ThumbsUp

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ICE-BASED THERMAL STORAGE: IMPACT OF WATER-QUALITY OVER METASTABILITY EFFECTS

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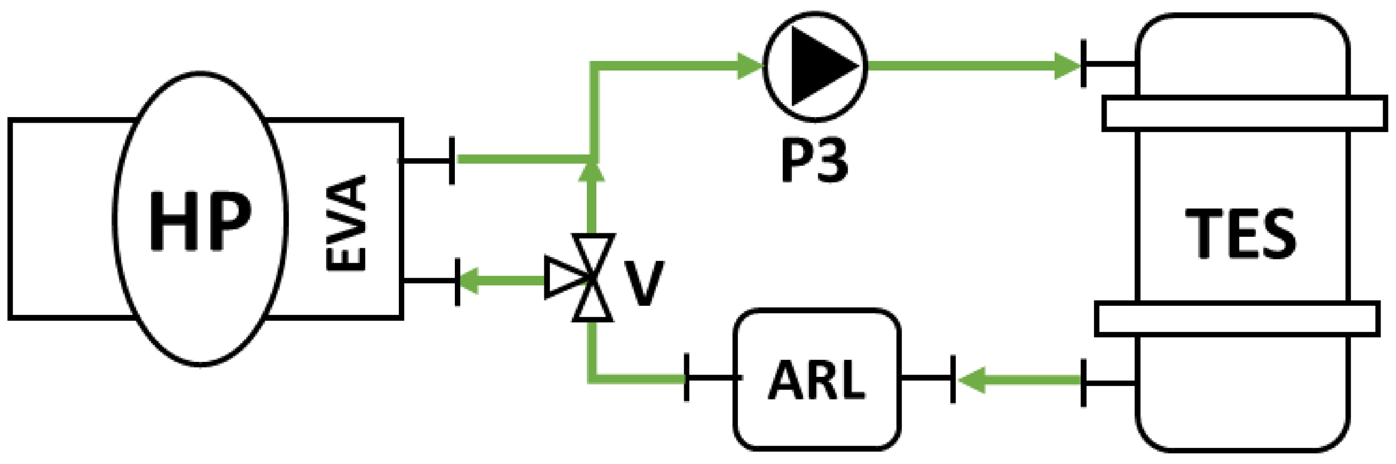
INTRODUCTION

Ice storage technology can be considered a proven PCM LHTES technology, particularly thanks to the easiness of its handling and its low CAPEX. Understanding the thermodynamic and kinetic properties of ice LHTES can facilitate/enhance their management and integration in different application, and it is relevant to highlight that i) LHTES performance analysis on large scale setups operating around the liquid density inversion temperature is still limited, and ii) the impact of water quality/water mixtures on ice LHTES has not been yet deeply investigated. Starting from a previous work [1] in this field, the performance of a shell & tube, ice LHTES was characterized in order to: 1) develop a SoC methodology based on level ratio of LHTES compensator; 2) benchmark charging/discharging phase processes for different water quality ice LHTES.

