Using waste heat recovered from coal-fired boiler flue gases to improve electricity generation efficiency

PhD thesis – abstract

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The aim of this doctoral dissertation is to analyze the use of waste heat recovered from the coal-fired boiler flue gases to improve the efficiency of electricity generation. The object of the analysis is a high efficient 900MW coal-fired power unit for supercritical steam parameters. For this power unit, the waste heat amounts to about 30 MWt, whereas for brown coal it is about 64 MWt.

This dissertation presents an analysis of three methods of using waste heat recovered from the hard coal- and brown coal-fired units. The heat may be used to:

1. heat the agent in low- and high pressure regeneration of the main cycle,

2. feed Organic Rankine Cycles (ORC's) operating with different agents featuring a low boiling point,

3. dry brown coal.

An analysis of the use of heat recovered from inter-stage coolers in the CO2 compression process is also carried out.

Heating the condensate with heat recovered from flue gases leads to a reduction in the mass flow of steam directed from the turbine bleeds to regenerative heaters. This results in a rise in the electric power of the turbine set at the same boiler efficiency or, vice versa, it is possible to reduce the amount of steam generated in the boiler for the same power capacity of the turbine set. The potential improvement in electricity generation efficiency for a hard coal-fired power unit may reach from 0.15 percentage points for heat recovery in low pressure regeneration to 0.60 percentage points for heat recovery in high pressure regeneration, and from 0.39 to 1.25 percentage points, respectively, for heat recovery in a brown coal-fired power unit.

The use of waste heat recovered from flue gases to feed ORC's is analyzed. Several low temperature agents are considered and the power capacity, the efficiency and the unit operation of these cycles are determined. The impact of the ORC regenerative exchanger on the increase in the efficiency and on the power capacity of the power plant is defined. For ORC's fed with hard coal flue gases, the highest power capacity of the ORC is achieved for the R218 agent (with a regenerative exchanger), and it amounts to 4.47 MW. An identical analysis is performed for ORC's fed with flue gases from a brown coal-fired power unit. In this case, the highest power capacity, amounting to 13.42 MW, is achieved for isobutane (with a regenerative exchanger).

Additional generation of power in the ORC results in an increment in the overall power capacity of the power plant by about 0.24 percentage points for a hard coal-fired power unit and by about 0.68 percentage points for a power unit fired with brown coal.
In the third variant, the use of the boiler flue gas waste heat to dry brown coal is analyzed. In this case, the potential increase in the power unit efficiency amounts to about 1.7 percentage points.

An analysis is also made of the possibility of using waste heat recovered from the coolers of the carbon dioxide compressor to heat the condensate in the power unit regeneration system. The achieved improvement in efficiency for a hard coal-fired power unit amounts to about 0.82 percentage points, whereas for a brown coal-fired power unit it is about 0.96 percentage points.

The use of waste heat recovered from inter-stage coolers in the CO2 compression process is also considered with respect to feeding ORC's. Several agents with a low boiling point are analyzed. For

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heat recovered from hard coal flue gases as a result of CO_2 compression, the total power capacity of ORC turbines amounts to about 20 MWe, whereas for brown coal flue gases it is about 26 MWe.

An economic analysis for different power unit configurations is also conducted. Economic profitability indices for different options of the power unit are determined.

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