24h Dynamic Simulation of a CSP Solar Tower

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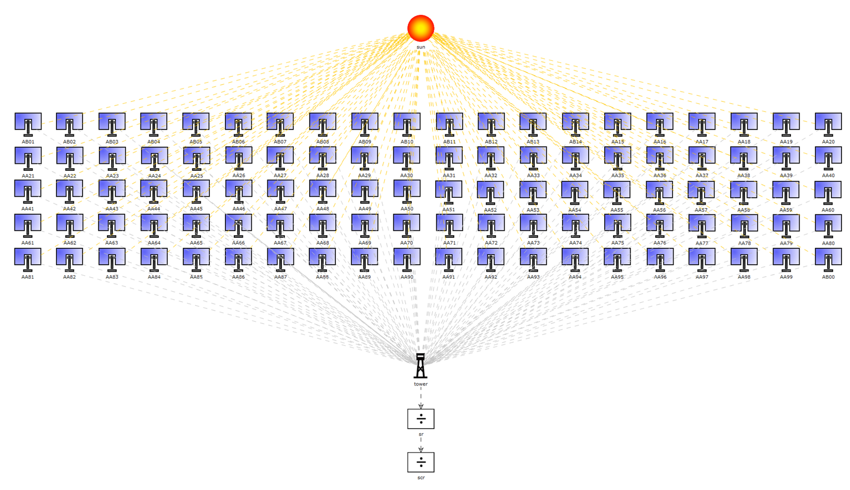
