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Prospect of Solar Thermal Power Plant in Bangladesh

Sheikh Sujan[1*], Shafiqul Islam[1], Fahadul Islam[2] and K. M. Kayes Ibne Zakir[3]

[1]Department of EEE BUET Dhaka, Bangladesh

[2]Department of EEE CUET Chattogram, Bangladesh

[3]Department of EEE IUT Gazipur, Bangladesh

***Corresponding Author:**
Sheikh Sujan, Department of EEE BUET Dhaka, Bangladesh.

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Abstract
According to 2016 Master Plan for the Power System of Bangladesh, renewable energy will produce 2.4 GW by 2021, accounting for around 10% of overall energy demand. 4GW by 2030 and 10.2GW by 2041, accounting for nearly 17% of total energy. Majority of them will be powered by solar energy. In these circumstances, Concentrated Solar Power (CSP) plays a critical role. In Bangladesh, 6% of total power will be produced from renewable energy within 2030 [1]. The deployment of CSP power plants in Bangladesh plays an essential role in meeting the current energy demand, according to a review of the Levelized Cost of Electricity (LCOE) of several CSP plants. Bangladesh government has already included CSP in the Renewable Energy Policy 2009 [2]. We have investigated the prospects of solar electricity from CSP in Bangladesh using parabolic trough technology, as well as a comparative assessment of the LCOE in various scenarios. In this study, a 10 MW CSP plant has been evaluated with various thermal storage hours under various conditions, as well as a CSP hybrid with a conventional thermal power plant. The LCOE for a 10 MW CSP plant has been found 13.76 cents/kWh using System Advisor Model (SAM).

Keywords: Renewable, Hybrid, Power, Energy, CSP, LCOE, SAM, NREL Bangladesh

Introduction
The role of energy is very important for our stability on earth. The world population is growing rapidly. Hence the demand for energy is rising. To meet this huge demand, the use of fossil fuels is also growing rapidly. Burning fossil fuels for electricity and transportation is a major source of Green House Gas (GHG) emissions. Climate is very important for our habitability on earth. But with the burning of fossil fuels for energy production and other sources of pollution, our atmosphere is now dangerously damaged. Another important point is that fossil fuel reserves are very limited. If we use fossil fuels at this rate, experts predict that by approximately 2100, we may have run out of fossil fuels. For these reasons, we need to look for alternative resources to meet the growing demand. Renewable is the best solution to this problem. They are abundant and clean. So, we need to move renewable energy as soon as possible and do research to find an economical way to generate electricity from renewable energy resources.

Solar energy is the most abundant and convenient renewable energy source, and it can be used in two ways: Photovoltaic (PV) and Concentrating Solar Power (CSP) are two types of solar energy technologies. PV is more popular compare to CSP technology of all countries in the world. But after a stagnation period of 15 years since 1990s, CSP is getting popular in recent years [2]. CSP generation increased by an estimated 34% in 2019 [3].

Bangladesh has an annual Direct Normal Irradiance (DNI) of almost 1,900kWh/m2, which is sufficient to run a CSP plant. This hybrid system is critical in meeting Bangladesh's energy demands. CSP plants in a hybrid system continue to operate during daylight hours. On a CSP power plant, the thermal storage system provides an advantage. The southeast parts of Bangladesh have superior solar potential for CSP technology, hence the regions of Chakaria, Cox's Bazar are chosen as an example. The simulations are run using SAM software. We obtained the LCOE results in a variety of conditions and compared it to the LCOE of existing thermal power plants and past research. The potentials for solar electricity from CSP in Bangladesh are the subject of this research.

Recent Energy Status of Bangladesh

Renewable Energy Scenario of Bangladesh

According to the Power Sector Master Plan (PSMP) 2016, the Government of Bangladesh aims to generate 24 GW by 2021, where renewable sources will include 10% (about 2.4 GW) [4]. By 2030, total generation will be 40 GW, with renewables accounting for 10% of that, or around 4 GW [4]. Within 2041, the target will be around 60 GW, with 17 percent coming from renewable energy resources, with an estimated 10.2 GW coming from renewable energy sources [4]. Observe Figure.1[4].

