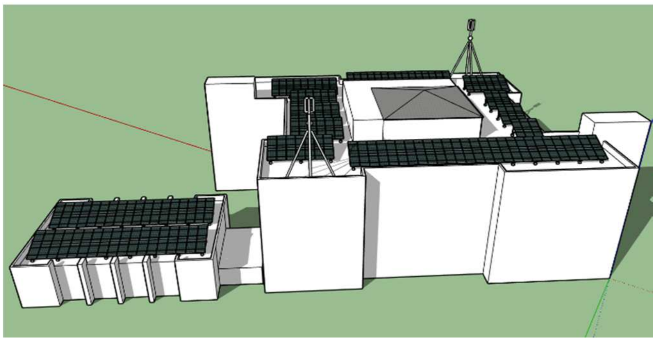
Fig. 13. Sketchup diagram for the forth case.

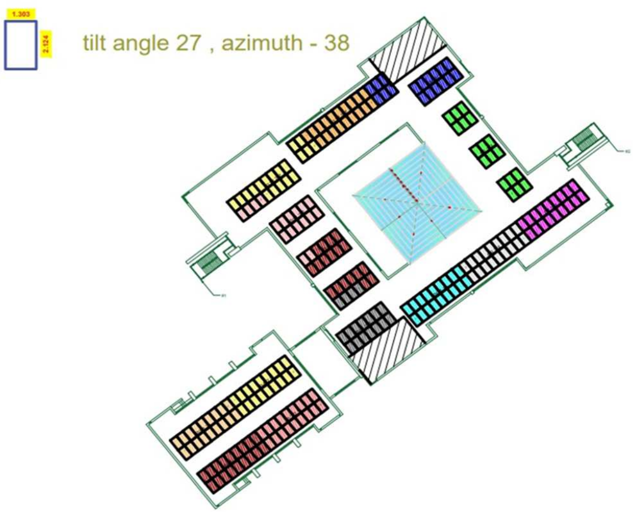

Fig. 14. Distribution of panels for the fifth scenario.

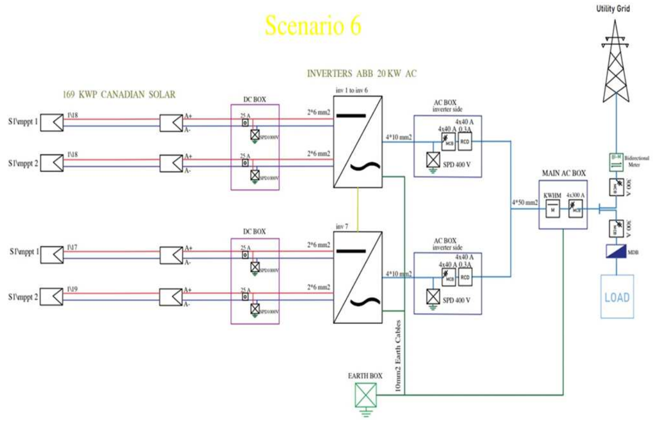

Fig. 15. Single line diagram of the system for the fifth scenario.

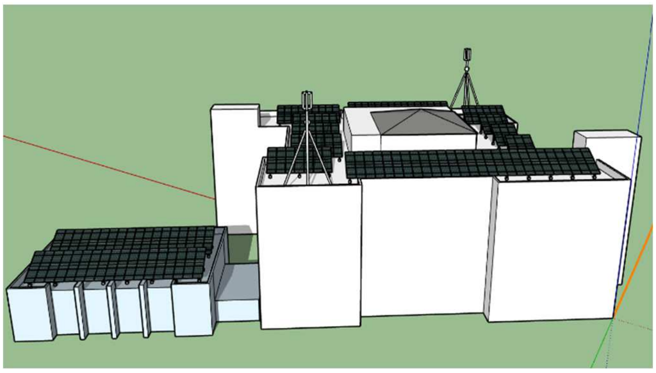
Fig. 16. Sketchup diagram for the fifth case.

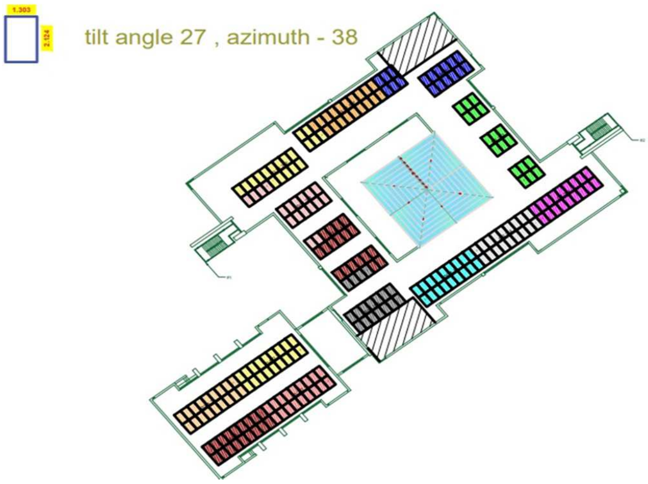

Fig. 17. Distribution of panels for the sixth scenario.

