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Data reconciliation for the overall thermal system of a steam turbine power plant

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HIGHLIGHTS

- Optimized data reconciliation system configuration for measurement uncertainty reduction.
- Improved data accuracy compared with previous sub-system studies.
- Integrated sensor and equipment performance monitoring for an overall system.
- Application to real-life measurement data from a steam turbine power plant.

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ABSTRACT

Accuracy of online measurement data is usually not satisfactory for coal-fired power plants due to constraints of measurement techniques. Data reconciliation can help to improve the accuracy of online measurement with no extra requirements on equipment upgrading. Traditionally, data reconciliation is applied to a sub-system of a coal-fired power plant, for instance, mass balance of a steam turbine system. In this work, we present a systematic approach where data reconciliation is applied to the overall thermal system of a real-life steam turbine power plant. Improvement of data accuracy is obtained via the proposed approach compared with sub-system studies. Optimization of system selection and configuration of a data reconciliation problem is analyzed. Results show that uncertainty of on-line measured data can be reduced by up to 50% in a 1000 MW ultra-supercritical coal-fired steam turbine power plant compared with previous studies.

1. Introduction

On-line performance monitoring, efficiency analysis and condition monitoring are widely used methods for efficiency and reliability enhancement of power plants [1]. Jiang et al. [2] developed a method for integrated sensor and equipment performance monitoring in power plants, which can detect and identify both sensor biases and equipment faults in the system. Blanco et al. [3] modelled a new process for multivariate detection of quasi steady states in power plants, and diagnosis outcomes could be applied to early warning systems. Nikpey et al. [4] applied a validated artificial neural network model to predict the performance parameters with high accuracy of a micro gas turbine. Promes et al. [5] investigated exergy and efficiency analysis of an IGCC power plant based on the design and operating parameters under steady state operation. Liu et al. [6] proposed an approach for the condition prediction and monitoring of nuclear power plant components based on a modified probabilistic support vector regression method.

Accuracy of on-line measured operational data is essential to the effect of these methods due to existence of measurement errors and uncertainty [7]. These measurement errors and uncertainty can also lead to inaccurate calculation of key performance indicators of a power plant, for instance, energy and exergy efficiency [8]. However, accuracy of industrially applicable measurement instruments cannot always meet the requirement of performance monitoring, due to harsh working conditions or consideration of operational costs. Therefore, data processing and correction aiming at reducing measurement errors and uncertainty with no extra requirements on measurement are of great interest to power plants [9].

In the thermal system of power plants, flow rate, pressure, and temperature are measured at various positions. These measurements are not independent. They can be linked to each other via mass balance, energy balance, heat transfer, and other

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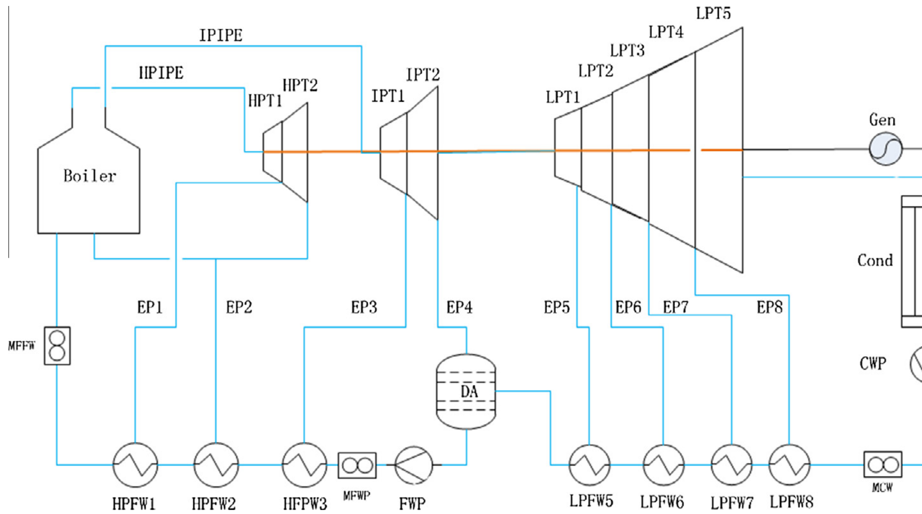

Fig. 1. An illustration of the overall thermal system of a coal-fired steam turbine power generation unit.

