Design Optimization, Simulation & Performance Analysis of 100MW Solar Tower Thermal Power Plant in Cox's Bazar, Bangladesh.

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https://doi.org/10.5109/4102507

出版情報：Proceedings of International Exchange and Innovation Conference on Engineering & Sciences (IEICES). 6, pp.305-312, 2020-10-22. Interdisciplinary Graduate School of Engineering Sciences, Kyushu University

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ABSTRACT: *Solar energy is the most copious source of energy worldwide and is regarded as a major substitute of fossil fuels in the field of electricity generation. Electricity can be generated from Solar energy by employing two different methods: Photovoltaic (PV) Conversion and the thermodynamic cycles powered by CSP technologies. Lower lifetime and efficiency of Photovoltaics have created an inclination towards the use and development of CSP technologies. In this study, a 100MW solar tower based thermal power plant is designed, optimized and simulated using System Advisor Model (SAM) to achieve a technically feasible project keeping the climate of Bangladesh in mind. A location (21°35'0"N 92°01'0"E) beside the river Bakkhali in Cox's Bazar receiving more or less constant DNI throughout the year (Annual DNI 1905Kwh/m²) is selected for the study. The simulation results show that the hypothetical power plant can supply 374.55 GWh electricity to the national grid annually while operating at 42.7% capacity factor with a gross to net conversion efficiency of 88.1%. The optimized design and performance of the power plant encourage further innovation and development of solar tower based thermal power plants in Bangladesh.*

Keywords: Concentrated Solar Power (CSP); Solar Energy; Solar Tower; Molten Salt.

1. INTRODUCTION

Fossil-fuel reserves are contracting everyday owing to the redundant use of energy. As a result, sources of renewable energy sources are getting remarkable attention all over the world. Solar energy is the most acknowledged one among all renewable energy resources since it is boundless and can easily be transformed into electricity[1]. Furthermore, it is environmentally-sound and at liberty. There are basically two ways in which solar energy can be harnessed. These are solar photovoltaic and Concentrated solar power(CSP). CSP technologies produce power that is dependable, pristine and environmentally-sound [2]. In case of CSP technologies such as-power tower, parabolic trough and dish/engine brisk development took place in their basic technology and market strategy. Nevertheless, the capital costs of electricity production increases concomitantly due to low power generation of CSP systems. For the development of CSP systems noteworthy endeavors have to be focused on the future research.[3].

Bangladesh is a riverine country and among all the deltas in the world, it is one of the largest. On account of its geographical location, it has a remarkable variation in topographic, climatic and socio-economic features [4]. Bangladesh turned out to be one the of most crowded countries due to its large growth rate over the last 100 years. [5]. Per capita energy utilization is much lower than many other countries in the world and in 2014, it was 311 Kwh [6]. According to the Bangladesh Petroleum Statistical Review of World Energy, aggregate power production in Bangladesh is 67.4TWh. Generally, Fossil-fuels such as-natural gas, oil, coal are used to meet this demand of energy. About 78.5 metric tons of carbon-di-oxide is produced due to igniting these fossil-fuels. Moreover, for fast economic advancement and population growth, energy usage rate is increasing everyday which results in the intensification of CO_2 emission. [6]–[8]. According to the final report of Power System Master Plan 2016 of Bangladesh Govt., target was set to produce 2470 MW and 3864 MW electricity by 2021 and 2041 respectively from renewable sources[9].

To reach this goal CSP technology can play an indispensable role due to accessibility of solar radiation and that too without intimidating the nature. According to a research report of Centre for Policy Dialogue (CPD), Bangladesh is losing at least 3.5% of GDP owing to the scarcity of power generation.[10].

1.1 Why solar energy is appropriate for Bangladesh:

For the advancement of a country like Bangladesh, energy plays a vital role. Solar energy is the safest source of electricity production out of all other resources if generation process is favorable. The sun produces 4×10^{26} watts of energy every second and the belief is that it will last for another 5 billion years[11].Solar Energy is accessible everywhere; but the largest amount is available between 15^0 and 35^0latitude north and south. Bangladesh is located between $20^0$43' north and $26^0$38' south latitude and hence Bangladesh is in a suitable position for the utilization of solar energy [12]. Solar energy is befitted for Bangladesh for socio-economic advantages as well. It is affordable and much reliable. It is much cheaper than nuclear energy. Solar energy reduces greenhouse gas emissions by up to 20%. Capital requirement can be reduced by using new technological applications. Coastal areas can also get electricity by utilizing solar energy. In Bangladesh, solar energy does not remain constant throughout the year. Bangladesh gains an average daily solar radiation of 4-6.5 kWh/m^2. Though solar energy has some drawbacks but that can be terminated by using modern technologies, aspiration and research. Monthly average solar radiation outline of Bangladesh is shown in the following figure-1[13]:

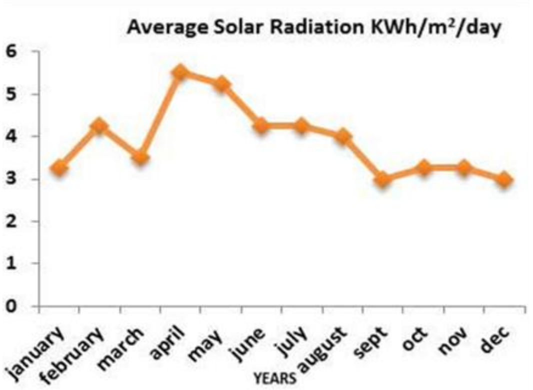

Fig. 1. Annual average Solar Radiation in Bangladesh.

1.2 Concentrated solar power(CSP) technologies: In simple words, Concentrating Solar Power (CSP) technologies utilize reflecting apertures incorporated with tracking system to focus the sun rays to a specified location to generate heat energy which is used to produce steam that runs a turbine to generate electricity. This method of power generation has been used since 1960's and is best suited for large scale generation. In recent times CSP technology has become a major part of power generation from renewable source worldwide. The reflected sunlight is focused onto a heat transfer fluid which carries energy to the power cycle or onto highly efficient photovoltaic chips. The heat transfer fluid exchanging heat with water creates steam which revolves a turbine coupled with electric generator. CSP technologies are highly preferred for locations receiving DNI of around 5.5kwh/m^2/day. At present per unit power generation from CSP plants costs about 15 to 23 BDT[14].Solar tower or central receiver system is one of the most efficient CSP technologies which is evaluated in this study in Bangladeshi climate.

1.3 Solar Tower or Central Receiver System: Power tower technology system utilizes the sun-tracking mirrors called heliostats to concentrate the solar radiation onto a receiver at the uppermost portion of a tower. A heat transfer fluid passed through the receiver is heated up to 600^0 which is used to generate superheated steam for the turbine. In early power tower, steam was used as the heat transfer fluid but nowadays molten salt is used as it has higher heat transfer and energy capabilities. From an optical perspective, power tower has satisfactory winter performance as the elevation of the sun in the sky is tracked by heliostat mirrors from east to west. It is also more efficient as its storage system eliminate the heat transfer oil, lowering the molten salt requirement and better compatibility with air cooling[15]. Parabolic trough and solar tower technology can be differentiated based on the method of accumulation of heat from the sun.

Yao et al. [16] modelled and simulated the pioneer 1 MW solar thermal central receiver system (CRS) in China. They prepared a power plant model by integrating the individual mathematical models of various sub-sections of the CRS using the energy balance approach. Li et al. [17] using the same approach, coined a thermal model of molten salt cavity receiver. The cavity receiver's thermal performance was evaluated based on different criteria such as the surface area of the receiver, incorporated heat loss and tube radius. Lu et al. [18] analyzed and optimized the associated heat transfer and exergy performance by developing a basic physical model for solar absorber pipe having solar selective coating. The literature reviews indicate the optimization of solar tower thermal power plants for locations receiving less or moderate DNI but not for the sub-continent or Bangladeshi climatic condition. In this research work, it has been shown very flawlessly.

The main objectives of this study are:

- To identify the appropriate design parameters for power generation using CSP technologies in a suitable location in Bangladesh.
- To model, optimize and simulate a solar tower thermal power plant with the help of System Advisor Model (SAM) software for Bangladesh or locations having similar climate.
- To inspect the annual thermodynamic performance of the proposed CSP based power plant.

