3.9 kW Floating solar project implementation

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Abstract: The global energy sector has shifted its focus towards sustainable and renewable energy sources to deal with the issues of climate change as well as energy security. The floating solar systems, also referred to as Floating Photovoltaics (FPV) and these are mounted on water bodies such as the water reservoirs, ponds or lakes among others. To the utilization of water surfaces, it has several advantages such as it occupies less land space, solar panels on water bodies cools naturally and thus enhances their efficiency, and it greatly reduces the evaporation from the water body. This paper is concerned with technical feasibility, economic feasibility, and the external or environmental factors feasible in the particular project. The paper reveals the huge perspective of floating solar systems as one of the prospective ways of energy production. Thus, synergizing the benefits of solar power and water, we would be able to achieve significant impact on the cutting down of greenhouse gas emissions, the improvement of energy security, and the call for a more environmentally friendly society.

Keywords: Floating solar systems, Floating Photovoltaics (FPV), Feasibility analysis, Renewable energy, Power efficiency, Power production.

Introduction

With the rising of global warming and issues about the availability of the non-renewable source of energy such as the fossil fuel, the quest for the renewable and sustainable source of energy has become essential. Among all the alternative energies, solar power is playing a critical role in the development of a low-carbon economy. This most available energy derives its power from the sun and possesses the ability to meet our energy demands without harm as by other energy sources. Normally, there were two ways of solar power utilization, with solar power plants with solar panels placed on the ground and rooftop solar power PV systems. These systems have been effective in extending clean energy options, however there are problems associated with them. As an example, land use competition and lower efficiency due to temperature differences. To address these issues, engineers and researchers are now exploring an innovative and potentially revolutionary solution like the floating solar systems.

Literature Review

Padmavathi and Arul described about performance analysis of a 3MWp grid connected SPV plant located in Karnataka State, India as per International ElectroTechnical Commission (IEC) Standard 61724. The data for the research was gained using monitored data in order to analyze different losses. The main aim of the research is to get maximum use of abundant solar energy (about 24 MWp) around the country avoiding the varies difficulties of generation. The paper descriptively depicts how to monitor a SPV system and to manage it. The paper presents Inverter failure losses and grid failure losses are estimated for two years of plant operation. However, the research conducted in large scale to uplift the performance of the system at 18°C - 40°C of temperature. [1] This paper was very helpful to understand the working principles of SPV power plant and way of identifying the obstacles in the system.

Concept making 100kW tracking type floating solar system by Choi and Young-Kwan at Hapcheon dam reservoir was described in the paper. There is a fixed floating solar system is already established in the reservoir and therefore information was gathered about tracking algorithm and rotation mechanism of the structure in order to have optimum output. The main aim of this research is to enhanced the efficiency of the prevailing system. It has been identified as 30% efficiency can be gained than fixed system. [2] It has been gathered much information about how to track solar PV system and it has improved the output. The article is not much more described about the safety issues when making a large movable system (over 20kW). This article contains developing methods of tracking system by applying different technologies in future. The article enlightened us about making the structure to be more exposed to sunlight.

A. Lohner, T. Meyer, A. Nagel represent a new panel-integratable inverter concept as a solution for conventional inverter concepts. The inverter is proposed as series resonant DC-DC converter and a line inverter. Mainly safety, flexibility, converted energy per year and cost were focused for making this concept analyzing various outputs of solar panels. Highly efficient output with low distortion and low-cost components can be identified in this concept (250W DC to AC inverter). The article got very helpful to study about the inverter mechanism in PV system. A limitation can be identified as the durability of the inverters were not mentioned in the article. But the article describes more positive responses regarding economically advantageous inverter concept as 2% rising of total energy conversion amount per year when using single MPPT. [3] The paper encourages us to reconsider about the effectiveness of manufacturing such type of inverter for our design.

Pimentel Da Silva, Gardenio Diogo, and David Alves Castelo Branco show how environmental impacts occur because of solar terrestrial and FPV concepts. A description about the effects to the environment during different phases of the implementation can be identified from this paper. A solar project requires a land area for construction about 2.2-12.2 acres/MW. The importance of mitigating the environmental effects is explained in this research. This article depicts how an instalment of FPV system can be possible with minimum impact to the environment. This paper not depicts about the economic viability to do minimize the environmental impact. FPV system expected to generate about 11% more electricity than land PV system. [4] However, this paper covers many areas of impacts which should be considered during implementation and operation. As our research is about implementation of FPV system this paper was very helpful to identify the environmental impacts.