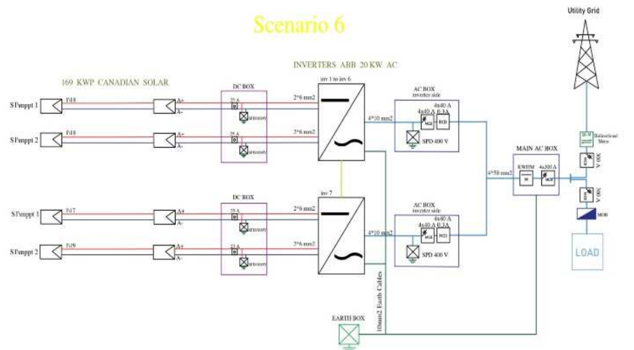

Fig. 18. Single line diagram of the system for the sixth scenario.

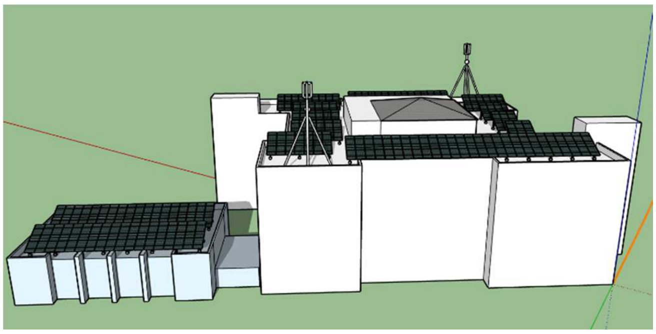

Fig. 19. Sketchup diagram for the sixth case.

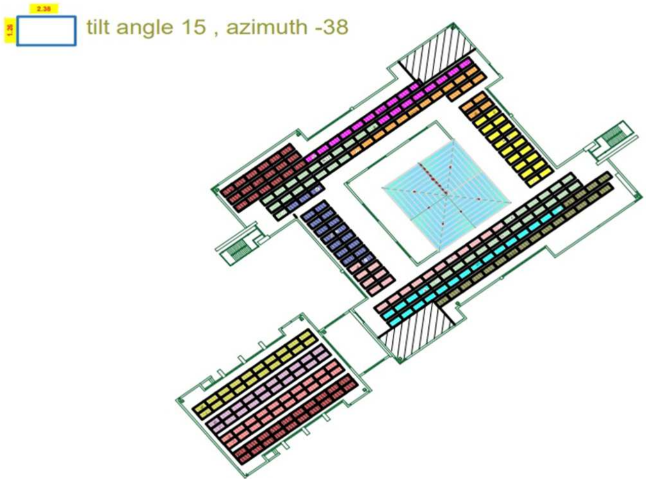

Fig. 20. Distribution of panels for the seventh scenario.

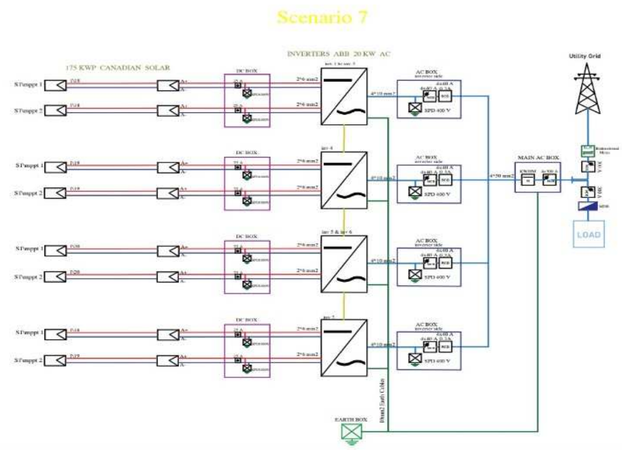

Fig. 21. Single line diagram of the system for the seventh scenario.