2. METHOD

This section deals with the design and optimization of the proposed solar tower based power plant in Cox's Bazar. The total design can be divided into the following sub sections:

1. Site Selection
2. Heliostat Field
3. Solar Tower and Receiver Sub section
4. Power cycle Sub Section
5. Thermal Energy Storage Sub Section

A schematic diagram of the power plant is shown in the figure below:

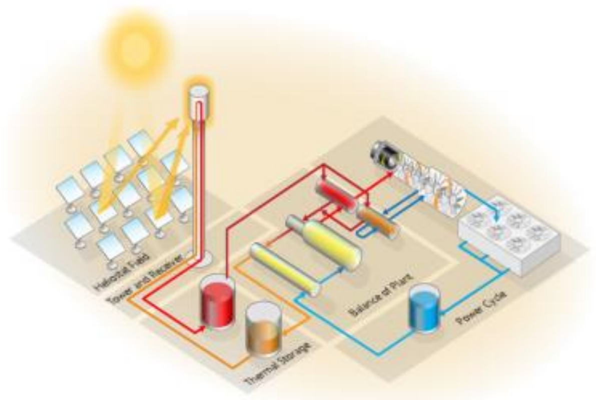

Fig. 2. Schematic Diagram of Solar Tower Power Plant.

Conventional Rankine Cycle is utilized to generate power. The hot heat transfer fluid coming from the receiver heats water and converts it to super-heated steam which runs the turbine and generates power. Following figure shows the T-S diagram of Rankine Cycle:

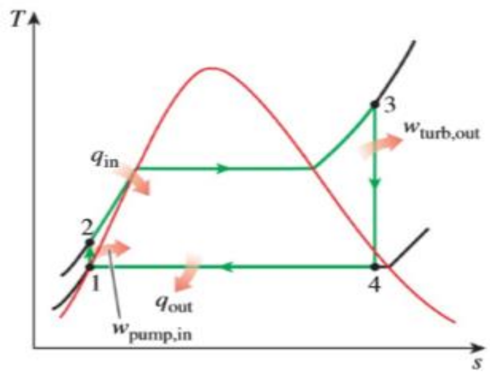

Fig. 3. T-S Diagram of Rankine Cycle

2.1 Site Selection:
The first and foremost challenge that arises while designing a project of such magnitude is the selection of an appropriate location that fulfills all the required criteria for its proper functioning. In case of the Solar Tower based power plant the major aspects to be considered about the site are availability of high and more or less constant solar radiation all around the year, adequate water supply for cleaning the heliostats and other equipment and easy access to the location. The total land area needed for the power plant is approximately 2980 acres, of which 2935.41 acres would be dedicated to solar field and the rest is for housing other necessary sub-sections. Taking all these points into account a location beside the river Bakkhali in Cox's Bazar is selected as the potential site for the hypothetical power plant. The location (21°35′0″N 92°01′0″E) receives 1905Kwh/m^2 DNI annually and being close to the river would provide access to necessary amount of water[12].

2.2 Heliostat Field Sub-Section: The heliostat field is designed considering the optimum design point DNI and Solar Multiple for Bangladeshi climate which are 800 W/m^2 and 2.9 respectively. Increasing the solar multiple may seem alluring since it increases the capacity factor and hence the energy generated, but at the same time the amount of land and number of heliostats needed also increases. So the selection of solar multiple is bit tricky. In this study solar multiple is selected considering the fact of getting maximum $\frac{Generated\ Power}{Land\ area}$ ratio.

A heliostat is a solar radiation reflecting device usually consisting of mirrors and having the capability of moving to counter the loss caused by the movement of sun in the sky throughout the day. It concentrates the solar radiation and reflects it to a predetermined location which in this case is a receiver. The heliostat field for this study is optimized and designed using the solar field geometry optimization function of SAM. The design considerations to be implemented require 12886 heliostats arranged in an oval shape land stretching a radius of about 2000m along east-west and 1500m along north-south. The design of the solar field is shown in the figure below:

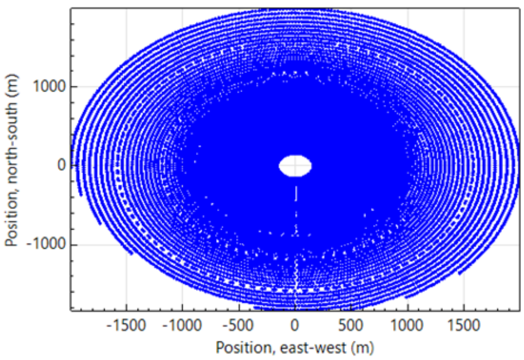

Fig. 4. Solar Field Heliostat Arrangement.

The optimization is performed considering an initial optimization step size of 0.06, maximum iterations 200 and optimization convergence tolerance 0.001. After about 50 iterations the values converged to the ones mentioned above.

