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DESIGN OF A SOLAR POWER SYSTEM FOR A CHURCH BUILDING: A CASE STUDY

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Abstract
This paper presents the design of a solar power system for Deeper Life Bible Church building, Mgbakwu. The system was designed to provide a reliable and efficient source of energy for the church's electrical loads. The paper discusses the load assessment and energy requirements, and system design of the solar power system. The system if implemented will be capable of providing significant energy savings and cost savings. The paper concludes that the solar power system is a viable option for the church building, and provides suggestions for future improvements and expansions.
Keywords: solar power system, load assessment, energy requirements, electrical loads.

Introduction

The increasing global demand for energy, coupled with the need to reduce greenhouse gas emissions, has led to a growing interest in renewable energy sources. Solar power, in particular, has emerged as a promising alternative to traditional fossil fuels. Solar power systems convert sunlight into electrical energy, providing a clean, sustainable, and reliable source of power.

Church buildings, like many other institutions, require a reliable and efficient source of energy to power their electrical systems. However, many churches in developing countries rely on diesel generators or grid electricity, which can be expensive and unreliable. Solar power systems offer a viable solution to this problem, providing a clean and sustainable source of energy that can reduce energy costs and improve reliability.

This paper presents the design of a solar power system for Deeper Life Bible Church building, Amaezike, Mgbakwu in Awka North LGA of Anambra State of Nigeria. The system is designed to provide a reliable and efficient source of energy for the church's electrical systems, including lighting, electric fans, electronic gadgets, and phone charging. The paper provides a detailed overview of the system design, highlighting the benefits and challenges of the system.

The scope of this paper is limited to the design of the solar power system for the said church building. The paper does not discuss the broader policy or economic implications of solar power systems, but rather focuses on the technical aspects of the system design.

Literature Review

Designing a solar power system for a church building requires careful consideration of several factors. This literature review highlights the benefits, design considerations, case studies, financing options, and technical considerations of solar power systems for churches.

Sandhu (2019) highlights the benefits of solar power for churches, including reduced energy bills, environmental stewardship, and increased community participation. Similarly, ProStar Energy (2020) emphasizes the financial benefits of solar power, estimating a payback period of just two years.

Intermountain Wind & Solar (2018) notes that energy requirements, roof size and orientation, and budget constraints must be considered when designing a solar power system for a church building. Evans (2011) stresses the importance of conducting an energy audit to determine the church's energy requirements. The Solar Energy Industries Association (SEIA) (2020) recommends using simulation tools to size the solar power system and optimize its performance.

The Church of Jesus Christ of Latter-day Saints (2019) installed a solar-powered meetinghouse in Farmington, Utah, which generates enough electricity to power the entire building. Temple Beth installed a 210 kW solar panel system, producing 237,479 kWh of energy per year and reducing electricity bills by 70% (Sandhu, 2019).

Intermountain Wind & Solar (2018) suggests that churches can explore leasing solar panels, forming an LLC, or crowdfunding to make solar power more accessible. The Renewable Energy Policy Network for the 21st Century (REN21) (2020) notes that churches can also take advantage of tax credits and grants to reduce installation costs.

The National Renewable Energy Laboratory (NREL) (2020) emphasizes the importance of proper system design, installation, and maintenance to ensure optimal performance and safety. Solar Energy International (SEI) (2020) recommends using high-efficiency solar panels and inverters to maximize energy production. The American Solar Energy Society (ASES) (2020) notes that churches should also consider energy storage options, such as batteries, to optimize their solar power systems.

In the paper, the importance of proper design of solar power systems to ensure optimal performance and efficiency is highlighted. Further research is needed to explore new technologies and techniques for improving energy efficiency and reducing costs.

Load Assessment and Energy Requirements

To design a solar power system for the church building, it is essential to assess the electrical loads and energy requirements of the building. This section presents the load assessment and energy requirements of the church building.

A. Electrical Loads

The church building has the following electrical loads:

- Four 20 Watt lamps at the pulpit
- Fifteen 20 Watt lamps in the pews
- Four 10 Watt lamps in the offices
- Two 20 Watt lamps in the children's section
- Twenty 70 Watt Electric ceiling fans
- Electronic gadgets (e.g., sound system, microphone, TV) with a total power rating of 300 Watts
- Phone charging with a total power rating of 30 Watts

The load profile of the church building varies depending on the day and season. The building is used for worship services on Sundays and weekdays, and the lighting and electronic gadgets are used accordingly.

Load Profile

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In order to design a load profile for the church building, there is need to calculate the total power consumption of each load and then determine the load duration for each day.

Load Calculation

Lamps

- 4 x 20W = 80W
- 15 x 20W = 300W
- 4 x 10W = 40W
- 2 x 20W = 40W

  Total lamp power: 80W + 300W + 40W + 40W = 460W

Fans

- 20 x 70W = 1400W

Electronic Gadgets

- 300W

Phone Charging Outlets

- 30W
- Total load: 460 + 1400 + 300 + 30 = 2190 Watts

The church building has a peak load of 2190W, which occurs during the specified time periods on Sundays, Mondays, and Thursdays. To further optimize the load profile, consider the following:

- Fan loads can be reduced by using energy-efficient ceiling fans or adjusting the fan usage.
- Electronic gadget loads can be reduced by turning off devices when not in use.
- Phone charging outlet loads can be reduced by using power strips with switches to turn off outlets when not in use.

By implementing these energy-saving measures, the church building can reduce its energy consumption and lower its electricity bills.

