Potential Assessment of 80 kW Floating Solar Photovoltaic System (FSPV) at Kaptai lake, Bangladesh

Kanij Ahmad[1], Arifur Rahman[2], Al-mahmud[3]
Department of Electrical and Electronics Engineering, Daffodil International University, Bangladesh.[1,2,3]

Abstract— Based on the massive amount of electricity generated, the world's lifestyle and economy have greatly expanded. However, due to the scarcity of fossil fuels, the provision of power is under pressure in this country. Renewable energy provides an exception at this point, and solar energy—among all the renewable energy sources—plays a prominent role because it is environmentally friendly and indestructible. The cost and accessibility of land, however, poses a significant obstacle to the construction of land-based, large-scale solar power plants in Bangladesh. In a riverine nation like Bangladesh, a floating solar photovoltaic system offers a solution with a lot more possibilities. This research will outline the potential for floating solar photovoltaic systems in Bangladesh's Kaptai lake area and discuss feasible investigations with location prospect, FSPV costs, project revenue, environmental aspects and further research opportunities. The potential investigation for the establishment of FSPV based on financial parameters will be validated in this paper using RET-screen energy management software.

Index Terms— Renewable Energy, Solar Power, Floating Solar Photovoltaic (FSPV), Kaptai lake, Bangladesh, GHG Emissions, Financial Feasibility, Investable

1 Introduction

With a massive population growth as well as a quick industrial development, the need for energy to produce electricity is rapidly growing day by day. The vast amount of energy needed cannot be supplied solely by fossil fuels, which are also running out [1]. On the other hand, fuel-related conflict between states is at an all-time high in today's world. The major noticeable component in so many recent conflicts is the competition for energy resources. The issue of global warming is being driven by the use of fossil fuels. The greenhouse impact on the environment is facilitated by the large volumes of carbon dioxide that are produced when fossil fuels are burned. Therefore, using renewable energy is getting the most attention in order to address the concerns with the energy crisis. To make the most of renewable energy, many different strategies are being investigated [2].

Among the renewable energy resources, solar power is always on the top. Sun is for all. Solar energy is a highly cost-effective alternation of fossil fuel with slight environmental impact and one of the most sustainable energy resources. The special features like clean, emission-free made it popular day by day. When compared to other renewable energy sources, such as hydro, wind, and geothermal, which are all site-specific sources of energy, solar energy is appealing due to its environmental friendliness and accessibility [3].

The geographical location of Bangladesh is in a hot region, which indicates the high potential of solar power implementation. As it is a matter of great concern for Bangladesh in recent times is that the economic and social development is highly restricted here due to an over population and lack of energy resources [4]. Implementation of solar power can meet the deficiency of energy but constrains of land in this highly populated agricultural-based country is a vital barrier to establishing ground based solar power system. In recent times, the floating solar system technology has several prominent advantages over ground-based solar power systems in terms of efficiency and maintenance.

Floating Solar Photo Voltaic (FSPV) systems show higher efficiency than land-based solar power plants [5]. FSPV do not require land space, can utilize unused water bodies and save water resources from evaporation. The specious features of FSPV make it an attractive option for solar power generation in countries like Bangladesh where consumption of land other than living and agricultural work is an alarming issue. In addition to the advantages described above, Bangladesh has a strategic advantage as it is a riverine country, full of lakes, rivers, beels, haors and ponds.

However, very few research has been done regarding the potential aspect of floating solar power plant in Bangladesh. There is no such prominent study which shows the feasibility including the cost, emission and other analysis for promoting floating solar panels in Bangladesh [6].

The purpose of this research work is to express the possibilities of the floating solar system and explore a prominent water resource area of Bangladesh for the installation of FSPV.

2 Prospect of FSPV in Bangladesh

Compared to other renewable energies like wind, tidal, or geothermal energy, Bangladesh has a lot of room to grow in terms of integrating solar energy. The lack of available land in Bangladesh is the biggest barrier to the construction of solar energy projects. Ground-based solar energy generation systems are therefore not a viable option [7]. Floating solar power plants could be an alternative because Bangladesh is a country with many rivers, lakes, beels and haurs, as well as several large and small ponds and, last but not least, a vast mangrove swamp.

