Concentrating Solar Power (CSP) and Its Prospect in Bangladesh

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Abstract: Concentrating Solar Power (CSP) is a promising technology for power generation in which the solar radiation is concentrated to generate high temperature for producing steam in a solar thermal power plant. No fossil fuel is used in this technology; therefore no greenhouse gases are emitted. With an average annual Direct Normal Irradiance (DNI) of 2,000kWh/m^2 the area required to generate 100MWe of electricity is about 2km^2. Bangladesh receives an average annual DNI of nearly 1,900kWh/m^2 which is sufficient to operate a CSP plant. By the year 2015 the capital cost of CSP plant will become $3,800/kWe. As there is no fuel cost in CSP, this can be an attractive choice to mitigate the power crisis of Bangladesh. In this paper the prospect of utilizing CSP in Bangladesh has been focused.

1. Introduction

The squandering use of fossil fuel in the last century has caused the massive climate change through the greenhouse effect and produced large scale environmental pollution. The paucity of non-renewable energy resources and the necessity for reducing CO_2 emission have impelled the world to lean towards the 'green energy' for electricity generation. Green energy refers to the environmentally friendly and non-polluting energy sources that include hydro, wind, geothermal and solar. The most abundant and convenient source of renewable energy is solar which can be harnessed in two ways: Photovoltaic (PV) and Concentrating Solar Power (CSP) technology. After a stagnation period of 15 years since 1990s, CSP is getting popular in recent years. The state of California is going to produce 20% of their total energy using solar renewable technology by 2010 and 33% by 2020. It has already announced to construct several solar power plants to generate 11.8GWe of which 88% will be CSP and 12% PV [1].

In Bangladesh, power generation from solar energy is monopolized by PV so far. The current installed capacity of Solar PV is 15MWe which is only 0.33% of the total power generation [2]. Bangladesh Government has already included CSP in the Renewable Energy Policy 2009 [2]. As CSP will soon become factor 3 cheaper than PV it would be a better choice to deploy CSP plants for harnessing solar energy in a large scale to minimize the current and future power crisis of Bangladesh.

2. Technology Overview

In concentrating solar power (CSP) technology sun's Direct Normal Irradiation (DNI) is concentrated to produce heat of temperature 400ºC to 1,000ºC [3]. This heat is used to produce electricity by conventional steam cycle, or combined cycle, or Stirling engine.

Based on the process of collecting and concentrating solar radiation, the CSP can be categorized into four major technologies: i) Parabolic Trough, ii) Solar Tower or Central Receiver, iii) Parabolic Dish and iv) Linear Fresnel Reflector (LFR).

i) Parabolic Trough: This technology uses parabolic trough shaped mirrors to concentrate the incident DNI onto a receiver tube which is placed at the focal line of the trough. The basic elements of parabolic trough power station are: a) Solar collector field, b) Conventional electricity generating unit (steam Rankine cycle or combined cycle) and c) Thermal storage (optional).

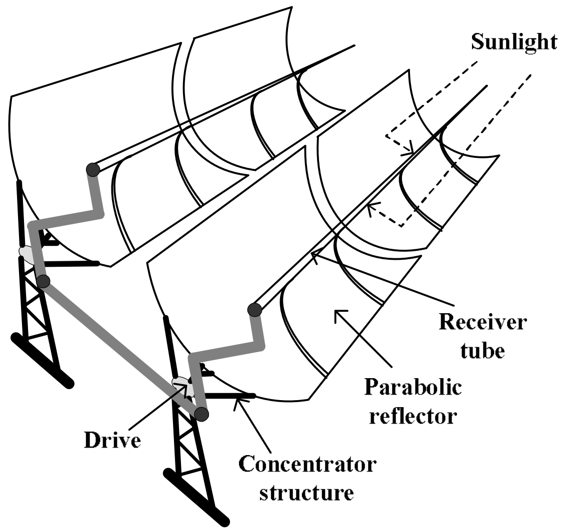


Fig. 1 Solar collector assembly

Fig. 1 shows the basic components of the solar collector assembly (SCA). The reflector is composed of a 0.85mm thick silver coated mirror on the back layer and a 4mm glass of high transmittance on top of it, acquiring the overall reflectivity of about 93.5% [4]. A stainless steel tube of 70mm diameter with high heat absorption coating encircled by a vacuum glass tube of 115mm diameter with antireflective coating comprise the receiver tube [5]. The tube circulates a heat transfer fluid (HTF), such as: synthetic thermal oil, which is heated up to 400ºC by the concentrated solar energy [3]. The