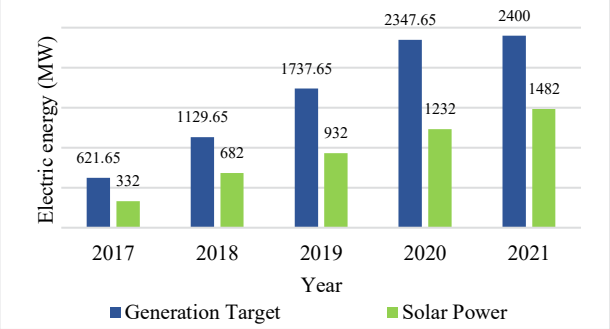

Figure 1: Renewable Energy Generation Target within 2021 [4]

Figure 1 illustrates that the Government of Bangladesh (GOB) aims for generating power from renewable energy sources by 2021 is 2400 MW, with 1482 MW coming from solar PV. To meet this goal, the government is taking steps to create renewable power plants. To meet the 2041 mission, the GOB intends to construct a number of renewable-based power plants across the country. Electricity is now available to 97 percent of the population [5]. As a result, the government has established a goal of delivering and ensuring energy to all by 2021 in order to ensure a consistent and high-quality supply at a reasonable price [5,6]. Due to the rapid depletion of fossil fuels, the GOB has implemented key efforts to generate renewable energy as part of its overall development strategy [5].

Scenario of Coal Based Power Plant in Bangladesh

The development of coal import infrastructure has a considerable impact on coal-fired power plants [7]. Around 75% of the world's coal-fired power stations are inefficient [8]. Therefore, we need to move from coal power plant to other power sources [9]. It is noticed that Bangladeshi coal quality is good due to its high heat generating capacity and low Sulphur content. observe 0[8]

Title	Value
Coal Production	995386
Coal Consumption	2099900
Yearly Deficit	-1104514
Coal Imports	3128923

Table 1: Coal Status (Metric Ton) in Bangladesh [8]

Table 1 shows coal production, coal consumption, yearly deficit, and coal imports. Barapukuria coal mine power plant is only one power plant which is operating by its own mined coal [9]. Other existing coal power plant required imported coal which provide by India, Indonesia [8].

Scenario of Natural Gas Based Power Plant in Bangladesh

Natural gas supplies over 70% energy consumption of Bangladesh. Currently 27 gas fields have been discovered in bangladesh. In 1993, the Retrievable gas reserve was estimated about 12.43 TCF. By 2011, the amount had risen to roughly 26.84 TCF, and by the end of 2017, it had risen to 27.12 TCF, where around 15.22 TCF has been used from this volume and 12 TCF is remaining that may be used in future [10]. Moreover, with that gas reserve, the country may be able to meet the increased demand for the next 10-12 years [11]. Due to gradual reduction of gas in the gas field, the Sangu, Bibiyana offshore gas field (case of over-production) is going dry of fuel [12].

Scenario Heavy Fuel Oil (HFO) and High Speed Disel (HSD) Based Power Plant in Bangladesh

The power sector in Bangladesh confronted a critical balancing act between satisfying energy demands and adhering to environmental regulations, with Heavy Fuel Oil (HFO) and High-Speed Diesel (HSD) distinguished by its high viscosity and energy density, remained a primary fuel for large-scale thermal power generation, contributing approximately 32% to the country's total electricity output [13]. Due to import of fuel and process expenses, overall electricity generation cost is higher. HSD was essential for backup power generation and for areas with unstable grid supply, accounting for around 15% of the national electricity generation [5]. However, the high cost and sulfur content inherent in HFO resulted in increased sulfur dioxide (SO2) emissions take to stricter regulations to lower sulfur content in diesel fuels in all sectors [9].

Scenario of Liquefied Natural Gas (LNG) Based Power Plant in Bangladesh

There is a significant imbalance between natural gas demand and supply, and this demand is developing rapidly due to

the rapid expansion in industrial sector. Bangladesh is temporarily reliant on the import of liquefied natural gas to meet this requirement (LNG). Petro Bangla and the American Corporation Excelerate Energy have already agreed to build Bangladesh's first Floating Storage and Re-Gasifying Unit (FSRU) at Moheshkhali for LNG import and processing [9].

Present buying prices of LNG is $14 per MMBTU because of its price volatility [14]. The LNG import infrastructure and the pipeline that connects it to the existing transmission network has been completed. Bangladesh intended to start operations in 2018 at a rate of 500 MMSCFD, or 18% of current natural gas demand. This percentage of imported LNG is predicted to increase by 70% by 2041 [15]. Expected cost of LNG based power plant in Bangladesh is 11 BDT/kWh [15].

