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Feasibility Studies of Solar Energy as an Alternative Energy Resource for Muscat International Airport

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Abstract

Airports have gained an important position in the modern world and is integral to connecting near and far corners of the world. The airports are also energy intensive and consume large quantities of electricity. This can place a great burden on the limited oil and gas reserves across the world. Converting fuel sources in the aviation sector can eliminate a large proportion of conventional energy usage. In this study, a grid-connected solar PV power plant is proposed for the new Muscat International Airport terminal. The electricity consumption of the airport is estimated using available equations. The software SISIFO is used to develop and simulate a PV power plant for the airport against live values of solar irradiation and temperature data. It was found that the monthly and annual values of power yield is sufficient to fulfill the energy needs of the airport and can be used to feed to the main electricity grid for local power supply and supply of power to the airport during winter months. Overall, the results established the general feasibility of a grid-connected PV system for the Muscat International airport. The PV system does not require a lot of maintenance. It also has a lengthy life of 25 years and can reduce the energy burdens in oil and gas reserves. The solar irradiance values, temperature and electricity yield of a solar power plant, as was seen from the results, is heavily dependent on the seasonal and daily variations in solar energy.

Keywords

Solar PV Power plant design, Solar-powered airport, Solar power feasibility study, Grid-connected solar PV system.

Introduction

Airports have facilitated reliable movement across various countries and geographical boundaries. A significant portion of global carbon emissions (1.3%) is also contributed to by the aviation sector. This includes the emissions from fuel production, the electricity used to run large airports around the clock, and other direct and indirect factors. In light of global warming and climate and energy crisis, the need to consider alternate sources of fuel has become ever prominent.

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The new terminal of the Muscat International Airport is one of the largest in the world. It is also endowed with some of the latest technologies and modern amenities. The airport is yet to implement sustainable energy projects. As a country that receives sunlight for most part of the year, solar energy is a promising prospect, especially in the airport location where there are large patches of unused land close by.

Integrating solar energy in airports can significantly reduce the consumption of conventional energy by a large amount (Zahedi, 2006). According to Anurag et al. (2017), the utility and application of solar energy is more than other forms of renewable energy because of its scalability. Solar PV technology has already been implemented in airports across the World, such as Singapore, London and India (Zhu, 2018). Additionally, researchers are studying the feasibility of solar energy systems in airports in developing countries like Vietnam (Hai Nam, 2019). Wybo (2013) addressed the challenge of glare of solar energy systems (PV or concentrated) that can interfere with air traffic control operations. It was noted by Zhu et al. (2018) that around 12 airside accidents each year are caused by glare from solar energy devices. Ruther and Braun (2009) established the feasibility of using Building-Integrated Photo Voltaics (BIPV) in airports in warmer climates to reduce the high air conditioning load among other energy demands.

The aim of the proposed project is to Study the feasibility of solar PV power utilization at the Muscat International Airport. The objectives are to collect daily, monthly and annual energy consumption data of the Muscat International Airport, to propose and design a suitable PV power generation system that can be connected with the main grid, and to simulate the performance of the proposed system using SISIFO or other similar software tools.

Methodology

SISIFO is a useful and reliable simulation tool for PV solar energy systems that was developed and distributed by IES-UPM. SISIFO is a relatively simple software that can still generate high quality output for the benefit of researchers who are studying PV systems. The software is available for free download and as open source, allowing users to modify code to suit individual requirements.

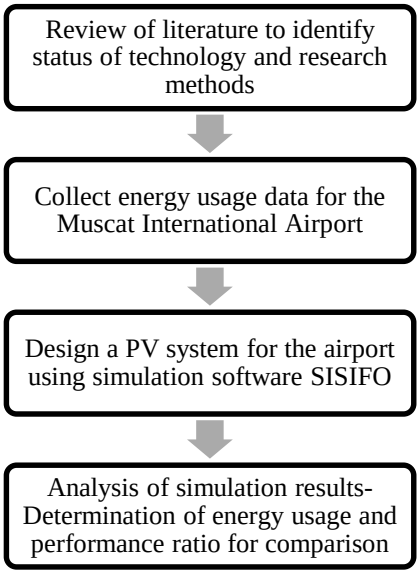

Figure 1. Research methodology

Capacity of the PV system is calculated by using the following formula and the data obtained from local authorities regarding energy consumption.

$$P = \frac{E_d}{H_S \times E_S} \quad (1)$$

Ed is the energy requirement of the airport in kWh on a daily basis
Hs is the number of hours of sunshine per day, on an average
Es is the system efficiency. This is assumed as 80% (Sukumaran and Sudhakar 2017).

