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Simulation of a coal-fired power plant using mathematical programming algorithms in order to optimize its efficiency

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HIGHLIGHTS

- Modeling and simulation of the flue gases circuit of a specific plant.
- Designing of modules in gPROMS FO (Foreign Objects).
- Simulation of the complete detailed plant with gPROMS.
- Optimization using a non-linear optimization algorithm of the plant's efficiency.

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ABSTRACT

Since most of the world's electric energy production is mainly based on fossil fuels and need for better efficiency of the energy conversion systems is imminent, mathematical programming algorithms were applied for the simulation and optimization of a detailed model of an existing lignite-fired power plant in Kozani, Greece (KARDIA IV). The optimization of its overall thermal efficiency, using as control variables the mass flow rates of the steam turbine extractions and the fuel consumption, was performed with the use of the simulation and optimization software gPROMS. The power plant components' mathematical models were imported in software by the authors and the results showed that further increase to the overall thermal efficiency of the plant can be achieved (a 0.55% absolute increase) through reduction of the HP turbine's and increase of the LP turbine's extractions mass flow rates and the parallel reduction of the fuel consumption by 2.05% which also results to an equivalent reduction of the greenhouse gasses. The setup of the mathematical model and the flexibility of gPROMS, make this software applicable to various power plants.

1. Introduction

Fossil fuels will remain the dominant source of primary energy worldwide with participation greater than three-quarters of the overall increase in energy use between 2007 and 2030 [1]. In fact, an expected average annual increase of 1.5% of energy demand for that period will result at 16,800 Mtoe from 12,000 Mtoe that is now, meaning a 40% total increase of the produced energy is expected. That increase will occur due to the immense growth of energy needs for power generation of the developing countries such as China. As expected, one such increase will lead to an increase of the CO_2 emissions about 1.5% annually as well, together with other greenhouse gases (GHG) emissions. The alternative which has been widely promoted relies on renewable sources. However, investments on renewable energy sources, as well as oil and gas, require great amounts of financial resources. Also, attractive pricing of fossil fuels gives them the lead over clean – and more expensive – energy sources. Taking into account all of the above, need for a more efficient use of fossil fuels as well as an optimized operation of the units that use them already is imminent. Many researchers focused to the optimization of the operation of power plants during the last decade. Simulation of the combustion chamber of the boiler by creation of a 1-dimensional pseudo-homogeneous mathematical model, using the physical properties of the fuel as variables by Rodrigues et al. [2] and Perrin [3] was conducted, proceeding to the optimization of the operation of a 500 MW power plant with the fuel cost being the objective function. This work was conducted with the help of MATLAB and produced satisfactory results apart from an 11% difference between the measured and calculated mass flow rate of the output high-pressure turbine's steam. Other related

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