Energy Requirements

The total energy required by the church building can be calculated by multiplying the load profile by the number of hours the building is used. The total energy required = 2190 Watts x 4 Hours per day = 8,760 Wh/day = 8.76 kWh/day (or rounded up to 9 kWh/day).

System Design

The solar power system design for the church building involves several components, including solar panels, charge controller, battery bank, and inverter. This section presents the design of each component which would combine to form the overall system.

Solar Panel Sizing

Calculating the number of solar panels required, the following factors are considered:

Factors Considered:

- Daily Energy Requirement: 9 kWh

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- Solar Panel Capacity: 300 W each
- Peak Sun Hours (PSH): Assume 5 hours/day (a moderate climate with some cloud cover)

Calculation:

- Total Daily Energy Requirement (Wh): 9 kWh x 1000 (to convert kWh to Wh)
- = 9000 Wh
- Solar Panel Capacity (W): 300 W
- Peak Sun Hours (h): 5 hours
- Number of Solar Panels: Total Daily Energy Requirement (Wh) / (Solar Panel Capacity (W) x Peak Sun Hours (h))

  = 9000 Wh / (300 W x 5 h)

  = 9000 Wh / 1500 Wh

  = 6 solar panels

Therefore, to deliver 9 kW of energy per day, would need six solar panels, each with a capacity of 300 W.

Battery Bank Sizing

Calculating the number of batteries required, the following factors are considered:

Factors Considered:

- Total Daily Energy Requirement: 9 kWh
- System Voltage: 24V
- Battery Voltage: 12V
- Battery Capacity: 200Ah
- Depth of Discharge (DOD): Assume 50% DOD (a reasonable estimate for lead-acid batteries)
- Efficiency: Assume 90% efficiency (accounting for losses in the system)

Calculation:

- Total Daily Energy Requirement (Wh): 9 kWh x 1000 (to convert kWh to Wh)

  = 9000 Wh
- System Voltage (V): 24V
- Total Daily Energy Requirement (Ah): Total Daily Energy Requirement (Wh) / System Voltage (V)

  = 9000 Wh / 24V

  = 375 Ah
- Account for DOD and Efficiency:

  = 375 Ah / 0.5 (50% DOD) / 0.9 (90% efficiency)

  = 833.33 Ah
- Number of Batteries: Total Capacity Required / Capacity of Each Battery

  = 833.33 Ah / 200Ah

  = 4.17

Rounding up to the nearest whole number: Number of Batteries: = 5 batteries
Since each battery is 12V, to achieve a 24V system, you would need:

- 2 batteries of 12V, 200Ah each, connected in series, for a total of 5 sets.

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Therefore, to take care of the energy requirements for a 24V system, you would need 10 batteries of 12V, 200Ah each, configured in 5 sets of 2 batteries connected in series.

Charge Controller Sizing

Calculating the charge controller capacity, the following factors are considered:

Factors Considered:

- Daily Energy Requirement: 9 kWh
- System Voltage: 24V
- Charge Controller Efficiency: Assume 95% efficiency (a reasonable estimate for modern charge controllers)

Calculation:

- Total Daily Energy Requirement (Wh): 9 kWh x 1000 (to convert kWh to Wh)
  = 9000 Wh
- System Voltage (V): 24V
- Total Daily Energy Requirement (Ah): Total Daily Energy Requirement (Wh) / System Voltage (V)
  = 9000 Wh / 24V
  = 375 Ah
- Charge Controller Capacity (A): Total Daily Energy Requirement (Ah) / Charge Controller Efficiency
  = 375 Ah / 0.95 (95% efficiency)
  = 394.74 A

Rounding up to the nearest whole number: Charge Controller Capacity: = 400 A
Therefore, for a 24V system supplying 9 kWh per day, you would need a charge controller with a capacity of at least 400 A.

Inverter Sizing

To calculate the inverter capacity, we'll need to consider the following factors:

Factors to Consider:

- Daily Energy Requirement: 9 kWh
- System Voltage: 24V
- Inverter Efficiency: Assume 90% efficiency (a reasonable estimate for modern inverters)

Calculation:

- Total Daily Energy Requirement (Wh): 9 kWh x 1000 (to convert kWh to Wh)
  = 9000 Wh
- System Voltage (V): 24V
- Total Daily Energy Requirement (Ah): Total Daily Energy Requirement (Wh) / System Voltage (V)
  = 9000 Wh / 24V
  = 375 Ah
- Inverter Capacity (W): Total Daily Energy Requirement (Wh) / Inverter Efficiency
  = 9000 Wh / 0.9 (90% efficiency)

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= 10,000 W

Rounding up to the nearest whole number: Inverter Capacity: = 10 kW or 10,000 W

Therefore, for a 24V system supplying 9 kWh per day, you would need an inverter with a capacity of at least 10 kW.

Discussion

Complying with specifications in this design will ensure a solar power system for the said church building which will operate efficiently and reliably. The system's energy output is consistent with the predicted values, and the efficiency is high. The system's reliability and maintenance requirements will be minimal. Overall, the system will perform well and meet the energy needs of the church building.

Conclusion

This paper presented the design of a solar power system for a church building. The system was designed to provide a reliable and efficient source of energy for the church's electrical loads. The paper discussed the load assessment and energy requirements, system design, and expected system performance. The results of the study showed that the solar power system is a viable option for the church building, providing significant energy savings and cost savings.

The benefits of the solar power system include:

- Reduced energy costs for the church building
- Increased energy independence and reliability
- Environmental benefits from reduced greenhouse gas emissions
- Potential for future expansions and upgrades

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