ANALYSIS AND PERFORMANCE MAPPING OF "COMPONENT TO SYSTEM" FOR A PARABOLIC TROUGH COLLECTOR APPLIED TO PROCESS HEATING APPLICATIONS

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SUMMARY

The slogan "Heat is half" is of importance to keep in mind that nearly 50 % of the final energy use is in the form of heat. The global efforts for future decarbonised heating systems are based on hydrogen and electrification of heating etc. Solar thermal technology is a key component of greener industrial heating solutions. Solar thermal technologies for process heating application has decade long history of implementation and are gaining significant interest from all around the world. The performance prediction of solar thermal technologies on the system level is more complicated compared to photovoltaic, due to the effect of performance on system boundary conditions such as variation in meteorological parameters, load demand, temperature levels, thermal storage type. The central focus of this paper is on the use of a parabolic trough collector (PTC) for process heating applications in the medium temperature range. The aim of this paper is to map the performance of PTC collector into an industrial system, and to analyse the decrease in collector thermal output from component level to system level. The simulations are implemented in TRSNYS and MATLAB. The results are visualized using QGIS tool to generate the heat map for performance parameters for a range of solar fractions.

PROBLEM DESCRIPTION AND AIMS

Industries consume a lot of heat in medium temperature range such as from 90 to 200 $_{o}$C. A majority of the industrial systems are based on boilers powered by coal, natural gas, oil etc. When designing such conventional systems, the knowledge of the expected peak load alone from industries is sufficient in many cases. However, integrating solar thermal collectors such as Parabolic trough collector (PTC) to a customer's existing heat network is an engineering-intensive task. The same system design requires an understanding of process characteristics, temperature level, temporal variation in heat demand on daily, weekly, and monthly basis. Typically, the thermal output of a collector is based on a "component level", i.e., performance based on only meteorological data, which is independent of customer's process boundaries conditions. However, the design of the system based on thermal output from the component analysis may result in a big uncertainty due to the non-inclusion of many critical parameters.

Therefore, expanding the PTC performance to system performance is critical. The experience gained thru several simulations and case studies suggests that if the industrial demand is all day around (as in the case of large industries), the solar thermal collectors can contribute to a limited solar fraction in any industrial process, typically below 40 %. Moreover, collector-specific performance on the system-level usually decreases at a higher solar fraction, due to spillage of some energy generated by the solar collectors, as to avoid excessively high storage volumes which may result in low economic feasibility. This paper aims to investigate

- to what extent this decrease can be observed from PTC component performance to system performance for given industrial boundary conditions in various climatic conditions.
- mapping of performance ratio (ratio of system performance to component performance) for several locations in a range of climatic zones.

- identification of various parameters and sensitivity analysis to see the effect on system performance.

METHODOLOGY

To achieve the above-specified aims, a PTC integrated industrial system is simulated in TRNSYS using meteorological data from 60 locations. The focus of the paper is limited to one country (India), as it represents a range of climatic zones and irradiation levels, and has a strong potential for solar process heating. Industrial boundary conditions are defined based on previous experience obtained from various case studies. The industrial heat demand is set to 10000 MWh/year at a steam temperature of 140 $_o$C and the condensate temperature is set to be 90 $_o$C. The simulation is the performed in 2 steps. In the first step, the collector is modeled without any load connected to it. This can be considered as if the collector operates under infinite load, and thus fully utilizing all the heat generated by the collector. The simulations are done using TRNSYS models, which is validated against data from real measurements. After the collector component simulation, the outputs are used for the system simulations. This is done using MATLAB tool. The tool dynamically simulates the collector interaction with the load, and several iterations are performed to obtain the collector area and storage volume for a range of solar fractions. The storage considered for simulations is pressurized water storage. Moreover, a digital numerical map approach is applied based on heat maps to visualize the performance of various indicators such as component performance and system performance at various solar fractions. The simulation results for all locations are exported to Microsoft Excel for calculations of collector efficiency on both component and system level. After this, the results are visualized in QGIS, which provides a heat map rendering to design point layer data with a kernel density estimation processing algorithm.

RESULTS

The results of component performance for various locations are shown in Figure 1. The results of component performance results majorly affected by irradiation, ambient temperature. The results are used as input for system performance mapping at various solar fractions to generate similar maps.

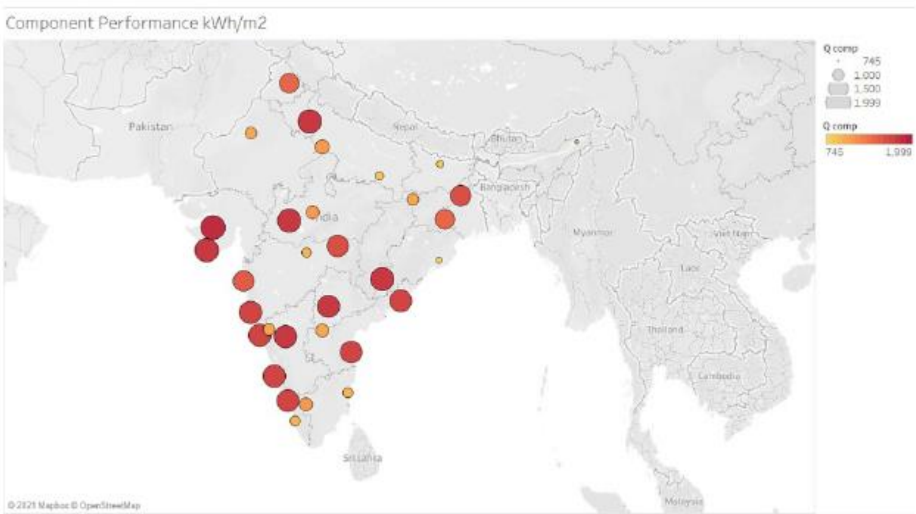

Figure 1 Component performance of PTC for various simulated locations.