Table 1
Detailed descriptions of the measurements.

Measurement name	Symbol	Description
No.1 high pressure steam turbine stage (HPT1)	HPT1_m_out1	Outlet steam mass flow rate
	HPT1_m_out2	Extraction steam mass flow rate
	HPT1_p_out1	Outlet steam pressure
	HPT1_p_out2	Extraction steam pressure
	HPT1_T_out1	Outlet steam temperature
	HPT1_T_out2	Extraction steam temperature
No.6 low pressure feed water heaters (LPFW6)	LPFW6_m_out1	Outlet feed water mass flow rate
	LPFW6_m_out2	Drain water mass flow rate
	LPFW6_p_out1	Outlet feed water pressure
	LPFW6_p_out2	Drain water pressure
	LPFW6_T_out1	Outlet feed water temperature
	LPFW6_T_out2	Drain water temperature
Deaerator (DA)	DA_m_out1	Outlet feed water mass flow rate
	DA_p_out1	Outlet feed water pressure
	DA_T_out1	Outlet feed water temperature
Condensate pump flow rate measurement (MCW)	MCW_m_out1	Outlet flow rate of condensate pump

relationships, which can be expressed in terms of mathematical equations. Comparing the measured data, the number of equations and variables in them (some variables are measured while some are not), it can be found that the number of equations is usually larger than the number of unknowns, *i.e.*, redundancy exists in this system. Data reconciliation is a technique which makes use of this redundancy to reduce the uncertainty of measured data [10].

Since 1960s, a number of studies have been conducted on theories and applications of data reconciliation and gross error detection [11], and up to now this method has become an important data processing technique with wide applications in industry, such as chemical reaction process [12–15], mineral and metal processing [16], absorption refrigeration system [17], chiller plants [18], air separation process [19], natural gas pipeline system [20], and others.

In the power plant industry, many studies have been conducted on nuclear power plants to improve data accuracy, operation safety and operation coordination. Langenstein et al. [21] employed

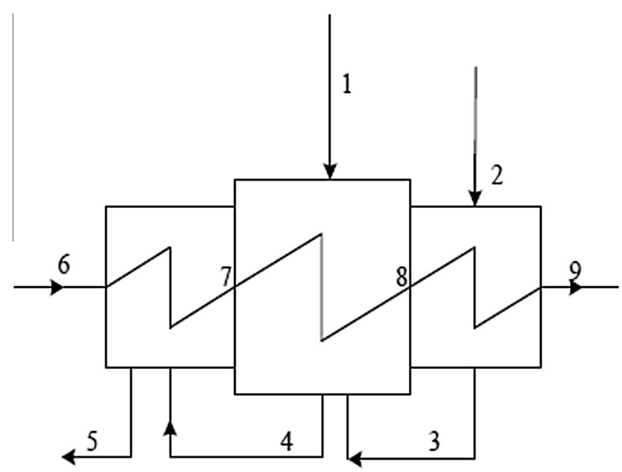

Fig. 2. Physical model of a three-zone heater.

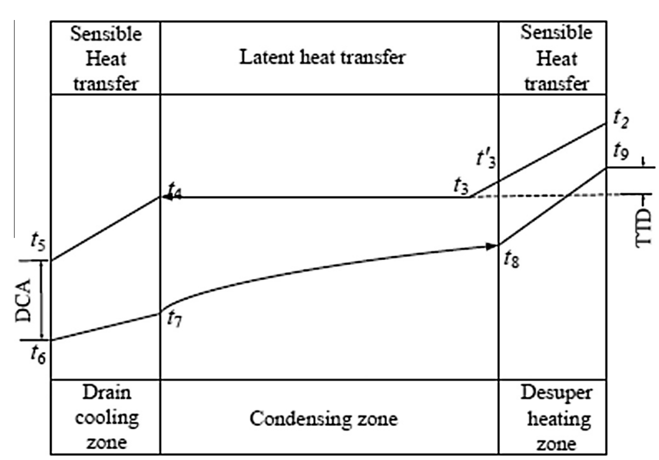

Fig. 3. Temperature profile in different zones of a three-zone heater.

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