FEASIBILITY STUDY OF CONCENTRATING SOLAR THERMAL (CST) PLANT FOR PROCESS HEAT APPLICATION IN TEXTILE INDUSTRY

Summary

Solar Heating for Industrial Process (SHIP) systems can greatly improve the efficiency of heat usage in industrial processes and decrease greenhouse gas emissions. However, SHIP systems require more specific engineering, technical analysis, and specialized installation compared to solar photovoltaic systems. Industrial processes often involve a range of temperatures, which can be classified into three categories: low (below 150°C), medium (150-400°C), and high (above 400°C). Solar thermal technologies are often used to generate hot water or steam for industrial processes in industries such as chemicals, food and beverage, machinery, mining, textiles, and wood, which typically operate at temperatures that can be easily produced using these technologies. High-temperature solar thermal energy technology comprises two categories, which include - Concentrated Solar Thermal Technologies (CST) for fulfilling heat requirements in industries, and Concentrated Solar Power (CSP) when the heat collected is used for power generation.

In this paper, technical and commercial feasibility of CST technology has been established for a textile industry in India through site survey, thermal energy demand assessment, selection of CST technology after comparative study, thermal energy generation estimation using Greenius software developed by DLR, technical integration of CST plant to existing system, project cost estimation and economic analysis in different scenarios.

Keywords: Concentrating Solar Thermal, Compound Parabolic Collector, Industrial process heating

Abstract

Concentrating solar technologies (CST) consist of reflectors or collectors that direct incoming solar radiation onto a receiver to reflect it, thus concentrating a large area of sunlight onto a single receiver. This concentrated heat energy is then used to heat a heat transfer fluid according to the specific needs of the process. Within CSTs, there are imaging and non-imaging technologies. Imaging concentrating systems can be either line-focus collectors or point-focus collectors. In this study, different types of CST technologies namely parabolic trough concentrator, paraboloid dish, compound parabolic concentrator and linear Fresnel reflecting concentrator have been evaluated for site specific conditions. The most appropriate CST technology has been selected based on site requirement such as output temperature range, suitability of system type for installation at available area at site, efficiency and thermal output at different temperature output at site specific DNI and GHI, cost and availability of technology in the local market etc. The CST plant has been designed accordingly for the selected textile industry and technical performance and economic analysis has been carried out.

The selected textile industry requires 100 kilolitres of hot water per day at 60ºC to 110ºC for different textile fabric processes. The thermal energy demand is met from a coal-fired boiler of capacity 6 tonnes per hour (6TPH). The boiler delivers steam at a temperature of 130ºC and pressure of 7.5 kg/cm^2. The boiler consumes about 1260 metric tonnes of coal per year. During the process, 30% of the water is recovered as condensate which is returned to the boiler feedwater tank to pre-heat the make-up water.

Based on the required process temperature and available area for installation, cross compound parabolic collector (xCPC) technology found to be most suitable for the proposed industry. System design and performance modelling has been carried out for the same. The proposed xCPC uses an evacuated absorber tube and a parabolic reflector to collect solar radiation. The collectors are installed at a fixed tilt facing south. This type of collector has a typical concentration ratio between two and five and an output temperature of about 150ºC could be achieved. The collectors will be mounted on the roof in an east-west direction and inclined to the south. The cross compound parabolic collectors can collect both direct and diffuse radiation. Since the collectors will be installed at a fixed tilted surface facing south, the radiation from the sun will not arrive perpendicularly to the solar collector, incidence angle modifier has been estimated and used for performance modelling and thermal energy output

calculation using Greenius software as shown in figure 1. The system will generate 436.80 MWh thermal energy per year.

The proposed CST system will be integrated with the existing heat supply system as per the block diagram shown in figure 3. The demineralized water from the make-up water tank is directly fed into CST system at ambient temperature (~ 20^0C) and output from the CST system fed in to the feed water tank to raise the temperature up to 90^0C. On non-sunny days, water at ambient temperature (20^0C) will exit the CST concentrators and enter the feed water tank as it currently does. The demineralised makeup water fed to the xCPC at about 20^0C. The solar concentrators make the water hot up to 110^0C to 150^0C depending on the time of the day and the season. The hot water from the xCPC is then mixed with the condensate water at the existing feed water tank and reached a desired temperature of 90^0C to 95^0C. There is an existing auxiliary air pre-heater connected to the feed water tank. This water is then fed to the existing coal-fired boiler to get steam at 135^0C which is the requirement of the textile process.