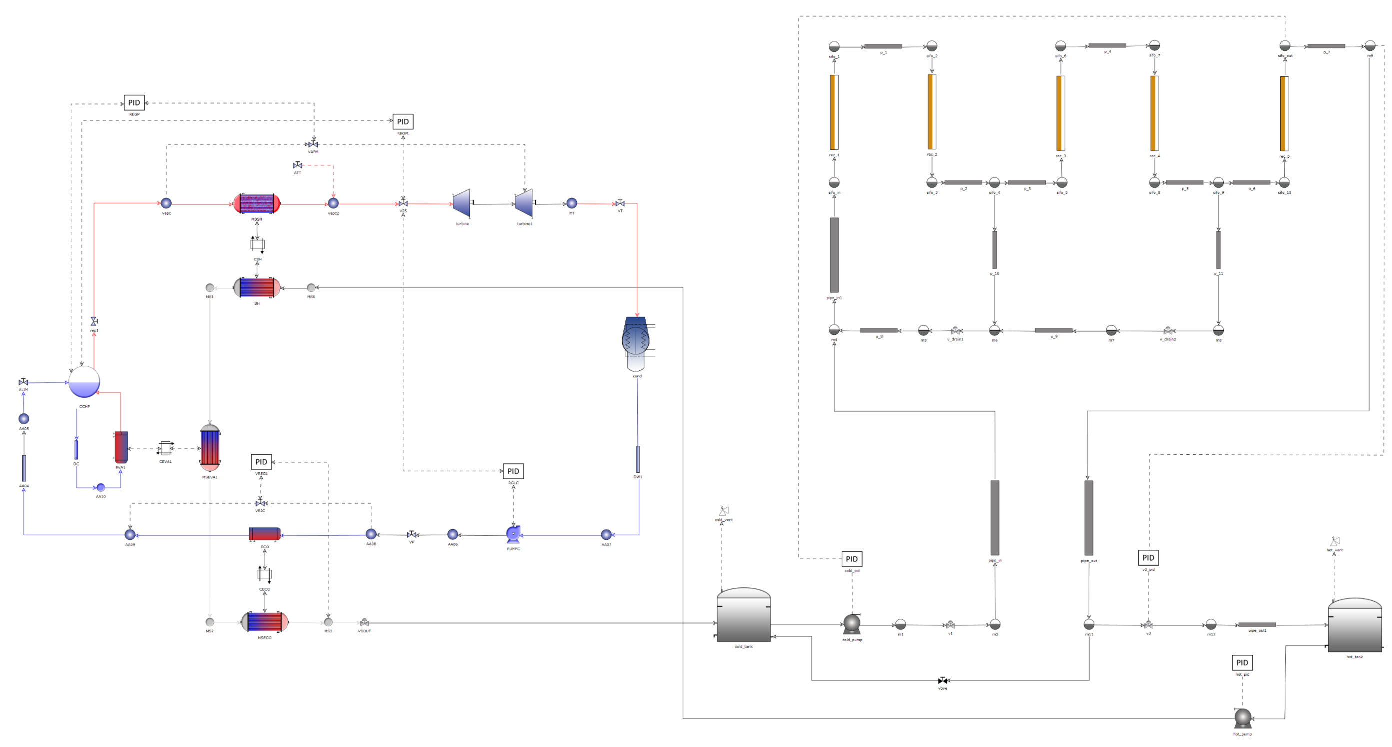
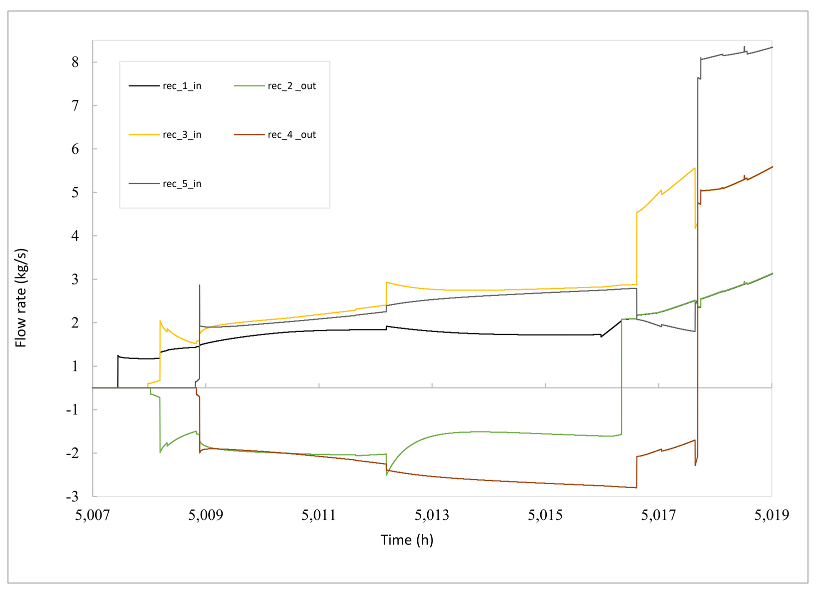
Introduction & Model description