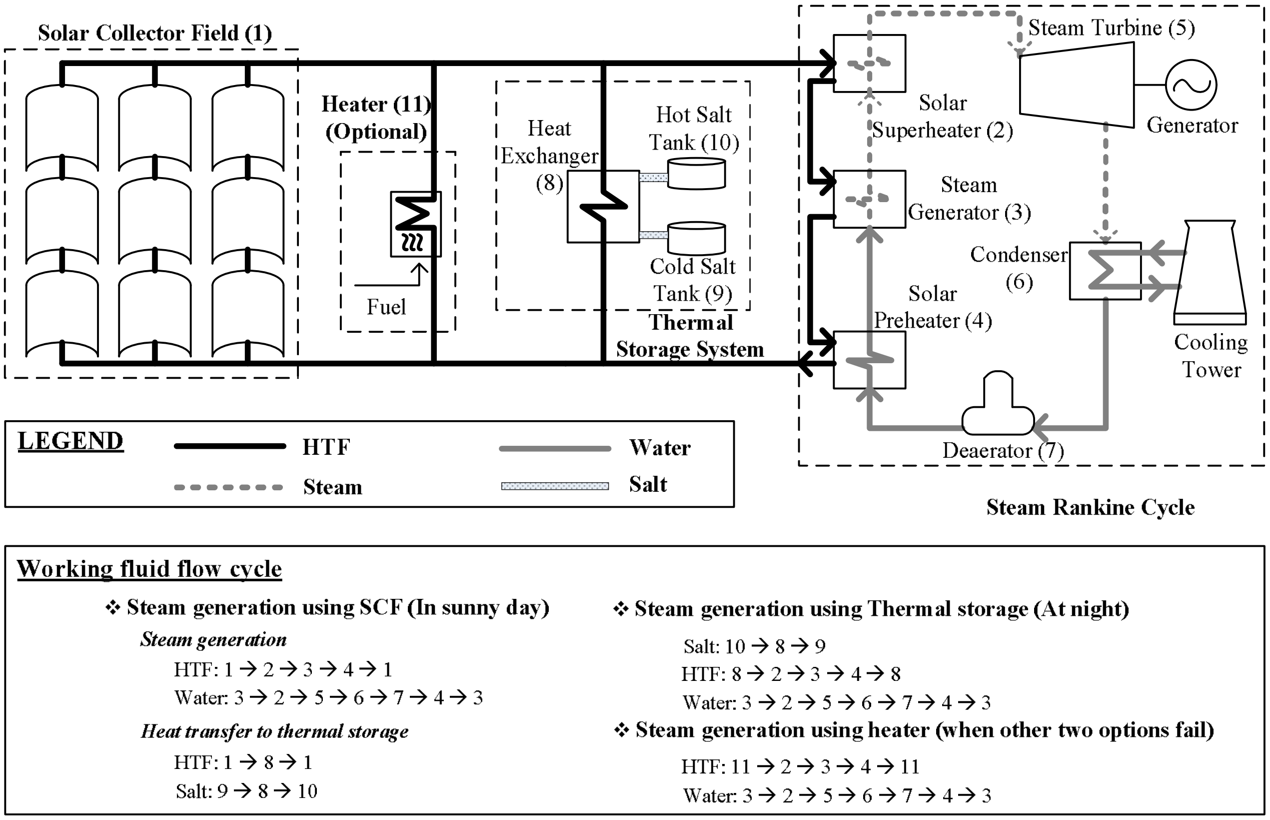


Fig. 2 Parabolic trough power plant with steam Rankine cycle and thermal storage (Hybridized with fossil fuel backup system)

construction that holds the mirrors and receivers is termed as concentrator structure. In order to collect the DNI effectively, each SCA is equipped with a local control system which automatically rotates the concentrator structure using a drive motor to track the sun from dawn to dusk. Numerous SCAs aligned in parallel rows on north-south axis create the solar collector field (SCF) of the parabolic trough power plant.

