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Long-Term Accumulation with Latent Heat in Storage Tanks with Experimental Enhancement

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Abstract

Utilization of Thermal Tank Energy Storage Systems (TTES) for efficient storage and release of thermal energy. TTES systems are an integral part of energy infrastructures that enable the storage of surplus energy in the form of heat and its subsequent use as required. We focus on the study of the benefits and challenges associated with the implementation of TTES systems and analyze their impact on temperature stabilization, minimization of heat losses, and overall efficiency. We also discuss the flexible control of tank charging and discharging in TTES systems. Finally, we conclude by reviewing further research aimed at optimizing TTES systems to achieve sustainable and efficient use of thermal energy in the future.

Keywords: renewable energy, long term storage, latent heat, solar energy, PCM substances

1 Introduction

Thermal energy storage (TES) is a key technology in the energy sector that allows surplus energy, especially solar energy, to be stored in the form of heat for subsequent use when needed. One of the key elements of TES systems is phase change materials (PCMs), which are known for their ability to store latent heat. These materials, referred to as phase change materials (PCMs), could absorb or release significant amounts of heat during phase transitions between solid and liquid states.

In addition, the use of water as a medium for TES systems is discussed, representing one of the most common and efficient methods for storing and utilizing heat. Another objective is to provide an overview of the different applications of TES technologies and discuss their benefits in current energy systems.

2 Energy Storage

Thermal Energy Storage (TES) is a fundamental technology enabling the storage of surplus energy in the form of heat for subsequent utilization as needed, as well as Figure 1. TES systems operate based on principles of physical chemistry, where energy is stored or released due to phase changes in the material. One of the most significant aspects of TES is latent heat storage, where energy is absorbed or released during the transition of the material between solid and liquid states. This process allows for efficient storage of large amounts of energy with relatively minor temperature changes [1].

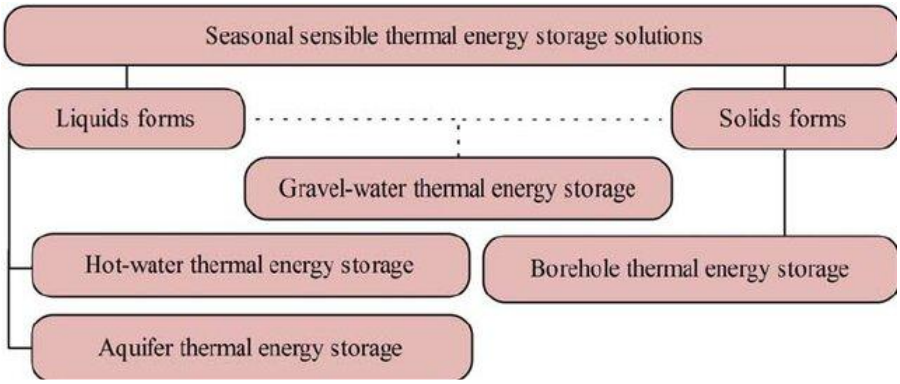

Figure 1: Various solutions for seasonal sensible thermal energy storage [2]

Phase Change Materials (PCM) are key components of TES systems. These materials have the capability to absorb or release significant amounts of heat during phase changes, making them ideal for energy storage. PCM materials are often utilized in the form of capsules or capsules placed in thermally insulated environments, enabling effective control of heat flow [3].

2.1 Pit thermal energy storage

Pit Thermal Energy Storage (PTES) is one form of TES technology utilized for storing surplus energy in the form of heat in underground spaces, as well as Figure 2. This system operates on the principle of a heat pump, where excess heat obtained from various sources (such as solar panels or geothermal heat pumps) is stored in underground environments, where it is retained until needed. When heat is required, it can be retrieved from the underground environment and utilized for heating buildings or other thermal processes [4].

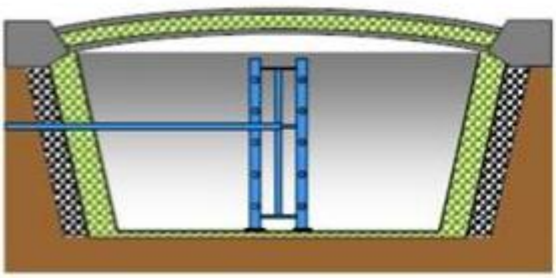

Figure 2: Pit thermal energy storage

PTES systems are popular due to their ability to efficiently store large amounts of energy with relatively low losses. These systems are also flexible and can be adapted to various needs and site conditions.