The present article is focused on the dynamic analysis and the control system implementation of a Molten Salt Solar Tower plant. The CSP model represents a 5 MWth Molten Salt Central Tower plant collecting energy coming from a solar field composed of 100 heliostats. The plant is completed by two molten salt storage tanks holding cold and hot MS in order to guarantee a night autonomy of 3÷5 hours. The Power Block, composed of a steam generator and a two stage medium pressure Steam Turbine, converts thermal power into electric power. The most important aspects taken into account are the drainage and filling procedures of the solar tower receiver system, with a description of the molten salt recirculation strategies in case of long absence of DNI and transient responses of the receiver to cloudy days.

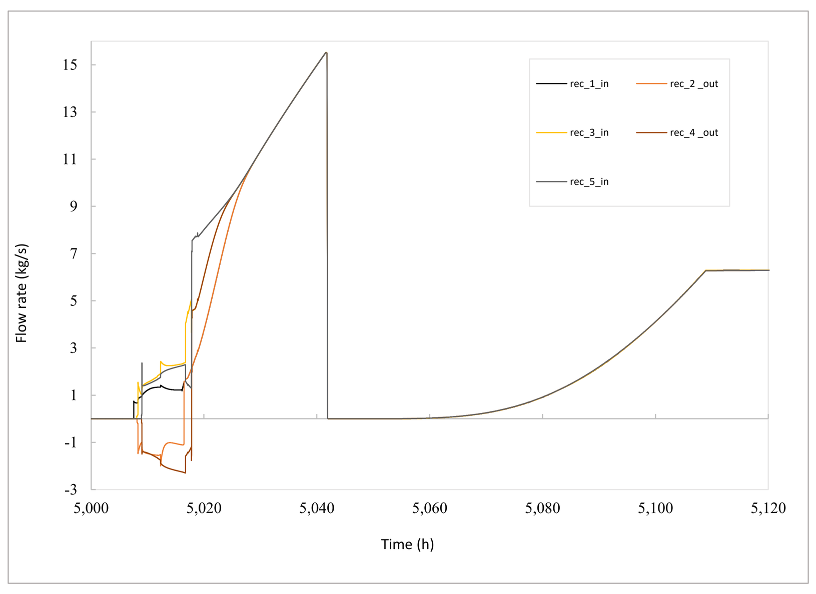




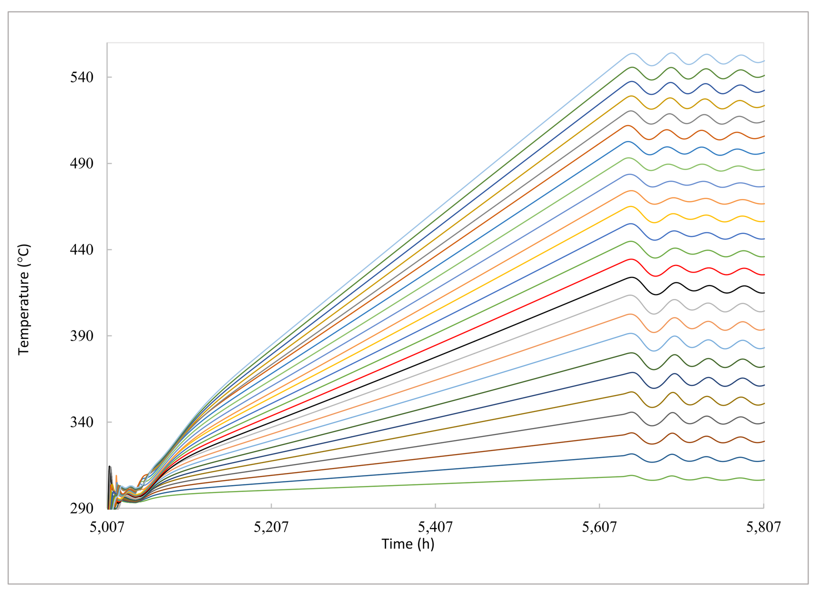
Filling results



The figure on the side represents the MS flow rates in the five panels during the filling of the receiver; the difference among the flow rates in each panel is due to the geometrical asymmetry of the receiver. Negative flow rates in panels 2 and 4 are due to the MS flow direction opposite to the normal circulation

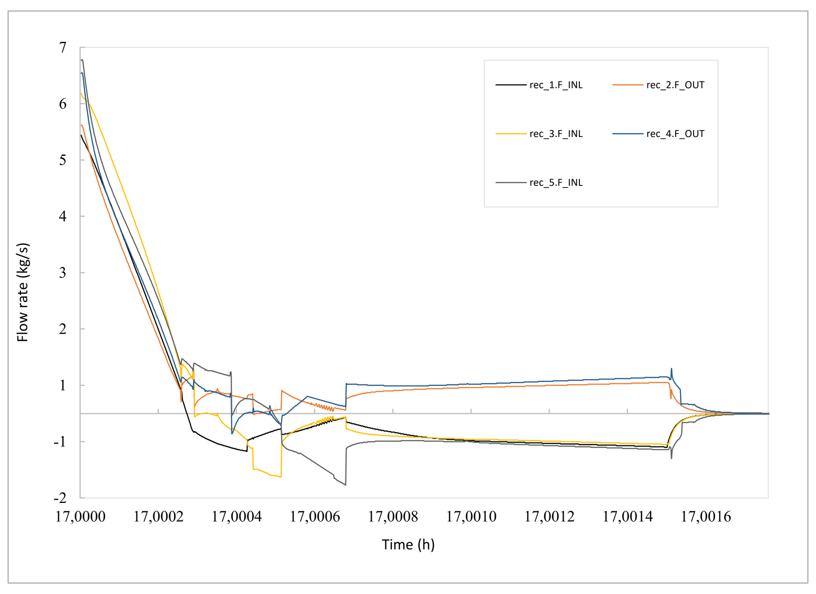


Full trend of each panel mass flow rate. After the complete filling of the receiver system (with the receiver outlet valve in closed position), the PID takes control of the flow rate in order to keep the MS outlet temperature at 550 °C