The heliostats considered for this study have square reflecting surface. A single heliostat has a reflective area of 144.375m^2. The focusing method is ideal and heliostat canting method follows equinox. The properties of the heliostats used are listed down in table-1

Table 1. Specifications of the Heliostats

Width of Heliostat	12.2m
Height of Heliostat	12.2m
Reflective Area to Profile Ratio	0.97
Total Reflective Area of Heliostat	1860414m^2
Image Error (Slope, Single Axis)	1.53 mrad
Reflected Image Conical Error	4.32749 mrad
Number of Heliostat Facets – X	2
Number of Heliostat Facets – Y	8

The total thermal energy captured by the heliostat field at a certain instant (Q_{sf}) can be calculated from the following equation:

$$Q_{sf} = DNI \times A_h \quad (1)$$

Here, A_h denotes the total heliostat reflective area.

A part of this incident energy is concentrated to the receiver system and the rest is lost due to cosine efficiency, blocking and shading, mirror reflectivity, tracking error, clean error, etc. [16]. The efficiency of the solar field (η_{sf}) can be calculated from the following equation:

$$\eta_{sf} = \frac{Receiver\ Thermal\ Power\ Incident\ (Q_{rec})}{Solar\ Field\ Thermal\ Power\ Incident\ (Q_{sf})} \quad (2)$$

To ensure least possible hindrance caused by one heliostat to other, the stow and deploy angles are selected to be 8°. For startup and sun tracking each heliostat would consume 0.025 kWe-hr and 0.055 kWe-hr respectively. When the wind velocity becomes higher than 15 m/s the heliostats stow automatically in order to prevent damage. As the solar radiation passes through the atmosphere it gets scattered due to the interaction with air molecules, water vapor and dust. This effect is known as atmospheric attenuation and some amount of energy is lost due to this. An average attenuation loss of 10.6% is thus incorporated in the calculation of total solar energy received from the solar field. Moreover heliostat availability losses are considered in the design which represents reduction of solar field output due to component outages, soiling or other events. The necessary parameters which contribute in determining the attenuation and availability losses of the solar field are listed in table-2:

Table 2. Parameters Related to Various Losses

Atmospheric Attenuation	
Polynomial Coefficient 0	0.006789
Polynomial Coefficient 1	0.1046 1/km
Polynomial Coefficient 2	- 0.017 1/km^2

Polynomial Coefficient 3	0.002845 1/km^3
Average Attenuation Loss	10.6%
Heliostat Availability Losses	
Mirror Relfectance and Soiling	0.9
Heliostat Availability	0.99

Some land is necessary for other parts of the power plant such as solar tower and receiver and for housing the power cycle. For that an extra land area of 45 acres is reserved for divisions other than the solar field. Heliostats are prone to loss efficiency if dust accumulates on the reflecting surface and for that they must be washed regularly. In this study it is considered that the heliostats are washed 63 times a year to keep them working at full potential. For this a large amount of water is needed considering 0.7 L water to wash per m^2 of reflecting surface.

2.3 Solar Tower & Receiver Design: A receiver is placed on top of a solar tower which receives the concentrated thermal energy provided by the heliostat field and transfers a part of it to the heat transfer fluid (HTF) flowing through it. The built-in function in SAM is used to calculate the optimum height of the tower considering the design of the heliostat field. The receiver tubes are coated with anti-reflective coating in order to increase the thermal energy absorbing capacity. A pump is used to raise the HTF from the cold storage tank to the receiver through the piping system where the fluid is heated to the operating temperature. The pump efficiency is considered to be 85%. Design parameters restrict the maximum flow rate of HTF to the receiver to be 2019.38 kg/s. The receiver used in this study can operate at a minimum turndown ratio of 25%. There's a delay of 12 minutes once the receiver is turned on to reach the operating conditions. The necessary parameters related to the tower and receiver dimensions, receiver heat transfer properties and its operation are listed in table-3

Table 3. Tower and Receiver Properties

Receiver Thermal Power	786.9 MWt
HTF Hot Temperature	600^{0}C
HTF Cold Temperature	290^{0}C
Tower Height	212.345 m
Receiver Height	24.608 m
Receiver Diameter	21.9055 m
Number of Panels	20
Outer Diameter of Tube	40 mm
Thickness of Tube Wall	1.25 mm
Coating Emittance	0.88
Coating Absorptance	0.94
Heat Loss Factor	1
Maximum Receiver Operation Fraction	1.2
Receiver Startup Delay Energy Fraction	0.25

The amount of solar radiation incident on the receiver (Q_{rec}) can be calculated from the following equation:

$$Q_{rec} = Q_{sf} \times \eta_{sf} \quad (3)$$

The material used for the receiver is Stainless AISI316 for its amazing heat resistant capability. It is necessary to choose the right flow pattern for the receiver to ensure best flowing conditions for the HTF. Various types of flow patterns used in solar tower design are shown in figure below:

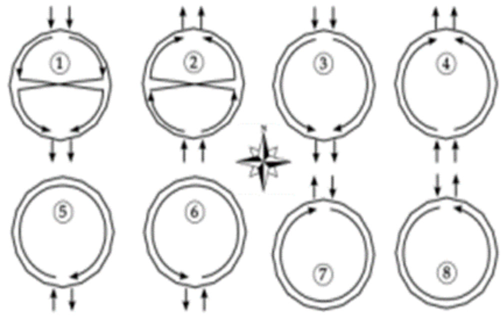

Fig. 5. Various Flow Patterns in Receiver Tower

Number-1 flow pattern is selected for this study as it gives least pressure drop. The maximum heat-flux incident on the receiver and heat loss are depended on the type of material and heat transfer fluid used, flow velocity of HTF and heat loss coefficients. The flow of the HTF through the piping system of the tower and receiver also causes some loss of energy and that is also included in the study. The equations used to account for various losses encountered in the receiver system are shown below [19]:

$$Heat\ transferred\ to\ the\ HTF, Q_{HTF} = Q_{rec} - Q_{loss,opt} - Q_{loss,conv} - Q_{loss,rad} \quad (4)$$

Where, $Q_{loss,opt}$ = Optical Loss, $Q_{loss,conv}$ = Loss of Heat due to Convection and $Q_{loss,rad}$ = Heat Loss due to Radiation.
This can also be calculated as follows:

$$Q_{HTF} = m'_{HTF}(h_{out} - h_{in}) \quad (5)$$

Where, m'_{HTF} = Mass Flow Rate of HTF Entering and Leaving the Receiver, h_{out} = Specific Enthalpy of HTF at Receiver Outlet, h_{in} = Specific Enthalpy of HTF at Receiver Inlet.
The conduction loss is much less compared to the other losses and hence it is neglected. The optical loss can be calculated as:

$$Q_{loss,opt} = Q_{rec} \times (1 - \eta_{opt}) \quad (6)$$

Where, η_{opt} = Optical Efficiency of the Receiver
Finally the efficiency of the receiver (η_{rec}) can be calculated from the following equation:

$$\eta_{rec} = \frac{Thermal\ Power\ Transferred\ to\ HTF\ (Q_{HTF})}{Receiver\ Thermal\ Power\ Incident\ (Q_{rec})} \quad (7)$$

The design considerations and parameters related to the receiver flux modelling and piping losses are listed in the table below:

Table 4. Receiver Flux and Piping Loss Parameters

Maximum Receiver Flux	1000 kWt/m^2
Estimated Heat Loss from the Receiver	30 kWt/m^2
Receiver Flux Map Resolution	12
Number of Days in Flux Map Lookup	8
Hourly Frequency in Flux Map Lookup	2 hours
Piping Heat Loss Coefficient	10.20 Wt/m
Piping Length Constant	0
Piping Length Multiplier	2.6
Piping Length	552.096 m
Total Piping Loss	5631.38 kWt

2.4 Heat Transfer Fluid (HTF): The HTF acts as the medium of energy carrying and storage. The main characteristics an ideal HTF should have are:

- Non-flammable
- High chemical stability
- High specific heat
- Less presence of impurities
- Needs less Maintenance
- Produced in a method that minimizes CO_2 emission.

Keeping these in mind mixture of nitrate salts (60% $NaNO_3$ + 40% KNO_3) is used as HTF. This salt can be operated within a temperature range of 260°C and 621°C. As the temperature starts to fall, the salt starts to crystalize at a temperature of 238 °C and solidifies at 221 °C [20].So the temperature of the HTF should be controlled using heating arrangements even when the power plant is not operating. The density varies with temperature but for simplicity it is fixed at 1799.97 kg/m^3. Moreover the nitrate salt mixture shows excellent corrosion performance. At 600 °C temperature, the average corrosion rate ranged less than 16.5 microns/year for 13 different alloys in a test conducted for 3000 hours[21].