For the Muscat International Airport, the daily energy requirement is approximated as 5.7 million units per year. This is roughly equal to 15, 600 units per day. Substituting in the above equation,
Installed capacity P = 15,600 / (11 x 80) = 17.73 kW = 1.8 MWp
Hence, in order to power the entire Muscat International Airport using renewable solar energy, it is required to install a PV plant of capacity 1.8 MWp.

The surface area of the new airport terminal at Muscat is 580,000 km^2. Annually, the terminal handles over 17.2 million passengers and is built to handle 12 to 24 million passengers per year. The airport is located at 23.36 N and 58.35 E. The airport is also located at 10m altitude and located at a time zone of GMT + 4 hours. No daylight-saving hours are established for the airport as of yet.

Table 1. Location details

Parameter	**Value**
Latitude	23.5880 N
Longitude	58.3829 E
Altitude	10m

In order to determine the number of modules that is required for powering the airport, the following formula is used:

No. of modules = Installed capacity / Maximum rating of the solar module

The airport installed capacity is required to be 1.8MWp. For such a large installation, thousands of modules are required. Busbars connect these modules in series and is linked as a string. The inverter input and the string is linked in parallel. Multiple strings are arranged together in a string combiner box. The peak voltage of the inverter in DC determines how many modules are connected in each string.

Simulation using SISIFO is a quick and simple process, especially so since the entire process is online and on cloud platform. There is no need for downloading heavy software onto local systems. The user can simply navigate through multi-step form and fill in the values specific to the case study. At the end of the sequence, the user is provided with a button to initiate the simulation. The user can choose between one simulation and N-simulations. A single simulation is opted for in this project.

Results and Discussion

The annual energy yield of the proposed system in terms of AC output when pump is connected is found to be 2002 kWh/kWp. The DC output when the pump is connected is 2068.05 kWh/kWp. The efficiency of the proposed system is hence = (output/ input) x 100 % = (2002/2068.05) x 100%= 96.8%. The following graph shows the yearly results for the energy yield.

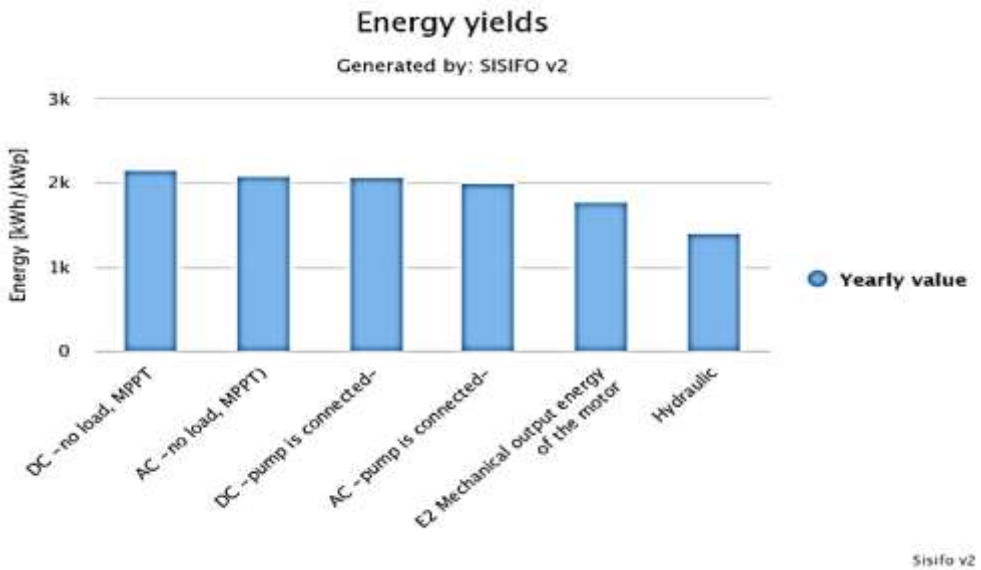

Figure 2. Energy yields

In the above figure, the monthly energy yield from the proposed system is presented. The energy generated values are presented in the order of 10^3. It is mentioned in kWp and translated to 1000s when linked to the unit of power of the local power utility plant. The maximum energy

generated is 210,000 kWh in May, whereas the least energy generation value is in December, equal to 82,000 kWh. The months of May and June sees an energy yield of more than 210 kWp. It can be seen that the energy yields are maximum for the months of May and June, exactly when the solar irradiation is also highest. Additionally, energy yield is minimum during the winter months when the irradiation is low. The importance of selecting areas with high irradiation levels when designing PV power generation systems is hence established.