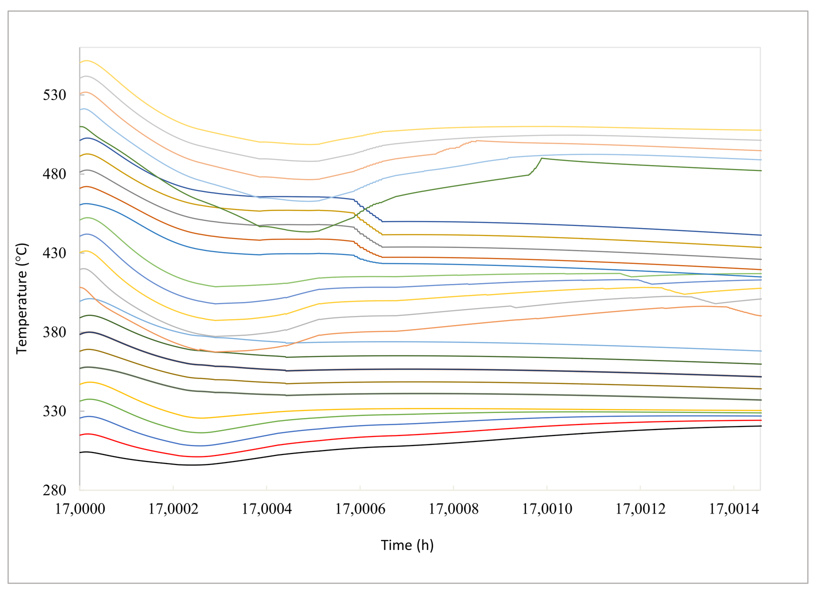


MS Temperature in the receiver for each panel. In the first phase of normal circulation, the control system waits for the MS to reach a certain temperature before controlling the outlet valve. In the right side of the figure, it can be observed how the flow rate regulation system impacts all the MS temperatures in the panels

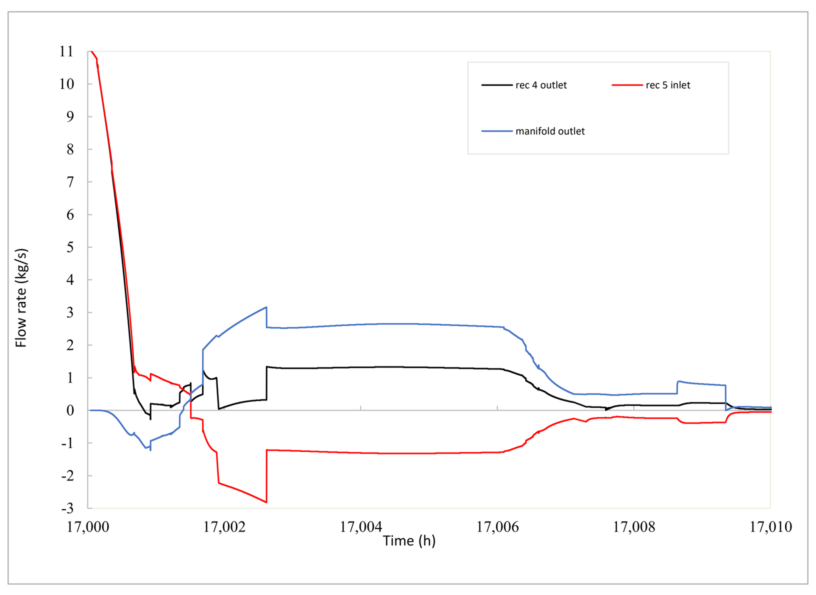
Draining results



MS flow rates during the drainage of the receiver; panels number 1, 3 and 5 show negative flow rates when the cold pump is no longer able to support the MS weight and, in that moment, they start to drain

