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Experiences with drying of lignite in a pressurized steam fluidized bed pilot plant

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1. Introduction

In Germany lignite is the largest energy source for electricity generation with a share of about one quarter of the power generation. The lignite has a moisture content up to 60 mass-%. Therefore in conventional lignite power plants about 20 % of fuel energy is used for drying prior combustion. The resulting water vapor is given together with the flue gas to the environment. The energy used to evaporate the water is thus no more available for power generation purposes. To increase the efficiency of future, more efficient, CO_2 lean lignite power plants with reduced emissions, using of dried lignite is a promising way. With the integration of a pressurized fluidized bed dryer in the overall power plant process the net efficiency increases up to 5 % - points. The required energy for the dryer is heating steam which has already done work in the steam turbine. The steam condensed in horizontal banks of tubes in the fluidized bed. The latent heat of the vapor produced during the drying is included again in the steam circuit of the power plant. The vapor has a high pressure and temperature level, which alleviates reuse of its energy in the power plant. The lignite drying under pressure leads to high heat transfer coefficients in the fluidized bed. The higher vapor density leads to reduced size of the dryer and pipes and allows higher fluidized bed, which is beneficial to the specific dryer throughput. In future CO_2 lean power plants the use of an efficient lignite drying process is important because in this way the efficiency loss of CCS (carbon capture and storage) can be compensated partly

2. Pressurized steam fluidized bed pilot plant

Construction work for the pilot plant located in Schwarze Pumpe, Germany, with a raw coal throughput of 10 tons/h and a maximum operation pressure of 6 bar (absolute) started in 2007. The pilot plant is in operation since October 2008. Until the end of 2010 14 test runs have been completed successfully. Design, construction and realization was done by Steinmüller Instandsetzung Kraftwerke GmbH. Based on the knowledge and experience from a drying facility with 0,5 tons/h raw lignite throughput from the Brandenburg University of Technology the

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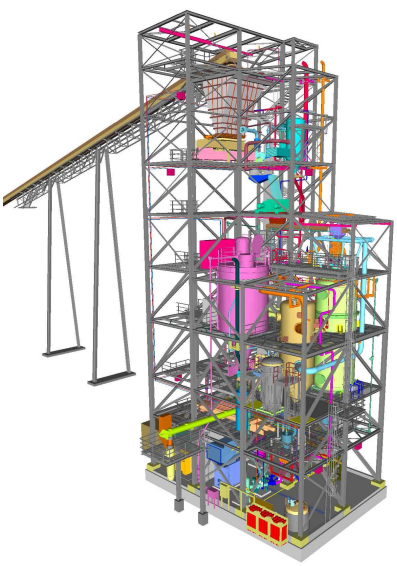
pilot plant is realized with a scale-up factor of 20 which is a reasonable step towards the realization in commercial scale.

The design point for the residual moisture content for the dry lignite ranges from 12 to 17 mass-% with a system pressure of 1 to 6 bar. The residual moisture content is basically a function of the overheating of the fluidized bed temperature and the system pressure thus the driving temperature. Overheating of the fluidized bed depends on the steam parameters used in the heat surface, where steam of up to 16 bar condenses at saturation temperature. The pilot plant is designed to cover a broad operation range with respect to throughput and system pressure in order to investigate the behavior under different loads and to find the optimum settings. Other factors that are analyzed are i.e. fluidization velocity, bed height or the influence of the particle size of the lignite. In total more than 100 measuring points are used for operation and are further processed and evaluated.

For the pilot plant wet refinement lignite with a particle size of 0 to 6 mm is used (coarse particles) that is milled with a hammer mill to a particle size of 0 to 2 mm. This is in favor of a high heat transfer coefficient in the fluidized bed and diminishes the need to have a separate milling after the drying process.



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3. Operation experience

Since the initial operation in 2008 more than 23.000 tons of raw lignite in more than 4.500 operation hours have been processed. In addition to that several thousand operation hours have been used for tests without lignite, i.e. nozzle pressure drop under different conditions, leakage steam measurement without lignite or start and shutdown tests. Continuous evaluation of the results, improvements in operation and design gradually increased availability and delivered important results for the further up-scale of the technology. The pilot plant is operated on a 3-shift basis round the clock with tests runs of more than thousand continuous operation hours. Results do therefore also include and give information about long term influences and stability, components wear and availability. Some of the main experiences are presented in the following.

