High temperature heat storage for the thermal centre Dürnrohr

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Motivation

The thermal centre Dürnrohr was erected in the course of the installation of the waste inclination plant Dürnrohr, which was extended later by the erection of a third line and a further steam turbine. Excess steam of the waste incineration plant and of the second unit of the coal power plant Dürnrohr is used to feed the thermal centre. The steam from the thermal centre is distributed to different consumer: At first the steam is used within a steam turbine to produce electricity. Based on the heat requirement steam is extracted from a steam turbine to feed the thermal centre. The steam from the thermal centre is distributed to the district heating network for the region Tulln and St. Pölten in Lower Austria, for the self-sufficiency of the waste incineration plant and as process steam for the bioethanol plant AGRANA.

Waste is a non-uniform substance resulting from a heterogeneous mixture of different reconditioned secondary fuels from household or industry. Therefore, the caloric value of the waste fraction at the combustion grate can have a considerable short-term fluctuation. This will result in a fluctuation of the produced steam of the single waste incineration line. These steam fluctuations at the entrance of the steam turbine can be 10 t/h up and down within a period of 15 minutes. A thermal energy storage can play an important role to smooth peak loads and to homogenise the load profile of the steam boiler.

The aim of the project was a detailed techno-economic design of the investigated thermal energy storage technologies to get a solid technical and economic basis for a targeted selection of an optimal thermal energy storage concept for the heating centre Dürnrohr.

Boundary condition for the storage design

The boundary conditions on required storage capacity, storage power, the charging- and discharging parameter as well as of the charging and discharging time for the usage of the storage technologies under investigation was determined from the project partner EVN based on in-house data for the thermal centre Dürnrohr (see Table 1).

Tabelle 1: Boundary condition for the storage design

Name	Parameter
Storage capacity	70 MWh_{th}
Storage power	10 MWh_{th}
Feed water temperature	40 °C
Charging parameter	Steam: 50 bar, 380 °C
Discharging parameter	Steam: 17 bar, 210 °C
Discharging time	7 hours

The discharging parameter show a temperature level of 210 °C at a pressure of 17 bar, which is higher than the saturation temperature of approx. 204.3 °C at 17 bar. Therefore, it is necessary for a storage technology, like the Ruth-storage, which can produce only saturated steam, to arrange downstream of the storage unit a heat exchanger for superheating the saturated steam. In the present case, this subsequent superheating of the saturated steam of approx. 6 °C does not represent a limitation for the selection of storage technologies. Therefore, no restrictions to any storage technology is given and all predefined storage technologies can be used for the investigation.

Funding agency and project partner

The research project was funded from the Austrian Research Promotion Agency (FFG) within the program line Energieforschung (FFG Project number 858916)

Storage design and cost analysis

For the thermal centre Dürnrohr four predefined storage technologies (Ruth storage, latent storage, packed bed storage and the SandTES-technology) are analysed for their eligibility for the integration into the thermal centre. For this purpose, different RI variants were developed for a possible integration of the individual storage technologies, based on the boundary conditions defined in the consortium for the operation of the storage. The individual storage units were then dimensioned and designed, and the costs for the main components of the storage units were requested from the corresponding component suppliers, which are necessary for determining the capital costs of the technologies. The project was rounded off with an estimate of the capital and operational costs for the individual storage technologies.

In principle, it must be noted that the storage task is of a latent nature on the process side, because it is about storing saturated steam at 17 bar. Due to the great flexibility of the local steam system, an operating solution could be designed at the Dürnrohr site, which also enables the use of sensitive storage technologies (sandTES and packed-bed regenerator). Depending on the concept, temperature rises in the range of 130 to 180°C could be realized. This is not in the optimal economic range for sensitive high-temperature storage (strokes between 200 and 400°C would be desirable), but it still allows the technically correct use of the technologies.

If the charging and discharging processes of the storage tanks are considered in detail, two different constellations emerge, which affect their design on the one hand and their mode of operation on the other.

During charging the storage, there is primarily a sensitive heat transport (a latent portion would only have to be taken into account in the case of a small partial condensation of the heat transfer medium) from the heat transfer medium.

During the discharging process of the storage tank, the heat transfer medium primarily receives an evaporation (the heat transfer medium is completely evaporated and then the saturated steam receives a very slight overheating of approx. 6 °C) and there is therefore a latent process.

The pinch point is of great relevance during the discharging process, as it plays an important role in the dimensioning of the heat exchanger. In addition, the pinch temperature difference has a significant influence on the temperature rise and, in the case of sensitive systems, on the storage size and the material mass flows to be circulated.

The cost analysis following the dimensioning of the storage showed that the Ruths storage due to its significantly higher investment costs (approx. 47% related to the costs of the SandTES technology with longitudinal ribs) in the present case (high storage energy of 70MWh_{th}) is clearly worse off economically. The costs for the SandTES technology, latent heat storage and fixed-bed regenerator, on the other hand, are of the same order of magnitude.

As already described above, the heat transfer processes that take place during energy charging and discharging are largely associated (especially in the case of discharging the storage tank) with a change in the physical state of the heat transfer medium. This operating behaviour of the heat transfer medium corresponds approximately to that of a latent heat storage device. With the same investment costs compared to the packed-bed regenerator and the SandTES technology, this speaks for a preferred integration of the latent heat storage technology in the Dürnrohr heat node.

If an immediate investment decision were to be made, it would also have to be taken into account that the SandTES technology has so far only been tested on a pilot scale with smooth tubes with longitudinal flow, and that the question of thermal ratcheting in large storage systems has not yet been sufficiently clarified in the case of fixed-bed regenerators.