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ScienceDirect

Energy Procedia 120 (2017) 439–446

Energy Procedia

www.elsevier.com/locate/procedia

INFUB - 11th European Conference on Industrial Furnaces and Boilers, INFUB-11

Local steam temperature imbalances of coal-fired boilers at very low load

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Abstract

In order to remain economically viable, even large coal-fired power plants must be operated more often in partial load. Due to an unfavourable coal mills configuration, the local temperatures in the combustion chamber can differ. This can affect the temperatures in two parallel steam lines so much that even a shut-down of the entire system would be necessary. The modelling and subsequent simulation of the plant is a proven way to identify problems and to show the limits of the minimum load.

Peer-review under responsibility of the organizing committee of INFUB-11

Keywords: Coal-fired power plant; simulation; local temperatures; steam lines; minimum load

1. Introduction

The German energy market is currently undergoing a fundamental change. More and more wind and solar energy is being converted into electric power. With the expansion of such highly fluctuating power generator facilities, larger amplitudes of load steps will be retrieved. These must be provided mainly from thermal power plants. Consequently, larger coal-fired power plants also have to expect an increasingly unsteady power plant schedule. There are many situations where it is beneficial to keep power plants running in low load instead of shutting down and restarting again. Decreasing the minimum load, while maintaining a stable operation point, is therefore an important factor for a sustainable energy system including increasing shares of fluctuating renewables.

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1876-6102
Peer-review under responsibility of the organizing committee of INFUB-11
10.1016/j.egypro.2017.07.206

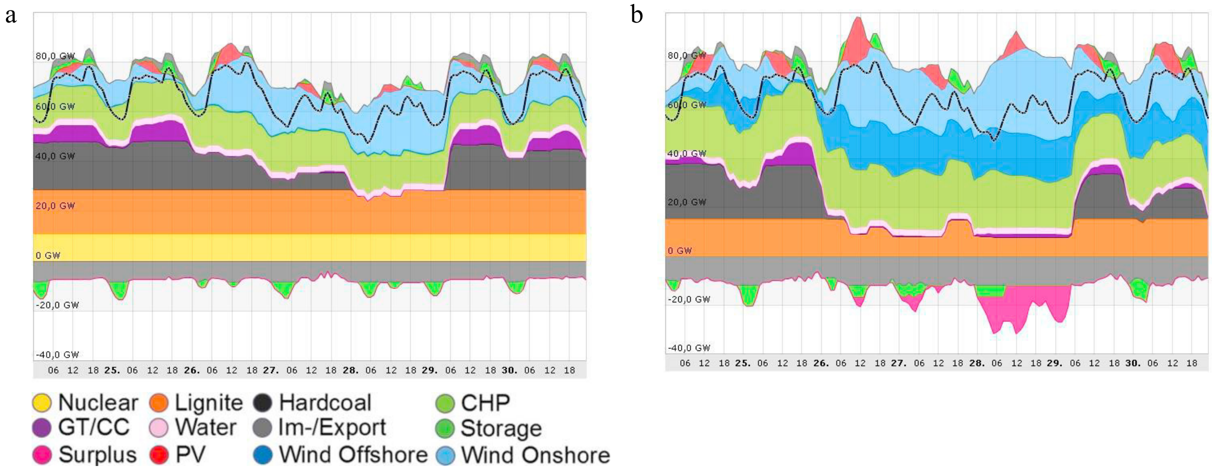

Fig. 1. Composition of the German electric energy for a winter scenario in (a) 2011; (b) 2023.

Figure 1 shows the share of electrical energy for a typical winter week in 2011 and a forecast for the year 2023 of the different types of power plants which contribute to the demand for electrical energy in Germany [1].

While in the past the base load has been provided by nuclear power plants, lignite coal-fired power plants and, with some limitations, hard coal-fired power plants, these will only be a minor share in the future.

The consumer load is represented in the graphics by the black line. Electrical energy cannot be stored efficiently and on an industrial scale, but supply and demand must be balanced at all times. The indicator for this is the mains frequency. Two different consequences can be observed. On the one hand, the residual load decreases, and on the other hand, the need for balancing power increases. In addition to economic considerations, this is the second reason why it is not always useful to completely shut down thermal power plants in windy and sunny times.

Therefore, the use of the power plant at minimum load becomes more important. The investigation of such scenarios is an important part of today's energy research because it presents new challenges for thermal power plants.

2. Modelling

All the investigations presented here are based on dynamic power plant simulation. By taking into account the transient thermal equilibrium in the balance equations, physical effects during the load change are visible and traceable. One potential use of the dynamic power plant simulation is to obtain accurate data on temperature and pressure gradients within components and thus to determine the loss of lifetime of system components by a load change. Another example would be to analyze the effects of soot blowers on the dynamic behavior of power plants. Such investigations can be found, in [2] [3] and [4]. This investigation is a purely static one. Therefore, all parameters in the following validation and result plots are related to a fixed power setpoint.

The model is based on the open-source, object-oriented programming language Modelica. As a development and simulation environment the commercial tool Dymola is used. Dymola supplies some model libraries as well as the numerical equation solvers. The DASSL (Differential-Algebraic System Solver) has been used for all simulation scenarios. Most models for the components of the power plant come from the non-commercial software ClaRa library(Clausius-Rankine-Cycle). Important material data are from the TILMedia library.

For each module, the mass and energy balance is solved for each simulation step. It is constituted as follows: