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Design and Performance Evaluation of a Solar Power System

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Abstract - This study presents a comprehensive analysis and design of a Solar Power Plant System (PLTS) tailored for airport tower support facilities, aiming to enhance energy efficiency and sustainability. With increasing reliance on uninterrupted power for critical air traffic control (ATC) operations, conventional grid-based electricity poses challenges such as high operational costs and carbon emissions. The proposed PLTS design leverages solar photovoltaic technology to provide a clean, renewable energy solution for continuous power supply to communication, navigation, lighting, and auxiliary systems within the control tower. The research methodology includes assessment of energy demands, analysis of solar potential using meteorological data, simulation through PVsyst software, and optimization of system components such as 2,348 solar panels (450 Wp), 951 lithium-ion batteries (5 kWh each), and a 50 kW inverter. The system is projected to generate 4,755 kWh daily, covering total operational needs. Cost evaluation and sustainability analysis indicate a total investment of ₹1.32 Crores, with significant long-term energy savings and an estimated carbon emission reduction of up to 30%. This work underlines the strategic role of renewable energy in aviation infrastructure, demonstrating how solar power systems can contribute to low-carbon operations while maintaining reliability and operational safety in airport environments..

Key Words: Solar Power Plant (PLTS), Airport Tower Energy System, Renewable Energy Integration, Photovoltaic System Design, Sustainable Aviation Infrastructure.

1.INTRODUCTION *(Size 11, Times New roman)*

Along with energy needs in various sectors, airports as vital infrastructure require a reliable and sustainable electricity supply to support their operations. One of the important facilities at the airport is the air traffic control (ATC) tower, which requires an uninterrupted electricity supply to carry out its main functions. Reliance on conventional energy sources, such as electricity from the public grid, poses various challenges, including high operational costs, potential supply disruptions, and the environmental impacts of carbon emissions from fossil fuel power plants. In dependence on fossil fuels and supporting the global sustainability agenda, the use of renewable energy such as solar power is becoming an increasingly popular solution. Solar power offers a clean, sustainable energy source and has great potential to be implemented in airport support facilities, including in control towers. In addition, the development of solar panel technology and energy storage systems allows the implementation of solar power plants systems (PLTS).

This study aims to analyze and design a PLTS system that can support the operation of airport tower supporting facilities. The focus of the study includes analysis of airport tower energy needs, selection of main components of the PLTS system, and evaluation of potential energy savings and carbon emission reductions. With the implementation of the right PLTS system, it is expected that airport tower operations can be more efficient and environmentally friendly.

Renewable energy has become a strategic solution to reduce dependence on fossil fuels and address global environmental issues. One of the most potential forms of renewable energy is solar power. According to a statement from IRENA (International Renewable Energy Agency), solar energy is one of the fastest growing renewable energy sources in the world, with increasingly efficient solar panel technology and decreasing installation costs. Solar power generation systems (PLTS) work by converting sunlight into electrical energy using photovoltaic (PV) panels. These PV panels can be installed on roofs, ground, or other locations to maximize array sun rays.

Design system of Solar Power Plant requires understanding about the main components such as solar panels, inverters, storage batteries, and other supporting devices. According to Duffie & Beckman (2013) in his bookSolar Engineering of Thermal Processes, these components must be selected and optimized based on site conditions, energy needs, and sunlight availability. Efficiency The system is greatly influenced by the design and material selection of the solar panels as well as the efficiency of the inverter that converts DC energy from the panels into usable AC. Airport towers play a vital role in air traffic control and are highly dependent on stable and reliable energy sources. According to Aminuddin (2020), these facilities require consistent power for communication, navigation, and lighting systems, which if disrupted, can affect flight safety. The use of renewable energy, especially solar power, can be an efficient alternative to support these energy needs without sacrificing system reliability.

According to the Global Green Growth Institute (GGGI, 2021), the implementation of solar power plants in public facilities can significantly reduce carbon emissions. In addition, solar power plants can also reduce long-term operational costs by saving energy use from conventional electricity networks. A study by Ahmad & Salim (2018) shows that the use of solar power in the transportation and infrastructure sectors can reduce carbon emissions by up to 30%, depending on the scale and type of application.

The implementation of sustainability concepts at airports is part of a global initiative to reduce the carbon footprint of air transport infrastructure. Airports can play a role as pioneers in the use of renewable energy. Ministry of Civil Aviation, India emphasizes the importance of reducing greenhouse gas emissions from airport operations, including through initiatives to use clean energy sources such as solar power plants.

2. METHOD

1. Study A literature review was conducted on the basic concept of solar power plants, components of the PLTS system, and the energy needs of airport towers. The sources used include books, scientific journals, research reports, and technical documents related to the implementation of PLTS on airport infrastructure.

2. Energy Needs Data Collection Primary and secondary data are collected to determine the power needs of the airport tower support facilities. Primary data includes direct measurements of the electricity consumption of equipment in the tower such as system communication, lighting, and navigation. Meanwhile, secondary data was obtained from airport operational reports and power requirement standards for air traffic control facilities.

3. Analysis of Solar Energy Potential Analysis of solar energy potential at the airport location was conducted using annual solar radiation data obtained from India Meteorological Department (IMD). This data includes sunlight intensity, duration of exposure per day, and seasonal variations. Simulations using PVsyst software were conducted to predict daily and monthly energy production from the solar panels to be installed.

