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# Unique challenges in the design and operation philosophy of solar thermal power plants

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**Abstract**

Solar thermal power plant design and operation philosophy involves unique challenges as compared to design of conventional thermal power plants. The solar receiver operation should be able to absorb maximum solar load during transient events like daily start-up and shut-down. This requires aggressive ramp rates for transient operation of the power plant. However, the component and system level limitations must be considered in formulating these modes of operation and ramp rates.
A solar receiver which usually receives heat from heliostats is designed to receive high heat flux to operate at high temperature and pressure during daytime. However, during night-time the receiver receives no heat flux and is losing heat to the environment. Day-night cyclic operation of a solar thermal power plant induces thermal cycles in the solar receiver pressure parts. Since solar receiver tubes are not insulated, the amplitude of thermal cycling is significant and needs to be addressed with proper tools and design approach. Besides, higher plant cycle efficiency requires higher operating temperature and pressure of a solar receiver, further increasing the amplitude of thermal cycling. The system level and component level response to these day-night cycles has a significant impact on modes of operation as well as on the life usage of various components. It also affects the design, specifications and operation of various plant level components.
The solar thermal power plant design and operation process is optimized by having a system level thermal-hydraulics model for the solar receiver to simulate the transient start-up and shut-down events. Since all of the major components of the system are included in the model, it reflects the transient response of each of the components on each other and on the overall system. This simulation can be used to generate input conditions for component level life usage analysis. The component level life usage analysis is done using the finite-element method. The component level life usage analysis determines the permissible ramp rates. The thermal-hydraulics dynamic simulation outlines the operational philosophy of the system.


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*Keywords:* Solar tower receiver; start-up; shut-down; transient; dynamic modeling; fatigue; FEA; Alstom; plant intigration, plant optimization

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## 1. Introduction

A variety of technologies are currently used for concentrated solar thermal power plants. With an eye on decreasing the cost of power generation using solar thermal technologies, there is a clear trend towards increasing the efficiency of the power plant. Various parameters need to be considered for calculating the efficiency of a solar thermal power plant including operating temperature, losses and concentration factor.

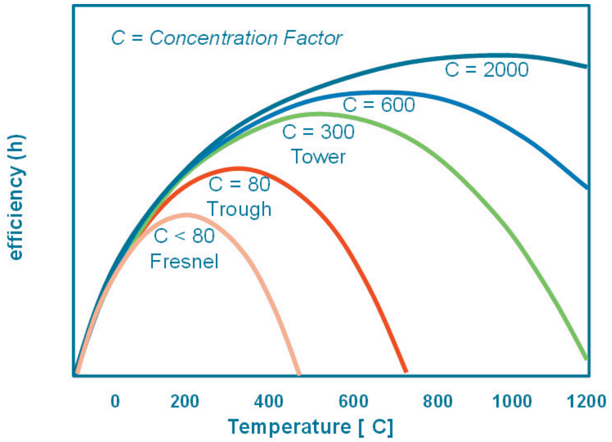


Fig. 1. Solar thermal plant efficiency variation with temperature

Fig. 1 illustrates the relationship between efficiency and temperature for different CSP technologies [1]. Among the major CSP technologies currently used, the tower receiver provides the highest efficiency. High heat flux and higher operating temperature results in increased overall efficiency of the tower type receivers. Besides, the water-steam cycle is designed for high pressure to raise the saturation temperature and thus the overall operating temperature in the rankine cycle.

Increased overall operating temperature and pressure imposes unique design and operational challenges related to start-up, shut-down and transient operation of solar thermal power plant. This paper explores these challenges and talks about Alstom's solution to address these challenges with emphasis on the solar power tower design along with consideration towards other important components in like the steam turbine.

### *1.1 High temperature and pressure*

Recent trends in direct steam tower receivers indicate operating temperatures in the range of 540$^{o}$C -585$^{o}$C and operating pressures in the range of 140bar to 190bar [2]. For example, Alstom's 250MWe solar thermal power plant is designed to supply steam at 585$^{o}$C and 170bar [1]. Considering the pressure drop within the steam piping and superheater section, the evaporator for these receivers is at even higher pressure (approximately 190bar). As the pressure increases, the thickness required for the pressure part components that carry water-steam through the various sections of the receiver also increases. This makes large diameter pressure part components like the steam drum, manifolds and headers very thick. Moreover, high grade alloy materials (like Grade 91) need to be considered for high temperature sections of the receiver like superheater and re-heater.

Similarly, high temperature and pressure requires use of high grade material in the steam turbine.

### *1.2 Cyclic operation*

A solar tower receives heat flux from the sun through large numbers of mirrors in the mirror field. The SRSG (Solar Receiver Steam Generator) is operating during day-time and is shut-down and not producing steam during night. The SRSG thus follows a cyclic operation due to the day and night cycles. Fig. 2 shows a typical plot of