2.2 Tank theral energy storage

Tank Thermal Energy Storage (TTES) is another form of TES technology utilized for storing thermal energy in tanks, as well as Figure 3. TTES systems operate on the principle of heating water or another thermal medium to high temperatures and storing this heat in a thermally insulated tank. When heat is needed, it can be extracted from the tank and utilized for heating buildings, heating hot water, or other thermal processes [5].

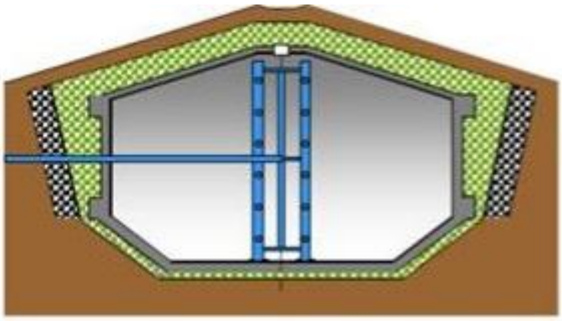

Figure 3: Tank thermal energy storage

One of the advantages of TTES systems is their ability to efficiently store thermal energy with minimal losses. These systems are also suitable for various applications, including industrial processes, solar thermal power plants, and building heating. TTES tanks can come in different sizes and shapes, allowing them to be tailored to specific needs and conditions.

2.3 The use of water as a medium for TES systems

Water is one of the most common and efficient mediums used in TES systems for storing and distributing thermal energy. It is readily available, cost-effective, and has a high thermal capacity, making it an ideal choice for many TES applications. Water is frequently utilized in various forms, including thermal tanks, hot water reservoirs, and other systems for heating and cooling buildings.

The advantages of using water as a medium for TES systems include its high thermal capacity, good thermal conductivity, easy availability, and environmental friendliness. Additionally, water is stable and non-flammable, reducing the risk of accidents and enhancing operational safety [6]. Despite its many advantages, the use of water also comes with some limitations, including the need for appropriate infrastructure for storage and distribution, as well as potential issues with freezing in colder conditions. However, with proper planning and technical solutions, water becomes an efficient and reliable medium for TES systems.

3 Measuring and optimizing TTES performance

Our storage tanks are powered by primary charging sources in the form of selectively heated collectors with an area of 225 m2. These collectors allow the overflow of warm glycol solution, transferring thermal energy into water. Subsequently, this heated water is stored in three thermal tanks with a capacity of 178 m3, as well as Figure 4. These tanks, made of special concrete and thermally insulated, are located beneath the building's surface.

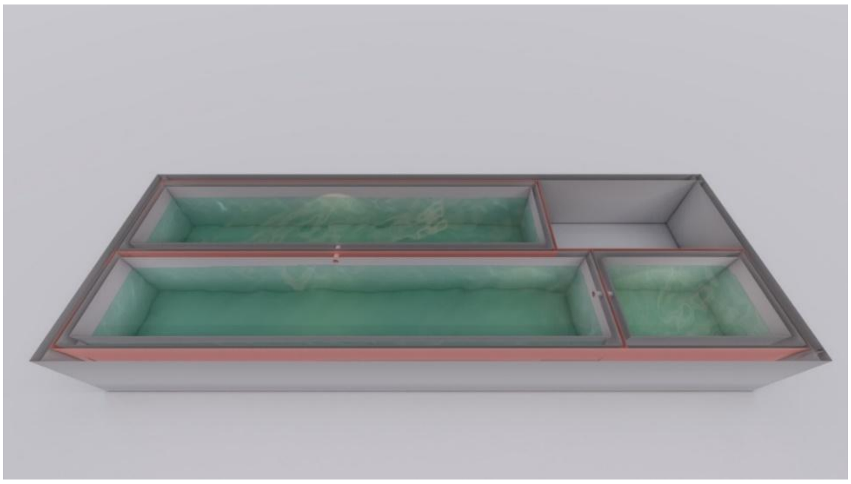

Figure 4: Heat energy storage in three different sizes.