Bangladesh has a lot of modern renewable energy potential, particularly solar energy. CSP plants can be deployed in Bangladesh for sustainable and green energy production. The southern area of Bangladesh has a lot of promise for CSP plants because there is enough DNI to generate power. Therefore, this paper is discussing the prospect of a hybrid CSP powerplant in Bangladesh.

Design of a 10 MW CSP Plant

Firstly, we selected a suitable site for CSP plant on the basis of solar radiation. Then we collected the meteorological data of that site. After that we decided to select one of the four technologies, parabolic trough, linear Fresnel or parabolic dish and power tower.

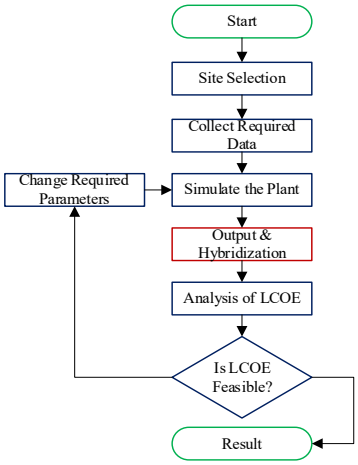

Figure 2: Methodology of Our Work

We simulated our proposed power plant with SAM (System Advisory Model) software. Then we compared the LCOE and optimized that. The methodology of our work is shown in Figure 2 Performance and financial model can be designed easily by SAM for helping people to work in the field of renewable energy to make decisions based on the performance predictions and cost of energy giving some inputs from the user. CSP technologies including Parabolic Trough and Power Tower systems and Photovoltaic (PV) can be modeled and simulated on SAM [16,17]. We have selected parabolic trough technology for the CSP plant as it is more suitable for our country [16]. Input parameters/variables for the simulation are depicted in Table 2.

Parameters/Variables	Values
Solar Multiple	2
Heat Transfer Fluid	Hitec Solar Salt
Collector Type	SkyFuel SkyTrough (with 80-mm OD receiver)
Receiver Type	Schott PTR80
Design point DNI	887 w/m2
Thermal Storage Hours	6 Hours
Land	91 Acres
The actual number of loop	35
Design HTF inlet temperature	293°C
Design HTF outlet temperature	525°C
Freeze protection temperature	150°C
Condenser type	Evaporative
Power Cycle	Rankine Cycle
Inflation Rate	6.68 %
Debt fraction	50 %
Annual interest rate	9 % /year
Income Tax rate	35 % /year
Sales tax (VAT)	5 % of the total direct cost
Discount rate	5 % /year
PPA Escalation Rate	1 %
Analysis Period	30 years

Table 2: 10 MW CSP Plant Input Parameters [18]

Table 3 summarizes the costs of our example 10MW CSP plant. We have assumed the land cost according to our country perspective.

Parameters	Cost
Site improvement	20$/$m^2$
Solar field	250 $/$m^2$
HTF system	50 $/$m^2$
Storage	25 $/kWhr
Power plant	875 $/kWe
Balance of plant	110 $/kWe
Land Cost	8000 $/acre
Fixed annual cost	0.5 % of total installed cost
Fixed cost by capacity	45 $/kW-yr

Table 3: System Cost of 10 MW CSP Plant [16,19,20,21]

Using those parameters, we have got the simulation result 17.48 cents/kWh. As the cost is not feasible for our country, we have done the optimization process.

Optimization of 10 MW CSP Plant

Solar multiple and storage hour are two parameters that can be varied to optimize CSP plant. At first, we have simulated the plant for different thermal storage backup. Our simulation result is shown in Figure 3. From the curve we have got optimum thermal energy storage time is 11 hours.

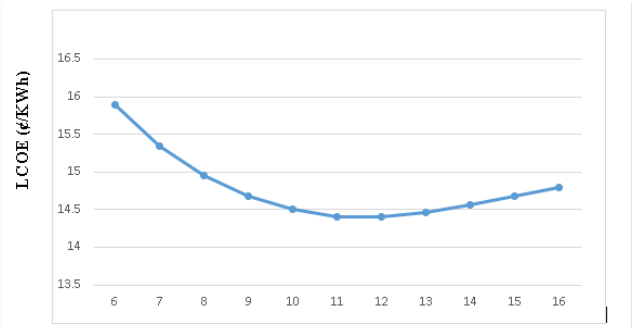

Figure 3: Simulation Result for Different Thermal Storage Backup

Then we simulated the plant for different solar multiple. Our simulation result is shown in Figure 4. From the curve we have got the optimum solar multiple is 4. We have used 3.6 to reduce the amount of land needed.