Bangladesh has 7,497 million hectares river area, 1,142 hectors of beels and haurs with 3,000 square kilometers of Kaptai lake shore, Rangamati, Bangladesh [8]. These water bodies have a huge potential for the implementation of the floating solar system. The idea of using water bodies as solar energy sources is not a novel one. A number of nations, including the USA, Korea, China, France, and India, have already successfully implemented floating solar panels [9]. The FSPV concept can be simply adopted by nations like Bangladesh to meet the demand for electricity. FSPV can offer a synthetic alternative to the need for considerable amounts of land resources in the production of energy. However, a feasibility study is required to launch a pilot project and create the essential systems and policies in this respect.

2.1 Features of FSPV

Solar cells employ the photovoltaic (PV) effect to convert solar radiation into clean electric energy. The amount of sunlight and temperature affect a panel's output.

Since solar cells are less efficient when they are shaded, dusted, or when the air temperature rises. It is inevitable to reduce the impact of temperature in order to achieve maximum efficiency. The loss of water from reservoirs is a significant loss for any waterbody. The ideal solution to any of these issues could be the implementation of FSPV [10].

Floating Photovoltaic (FSPV) systems are efficient and more productive than land-mounded Solar systems due to its temperature-regulating mechanism and by installing it in the middle of a water reservoir, it also reduces shading effects. Because of some attractive features the largest portion of solar power will achieved from FSPV.

The most attractive features of FSPV are

- Increased larger installation capability per unit area for solar panel.
- A FSPV project which is co-located with hydropower highly reduce the capital prices.
- A prominent loss in hydropower plants due to evaporation of water can be minimized.
- The temperature rise of FSPV panels is lower compared to roof prime solar energy panels because of the naturally cooling effect by water bodies.
- Water quality is improved because the growth of unwanted algae is reduced.
- FSPV panel output gain is 7 to 14 percent more than land-based system [11].
- Improve the performance of solar panels by reducing shading effects.
- The installation of FSPV is simple and eliminates the problems associated with solar power systems that are related to land consumption.
- By reducing carbon dioxide gas (GHG) emissions by 83.42 KT CO2/year, FSPV significantly contributes [12].
- The floating solar PV system shields fish from bird feeders.

3 Location Study

This research focuses on the investigation and evaluation of installing an FSPV-based solar power system along the shore of Kaptai Lake, close to Bangladesh's sole hydroelectric facility and it is the largest lake of Bangladesh. With an average temperature of 23.30 and a relative humidity of 71.6%, it is located in latitude 22.50 and longitude 92.20. The area's average yearly solar radiation is 4.71 kWh/m2, while the wind speed is 2.2

	Unit	Climate data location	Facility location	Source
Latitude		22.5	22.5	
Longitude		92.2	92.2	
Climate zone		2A - Hot - Humid		NASA
Elevation	m	244	28	NASA – NASA
Heating design temperature	°C	11.6		NASA
Cooling design temperature	°C	30.6		NASA
Earth temperature amplitude	°C	14.1		NASA