Fig. 2 delineates the integration of different components of the entire parabolic trough power station. During sunny days the HTF in the receiver tube heated by the concentrated solar energy is circulated to the steam power plant where the HTF preheats the water, generates steam in the steam generator and also superheats the steam. After discharging heat in the power plant the cooled HTF is circulated back to the SCF to get heated again thereby completing the cycle. To continue electricity generation at night or in cloudy days the system can be equipped with the optional storage system. ‘Two-tank molten salt storage system’ is the most popular one which consists of a hot tank, a cold tank and a heat exchanger. During daytime a portion of the heated HTF is diverted to the heat exchanger. Cold molten salt pumped from the cold tank receives thermal energy from the HTF in the heat exchanger and is stored in the hot tank. At night or in cloudy days the above mentioned storage cycle is reversed; the hot molten salt returns its thermal energy to the cold HTF which is then used to produce steam. An annual capacity factor of 70% or higher can be achieved by using the thermal storage system [6]. For supplying the peak load in sunny days or to continue operation in cloudy days the solar thermal power plant can be hybridized with fossil fuel fired backup system.

Combined cycle can also be employed instead of steam Rankine cycle where the flue gas from the gas turbine preheats or superheats the steam generated by the Rankine bottoming cycle. This thermal efficient power plant is termed as Integrated Solar Combined Cycle System (ISCCS).

ii) Solar Tower or Central Receiver: The main difference between parabolic trough and solar tower technology is the way heat is accumulated from the sun.

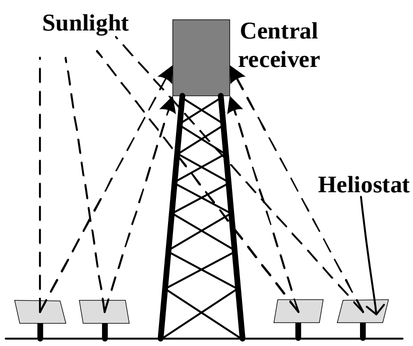


Fig. 3 Solar Tower or Central Receiver

In the solar tower technology, the SCF contains a radial arrangement of several individual computer controlled sun tracking large mirrors (named as heliostat) that concentrate the solar energy onto the receiver placed on top of a central tower. The HTF (usually molten nitrate salt) is heated up to approximately 1,000ºC in the receiver

Table 1 Different CSP technologies

Technology	Focus	HTF [3]	Tempe-rature [3]	Hybrid Operation	Cost ($/KWe)	World Capacity, MWe [8]		
						Operatio-nal	Under construction	Announced
Parabolic Trough	Line	Synthetic oil	400ºC	Possible	4,156♠	570	1550+140 ISCC	5775.1
Solar Tower	Point	Molten salt	1,000ºC	Possible	4,500♣	34	22	1514
Parabolic Dish	Point	N/A	750ºC	Still in R&D phase	6,000 [11]	0.5 [3]		1600.08
Linear Fresnel	Line	Steam	270ºC [9]	Possible	2,200 [12]	8.4		487

♠ Nevada Solar One [10] ♣ Ivanpah 1 [3]

[3]. The rest of the procedure of electricity generation is almost same as that of parabolic trough technology.

iii) Parabolic Dish: This technology uses a parabolic dish-shaped solar concentrator that concentrates the sunlight onto a receiver (solar heat exchanger) placed at the focal point of the dish. The dish usually tracks the sun in two axes (azimuth and elevation) with the help of a tracking system. The heat generated in the receiver is used to drive a Stirling engine that is attached to the receiver. The working gas of the Stirling engine is hydrogen or helium which is heated up to 750ºC [3]. The mechanical energy produced by the engine is converted to electrical energy by an alternator. A parabolic dish of 25kWe output requires a diameter of 37 feet. [3]

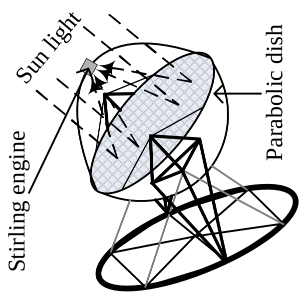


Fig. 4 Parabolic dish

iv) Linear Fresnel Reflector: In LFR technology, an elevated ground facing linear receiver collects the concentrated solar radiation reflected by a group of nearly flat reflector placed on the ground.

