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Improvement of existing coal fired thermal power plants performance by control systems modifications

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ABSTRACT

This paper presents possibilities of implementation of advanced combustion control concepts in selected Western Balkan thermal power plant, and particularly those based on artificial intelligence as part of primary measures for nitrogen oxide reduction in order to optimise combustion and to increase plant efficiency. Both considered goals comply with environmental quality standards prescribed in large combustion plant directive. Due to specific characterisation of Western Balkan power sector these goals should be reached by low cost and easily implementable solution. Advanced self-learning controller has been developed and the effects of advanced control concept on combustion process have been analysed using artificial neural-network based parameter prediction model.

1. Introduction

Emission mitigation and thermal power plant (TPP) efficiency improvement are particularly important projects in terms of reducing climate changes [1]. The necessity for such projects is formulated in the Kyoto Protocol and EU directives. Environmental related issues are specially emphasised for West Balkan region where most of power is generated by coal fired thermal power plants. Power sector in Western Balkan region is characterised by low thermal power plant efficiency, high NO_x, SO_x and CO_2 emissions and low quality of coal that is used for power generation. Limited investment potential impose the need for easily implementable, low cost solutions that encounters emissions related issues and raises thermal power plant efficiency. Usage of advanced control technology in power generation represents potential for improvement in the terms of processes optimisation, emissions reduction and efficiency improvement. Their impact depends on technical characteristics and status of existing instrumentation and control systems as well as on design characteristics and actual conditions of installed plant components.

During combustion process in thermal power plant nitrogen oxides (NO_x) are formatted due to nitrogen bounded in fuel (fuel NO_x), high-temperature combustion and residence time of nitrogen molecules at high temperatures (thermal NO_x) and reaction of atmospheric nitrogen during combustion (prompt NO_x). One solution for emission mitigation problem is implementation of secondary measures technology in existing thermal power plants (selective catalytic reduction, selective non-catalytic reduction etc.) [2]. Another solution is getting primary measures closer to the power plant processes limits using advanced techniques regarding power, temperature and combustion control as one of combustion treatments. These measures optimise fuel and air distribution to suppress NO_x formation and they can be very useful and cost effective [3]. Combustion control technology is one of the most cost-effective measures in NO_x emissions reduction [4]. Although effective in terms of emission reduction, these measures could reduce thermal power plan efficiency due to increase of auxiliary power consumption. Design and simulation of combustion models by means of mathematical, physical and chemical analysis often require extensive computational resources which is usually impractical for on-line control [5].

Artificial intelligence systems (AIS) are widely accepted as a technology offering an alternative way to tackle complex problems. Their general goal is to devise models that are analogous to human-

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brain-like models or biologically inspired networks. They can learn from examples, they are fault tolerant (limited by complexity of analysed system) in the sense that they are able to handle noisy and incomplete data, they are able to deal with non-linear problems, and once trained, they can perform prediction and generalization at high speed. They have been used in diverse applications in control [6], robotics [7], pattern recognition [8], prediction [9–13], medicine [14,15], power systems, monitoring [16,17], manufacturing [18], optimization [19,20], signal processing [21], and social/psychological sciences [22]. Advanced control technologies for improving system operability and environment maintainability based on artificial-intelligence (AI) seems to be promising approach for modelling [23,24] and controlling large and nonlinear power generation processes. They are particularly useful in system modelling such as in implementing complex mappings [25] and system identification [26].

Artificial neural networks (ANN) and neuro-fuzzy models are currently the most researched approaches to NO_x emission modelling [27]. They have proved their effectiveness on emissions prediction and control [28]. Artificial neural networks can achieve good NO_x emission prediction effects under various operating conditions [29]. For coal combustion modelling, support vector regression approach [30] and generic algorithm approach [30] are used, where unknown parameters act as random variables with a known prior probability distribution. The process identification starts with process observation (measured data). Using measured data (thermal power plant database), artificial neural network combustion models can be created. ANN models are more useful than physical models as these can be trained occasionally with latest data, taking care of the degradation of the plant [31]. An artificial neural network visual model of the circulating fluidised bed process and emissions can be also efficient in coal combustion modelling.

In the recent time, Evolutional Algorithms (EAs) are used as optimisation techniques which simulate biological systems for optimisation problems. Such algorithms have been developed to solve large-scale optimisation problems, for which traditional mathematical techniques may fail. The typical EAs include genetic algorithm (GA), particle swarm optimization (PSO) and ant colony systems (ACO). The ant colony optimization algorithm draws its inspiration from the behaviour of real ants as they move from their nest towards a food source, while PSO is inspired by social behaviour of bird flocking. Among these optimization methods, only GA is used by few studies to optimize operational conditions of the boiler for NO_x emissions abatement and for efficiency maximisation [32,33] while optimization technology based on ACO and PSO [34] systems are widely used in many science and engineering fields [5].