Month	Air temperature	Relative humidity	Precipitation	Daily solar radiation - horizontal	Atmospheric pressure	Wind speed	Earth temperature	Heating degree-days 18 °C	Cooling degree-days 10 °C
	°C	%	mm	kWh/m²/d	kPa	m/s	°C	°C-d	°C-d
January	17.6	54.6%	6.60	4.64	97.5	2.1	17.4	11	237
February	20.3	52.8%	20.28	5.22	97.4	2.3	20.7	0	289
March	23.6	57.2%	45.22	5.64	97.2	2.4	25.1	0	421
April	25.2	68.1%	98.41	5.66	97.0	2.2	26.9	0	456
May	25.9	76.7%	325.93	5.14	96.7	2.2	27.4	0	492
June	25.9	84.7%	402.37	4.35	96.4	2.8	26.6	0	478
July	25.7	86.3%	375.54	4.21	96.5	2.8	26.0	0	486
August	25.7	85.2%	329.97	4.35	96.5	2.5	26.0	0	487
September	25.3	83.8%	368.16	4.33	96.8	2.1	25.6	0	459
October	24.4	77.7%	223.08	4.40	97.1	1.8	24.3	0	446
November	21.8	69.9%	41.38	4.29	97.4	1.9	21.3	0	353
December	18.7	61.2%	7.20	4.36	97.6	1.9	18.1	0	269
Annual	**23.3**	**71.6%**	**2,244.15**	**4.71**	**97.0**	**2.2**	**23.8**	**11**	**4,872**
Source	NASA	NASA	NASA	NASA	NASA	NASA	NASA	NASA	NASA

Fig. 1. Location study and specification of Kaptai Lake, Bangladesh @RET Screen expert.

m/s. The only source for location-specific information is the RET Screen-Clean energy management system.
The pertinent data for the study's location, including relative humidity, air temperature, precipitation, atmospheric pressure, daily solar radiation, and wind speed, is shown in Fig. 1.
According to the location analysis shown in Fig. 1, the area around Kaptai Lake receives an average solar radiation of 4.71 kWh/m2/day throughout the year, which is high enough compared to Bangladesh where the average solar radiation is roughly 4 to 5 kWh/m2/day approximately [13].

4 FSPV System Design Specifications and Considerations

This study compares the costs of using that much electricity from the grid during peak hours with those of an off-grid floating solar power-based electrification project. It also gives specs for the project. Here the cost of diesel is taken as 1.063 $/per litre [14] and the cost of electricity per kWh is 0.088 $ [15].

4.1 Specifications of photovoltaic energy model

For the project analysis, a photovoltaic system model with the required details is being taken into consideration.
This article designs an 80-kW photovoltaic system using mono-Si-SPR-320E-WHT solar panels from Sunpower.

Photovoltaic - Level 2			
Resource assessment			
Solar tracking mode			Two-axis
Show data			
Photovoltaic			
Type			mono-Si
Power capacity	kW		80
Manufacturer			Sunpower
Model			mono-Si - SPR-320E-WHT
Number of units			250
Efficiency		%	19.62%
Nominal operating cell temperature		°C	45
Temperature coefficient		% / °C	0.4%
Solar collector area		m²	408
Miscellaneous losses		%	2%
Inverter			
Efficiency		%	98%
Capacity		kW	100
Miscellaneous losses		%	1%
Summary			
Capacity factor		%	23.2%
Initial costs	$/kW		3,900
		$	312,000
O&M costs (savings)	$/kW-year		48
		$	3,840
Electricity export rate			Electricity exported to grid - annual
		$/kWh	0.088
Electricity exported to grid	MWh		162
Electricity export revenue		$	14,290

Fig. 2. Energy model specifications

The efficiency of the panel is 19.62%, capacity per unit is 320 watt and frame area are 1.612 m². To generate 80 kW of solar power, approximately 250 solar units are required.
The design is also considered a 100-kW inverter with 98% efficiency and 1% loss.
The planned photovoltaic installation has a capacity factor of 23.2%.
All the necessary specifications for the design of the photovoltaic system are shown in Fig. 2.
A two-axis solar tracing mode is taken into consideration for maximum output.
The project's preliminary startup and operating costs are provided by RETScreen. For further analysis, the other pertinent project expenditures such as the assessment research, site survey, legal processing, design engineering, proposed power system, Balance of System, and miscellaneous are included.

4.2 Financial Parameter

The predicted inflation rate of 6.95% [16] and interest rate of 8% [17] for the years 2021–2022, respectively, are taken into consideration for the project's financial analysis.
Financial leverage that means project debt being valued as 55%. The project's financial parameters are shown in Fig. 3 for the analysis using RET-Screen. These financial specifications apply to fine the overall project cost and revenue. The final output for the analysis is determined based on cost and revenue.