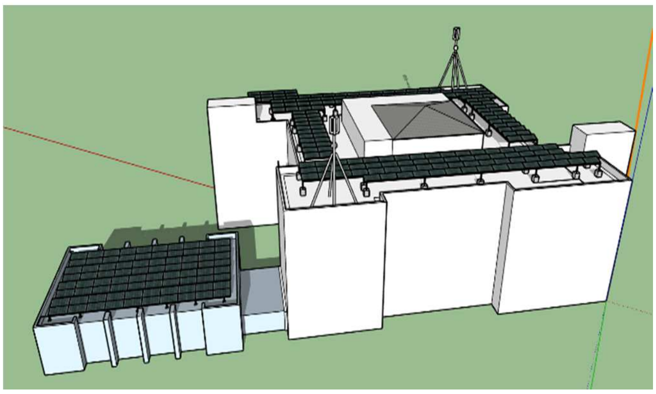

Fig. 22. Sketchup diagram for the seventh case.

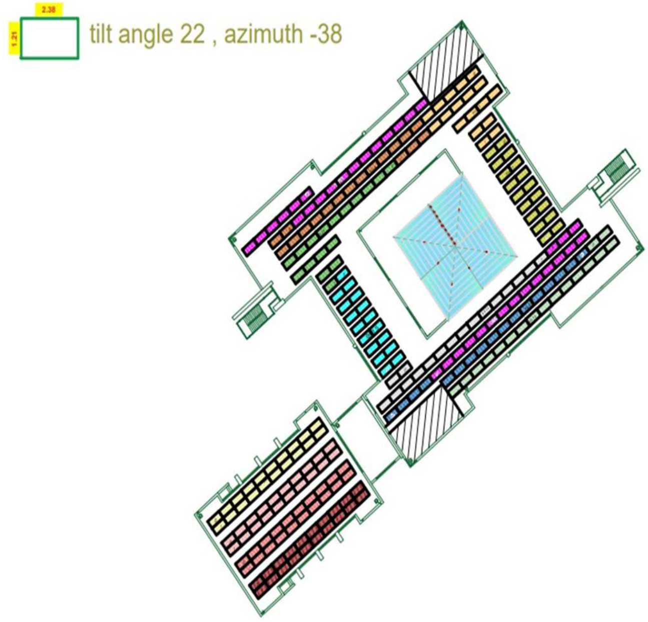

Fig. 23. Distribution of panels for the eighth scenario.

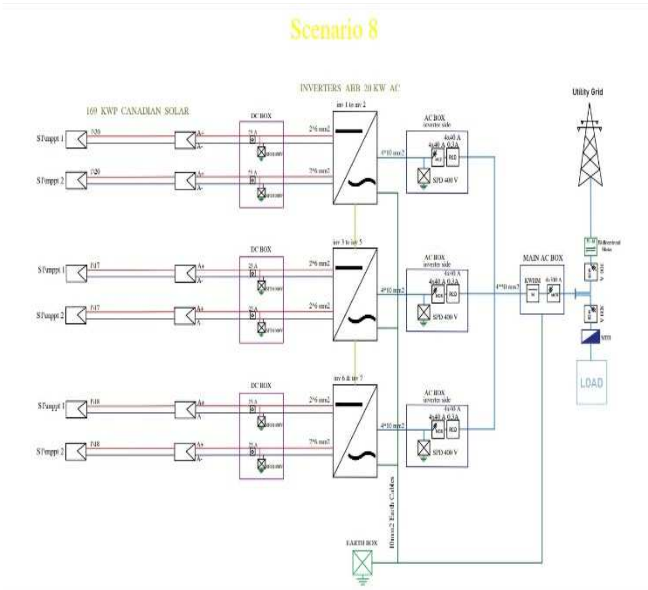

Fig. 24. Single line diagram of the system for the eighth scenario.

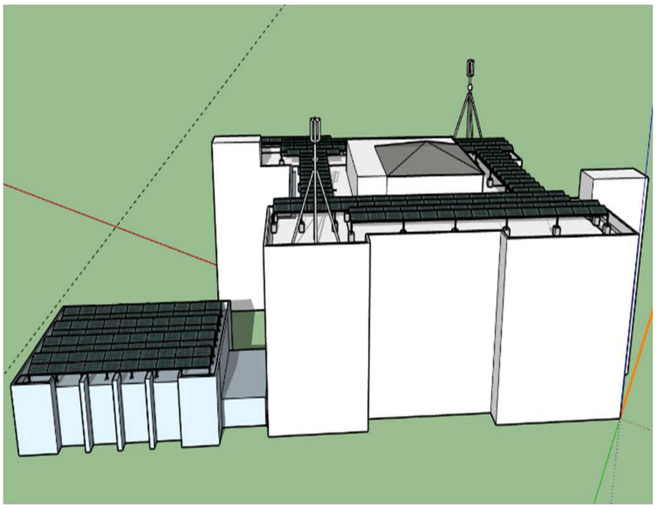

Fig. 25. Sketchup diagram for the eighth case.