The project cost is estimated based on the bill of materials as per design, the present market situation in India, and the price collected from the manufacturers for the design, supply and installation of the project on a turn key basis. The total project cost for 427.5 m^2 effective collector area with 95 arrays of xCPC supplied with all equipment and accessories, engineering design, installation, testing, commissioning and contingency is estimated to be USD150,000. Operation and maintenance cost per year is considered as 1% of the project cost with an escalation of 3% per year. Based on the cost of coal (USD125/MT) used by the textile industry and available fiscal benefits in India (15% capital subsidy and 40% accelerated depreciation) the project payback period has been estimated to be 4 years.

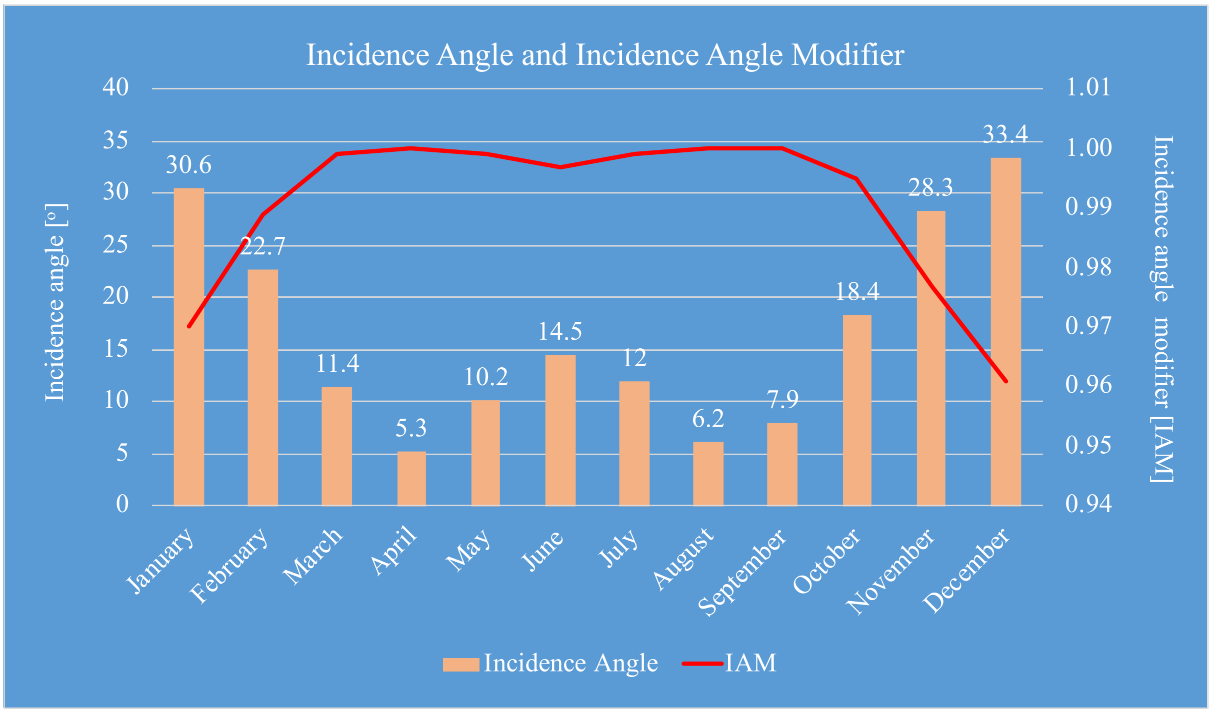

Figure 1: Incidence angle and incidence angle modifier using Greenius software (Source: Author)