3.1. Leckage steam

As a result of the high system pressure one of the main technical challenges is the product feed into the pressure vessel. A rotary feeder is used for feeding the raw lignite into the dryer vessel and to realize sealing with a pressure difference up to 5 bar between the atmospheric and the maximum operation pressure. With several thousand operation hours a lot of knowledge regarding means of sealing, feeding performance under different pressure conditions, heating of casing and rotor have been gained. Ongoing optimizations and the installation and evaluation of new components help to further increase availability and knowledge generation.

The vapor generated during the lignite drying process is used energetically in a future power plant unit. Thus, vapor losses especially under pressurized operation containing more exergy than under atmospheric pressure need to be minimized. Nevertheless, entry and discharge components usually have some sort of leakage, which increase with system pressure. To evaluate the losses it is necessary to measure the amount of leakage steam in different operation states. The amount of leakage steam provides information about the quality of the used sealing system or the component wear. Furthermore, it is a very important measure to compare and evaluate different feeding systems.

3.2. Residual moisture content and heat transfer coefficient

The residual moisture content is influenced by system pressure and fluidized bed temperature. Whilst the system pressure is an operation value, the necessary bed temperature depends on the dryer design, basically the dwell time, and can only be determined by experiment. By varying the drying parameters it is possible to extract several desorption isobars – an equilibrium of temperature and residual moisture content for a given pressure and throughput – from the process data.

Another design specific parameter is the necessary heat surface temperature. A certain heat flux is dependent on the heat surface area, the driving temperature between heat surface and bed temperature and the heat transfer coefficient, the U-value. Data from the pilot plant show high heat transfer values of more than 400 $W/(m^2 * K)$ under atmospheric pressure. The heat transfer value is expected to increase with system pressure which has been shown at the test unit at Brandenburg University of Technology and also could be reproduced at the pilot plant.

3.3. Load change behavior

The investigation of load change behavior of the pilot plant is important for the scale up of the technology when implemented in a new or existing (drying upgrade) power plant. In a direct coupling between boiler and dryer very high speeds of load change are needed to meet the grid requirements. The operational challenge is to stay within the required fuel specification for the boiler to not exceed firing temperature and to stay within the limits of the flue gas capacity. Both are related to too low and too high residual moistures contents of the dried lignite delivered to the boiler, respectively. Results from the pilot plant show that even under erratic load changes speeds of up to 40 % the residual moisture content of the dried lignite stays within +/- 1 mass-% limit. A control algorithm based on a characteristic map that links a specific lignite type and the target residual moisture with the required bed overheating is used.

3.4. Dry lignite production for Oxyfuel pilot plant

The PFBD-pilot plant is equipped with a dry lignite tanker loading unit. Therefore dried lignite with specific parameters like residual moisture content or particle size that varies from standard coal dust products from refining facilities can be delivered. Furthermore, the capacity of the PFBD-pilot plant equals the raw coal requirement of the Oxyfuel pilot plant. The boiler with a thermal capacity of 30 MW_{th} is usually fired with dry lignite dust of about 10 mass-% moisture content which can be substituted with dry lignite from the PFBD-pilot plant.

First test were finished successfully at the end of 2010 delivering more than 600 tons of dry lignite with a moisture content ranging from 6 to 14 mass-% with deviations of as low as +/- 1 mass-% to the Oxyfuel pilot plant. The pilot plant proved stable operation with a very high overall availability of over 95 % in several hundred operation hours. Load change behavior regarding throughput and moisture content in continuous operation met the

expectations. The test run successfully proved the coupling of advanced drying and boiler technology as it will be present in future power plant generations.

4. Prospects

Vattenfall intends to build a CCS demonstration plant in Jänschwalde that will investigate two CCS technologies, Oxyfuel and postcombustion capture. The 250 MW_{el} Oxyfuel boiler will use dry lignite, produced in an integrated PFBD-plant. The integration of pre-drying technology is necessary to cover some of the high efficiency losses due to the installation of CCS-technology. Drying technology is not only an important factor for CCS-technology but also an option for existing units. Lignite pre-drying technology can be used as an upgrade to process a fraction of the total lignite consumption of the unit to increase the overall plant efficiency and lower CO_2-emissions.