The storage management system allows manual adjustment of charging and discharging according to current needs, necessitating switching between tanks based on seasonal changes, as well as Figure 5. An experimental building was constructed above the tanks to simulate seasonal conditions as accurately as possible.

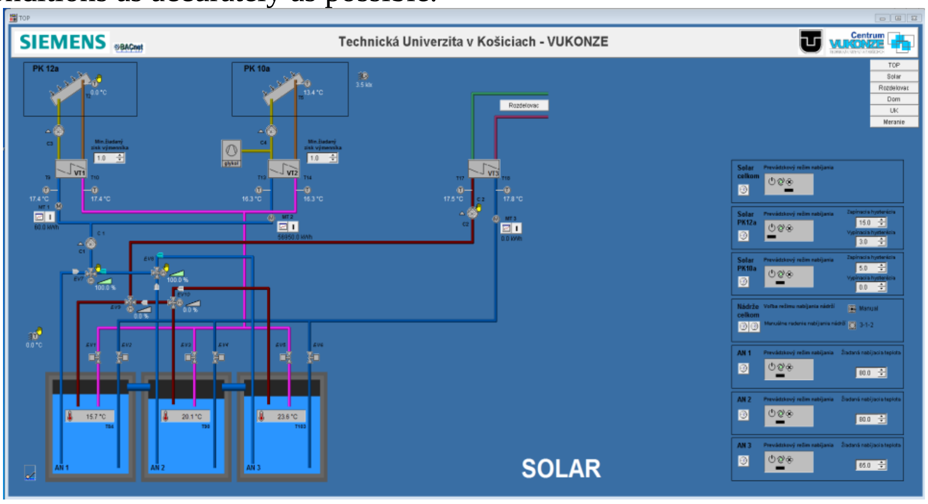

Figure 5: TTES control scheme

3.1 Measurement and Optimization of System Performance

We began by analyzing tank AN1 with a volume of 24 m3, which is the smallest thermal tank in our study. This tank exhibited significant thermal losses due to water evaporation from its surface. Measurements were conducted over a period of two years, as well as Figure 6.

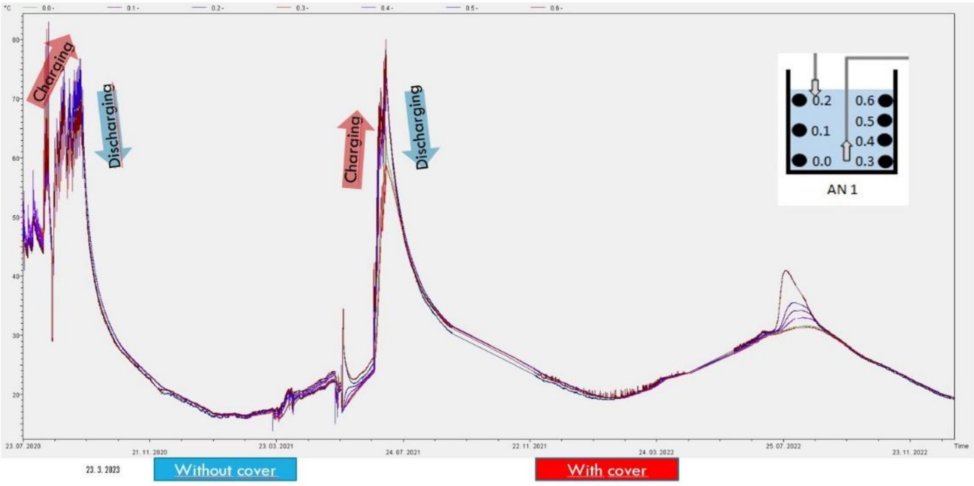

Figure 6: Temperature readings recorded over a two-year period within the AN1 tank.

During the first measurement period, significant thermal losses were observed due to water evaporation from the ground.

