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Development of artificial neural network model for a coal-fired boiler using real plant data

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ABSTRACT

Development of artificial neural network (ANN) models using real plant data for the prediction of fresh steam properties from a brown coal-fired boiler of a Slovenian power plant is reported. Input parameters for this prediction were selected from a large number of available parameters. Initial selection was made on a basis of expert knowledge and previous experience. However, the final set of input parameters was optimized with a compromise between smaller number of parameters and higher level of accuracy through sensitivity analysis. Data for training were selected carefully from the available real plant data. Two models were developed, one including mass flow rate of coal and the other including belt conveyor speed as one of the input parameters. The rest of the input parameters are identical for both models. Both models show good accuracy in prediction of real data not used for their training. Thus both of them are proved suitable for use in real life, either on-line or off-line. Better model out of these two may be decided on a case-to-case basis depending on the objective of their use. The objective of these studies was to examine the feasibility of ANN modeling for coal-based power or combined heat and power (CHP) plants.

1. Introduction

Accurate modeling and simulation of components of power plants are very important for training, strategic planning and maintenance, techno-economic decisions as well as continuous monitoring of the operation of the plant. With increasing concern for environment and market that is more competitive after the deregulation of electricity, the need for better and more user-friendly simulation and monitoring tools is even more stringent.

Physical models used for simulation are based on physics of the processes and consist of equations representing these processes. These models are rather complex. Moreover, uncertainty of a physical model increases with time as the equations representing the plant processes may become inappropriate due to the degradation of the plant.

In existing plants, large number of operational data is captured continuously by the on-line plant's monitoring system for its proper operation. These are usually stored as database only. Using these data, artificial neural network (ANN) models can be created for the simulation of the plant operation. ANN models are more useful than physical models as these can be trained occasionally with latest data even to take care of the degradation of the plant. Moreover, by comparing the prediction of previous ANN model with that of a later model, plant degradation may be assessed. These models are easy to use, fast in response and thus suitable for 'off-line' and 'on-line' applications.

Kalogirou [1] has presented a brief review of applications of ANN in different energy systems. Mellit [25] outlines an understanding of how artificial intelligence systems operate by way of presenting a number of problems in photovoltaic systems application. The use of soft computing techniques for simulation of thermodynamic systems is presented by Kesgin and Heperkan [2]. It is particularly useful in system modeling in implementing complex mapping and system identification. Several authors [3–5] have reported the capability of ANN to replicate an established correspondence between points of an input domain and points of an output domain to interpret the behavior of phenomena involved in energy conversion plants. Thermal Power Engineering Division of the Department of Energy Sciences, Lund University has carried out several investigations in this field and ANNs have been shown to be a good candidate for fault diagnosis, process identification and modeling of the non-linear systems in energy field [6–8]. The boiler is undoubtedly an important equipment of a power plant or combined heat and power (CHP) plant. Physical modeling of a boiler is difficult and complicated [9–18]. However, ANN models can be developed for them with definite objective

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Nomenclature

F	transfer function
m	mass flow rate (kg/s or t/h)
p	pressure (bar)
r	coal carrying belt conveyor rotational speed (rpm)
t	temperature (°C)
w	weight
x	input parameter
y	output parameter
Φ	valve opening (deg)

Subscripts

h	hidden layer
o	output
fs	steam
fw	feed water
fuel	fuel (coal)
1–4	coal carrying belt conveyors 1–4

Superscripts

B	boiler
in	inlet
out	outlet
V	valve

and training with data from existing plant with lesser effort but with great utility. However, there are very few reported works [19–22] on the modeling of conventional coal-fired boilers using ANN and neither of them is using real plant data.