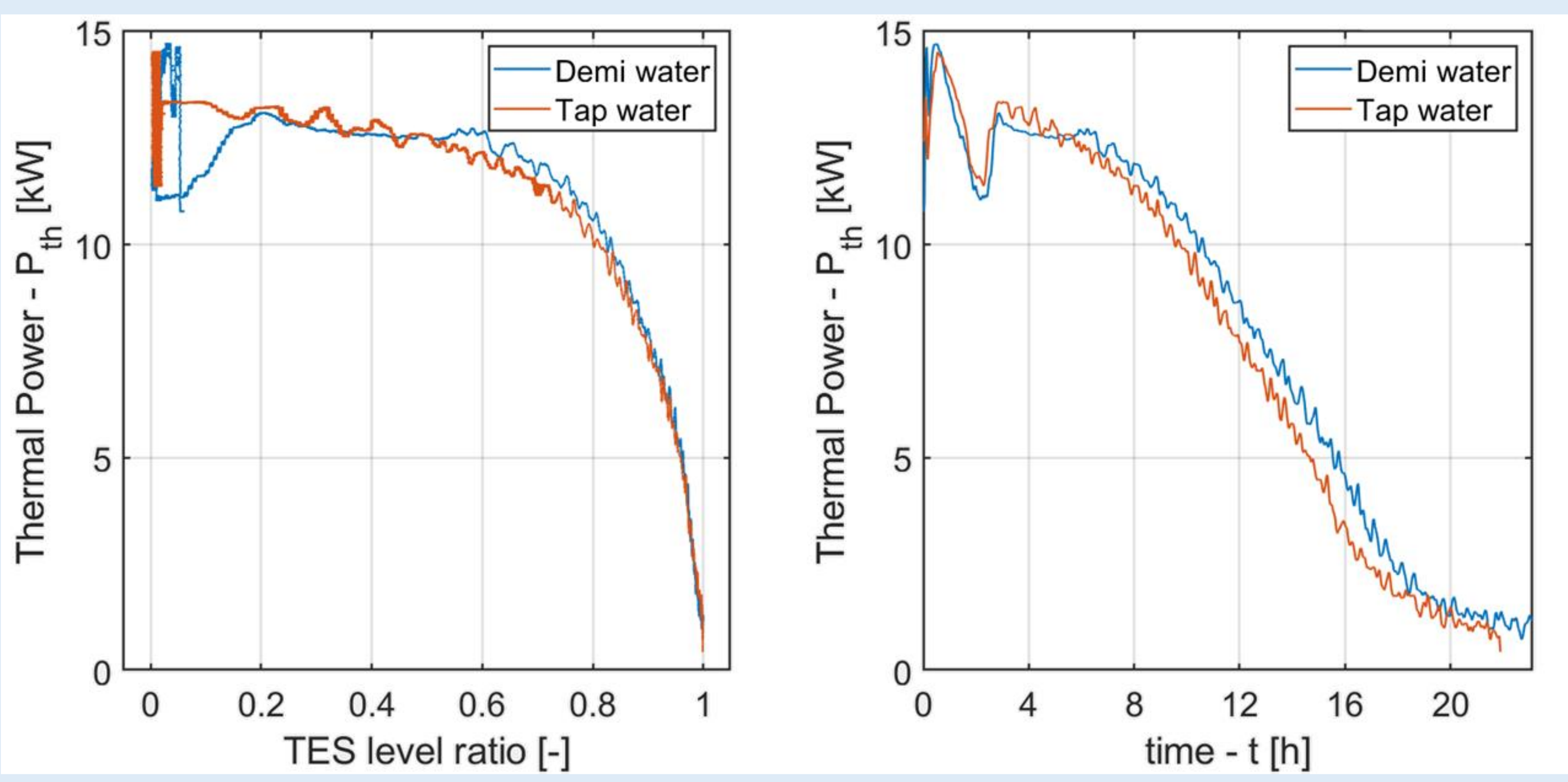
Experimental setup and SoC assessment methodology