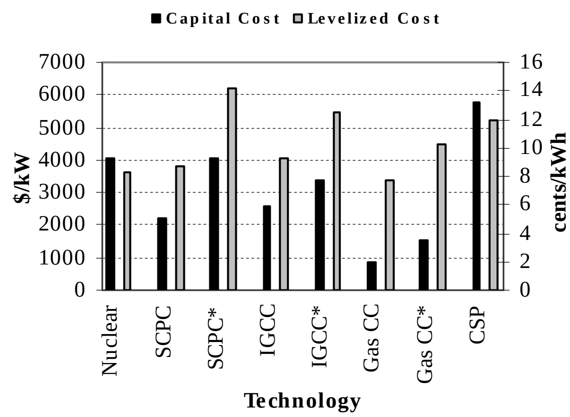
3. Comparison of Technologies

All the CSP technologies have the key advantage of generating clean energy with no fuel cost; but the huge land requirement is their main drawback. The SEGS (Solar Energy Generating Systems) plants in Mojave Desert, California occupy 6.5 km^2 of land area to produce 354 MWe (17,000m^2 per MWe) [3]. But the land use requirements for CSP plants are in fact less than hydroelectric plants or coal plants if the size of the artificial lake or the land required for mining and excavation of the coal are taken into account [7].

Each of the CSP technologies has some advantages as well as disadvantages. The operating temperature of HTF in parabolic trough is only 400ºC which makes the overall solar radiation to electricity efficiency to only 14% [3]. Yet the advantages of lowest materials demand, good land-use factor, modularity, thermal storage etc. make parabolic trough the most popular CSP option. 93% of the current operational and 67% of the under construction and announced CSP plants are parabolic trough technology based [8]. Although parabolic dish has the highest efficiency (31.25%) its hybrid operation is still in the R&D phase [3]. Table 1 shows the different aspects of the four technologies at a glance.

4. Power Scenario of Bangladesh

According to Bangladesh Power Development Board (BPDB), its present electricity generation capacity is 4,931MWe [13]. In July 2009, average maximum generation and average demand on weekdays were 3,909MWe and 4,538MWe respectively giving rise to average load shedding of 629MWe. To tackle this alarming situation and to meet the future demand, the government of Bangladesh is planning to construct some new power plants [14].



*SCPC = supercritical pulverized coal; IGCC = integrated gasification combined cycle; CC = combined cycle; * = with carbon capture and storage*

Fig. 5 Cost comparison of different power generation methods [15]

From Fig. 5 it is seen that the capital cost of CSP is somewhat greater than other technologies but the levelized cost is lower than SCPC and IGCC with carbon capture and storage. The shortage of domestic gas and coal leads the government to think of imported coal and furnace oil based power plant. Considering the environmental issues and the colossal work of importing and storing such a large amount of fuel, renewable energy, especially CSP can be a worthy choice for new power plant construction.

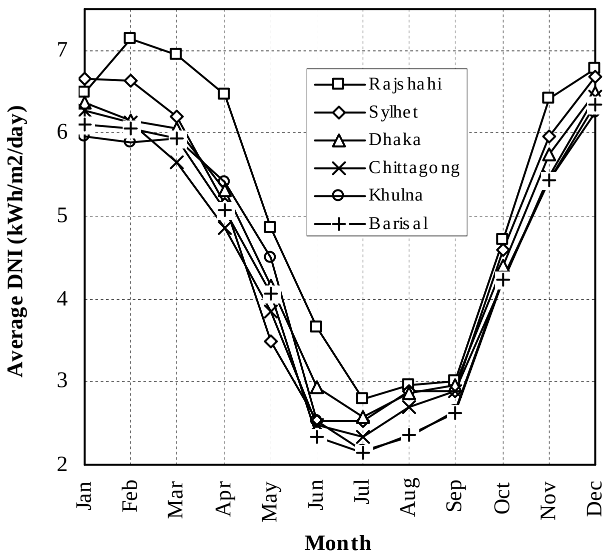


Fig. 6 Monthly Average DNI per day in Bangladesh [16]