2.5 Power Cycle Design: The thermal energy stored in the HTF is converted to electricity in the power cycle by operating a steam turbine. Exchange of thermal energy takes place between hot HTF and water in the heat exchangers to produce steam which rotates the turbine coupled with a generator. The power cycle operates under conventional Rankine cycle. A thermal energy storage (TES) system can run the power cycle for 6 hours in absence of solar energy and thus power generation is possible during night and cloudy conditions. Under suitable operating conditions the power cycle can produce a gross output of 111MW-e with a gross to net conversion factor of approximately 90%. The efficiency of the heat exchanger system (η_{HX}) and power cycle (η_{pc}) can be calculated from the following equations:

$$\eta_{HX} = \frac{Power\ Cycle\ Thermal\ Energy\ Input\ (Q_{pc})}{Field\ Thermal\ Power\ Incident\ in\ HTF\ (Q_{HTF})} \quad (8)$$

$$\eta_{pc} = \frac{Power\ Cycle\ Electrical\ Energy\ Output\ (Q_e)}{Power\ Cycle\ Thermal\ Energy\ Input\ (Q_{pc})} \quad (9)$$

Other necessary parameters related to the power cycle are listed in the table below:

Table 5. Parameters Related to Power Cycle

Cycle Thermal Power	271.341 MWt
Cycle Thermal Efficiency	41%
Estimated Net Output	100 Mwe
Cycle Design HTF Mass Flow Rate	580.3 kg/s
Pumping Power for HTF through Power Block	0.55 kW/kg/s
Fraction of Thermal Power Needed for Stand-by	0.2
Power Cycle Startup Time	30 Minutes
Fraction of Thermal Power Needed for Startup	0.2
Minimum Turbine Operation	0.2
Maximum Turbine Over Design Operation	1.05
Boiler Operating Pressure	85 bar
Steam Cycle Blowdown Fraction	0.02
Turbine Inlet Pressure Control	Fixed Pressure
Type of Condenser	Air-Cooled
Ambient Temperature at Design	42°C
ITD at Design Point	16°C
Reference Condenser Water dT	10°C
Approach Temperature	5°C
Condenser Pressure Ratio	1.0028
Minimum Condenser Pressure	1.25 inHg
Cooling System Part Load Levels	8

2.6 Thermal Energy Storage System (TES) Design: The power plant designed has a TES system in order to store the solar energy for running the power cycle during cloudy condition or after sunset for 6 hours. This system is much needed in Bangladesh since the peak demand of electricity here is after the sunset. In this study direct TES system is considered i.e. the same HTF is used as storage media. Two pairs of tanks are available for HTF storage, each of which has a tank dedicated for hot HTF and other for cold HTF. A pump circulates the HTF throughout the system. The tanks are equipped with heaters so that the temperature of HTF in cold tank doesn't fall below the operating temperature and forms precipitation and also ensures that the temperature of HTF in hot tank is not below 500°C. Sizing the TES system is a crucial design aspect and to calculate the required storage volume (V_{TES}) and thermal capacity (TES_{cap}) of the TES the following equations can be used [22]:

$$V_{TES} = \frac{C \times 10^6 \times 3600}{\rho_{HTF} \times C_{HTF} \times \mu_{HX} \times 1000 \times (T_{sf,out} - T_{st,in})} \quad (10)$$

$$TES_{cap} = t_{full,load} \times \frac{W_{des,gross}}{\eta_{des}} \quad (11)$$

Here, C = Thermal Capacity, ρ_{HTF} = Density of Heat Transfer Fluid, μ_{HX} = Heat Index, $T_{sf,out}$ = Solar Field

Output Temperature, $T_{st,in}$ = Steam Turbine's Inlet Temperature, $t_{full,load}$ = number of hours per day the plant operates at full load.

Only the energy harnessing part of the power plant i.e. the heliostat field, receiver and TES system can be operated during day time to store thermal energy and the power cycle can be operated solely during the high demand period using the stored energy. The TES design parameters are listed in the following table:

Table 6. TES Design Parameters

TES Thermal Capacity	1628 MWt-hr
Available HTF Volume	6963 m^3
Tank Height	10 m
Tank Fluid Minimum Height	1 m
Storage Tank Volume	7737 m^3
Parallel Tank Pairs	2
Tank Diameter	22.2 m
Wetted Loss Coefficient	0.4 Wt/m^2-K
Estimated Heat Loss	0.61 MWt
Percentage of Hot HTF Initially	30%
Heater Temperature Set-Point for Cold Tank	290°C
Cold Tank Heater Capacity	25 MWe
Heater Temperature Set Point for Hot Tank	500°C
Hot Tank Heater Capacity	25 Mwe
Tank Heater Efficiency	98%