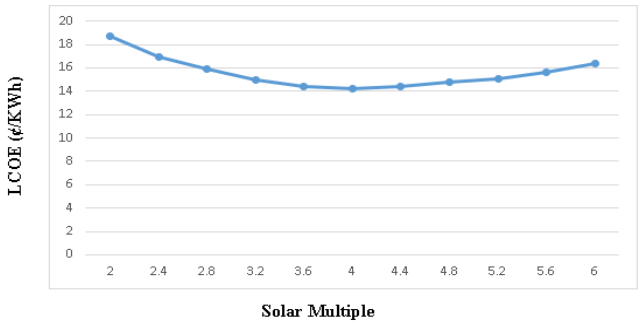

Figure 4: Simulation Result for Different Solar Multiple

Taking storage backup 11 hours and solar multiple 3.6, the optimum result is 13.76 cents/kWh. To make the parabolic trough CSP plant more feasible in our country, we have introduced a hybrid system in the next section.

Hybrid System of CSP with Existing Power Plant

The world's supply of fossil fuels is finite. Solar thermal power or concentrated solar power (CSP) is an appropriate technology to combine with other energy sources for power generation. CSP shares technology with conventional power generation and can easily be integrated with other energy types into a synergistic system which has a number of potential benefits, including increased dispatchability and reliability, improved efficiency, reduced capital costs through equipment sharing, and the ability to operate more flexible by alternating between energy sources, which can lead improved overall efficiency through the synergy of the different energy sources [22]. Another benefit of CSP technology is the ability to store energy quickly via thermal energy storage (TES), making intermittent solar resources more dispatchable.

Depending on the hybrid energy source, the location of the plant, the CSP technology employed, and the plant architecture, hybridized CSP plants exhibit various types and levels of synergy [23]. Coal, natural gas, and biofuel hybrids with CSP offer a variety of ways to infuse solar heat at different temperatures. These combustible fuels are reliable, dispatchable, and flexible, but they are not completely renewable (with the exception of biofuels). Geothermal, wind, and PV hybrid systems with CSP can be completely renewable, although they lack some of the advantages of fossil fuels. The creation of optimum CSP hybrid systems is an important research topic since it enables for the advancement of CSP technology while also giving an urgent solution that boosts solar power usage.

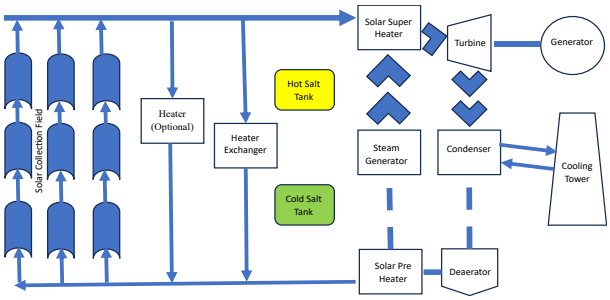

Figure 5: Hybrid CSP with an Existing Conventional Power Plant

Figure 5 depicts a typical hybrid CSP power plant. Here a parabolic trough CSP plant has been combined with an existing conventional power plant. We can use same boiler, turbine, heat exchanger, cooling tower etc. of current power plant. When there is adequate sunshine, the system will determine whether the heat level of the CSP is sufficient. It is permissible to generate steam if the temperature is high enough. To combine a CSP and a thermal power plant, four additional pieces of equipment are required: a solar energy collector, a reception tube, heat transfer fluid, and a tracking system [21].

A. Present Energy Cost Scenario of Bangladesh

There are numerous power generation companies in Bangladesh. The cost of electric power is mostly determined by the price of fuel, the availability of fuel, the plant's operating period, and other factors. Electricity costs in Bangladesh range from BDT 3 Tk/kWh to 218.79 Tk/kWh [24]. The cost of electricity generation for various power plants is shown in table 4.