Financial parameters		
General		
Inflation rate	%	6.95%
Discount rate	%	7.1%
Project life	yr	20
Finance		
Incentives and grants	$	
Debt ratio	%	55%
Debt	$	70,565
Equity	$	57,735
Debt interest rate	%	8%
Debt term	yr	10
Debt payments	$/yr	10,516

Fig. 3. Financial paramerters of the project

3 Feasibility Analysis

RET Screen software is used to do a feasibility study on the installation of an FSPV in Kaptai Lake, Bangladesh.
The RET Screen software offers a powerful platform for creating an in-depth study for a renewable system.
The primary analysis comprises a project's energy, cost, emission, financial, and risk analyses [18]. RET Screen is capable of doing a fundamental level of feasibility analysis to suggest a renewable energy-based power station.

3.1 Cost Analysis

RETScreen offers the provision of figuring out the whole cost of establishing a renewable project and aids in identifying savings and income related to fuel-based electricity generation or grid usage.

Costs | Savings | Revenue			
Initial costs			
Feasibility study	0.08%	$	100
Development	0.08%	$	100
Engineering	0.08%	$	100
Power system	93.5%	$	120,000
Balance of system & miscellaneous	6.2%	$	8,000
Total initial costs	**100%**	$	**128,300**
Annual costs and debt payments			
O&M		$	3,840
Debt payments - 10 yrs		$	10,516
Total annual costs		**$**	**14,356**
Periodic costs (credits)			
Periodic costs - 20 yrs		$	100
Annual savings and revenue			
Oil cost		$	34
Electricity export revenue		$	14,290
GHG reduction revenue - 5 yrs		$	8,224
Total annual savings and revenue		**$**	**22,547**

Fig. 4. Cost summery of the project

Fig. 4 firmly represents the overall costs of initial cost and O&M cost annual savings and revenues.
Here, 128,300 $ is the initial cost and 14,356 $ of O&M cost of the project with 22,547$ total annual savings and revenue which includes oil cost, electricity export revenue and GHG reduction revenue.

3.2 Emission Analysis

In emission analysis, GHG analysis is employed to assess the total impact of green-house gas emission of a fuel for the production of electricity which is totally not a concern for any renewable energy-based electricity generation process.

GHG emission		
Base case	tCO_2	164.5
Proposed case	tCO_2	0.0
Gross annual GHG emission reduction	tCO_2	164.5

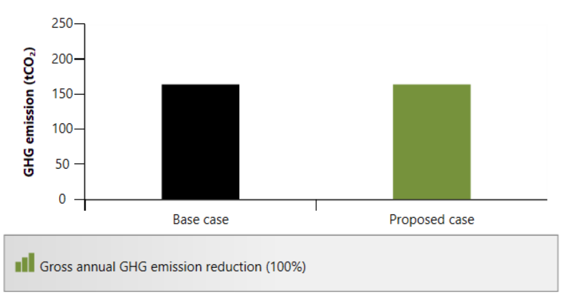

Fig. 5. GHG emission reduction summary of the project

For diesel (oil#6), the CO_2, CH_4 and N_2O emission factors are 74.1 kg/GJ, 0.0029 kg/GJ and 0.0019 kg/GJ respectively, which generates a cumulative GHG emission of 164.5 tCO_2 as GHG emission factor is 1.013 tCO_2/MWh [19].
The gross annual GHG production is zero, which means the GHG emission reduction is 100% for the proposed project as shown in Fig. 5.
This GHG emission reduction generates GHG reduction revenue for the project [20]. The GHG reduction credit rate is 50 $/$CO_2$ and the credit duration is 5 years. Here, net GHG reduction revenue for the proposed project is 8,224$ throughout the 20-year life span. Fig. 6 displays the greenhouse revenue summery of the proposed project.

