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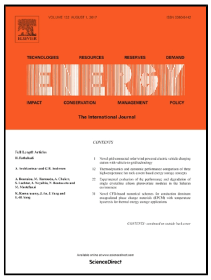

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TRANSIENT RESPONSE SIMULATION OF A PASSIVE SENSIBLE HEAT STORAGE SYSTEM AND THE COMPARISON TO A CONVENTIONAL ACTIVE INDIRECT TWO-TANK UNIT

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Abstract

This work presents a 1-D numerical model of a passive sensible thermal energy storage (TES) system using high-temperature concrete as storage medium. It is successfully validated against experimental data obtained from a pilot-scale concrete storage module. A specific Nusselt number correlation is developed providing better accuracy for the specific heat transfer fluid (Therminol VP1) and observed Reynolds numbers, than conventional general purpose heat transfer correlations for forced convection inside tubes. Then, the model is up-scaled to a commercial-sized thermal capacity of 504 MWh, providing grid-independent solutions and cyclic-steady-state initialization values for further use in a general purpose CSP model library. The proposed implementation in Modelica provides a flexible and intuitive simulation tool, which is not limited to a single simulation platform.

Next, the presented model of the concrete TES system is used to compare its transient response with that of a conventional active indirect two-tank heat storage system. Whilst the concrete TES system shows lower maximum rates of change in HTF outlet temperature right after the switching of operating modes, the conventional two-tank TES system has the important advantage of steady-state operation, providing constant HTF outlet temperature, which is very favorable considering steam cycle efficiency and thermal fatigue management.

Keywords: Concentrated solar power (CSP); thermal energy storage (TES); transient response

1 Introduction

Solar thermal power, also known as concentrated solar power (CSP) or solar thermal electricity (STE) can be considered as a highly promising technology when it comes to dispatchable and thus grid-friendly supply of renewable electricity. This is due to the possibility of thermal energy storage (TES), the key advantage over other renewable technologies (such as wind or photovoltaic), which enables the decoupling between solar energy collection and electricity production. Given the abundant amount of solar power available for terrestrial solar collectors (85 PW) [1], which exceeds the current world's power demand (15 TW) several thousand times [1], CSP is a highly promising alternative to conventional fossil-fuel or nuclear technology, setting new standards in terms of environmental impact, sustainability, safety, and thus quality of life.

Unfortunately, currently the cost of electricity generation for CSP (≈14 c€/kWh [2]) is still clearly above conventional technology and other renewables (wind and photovoltaic reach 6 c€/kWh on average [2]). However, rather than comparing the pure cost, one should compare the true value of CSP for grid operation and capacity [2] when considering an increasing fraction of not dispatchable renewables. Solar thermal electricity is not to be seen as competitor of photovoltaic, in fact, it will be the enabler. Additionally, it must be said that up to the present day, irreversible long-term damages of conventional fossil and nuclear technology are not taken into account in the cost calculations, which makes a pure cost-based comparison definitely unfair.

In summary, TES is the big advantage of CSP and the conceptual implementation and operation has to be optimized. In particular, due to the highly intermittent nature of solar energy (cloud movements) the transient performance of TES systems and, especially, the ability of performing fast changes in load are