Power Plants	Capacity	Plant Factor	Generation Cost
	MW	*%*	*BDT/kWh*
Gopalgonj Peaking Power Plant	100	0	218.79
Rangpur Gas Turbine Power Station	20	1	150.66
SBU Haripur	40	1	130.44
Bheramara Power Station	60	1	112.16
Sayedpur Gas Turbine Power Station	20	1	95.47
Hatiya Diesel Generator	2.20	18	66.61
Faridpur Peaking Power Plant	50	4	46.96

Table 4: Cost of Electricity Generation in Bangladesh [24]

The power plants mentioned in TABLE IV remain off most of the time due to shortage of fuel. That's why the per unit cost of these power plants is high. Moreover, the cost of high-speed diesel (HSD) and heavy fuel oil (HFO) is higher than coal and gas. This is another reason for high cost.

Hybrid CSP Plant with Some Existing Power Plants in Bangladesh Which Have High Per Unit Cost

Here we have taken some existing conventional power plants of different locations and combined with parabolic trough CSP plant. For simulation, we have taken almost the same input parameters given in section III. In this case, we have omitted some capital cost while simulating hybrid plants as we have shared some equipment of the existing power plant. We have taken also new solar radiation data of existing power plants location for our simulation. At first, we designed and simulated stand-alone CSP plants for the existing power plant locations. Then we optimized the plants according to section IV. After that, we hybridized the CSP plants with the existing conventional plants. Then we simulated the hybrid plants without fuel backup. We also simulated the hybrid plants with 12% fossil fuel backup. In this case, we included 12% fuel backup cost for the simulations. Simulation results are shown in table 5. Here we can see that the generation costs of hybrid CSP plants are lower than the present costs of existing conventional fossil fuel plants.

Power Plants	Fuel	Hybrid CSP without fuel backup Simulated Per Unit Cost	Hybrid CSP with 12% fuel Backup Simulated Per Unit Cost	Present Per Unit Cost of existing plants
		BDT/Unit	*BDT/Unit*	*BDT/Unit*
Barapukuria Power Station I	Coal	12.1	10.9	11.24
Barapukuria Power Station II	Coal	9.9	8.7	8.82

Matarbari Coal-Fired Power Plant	Coal	11.2	9.71	13.5
Bera Peacking Power Plant	HFO	10.01	10.94	32.75
Faridpur 50 MW Peaking Power Plant	HFO	10.1	11.2	46.96
Baghabari 50 Peaking Power Plant	HFO	9.9	10.82	14.52
Hatiya Diesel Generator	HSD	11.26	12.4	66.61
Rangpur Gas Turbine Power Station	HSD	12.13	13.62	150.66
Sayedpur Gas Turbine Power Station	HSD	11.42	12.56	95.47
Barishal Gas Turbine Power Station	HSD	11.21	12.35	241.22

Table 5: Simulation Result of Hybrid CSP [24,23]

Conclusions

Bangladesh is an oil-free country, with coal reserves that will last only a few decades and recoverable gas that will be gone shortly. As a result, solar energy will become Bangladesh's primary energy source in future. By building and deploying CSP technology, the current power crisis can be considerably addressed without relying on conventional fossil fuels, oil, or gas, and without endangering the environment. To validate the feasibility of nonpolluting and CO2-free CSP technology, a pilot project should be undertaken as soon as possible. The parabolic trough is ideal for large-scale power generation in Bangladesh. Solar power plant should be the second choice to utilize the land. On the other hand, Parabolic dishes are ideal for small-scale power generation.

We will achieve the best results if we combine a CSP system with an existing thermal power plant. It provides a significant thermal storage benefit in CSP power plants. When compared to solar PV cells, the fundamental difference is that storage is not available in PV systems. The expense of storing Li-ion batteries is relatively expensive. Large-scale PV generating is, once again, complicated and expensive. As a result, CSP is more efficient, dependable, and secure than other renewable energy sources. Using common equipment from the existing power plant in our country, we will be able to reduce per unit cost of the CSP plant. We will also be able to run the conventional plants most of the time using CSP technology. As natural gas reservoir in our country may be depleted soon, hybrid CSP will play an important role to save the natural gas-based power plant. Imported coal-based power plant has high per unit cost compare to hybrid CSP in our country. In future, to meet the energy demand hybrid CSP can be a good option along with Solar PV. Hybrid CSP is more feasible compare to LNG, HSD and HFO based conventional fossil fuel power plants in our country.

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