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Improvement of load-following capacity of grate boilers based on the combustion power soft-sensor

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Abstract

For improving the load-following capacity of existing grate boiler units, a model predictive control concept based on the combustion power soft-sensor is developed. Because the combustion power estimation has a very quick response to the primary air flow input, the load-following speed of the boiler control system will be improved considerably. The proposed model predictive control strategy is tested with the BioPower 5 combined heat and power plant data and the results are presented, analyzed, and discussed.

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*Keywords:*combustion; power; soft-sensor; grate; load; capacity

1. Main text

Renewable energy sources are considered on the priority level of energy policies in Europe and many other contries worldwide. The European commission has endorsed a mandatory target of a 20 % share of energy from renewable sources in overall consumption by 2020. This leads to an introduction of an increasing share of energy produced from natural resources, such as hydro power, wind, solar, wave, geothermal, waste fuels, as well as biomass and waste heat, into the existing energy networks. With more and more wind power and solar power units integration on power systems, there has been an increased demand on the load-following capabilities of the other power units.

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In [1], Wang et al. proposed an improved coordinated control strategy (CCS) combined with cold flow adjustment on account that cold source parameter has rapid and large influence on the turbine power output. The control strategy utilizes cold source flow adjustment (CSFA) to accelerate the load following capability, coal feeder rate to ensure the control accuracy of turbine load, and the turbine governor valve to avoid large fluctuation of main steam pressure. The simulation studies on the 300 MW unit showed that after 10 MW step order of turbine power is given, the turbine power with improved strategy reached its equilibrium state after about 7 seconds. However, it took over 50 seconds when using the traditional CSS. In addition, the improved strategy had a much smaller overshoot than traditional CSS.

Mortensen et al. [2] developed a control concept based on a scheduled linear-quadratic-Gaussian (LQG) controller with coordinated feedforward from the boiler load demand to fuel flow and feedwater flow for the purpose of improving the load-following capability of existing power-plant units. Field tests on the 265 MW coal-fired power plant unit revealed that the maximum allowable load gradient can be increased from 4 to 8 MW/min without further plant stress.

Wang et al. [3] developed a new method for the boiler control system based on radiation intensity for improving the load-following capacity of a coal-fired power plant. Field tests on a 300 MW coal-fired plant revealed that the improved boiler control system increased the load-following capacity. Also, indirect methods have been used to measure radiation intensity or combustion power in the furnace. According to the theoretical studies and practical tests by Kortela and Lautala [4] at the coal power plant, the fuel combustion power can be estimated on the basis of the measured oxygen consumption. The method assumed a constant fuel moisture content, although the relative ration of oxygen in flue gas is affected by the variation of the fuel moisture content, which introduces the error to the estimation.

Recently, the above mentioned combustion power method was improved by Kortela and Jämsä-Jounela [5] who estimated the fuel moisture content from the dynamic energy balance of the secondary superheater involving the combustion power estimation. Because the combustion power estimation has a very quick response of less than 1.5 minutes to the primary air flow input, the load-following speed of the boiler control system will be improved considerably.

In this paper an improvement of load-following capacity of BioPower 5 combined heat and power (CHP) plant plant is presented. The paper is organized as follows: Section 2 presents the BioPower 5 CHP process. The developed model predictive control (MPC) strategy is presented in Section 3. The test results are given in Section 4, followed by the conclusions in Section 5.

2. Description of the BioPower 5 CHP process

The BioPower 5 CHP process consists of two main parts: the furnace and the steam-water circuit. The heat used for steam generation is obtained by burning solid biomass fuel – consisting of bark, sawdust, and pellets – which is fed into the furnace together with combustion air. The heat of the flue gas is transferred by the heat exchangers to the steam-water circulation, where superheated steam is generated [6].

In the BioGrate system, the fuel is fed onto the center of a grate from below through a stoker screw, as shown in Fig. 1. The grate consists of alternate rotating and stationary concentric rings with the rotating rings alternately rotated clockwise and counter-clockwise by hydraulics. This design distributes the fuel evenly over the entire grate, with the burning fuel forming an even layer of the required thickness.