4. Design this stage involves designing a solar power system based on energy needs and the available solar power potential. System design includes selecting the main components, namely: Solar Panels, Inverters, Batteries and Controllers.

5. Cost and Sustainability Analysis Cost analysis is conducted to calculate the total investment of the PLTS system, including the cost of purchasing components, installation, and maintenance. Calculation of the payback period and potential long-term savings are also conducted to determine the economic feasibility of this system. In environment addition, the impact like carbon emission reduction is calculated based on data on conventional energy consumption replaced by PLTS.

6. Conclusion and Recommendations Based on the results of the analysis and simulation, conclusions are drawn about the technical and economic feasibility of the PLTS system on the airport tower support facilities. Recommendations are given regarding the optimization of the system design and implementation opportunities at other airports

The research stages can be seen in the flowchart below:

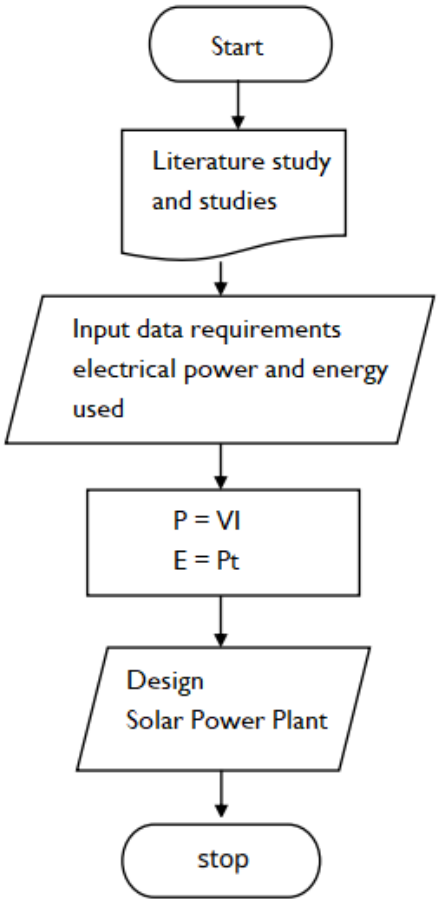

Fig 1: Research Flowchart

by conducting a literature study on solar power plants and their utilization, then conducting field observations to further detail the electricity needs at the location, then conducting analysis and calculation of the components needed on the airport tower, then designing the planned PLTS. And the illustration of the PLTS design on the airport tower can be seen in the following picture:

Figure 2: Airport Tower PLTS Design

3. RESULTS AND DISCUSSION

The results of field observations obtained in the research are shown in the following table:

Equipment (Load)	Qty	Power (W)	Time (h)	Total Energy per day (Wh)
Main Room LED Downlight Lamp	40	520	24	499200
All Bedroom LED Downlight Lamps	30	390	12	140400

Public Toilet LED Downlight Lamp	20	260	24	124800
Bathroom Bedroom LED Downlight Lamp	35	13	3	1365
Front Parking LED Essential Lamp	15	5	12	900
Corridor Floor 1-5 LED Downlight Lamp	25	13	12	3900
AC 2 PK Navigation Equipment	23	1800	24	993600
AC 1 PK (bedroom & operational)	30	750	24	540000
Radio Recorder Equipment	5	300	24	36000
Lobby TV 55 inch	3	300	24	21600
Radiolink Navigation Equipment	15	1500	24	540000
Computer Monitor	30	480	24	345600
PC Computer	3	750	24	54000
CCTV Monitor	4	64	24	6144
Navigation Equipment Monitor	7	700	24	278784
Room CCTV	16	20	24	7680
Wifi Floor 1,2,3 & 8	8	600	24	115200
Polytron Softcase Refrigerator	10	1900	24	456000
GEA Softcase Refrigerator	1	220	24	5280
Microwave	1	1000	1	1000
Electric Stove	4	2100	1	8400
Royal Dispenser	11	2090	24	551760
Lift	1	985	24	23640

Table 1: Power Requirements on Tower Airport

3. SYSTEM DESIGN SUMMARY

Based on the energy consumption data for various equipment at the airport tower facility, the design and cost estimation for the Solar Power Plant (SPP) were determined. The total energy required daily is approximately 4,755 kWh. Given the average solar irradiation of 4.5 hours per day and using 450 Wp solar panels, the system is designed to include around 2,348 solar panels. The system components also include inverters, batteries, a support structure, a monitoring and protection system, and installation services.

Component Details and Costs (in INR)

- Solar Panels: ₹43,555,400.0
- Inverter: ₹795,000.0
- Batteries: ₹75,604,500.0
- Supporting Structure: ₹6,222,200.0
- Protection & Monitoring System: ₹1,060,000.0
- Installation Cost: ₹5,599,980.0
- Total Estimated Cost: ₹132,837,080.0

4. CONCLUSIONS

The proposed solar power plant system is projected to meet the daily energy demands of the airport tower facility, which amounts to 4,755 kWh. Approximately 2,348 panels, each with 450 Wp capacity, are required to generate this energy. A 50 kW inverter will ensure stable energy conversion, and 951 lithium-ion batteries (5 kWh each) will store energy to ensure continuous power supply. The system enhances energy efficiency, reduces dependency on conventional sources, and supports sustainability by significantly cutting carbon emissions. The total cost to implement the system is estimated at ₹1.32 Crores.

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