GHG reduction revenue		
Net GHG reduction	tCO_2/yr	164
Net GHG reduction - 20 yrs	tCO_2	3,289
GHG reduction credit rate	$/$tCO_2$	50
GHG reduction revenue	$	8,224
GHG reduction credit duration	yr	5
Net GHG reduction - 5 yrs	tCO_2	822
GHG reduction credit escalation rate	%	31%

Fig. 6. GHG emission revenue summary of the project

3.3 Financial viability Analysis

Financial viability means having a successful balance between initial, operating and maintenance expenditures, long term debt and operating revenues. For a project, net present value, equity payback, benefit to cost ratio and Internal Rate of Return on equity and asset etc assess the financial feasibility of a project [21].
The whole analysis done on RETScreen helps to determine the financial parameters and regulates the decision making regarding the project.
A high pre-tax IRR on equity and positive pre-tax IRR on assets make a project financially feasible based on commercial reasons [22].

Pre-tax IRR - equity	%	20.9%
Pre-tax IRR - assets	%	4.4%
Simple payback	yr	6.9
Equity payback	yr	3.6
Net Present Value (NPV)	$	50,051
Annual life cycle savings	$/yr	4,761
Benefit-Cost (B-C) ratio		1.9
Debt service coverage		2

Fig. 7. Financial Summary of the project

Here, fig. 7 exhibits all the financial points which need to analyse for the evaluation of the project.
20.9% pre-tax IRR on equity and positive 4.4% pre-tax IRR on

asset point out the financially beneficial aspects of the project. Net present value (NPV) exposes all the upcoming cash in and out flow of a project [21]. A positive NPV of a project is favorable as it means the project may give a return on the investment.

So, the positive 50,051$ NPV of the proposed project indicates that the investment on this project is considerable.

Another term called Benefit-Cost (B-C) ratio is also determined to assess the viability of a project as it shows the monetary relation between related cost and benefit of a project [22]. B-C ratio greater than one that means benefit exceeding cost, specifies the profitable aspect of a project. The benefit-cost ratio is 1.9 for the proposed project, which means the project is profitable.

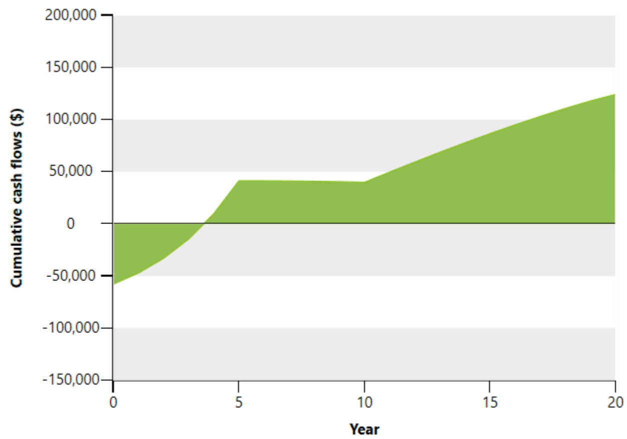

Fig. 8. Yealy Cashflow curve of the project

The equity payback period means the period needed to back the investment with a positive net value and dept repayment is only guaranteed if the equity payback is accomplished, possibly in a period shorter then 10 years.

Here, for the proposed project, equity payback is 3.6 years which is less than one third of the project life cycle expresses in Fig 8. It is also a considerable point for the proposed project establishment.

4 Conclusion

Based on the government's goal of ensuring sustainable clean electricity production in Bangladesh, this study investigated the viability of using floating solar photovoltaic panels in one of the largest lakes of Bangladesh. It also proposed a decentralized off-grid electrification system in Kaptai, Bangladesh collocated with Hydro power plant. The annual savings for the analysis are calculated by comparing the costs of using diesel fuel and exporting energy to the grid. The GHG emission component is also taken into account to assess the environmental impact of the project. In order to attract Bangladeshi solar project investors, the study focuses solely on the financial factors and overall costs associated with producing power over a 20-year period by installing floating solar panels. The research's flaw is that it does not account for the boost in efficiency brought on by FSPV's reduced water evaporation.

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