SISIFO generates detailed analysis of the designed PV system, including details on the performance ratio and plant efficiency. It was found that the designed system could demonstrate a performance ratio of 83.39% on an average per year. The performance ratio values (monthly data) is presented in the graph below. It is observed that the performance ratio is lowest during the summer months and higher during winter months. This shows that system losses are higher during summer months and lower during winter months. This is also in line with the study published by Sukumaran and Sudhakar (2017) for the Raja Bhoj Airport in India. An inverse relationship is established between energy yield and the performance ratio of the plant.

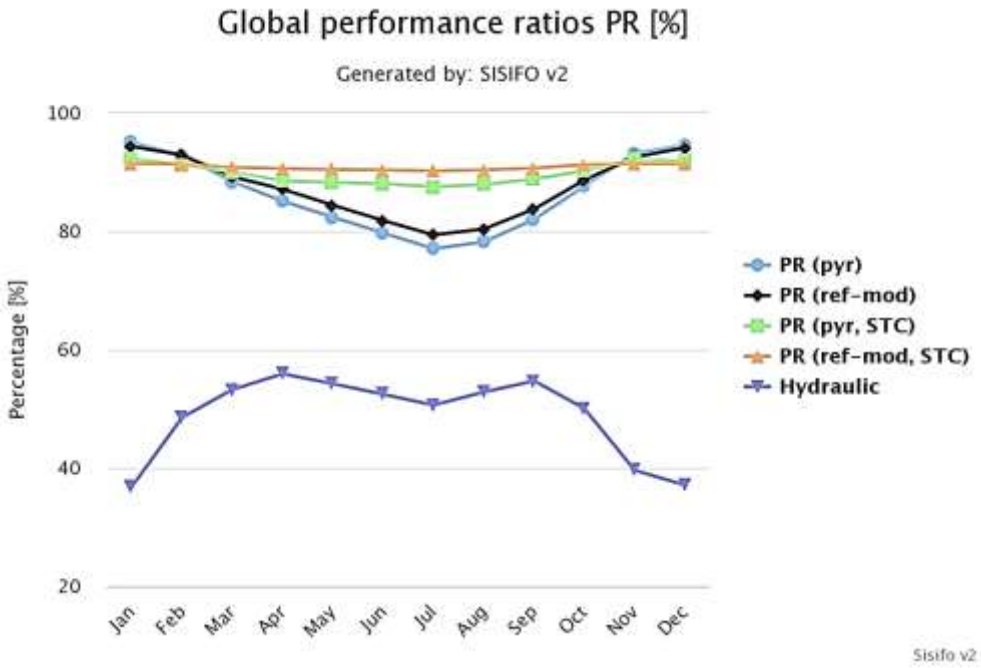

Figure 3. Performance ratios

The solar irradiance values, temperature and electricity yield of a solar power plant, as was seen from the results, is heavily dependent on the seasonal and daily variations in solar energy. While in summer months more energy can be generated than is needed, the energy in winter months may need to be supplemented by power from the main grid. As a result, for commercial operations like the airport where power should be continuously supplied, it is important that the PV system is grid connected. In this case, excess power can be fed to the main grid and then supplied for airport operations when consumption exceeds the energy yield. The excess energy yield can also be used to compensate for the spike in cooling loads during the summer. This is particularly relevant in Oman where summer temperatures can rise greater than 50 degrees Celsius.

Overall, the results establish the general feasibility of a grid-connected PV system for the Muscat International airport. The PV system does not require a lot of maintenance. It also has a lengthy life of 25 years and can reduce the energy burdens on oil and gas reserves. The excess energy supplied to the main grid can be used to supplement the conventional power supply and reduce the load. The lower cooling loads can further bring down the energy loads and associated costs.

Conclusions

The simulation tool SISIFO was utilized to study the energy output and performance of a 1.8 MWp solar PV power plant against live solar irradiance and temperature data. It was found that the proposed system could generate 2002 kWh/kWp of energy annually. The kWp unit allows to easily convert the value in terms of the measurement units of the local utility plants. For commercial operations like the airport where power should be continuously supplied, it is important that the PV system is grid connected. In this case, excess power can be fed to the main grid and then supplied for airport operations when consumption exceeds the energy yield. The result indicates that allowed to establish the PV power system in the Muscat International Airport.

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