In this paper, development of ANN models of a coal-fired boiler of a CHP plant in Slovenia is presented. ANNs were trained with the real-life data from the same plant. The objective of the model was to predict mass flow, pressure and temperature of steam exiting the boiler. Required input parameters were initially selected on the basis of expert knowledge and previous experience. However, the final set of input parameters was decided through sensitivity analysis for an optimization between the number of input parameters and the desired accuracy of prediction. An alternate model with belt conveyor speeds as input parameters instead of mass flow rate of coal has also been discussed as the belt speeds are real controllable parameters for the mass flow rate of coal. Both models are found to be quite good in prediction of steam properties from the boiler. Issues related to proper selection of data from available data for training of ANN and possible reasons of errors in prediction by the model have been discussed. Developed model was also checked with real operational data not presented to the ANN during training for validation of the model for real-life applications. Both models are found to be suitable for 'on-line' applications also. This work is one of the series of studies made on ANN modeling of coal-based power plants and CHP plants. These studies explore the aspects of generalization of ANN modeling of such plants, if any and establish a road map for future studies.

2. Brief description of the boiler

The schematic diagram of the boiler is shown in Fig. 1. The boiler is of a drum type without steam reheating. It is fired with brown coal and has four pulverizers or mills. Two or three are in operation while one or two are in reserve. Each pulverizer has a burner with two low-NOx nozzles with circular cross-sections. Boiler produces 50 kg/s of fresh steam with temperature of 535 °C and pressure of 95 bars. The lower calorific value of coal can vary from 18 to 21 MJ/kg. In the period used for analysis in this study lower calorific value of coal was approximately constant, i.e. 18.2 MJ/kg.

Air pre-heating is carried out by two parallel rotating regenerative single-pass air heaters. Sack filters are used for flue gas cleaning. Total heat transfer surface of air heaters is 17,800 m^2.

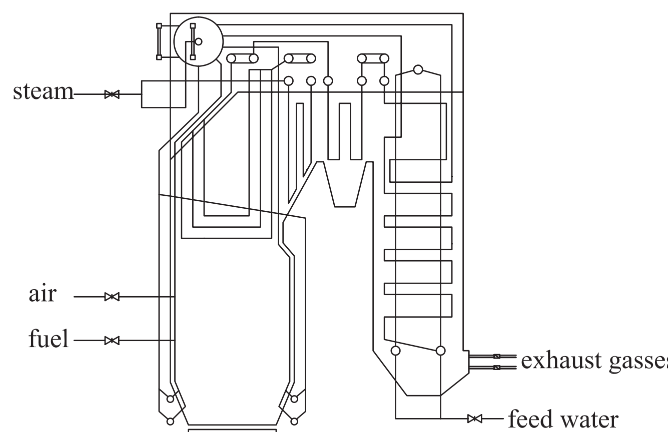

Fig. 1. Schematic diagram of the boiler.

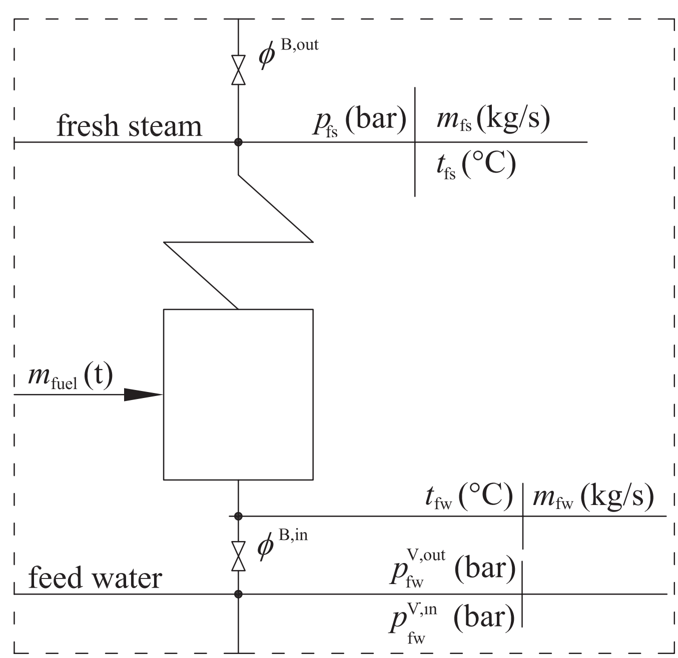

Fig. 2. Block diagram of the boiler and significant parameters.