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Convolutional neural network approach for reduction of nitrogen oxides emissions from pulverized coal-fired boiler in a power plant for sustainable environment

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ABSTRACT

Coal-fired power plants are the main electric power source across many countries and cause major air pollution problems such as acid rain, smog, ozone depletion, and global warming. According to the best of the authors' knowledge, this is by far the first study that proposed 1-dimensional Convolutional Neural Network (1d-CNN) in combination with teaching learning self-study optimization (TLSO) algorithm for NOx emissions reduction by optimizing process input variables in a pulverized coal-fired power plant. The proposed model reduced the NOx emissions by 50.9%. In addition, the reduction experiment resulted in the early convergence superiority of the TSLO (130 s, 30th iteration) compared to genetic algorithm and Bayesian optimization. Based on the result, it is evident that combination of computationally inexpensive 1d-CNN and relatively fast converging TLSO could help process engineers reduce NOx emissions, which could ultimately contribute towards the goal of a sustainable environment.

1. Introduction

To meet energy demands, the world is still employing coal-fired boilers (CFB) in power plants. In addition to the energy benefits, there are some inevitable side effects, such as NOx emissions, of CFB that are causing serious damage to our environment and human health. According to the International Energy Agency report in 2019, coal-fired power plants accounts for approximately 30% of global carbon dioxide emissions, making them the single largest source of greenhouse gas emissions (IEA, 2019). The report also pointed that despite efforts to reduce emissions from CFBs, NOx emissions remain a significant challenge. Developing new technologies and strategies to reduce NOx emissions from CFBs is a critical priority for addressing the global impacts of coal-fired power generation. One of the core research objectives in CFB-based power plants is the development of NOx emissions monitoring and reduction techniques (Korpela et al., 2017). The NOx emission from CFB is very complex and involves large deviations and non-stationarity because of the physical and chemical processes involved. Therefore, modeling data, such as NOx emission data, puts upper-level challenges when it comes to the prediction and reduction of the NOx concentration from CFB (Yin et al., 2022).

The NOx emissions concentration is directly dependent on the process variables involved including coal feed flow rate, primary and secondary airflow, mill differential pressure, and others such as generated power (megawatt, MW) (Kim et al., 2018). All those process variables require different types of sensors to log data. Therefore, most power plants employ distributed control systems for data logging which is used in establishing a NOx concentration prediction model. However, technical glitches in real-time plant operation are also inevitable and cause disturbances in data logging (Al-Malak et al., 2016). A continuous emission and monitoring system (CEMS) is installed in the chimney to log NOx emissions concentration and hence face a harsh environment. Therefore, because of the harsh operating environment, CEMS requires periodic maintenance that also causes disturbance in data logging.

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