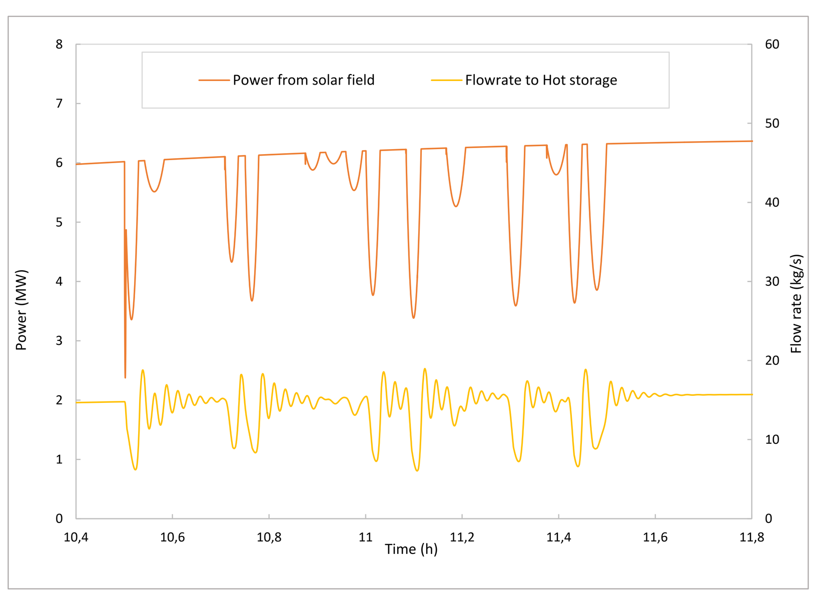


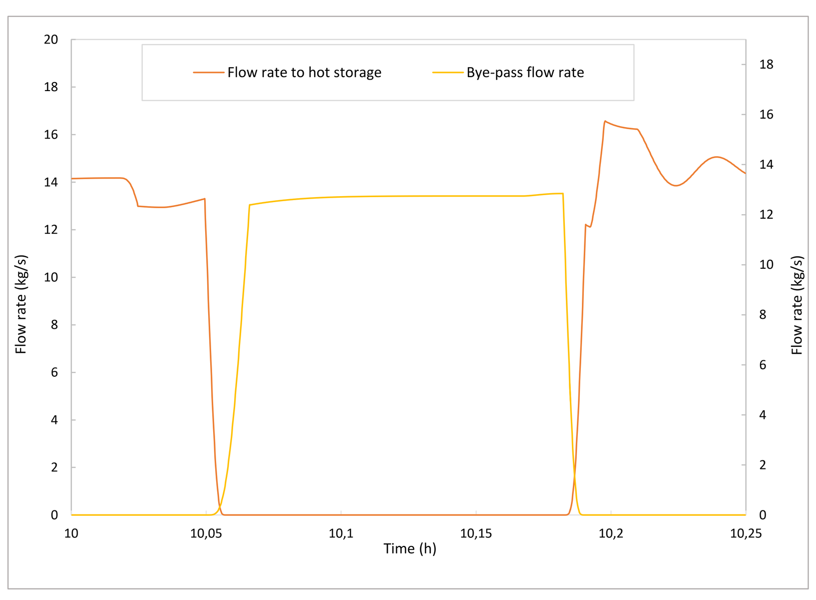
Temperature of the MS in each panel during the drainage procedure. The thermal behavior of panels 3 and 5 is quite interesting to analyze; in fact, they share the bottom manifold with panels 2 and 4 respectively; these two panels contain colder MS with higher density and, for this reason, they will drain easier. MS is kept for a longer time in panels 3 and 5 where it loses more energy to the environment.

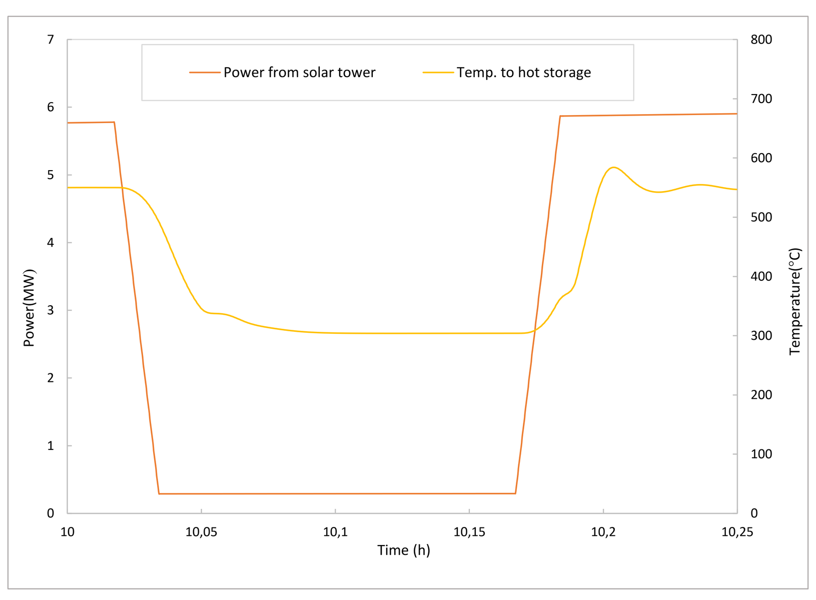


It's interesting to analyze the trends of the flow rates in the bottom manifold shared between the panels 4 and 5. When the flow rates of the panels decrease, they create an aspiration of the MS present in the outlet line of the manifold (blue trend). Only when the panels flow rates are close to zero the drainage can begin.