3. SIMULATION & RESULTS: Once the optimized power plant is simulated for one year using SAM it is seen that the power plant can supply a net electricity of 374.55 GWh annually to the grid with a capacity factor (CUF) of 42.7% and gross to net conversion factor of 88.1%. This performance is quite satisfactory since grid connected utility scale solar thermal power plants operate only at 18% capacity factor on average[23]–[25].Annual water usage for maintenance and cleaning purpose is 109,485m^3. It is also observed that maximum energy is produced in the month of January (41.67 GWh) and the lowest in the month of July (15.29 GWh). The power cycle needs to be provided with water for makeup and cooling purposes at a rate of 1.826 kg/s. The monthly power generated from the power plant is shown in the graph below:

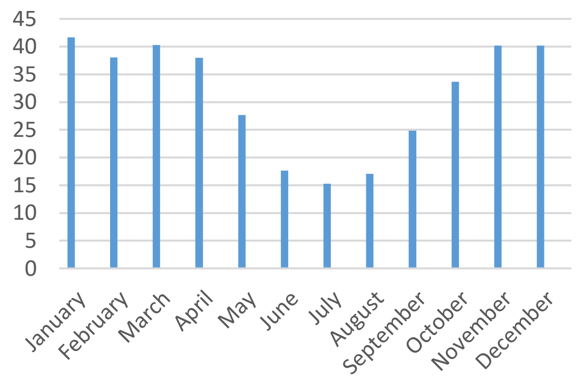

Fig. 6. Monthly Power Generation in GWh-e

The parameters presented in figure-7(a-g) below are analyzed to find the efficiency of each of the sub sections and the power plant as a whole using the equations mentioned previously. The results are presented in table-7.

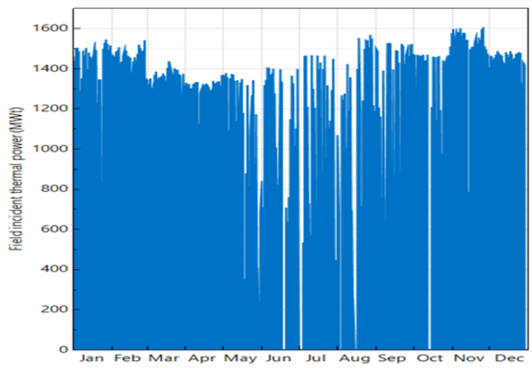

Fig. 7(a). Annual Field Incident Power (MWt)

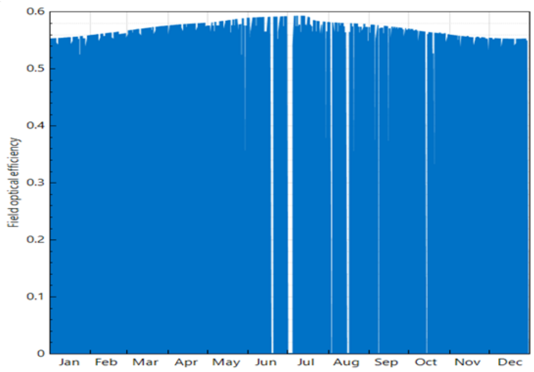

Fig. 7(b). Field Optical Efficiency throughout the year

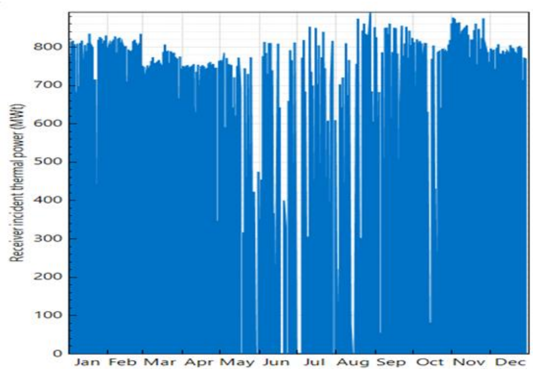

Fig. 7(c). Annual Power Incident on Receiver (MWt)