Bakar, Muhammad S. A., and Jobrun Nandong present a technical and economic evaluation of 1GWh electricity generation using a floating solar PV (FSPV) system implemented on the Bakun Lake. In this paper five PV brands are examined for 2x2, 3x3, 4x4 and 5x5 layout designs under total capital cost, total platform area, stability or percentage weight distribution, product warranty and PV efficiency. The scope of this research is to determine the best design fit to evaluating criteria. This paper guides us to ensure that our design will be more cost effective and durable under this evaluation. But this paper hasn't mention about environmental impacts. The paper concluded that based on optimization results the best design is 5x5 layout for Panasonic brand. [5] This paper makes a better understanding on how to make a choice of design to be durable for a long time as well as cost effective to have a maximum output.

D. Sen, P. Sharma and B. Muni designed a 10 kW floating solar PV system. Float solar panels on water bodies is the aim of their project. Solar power plants need huge space. Lack of land is the main problem for solar power plants. So, these researches focus on solving this problem. They mentioned about challenging parameters that they were faced. So, when we implementing our FPV plant we have considered parameters such as maximum wind speed, temperature limits for a maximum efficiency from the power plant. But they did not mention about the tilt angle and the azimuth angle of the power plant. The air just above the body of water has high humidity, which naturally cools the panels and reduces evaporation by 70%. But the investment is about 1.2 times that of conventional land-based solar power plants. [6] So, these design parameters should be considered while operating our floating solar power plant.

Methodology

Floating solar is a popular technology in the world these days. But it is a new technology to Sri Lanka. So, it needed to do more research on the current floating solar power plant in the premises. More research papers were referred related to the floating mechanism, how solar panels generate DC current and the anchoring and mooring system of FPV system. Hence, a thorough study about the background of floating solar PV system was done. HDPE (high density polyethylene) pipes are more durable, lightweight material which is resistance to corrosion and can be anchored using bank anchoring. Galvanized steel can be manufactured in low cost and have adjustable module inclination. 1 or 2 axis tracking have several moving parts which can be used with adjust the azimuth angle. Membrane structure is also flexible and durable as it is made using HDPE or EVA (ethylene vinyl acetate). It has a mooring system based on aquaculture.

Data was collected from both current floating solar and roof top solar located in Kilinochchi premises. Since the roof top solar plant is 60 kW and the FPV system 42 kW some difficulties were raised when comparing these two plants. So, the collected data of both power plants were converted to per unit system to have a fair result. Then a comparison between these two was done to identify which arrangement was more efficient. The materials needed for the floating structure such as HDPE pipes, structural Al and profile Al was analyzed. Floating solar is more complex than the ground mounted solar power plants because of the anchoring and the mooring systems. When implementing the structure wind patterns and other climate factors should be considered to not be affected from worst weather conditions.

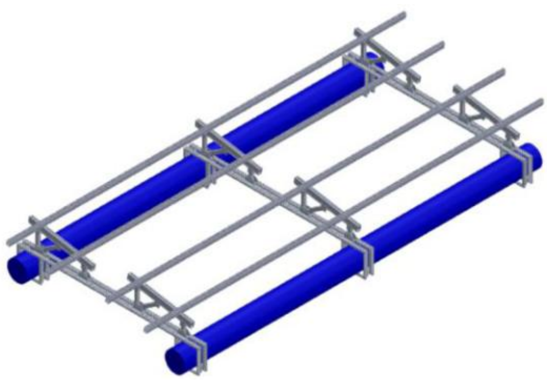

Figure 1: Strucural design using SolidWorks

It is very important to satisfy the consideration according to the Sri Lankan point of view from the side of the design as it needed to be suited. The testing of the system is very important as this will a prototype for a large-scale production. Implementation and testing will the final and most important stage of this research project as it will be evaluated further through many areas expanding the feasibility of enhancing the efficiency of the floating solar system technology. As a result of development in the technology and the materials available perform speedy advancement of floating solar systems.

Calculations

To ensure the system floats, the total load must not exceed the buoyant force. The buoyant force is primarily provided by the HDPE pipes. For safety, we assume the HDPE pipes can be submerged up to a maximum of 80% of their volume.