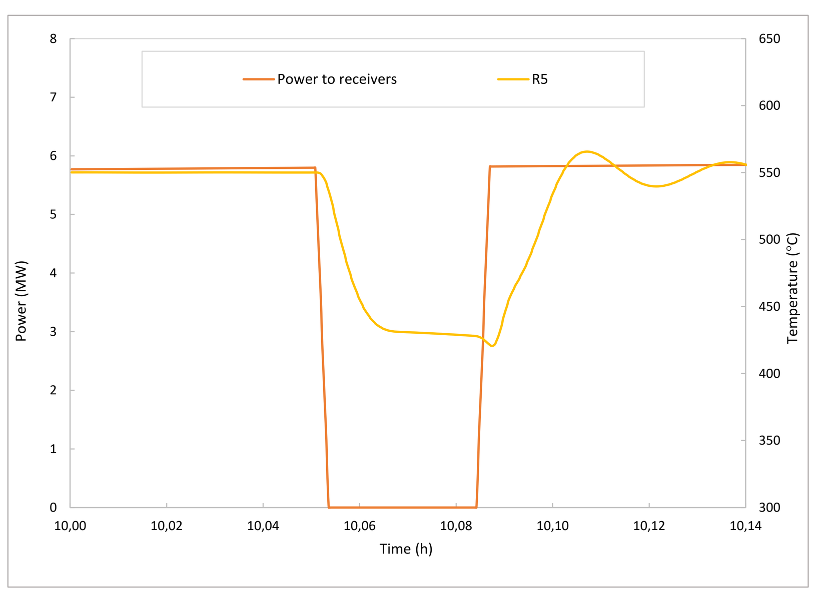
Alternative scenarios

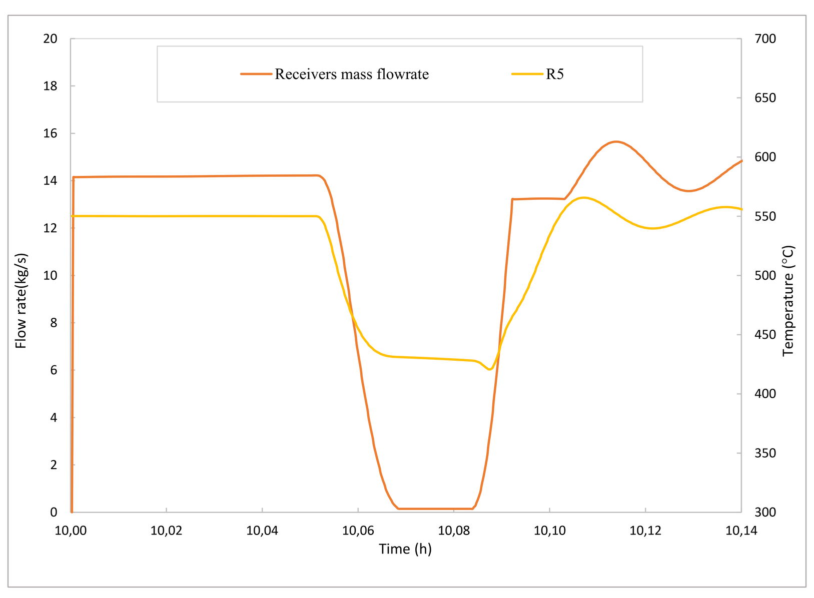






(1) A cloud generator was applied for about 1 hour; the regulation system tries to keep the receiver outlet MS temperature at 550 °C varying the rotational speed of the feed pump and the lift of the hot storage tank inlet valve. (2 and 3) When highly opaque clouds last for a long time, the by-pass valve opens and, simultaneously, the main hot storage valve closes. After the passage of the cloud, the system switches to nominal state condition restoring the base receiver control system





Total shadowing of solar field. The absence of solar irradiation is extended for 120 seconds; the regulation system tries to keep the outlet MS temperature at 550 °C by lowering the MS flow rate. In total absence of DNI the MS flow rate is lowered to a value close to zero in order to avoid the MS temperature degradation inside the receiver. When a regular DNI is restored, the regulation system increases the MS flow rate to nominal values

Conclusion

The base model developed in the simulation platform ISAAC Dynamics shows only some phenomena present in a Solar Tower plant. Using the plant model, a very accurate analysis could be possible. During the design phase, the plant simulation is of great importance in order to prevent mistakes that could not differently be observed. If used after the plant construction, such a simulation can improve the performance of the entire plant increasing its efficiency

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