2. Artificial intelligence control systems

If the standard controller is replaced with neural networks or fuzzy inference systems, then the system is called neural network or fuzzy control system. Neuro-fuzzy control refers to the design methods for fuzzy logic controllers that employ neural network techniques which have properties such as learning ability, parallel operation, structured knowledge representation and better integration with other control design methods.

Combustion control in TPP is mostly conducted through fuel and air flow control. Conventional air flow control in coal TPPs burners consist of cascade of PI controllers, described in Ref. [35]. Values of total, secondary and tertiary air flows in air flow control are often in non-optimal range due to linear approximation of required air flows regarding input parameters. Additional/correction coefficients could be implemented into conventional air flow control in order to give more realistic input signals and to improve overall process control. Potential locations of providing correction coefficients based on AIS technology into conventional TPP air flow control are shown in Fig. 1.

ANN's are widely used tool in area of Power System Control (PSC). They have been used and tested in economic load dispatch, loss reduction, frequency control, load forecasting, power system analysis, fault detection and diagnosis and security assessment and

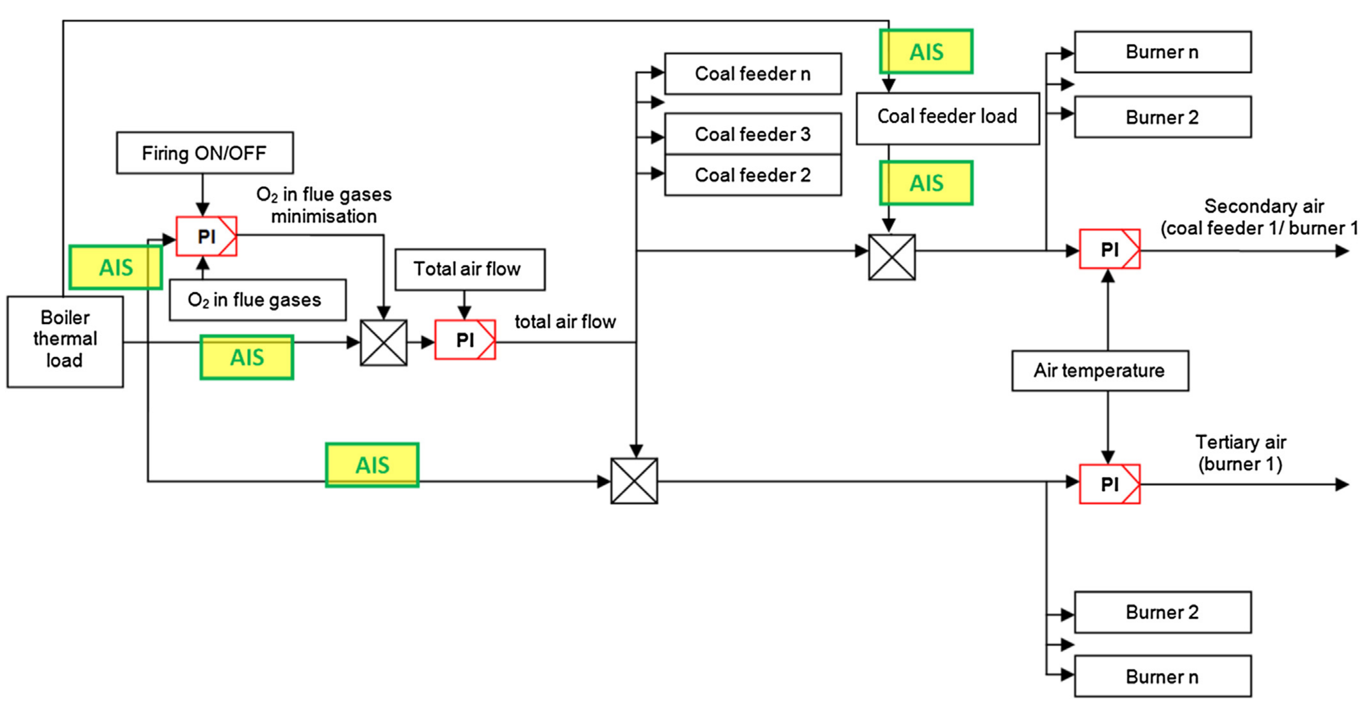

Fig. 1. Potential places for Artificial Intelligence Systems introduction to conventional TPP air flow control [35].