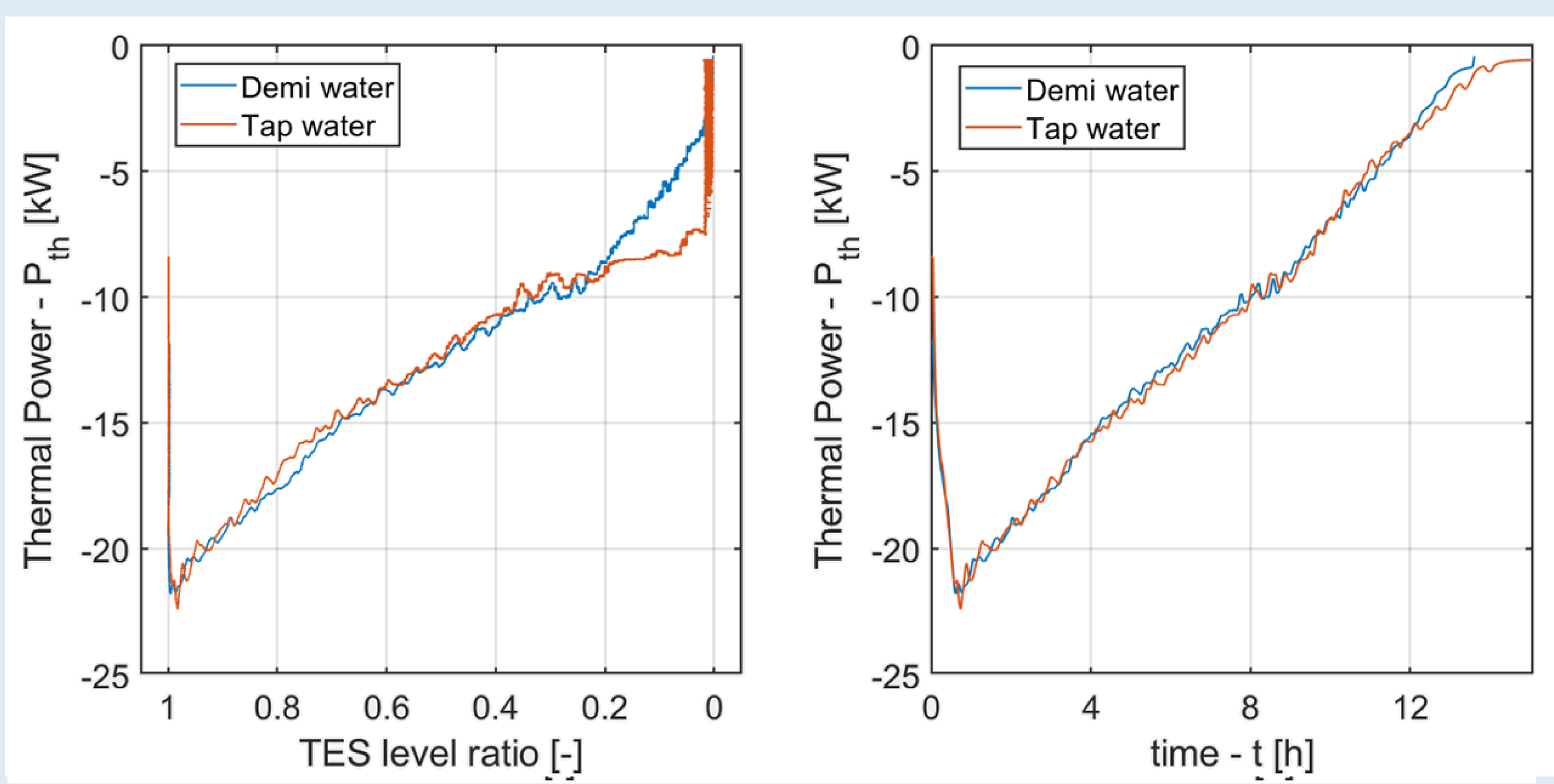
The experimental setup is composed: i) a 10 kWel Heat Pump, ii) a 30 kW Auxiliary Resistive Load (ARL) – to be used during the charge and discharge operations of the TES rig, iii) a finned shell & tube TES, where the Heat Transfer Fluid (HTF - made up of a blend of water and 47% ethylene glycol) circulates inside the tubes and the PCM is housed in the outer shell [1]. Through the three-way valve V it is possible to activate the "charge operation circuit" (HP-TES-ARL) or the "discharge operation circuit" (HP-ARL). The pressure change due to expansion during the icing / melting process (compensated through a dedicated external 500 l compensator) allows to estimate the amount of solid/liquid present in the TES and, thus, its SOC. Since the pressure values could depend on the initial pressure value (initial pressurization) and, there could be no linear correlation between pressure and quantity of PCM already solidified / melted, the Level Ratio – LR is here introduced:

$$LR = \frac{\Delta L_x}{\Delta L_{max}} = \frac{p_f}{p_x} \cdot \frac{p_x - p_{in}}{p_f - p_{in}} \qquad \textbf{(1)}$$

where $\Delta L_x / \Delta L_{max}$ are the current/maximum variation in liquid level in the compensator,, $p_x/p_{in}/p_f$ is the current/initial/final pressure of the compensator. Thanks to this approach LR and p_x are linked with no need to know also the final pressure of the test, as ΔL_{max} depends only on the PCM and the size of the vessel, it is possible to consider initial / final pressure values those found during any full charge-discharge operation considered as reference.



Demi VS Tap water in charging operation over LR (left) and time (right)



Demi VS Tap water in discharging operation over LR (left) and time (right)

Experimental setup and SoC assessment methodology

A full-charging/discharging of the TES were performed with "standard process conditions", as done in [1] (1.2 kg/s - Tin = -6°C/-9°C for charging/discharging operation) using both tap and demi-water. A metastable phase preceding the incipient freezing phase during the Charging was identified. This behaviour directly affected TES thermal power (discontinuity in the thermal power visible around 2nd hour): however, demineralized and tap water are impacted similarly and the thermal power trend over time is more or less the same in both cases (tap and demi water). Anyway, an important difference between demineralized water and tap water is clearly visible: the presence of the metastable phase seems not to affect the TES pressure (and – thus – the LR) avoiding the discontinuity in the LR range 0-0.2 using tap water. This difference could be explained by a different behaviour of the tap water or by an effect of the initial pressurization of the compensator. Further tests need be carried out to properly explain this difference. Looking at discharging operation, thermal power trends are more or less identical for demi and tap water. Anyway, LR in the 0-0.2 range follows different paths again probably due to above mentioned reasons for the charging phase.

[1] T. Reboli, M. Ferrando, A. Traverso, and J. N. W. Chiu, "Thermal energy storage based on cold phase change materials: Charge phase assessment," Applied Thermal Engineering , vol. 217, 2022.

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