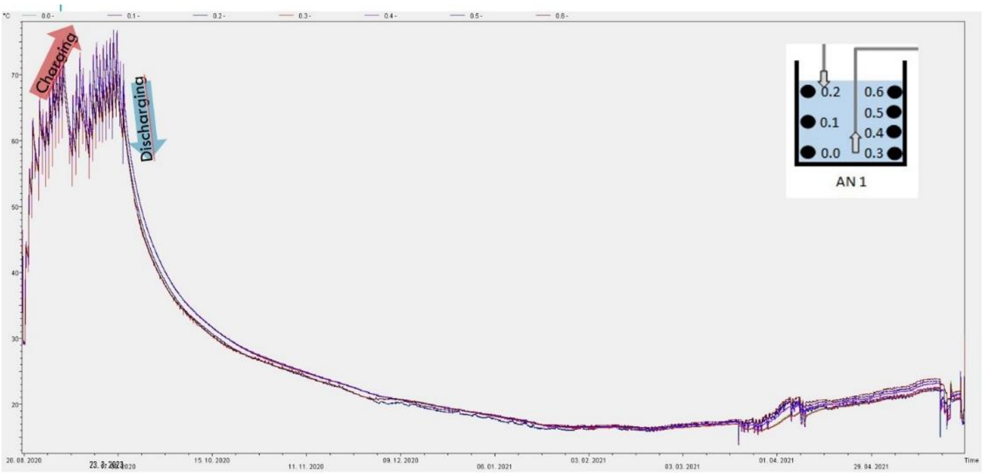

Figure 7: Temperature readings during the first year without any masking.

From the collected data, it is evident that the discharge rate exhibited a quadratic decline without energy consumption, as well as Figure 7.

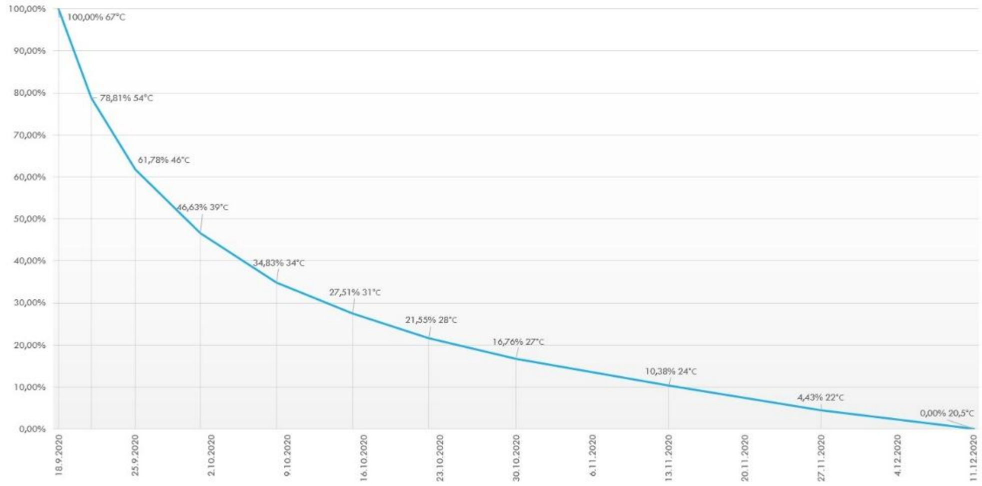

Figure 8: Graph of percentages without coverage

The graph shows a rapid temperature decrease from a maximum average temperature of 67°C to an initial charging temperature of 18°C over 85 days, as well as Figure 8. However, such rapid discharging does not represent an efficient use of energy. During the second measurement period, we applied a thermal insulation with a thickness of 20 mm to the tank's surface to minimize heat losses due to evaporation.