Bangladesh is a country with abundant solar radiation. The DNI trend over the year is shown in Fig. 6. The annual DNI is nearly 1900kWh/m^2 [16] in the northern side of the country which is moderately high compared to the required DNI (2000kWh/m^2) for a suitable CSP site [3].

Bangladesh is a densely populated country. Therefore it is difficult to find a huge and vacant area that is needed for CSP technology. But CSP can also be deployed in smaller scale in dispersed areas. In the cities, especially in the capital Dhaka, solar dish technology can be easily employed on the roof top of countless high rise buildings. In the rural areas, one solar dish of 25KWe placed in an open place can serve nearly 200 families.

Glass and steel are the main materials for parabolic trough power plant. Bangladesh has currently become self-sufficient in glass production; even glasses are now also being exported to many countries [17]. Furthermore, nearly 250 steel re-rolling mills are manufacturing steels in the country [18]. If domestic glass and steel are used to construct the solar field of the parabolic trough power plant, the plant can be erected with much less capital investment. Therefore, for large scale production, parabolic trough technology can be implemented in rural areas.

The largest PV solar home system (SHS) available to date in Bangladesh is of 120We with a price of 713$ [19]. The cost of a solar dish of 25kWe is 150,000$ and is expected to become 50,000$ soon [11]. The cost/W for SHS and solar dish are 5.94$ and 2$ (projected) respectively. The CSP technology therefore can be a lucrative choice for the vendors to deploy in large scale or off-the-grid fashion.

4. Case Study: A Proposal for a Pilot CSP Project of 1MWe in the District of Rajshahi

The investment required to construct a 1MWe parabolic trough power plant is estimated in this paragraph. The estimation is based on Andasol 1 power plant situated in Granada Province in Spain. The location proposed is a silt area on the bank of River Padma in Rajshahi district (adjacent to the Varendra Research Museum) with coordinates 24.3409N, 88.5679E. The proposed area has been selected with the use of Google Earth® and Google Earth Path softwares. The features of the proposed pilot project are shown in Table 2 along with that of the Andasol 1 project.

Table 2 Features of proposed pilot project [20]

	Andasol 1	Pilot project
Electricity Output	50MWe	1Mwe
Annual DNI	2136 kWh/m^2	1900 kWh/m^2
Land area	2 km^2	44,400 m^2
HTF	Synthetic oil (400ºC)	
Thermal storage	Molten salt (60% $NaNO_3$ and 40% KNO_3)	
Investment cost	$380 million	$7.2 million

The DNI of the proposed plant is slightly (11%) less than that of the model plant; hence the area required for the proposed plant and the solar field investment cost are to increase with the same ratio. On the other hand due to the lower labor cost in Bangladesh compared to that in Europe or USA, a 15% reduction in solar field investment cost is expected [21]. These considerations are incorporated in the land area and investment cost calculation.

5. Conclusions

Whereas in mobile communication sector Bangladesh has attained the state-of-the-art technology within a few years, the power sector is still stumbling with the primitive machineries. It is high time the government of Bangladesh should ponder over the way power is generated in the country.

To verify the viability of the non-polluting and CO_2 free CSP technology a pilot project should be taken as early as possible. The use of local manpower for assembling different components and erecting the solar power plant will reduce the investment cost by 30%. Furthermore, the regular operation and maintenance of the plants will create thousands of new permanent jobs which will help to reduce the country's grave unemployment problem to some extent. Therefore, the government of Bangladesh should take necessary steps to adopt parabolic trough technology for large scale power generation and install parabolic dishes as small scale discrete power generating units.

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