Total Bouncy force = Total volume underwater* ρ_water*g

Total volume underwater = HDPE pipe volume under the water

The total volume under water produced by HDPE pipe (80% of the pipe) = Total volume * 0.8
= (π * r^2 * h * no. of HDPE pipe) * 0.8
= (π * (0.355/2)2 * 6.4 * 2) * 0.8
= 1.01355 m^3

Therefore,
Total volume underwater = 1.01355 m^3

Because of that,
Total Bouncy force = Total volume underwater * ρ_water* g
= 1.01355 * 1000 * g
= 10135.5 N
= 1013.55 kg

Then the weight of the system is calculated.

Total weight of the system = HDPE pipes + Al structure + Connector weight + PV panels

No. of HDPE pipes = 2

Total weight of the HDPE pipe
= weight of one * no. of pipes
= (length * density) * no. of pipes
= (6.4 * 14.9) * 2
= 190.72 kg

Total weight of the structure= 102.31 kg
Total connector weight = 25 kg
Total weight of PV panels = weight of one * panels per line *no. of lines per set
= 28.6 * 3 * 2
= 171.6 kg

Therefore,
Total weight of the system = HDPE pipes + Al structure + Connector weight + PV panels
= 190.72 + 102.31 + 25 + 171.6
= 489.63 kg
Total Bouncy Force of the system = 1013.55 kg

Therefore, the total weight of the system is less than the total bouncy force of the system. So that, we can float the system without any problem.

Results & Discussion

Power Production

The following figure explains how the floating solar system provides energy than the rooftop solar system. They are implemented at the Faculty of Engineering, University of Jaffna. The data gathered are for the period between March 2020 and March 2022. On average, the floating solar system produces 23 MW electricity during the day. It has been estimated to be 23.61 % higher in power than the rooftop solar system.

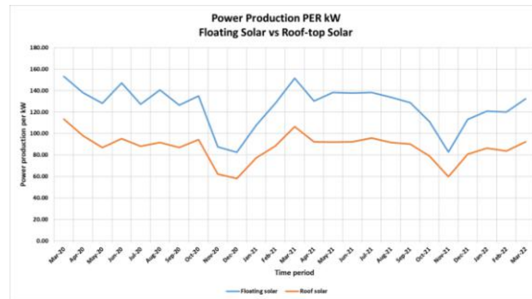

Figure 2: The power production of roof-top vs floating solar

In this case, the floating solar system is oriented east to west, while the rooftop solar system is oriented north to south. Despite the current design of the floating solar system not being ideally suited for our environmental conditions, it still generates more power than the rooftop solar system.

Environmental Impact

A floating solar system can establish a new ecosystem. As an example, the shade provided by the system can help for small fish to grow underneath, leading to an increase in the fish population in the lake. This can boost the income of local fisheries. To calculate the evaporation rate at the lake in the Faculty of Engineering, we have gathered the following information.

- Wind velocity (Average) : 5.01 m/s
- Water temperature (Average) : 30 °C
- Air temperature (Average) : 36 °C
- Saturation vapor pressure at the water temperature : 4248 Pa
- Saturation vapor pressure at the air temperature : 5948 Pa

We determined the average evaporation rate of the lake to be approximately 0.9909 liters per square meter per hour. With the installation of the floating solar system, we can significantly reduce this evaporation rate.

Economic Analysis

We have estimated the power production and return on investment for the new floating solar system over a 30-year period. The total cost of the system is Rs. 3,599,607.34. Based on this investment, we anticipate a total return of 188% over 30 years. The payback period for the system is approximately 9 to 10 years.

Figure 3: The summery of the financial report for 30 years

Conclusion

As the global energy landscape shifts towards cleaner and more renewable power sources, Floating Photovoltaic (FPV) systems have emerged as a promising solution to the challenges of energy storage and supply. Through a comprehensive analysis of existing literature, technical evaluations, and real-world data, this study has demonstrated the significant potential of FPV systems to contribute to sustainable energy production. The objectives of this research, which included exploring the interrelationships among FPV components, evaluating buoyancy materials, and assessing the environmental impact of FPV installations on water bodies, have been successfully met. The real-world case study provided not only practical insights but also underscored the multifaceted benefits of FPV systems from technological, economic, and environmental perspectives. This research highlights the importance of further exploring FPV systems as a viable alternative in the quest for energy resilience at the local level. By combining technical feasibility with environmental considerations, FPV systems stand out as a forward-looking approach that can contribute significantly to greenhouse gas reduction and sustainable energy goals. The findings of this study not only emphasize the current value of FPV systems but also set the stage for future research and innovation in this field. The potential for FPV systems to play a pivotal role in the global shift towards environmentally responsible energy solutions is both significant and promising.

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