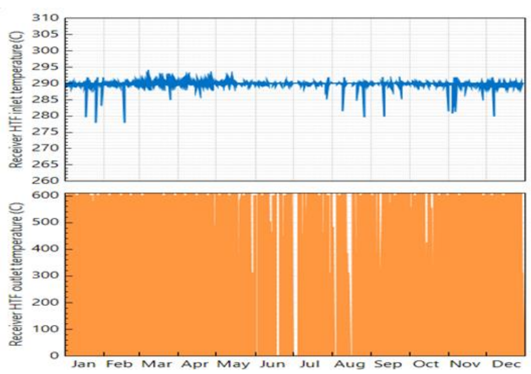

Fig. 7(d). Receiver HTF Inlet & Outlet Temperature

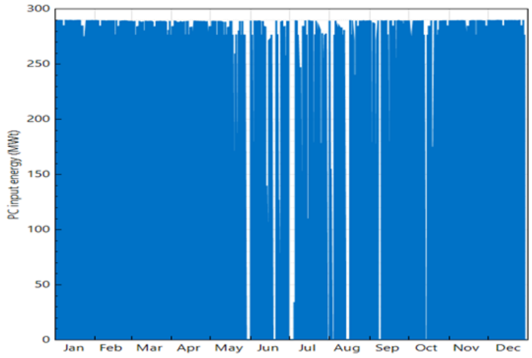

Fig. 7(e). Annual Power Cycle Input Energy (MWt)

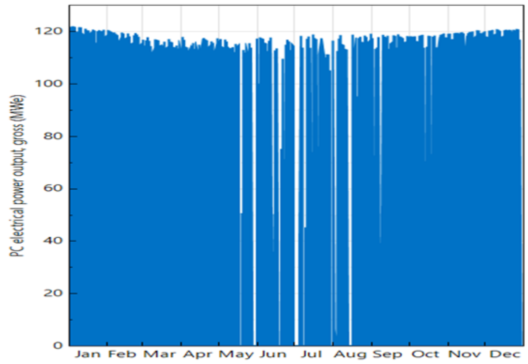

Fig. 7(f). Gross Annual Electricity Generated (MWe)

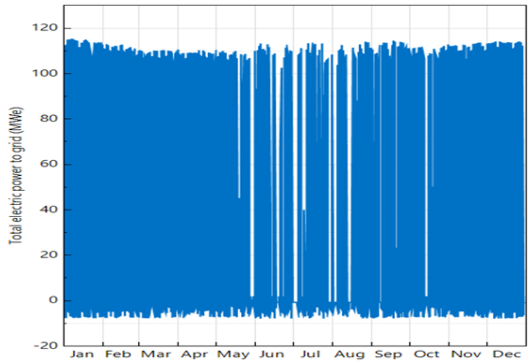

Fig. 7(g). Annual Electricity Supplied to Grid (MWe)

Table 7. Efficiency of various sub-sections

Solar Field Efficiency	41.34%
Receiver Efficiency	90.62%
Heat Exchanger System Efficiency	99.84%
Power Cycle Efficiency	41%
Annual Power Plant Gross Efficiency	14.6%

A comparison of performance made between the designed power plant with other literature works related to CSP in Bangladesh (Table 8) and solar tower thermal power plants operating worldwide (Table 9) shows the project is technically feasible.

Table 8. Performance Comparison with Other Literature Works Related to CSP in Bangladesh.

Author	Location	Capacity (MW)	Net Annual Electricity (GWh-e)	CUF (%)
This Work	Cox's Bazar	100	374.55	42.7
N. Bhuiyan et al [26]	Cox's Bazar	50	171.08	39.5
Md NSK. Shabbir et al [22]	Chottogram	150	218.032	16.6

Table 9. Performance Comparison with Running Solar Tower Power Plants Around the World.

Project Name	Location	Maximum Rated Power (MW)	Annual Production (GWh-e)
This Work	Bangladesh	100	374.55
Ashalim Power Station	Israel	121	320
PS20 Solar Power Tower	Spain	20	44
Khi Solar One	South Africa	50	180

4. CONCLUSION: In this study a 100MW solar tower thermal power plant is designed, optimized for Bangladesh and simulated using System Advisor Model. The power plant's performance results have also been compared with other similar plants operating across the world and validated. The key conclusions of the conducted study are as follows:

1. Several aspects of the CSP technology used in the study can be compared by using the necessary data derived from the analysis.
2. The study can provide a good starting point for designing a solar tower power plant in Bangladeshi climatic condition.
3. The optimized power plant showed reasonable thermal performance and can be used to predict the performance of similar power plants at any location. Moreover the power generation at the actual site would be higher than the simulated result since annual DNI value at that location is 17.55% higher than the one considered in this study due to limitation of availability of weather data.
4. Developing such large scale power plants running on renewable energy source is indispensable for fulfilling the future energy demand of Bangladesh. As Bangladesh gets adequate solar energy throughout the year, considering various CSP technologies in the power generation sector would be a great idea.
5. However, further research works and sensitivity analysis in this field is necessary to ensure smooth operation and economic viability of solar tower technology in Bangladesh.

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