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High temperature latent heat thermal energy storage integration in a co-gen plant

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Abstract

Within the framework of the project TESIN funded by the German Ministry of Economic Affairs and Energy, a high temperature latent heat thermal energy storage unit is being developed and will be designed, built, commissioned and tested in an operating cogeneration plant in Saarland, Germany. This plant provides superheated steam to industrial process customers from a gas turbine with a heat recovery steam generator. Currently, a secondary boiler is operated at minimal load, from which it can be heated to full load in 2 minutes. With the integration of the thermal energy storage into the plant, the secondary boiler will be reduced from minimal to warm load operation. In case of a failure of the gas turbine, the storage will produce steam for 15 min. while the secondary boiler is heated from a warm to a hot operating load. This standby load reduction in the secondary boiler will reduce the use of fossil fuels.

The steam demand from the thermal storage is for 8 t/h at around 25 bar and a minimum temperature of 300 °C. This results in a high power level of about 6 MW_{th} and a necessary storage capacity of 1.5 MWh. At this pressure level, the steam is superheated about at least 75 K. The combination of the superheating and the required power level has led to a smaller tube distance than in previous storage units as well as a new axial fin design. The basic storage as well as the fin design combined with nitrate salts as the storage material have been analyzed with simulation tools. Detailed design planning, permitting and build of the system are the coming steps in this part of the project. The design of these fins, storage unit design and planned integration in the cogeneration plant are presented here.

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Keywords: Latent heat storage; standby; superheated steam

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1. Introduction

The cogeneration plant in Saarland consists of a gas turbine with a heat recovery steam generator (HRSG) and two back-up boilers. The gas turbine burns mine gas from the mine gas network existing in Saarland. Due to the nature of mine gas, the methane content in the supply sometimes varies. This – and technical issues always possible in a heat generator – can result in the gas turbine tripping and the supply of steam to the customer sinking in quality. The customer requires a very constant steam quality for the production processes. To ensure this delivery, Steag New Energies has a back-up boiler running on minimal load. At minimal load, there is a constant firing of fossil fuels. The steam created by this firing is disposed of. In the case of the turbine tripping, this back-up boiler can be transitioned to full load within two minutes, during which time the HRSG produces residual steam. With the integration of a thermal energy storage unit, the back-up boilers can be reduced to a warm load. At warm load, in comparison to minimal load, much less fossil fuel has to be burned in order to keep the pressure vessels at a high temperature. From warm load, it takes 15 minutes to transition to full load. During this time span, the thermal energy storage will supply the necessary steam to the steam main. This standby load reduction in the secondary boiler will reduce the use of fossil fuels.

2. Methodology

2.1. Planned integration into the cogeneration plant

The steam demand for the customer is for 8 t/h at about 25 bar and a minimum temperature of 300 °C. The steam is produced in the HRSG using feedwater with an inlet temperature of 103 °C. In order for a thermal storage unit to allow the standby boiler to be run at warm load, it has to produce steam from this feedwater at the power level of 6 MW for a minimum of 15 minutes. The minimally required storage energy capacity is thereby 1.5 MWh.

Since evaporation is required for discharging, a latent heat thermal energy storage unit has been developed for integration. In a latent heat thermal energy storage unit, the storage material undergoes a phase change from liquid to solid and back again for discharging and charging, respectively. During phase change, the material supplies or stores the latent energy. Each material has its inherent material properties and therefore a set phase change temperature. The higher the specific capacity of the material, the more sensible energy it can store as well. Ideally, the material has a high thermal conductivity, in order to charge and discharge quickly. However, this is often not the case [1]. Due to this low thermal conductivity, various designs and storage concepts have been researched and tested [2]. A method tested in various storage units at DLR is the use of extended fins to increase the overall surface area of the tubes [3]. Extended fins allow for heat to be transferred from the phase change material (PCM) that is far from the tube, while allowing the heat transfer medium to be pressurized in a steel tube. Essentially, the design of extended fin storages is similar to tube-and-shell heat exchangers, so that a foundation of design knowledge for headers and flow can be relied upon. The axially oriented fins analyzed and planned for this storage unit offer potential cost reductions in the assembly and also have thermodynamic benefits. The nitrate salts used as PCMs in the temperature range between 140 °C and 350 °C undergo a volume change during phase change [1]. As PCM will melt along the axial fins during charging, this liquid PCM provides its own channel for movement to the top of the storage area and the volume change in the PCM is no longer critical.

As shown in the integration schematic in Fig. 1, the storage will be charged with steam from the HRSG and discharged with feedwater.During discharging, feedwater(blue line from the feedwater tank at the bottom right) flows into the bottom of the storage, evaporates to steam and is superheated as it rises through the tubes in the storage, leaving the storage as superheated steam. Heat is transferred from the storage material to the water/steam, thereby leading to a solidification of the storage material.