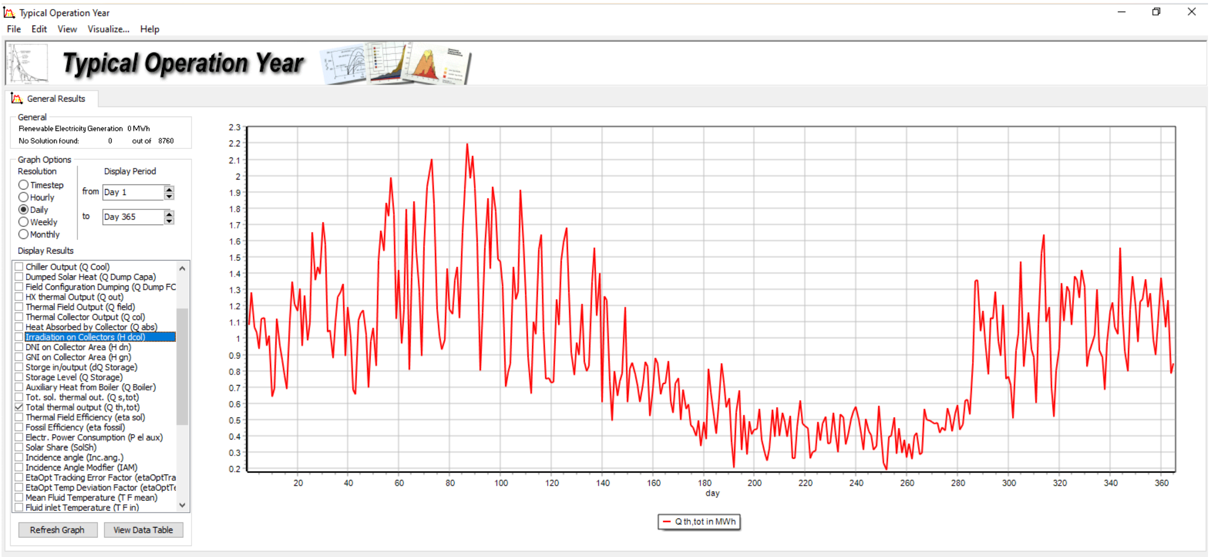

Figure 2: Daily thermal energy output analysis (Source: Author)

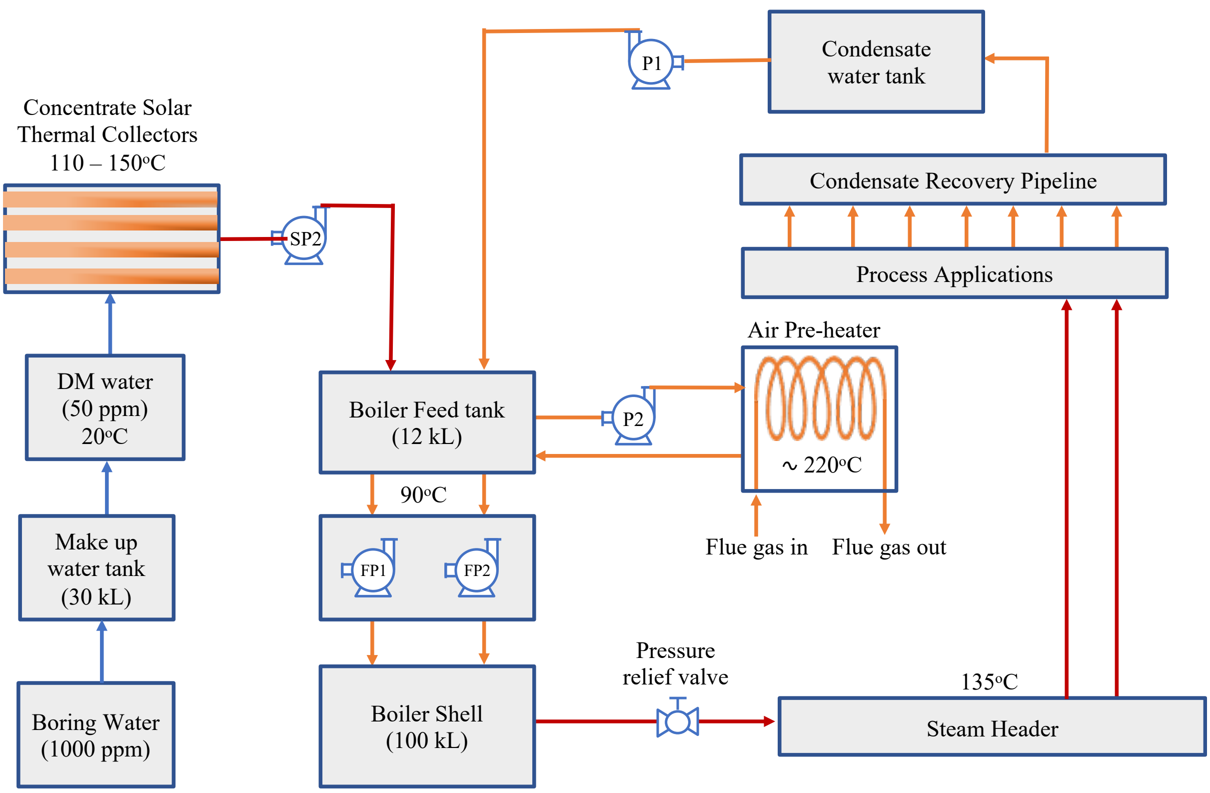

Figure 3: Block diagram of solar integration (Source: Author)

Reference

[1] Renewables Global Status Report 2022

[2] India's CST Sector Vision 2022, MNRE-GEF-UNIDO

[3] Information package for Concentrating Solar Thermal Technologies, UNIDO