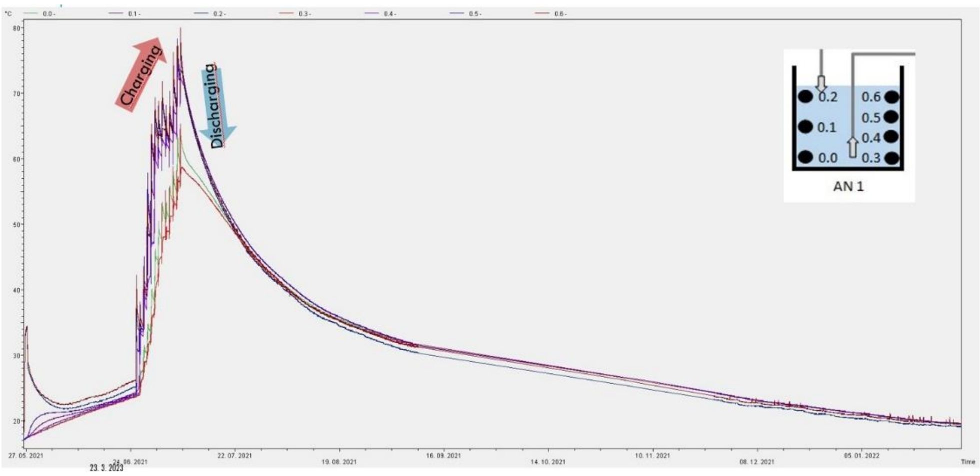

Figure 9: PTES system efficiency 39% in 2017

Regular temperature readings indicate a slower discharge rate compared to the previous period, transitioning from quadratic to linear at specific temperatures, as well as Figure 9.

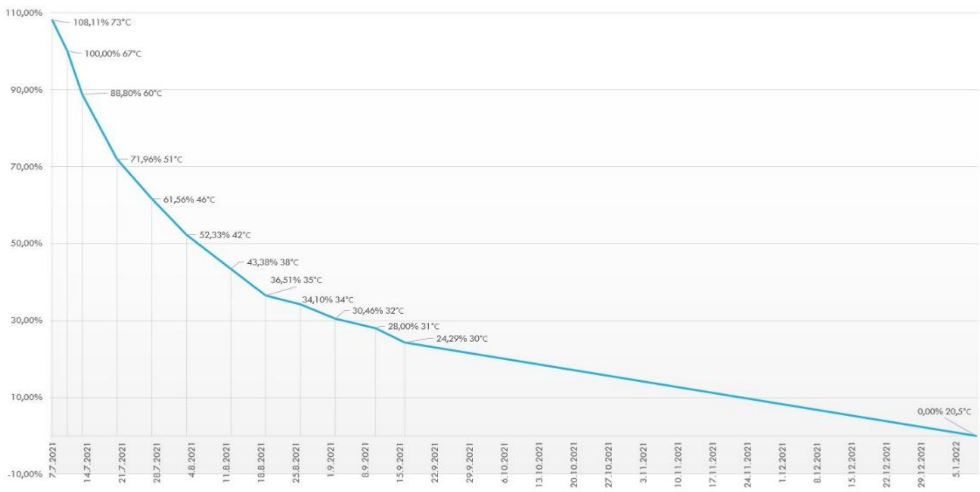

Figure 10: Presents a percentage graph with the coverage

Although we charged the tank up to a temperature of 73°C, for comparison purposes, we standardized it to 67°C. The thermal cover proved to be effective, as demonstrated by the temperature readings. For example, after 3 weeks of discharging, the temperature dropped from 34°C before covering to 46°C after covering, as well as Figure 10. It took 183 days for the tank to discharge back to its original temperature of 18°C.

4 Conclusion

We discuss the latest innovations in thermal energy storage (TES) and analyse the potential challenges and opportunities that lie ahead. We also consider the possible direction of development in this field and the impact that new technologies and societal trends may have on the future of TES.

Considerations for the use of phase change materials (PCMs) in our thermal energy storage in tanks (TTES) research open the door to improving the efficiency and performance of our system. PCM materials could absorb and release large amounts of heat during phase change, allowing for efficient thermal energy storage and release.

Incorporating PCM materials into TTES systems could lead to stabilization of tank temperatures and minimization of heat losses. In this way, we could optimize the use of thermal energy and increase the efficiency of our system, allowing us to better utilize the stored thermal energy for building heating and other thermal processes.

In addition, the use of PCM materials would allow more flexible management of the charging and discharging of the tanks according to actual needs and seasonal changes. This would allow us to use thermal energy more efficiently and improve the overall efficiency of our TTES system.

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