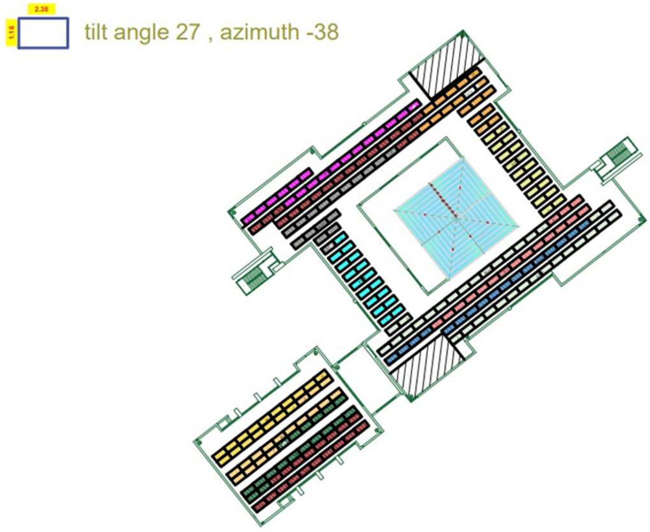

Fig. 26. Distribution of panels for the ninth scenario.

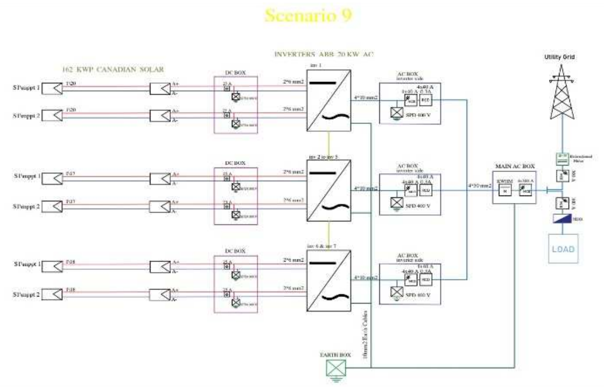

Fig. 27. Single line diagram of the system for the ninth scenario.

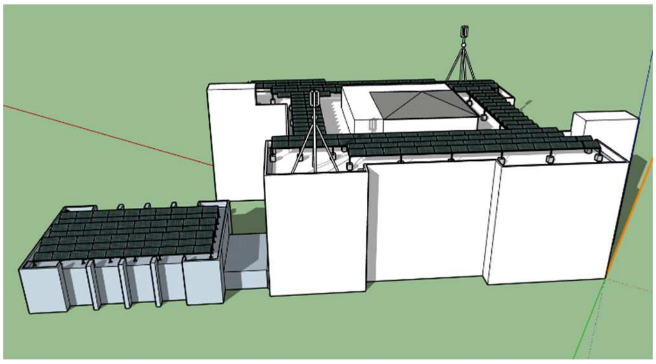

Fig. 28. Sketchup diagram for the ninth case.

The energy productivity for each scenario is demonstrated in the following table.

TABLE I. ENERGY PRODUCTION FOR EACH SCENARIO.

Scenario number:	Energy production (MWh/year)
Scenario (1)	265.2
Scenario (2)	254.7
Scenario (3)	259.8
Scenario (4)	324.8
Scenario (5)	276.5
Scenario (6)	275.3
Scenario (7)	283.3
Scenario (8)	274.8
Scenario (9)	263.2

The calculated simple payback period for each scenario is demonstrated in the following table.

TABLE II. SIMPLE PAYBACK PERIOD FOR EACH SCENARIO.

Scenario number:	SPBP(Year)
Scenario (1)	2.172
Scenario (2)	2.293
Scenario (3)	2.263
Scenario (4)	3.226
Scenario (5)	2.132
Scenario (6)	2.176
Scenario (7)	1.997
Scenario (8)	2.418
Scenario (9)	2.472

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IV. CONCLUSIONS AND RECOMMENDATIONS

The proposed study has presented the design of a grid-connected PV system for the Munib Al-Masry building. Multiple scenarios were designed and evaluated, and the optimal scenario was chosen based on a combination of factors including energy production, economic cost, and environmental impact. Based on the obtained results, the optimal scenario is the optimal scenario is scenario (4), where this scenario has a tilt angle of 22 degrees and an azimuth angle of 52 degrees. It is expected to produce 324.8 MWh/year of electricity. Scenario (4) has a slightly longer simple payback period than some of the other scenarios, at 3.226 years. However, it has the highest energy production and the greatest potential to save the building money on electricity bills. Additionally, the environmental benefits of the system are significant.

The following recommendations are made for the implementation of the PV system:

- Install zero export inverters to prevent energy from being returned to the main grid.
- Use a storage system (batteries) to store excess energy.
- Change the configuration of the inverter so that it can be involved in the dispatching operations of the network.

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