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A SIMULATION-BASED STUDY OF THERMAL POWER PLANT USING A FLUID DYNAMIC MODEL AND A PROCESS SIMULATION MODEL

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ABSTRACT

The role of thermal power plants is becoming more and more important in Japan because of the reducing number of nuclear power plants after Tohoku Pacific Ocean Earthquake. Renewable energy supply is expected as an alternative in terms of energy security but it is difficult to secure the energy in a very stable manner. As a result, unexpected demands on thermal power generation irregularly happen to cover the fluctuation of power supply and/or demand. Under these circumstances, the usage of thermal power plant equipped with a coal-fired boiler is changing towards a more dynamic and complicated manner of operation. This research conducted a study with the two types of simulation models to clarify this operation; namely, a fluid simulation model of coal-fired boiler; and a process simulation model of thermal power plant. This paper shows these two types of modeling approaches and discusses the feasibility of the models implemented in this study to propose a simulation-based solution for adaptable power plant operation.

1 INTRODUCTION

In response to the Great East Japan Earthquake that occurred in 2011, all of the nuclear power plants were fundamentally inspected and the number of nuclear power plants operating in Japan have been drastically reduced. Thermal power plants basically has been playing an important role in power supply in Japan so far, but its demand is getting higher after the earthquake. From the viewpoint of energy security, renewable energy, such as solar power generation and small hydropower generation, has attracted attention as an alternative power source to cover the power supply in Japan. Since it is difficult to secure such renewable energy supply in a stable manner, unexpected demands irregularly happens to thermal power generation in order to cover the fluctuation of power supply and/or demand. Under these circumstances, the usage of thermal power plant equipped with a coal-fired boiler is changing towards a more dynamic and complicated manner of operation to control the appropriate flow rate balance of water and steam by determination of various inflow using fine damper adjustment for the optimized power generation. Power plants are basically under automatic operation, however, its fine tuning and critical operation control is still managed by human experts, which means that internal procedure of power plant operation is still unclear in many situations. This research implemented two types of simulation models, which are a fluid simulation model of coal-fired boiler and a process simulation model of thermal power plant to help clarifying the operation. This paper shows these two types of approaches using these models and discusses the feasibility of the models implemented in this study.

2 DESIGN PARAMETER REVIEW USING A FLUID SIMULATION MODEL OF COAL-FIRED BOILER

The first approach of this study was based on a fluid simulation model (CFD) of coal-fired boiler, which is composed of various components such as 1st/2nd economizers, 1st/2nd/3rd/4th super heaters, 1st/2nd reheaters, steam separator, furnace wall tube, roof tube, etc. Simulating the flow balance of tubes in each component, the flow velocity of the fluid in the model was calculated. Focusing on the fourth super heater component, fluid dynamic simulation was conducted in a various conditions. As a result, it was found that the pressure loss was caused by the variation in the flow rate of each tube. Therefore, homogeneity of the flow rate was adjusted by inserting an orifice at the entrance of each tube. As a result, the flow rate balance was achieved by the combination of orifice-inserted tubes.

3 OPERATION PARAMETER REVIEW USING A PROCESS SIMULATION MODEL OF THERMAL POWER PLANT

The second approach of this study was based on a process simulation model (PSM) (Joines and Roberts 2015; Kelton et al. 1998; Smith et al. 2015) of a basic thermal power plant, which is composed of flow processes of air, water, and fuel as input entities, whereas electricity as an output entity in the model. The operation of the thermal power plant uses the numerical values of the operating parameters such as the inflow parameters of fuel/air/fluid, the opening degree of the damper for adjusting the air inflow, the processing time at each device, and the output power from the power plant. A process model using these parameters were implemented in this study to simulate the plant operation based on the collected data from a running plant. For verification of the model, simulation experiments were conducted using a series of parameter combination, including process time in coal mill, burner, furnace, re-heater, and turbine. Using variation of inflow parameters of air and fuel in the model, efficiency of power generation was calculated and reviewed to study the performance of the plant model. As a result, the process model of the thermal power plant worked as a workbench to study the operating parameters from a difference point of view.

4 CONCLUDING REMARKS

The usage of thermal power generation plant equipped with large boilers has shifted towards a more dynamic and complicated manner of operation because of the changes in the supply ratio of electric energy generation in Japan. It is difficult to cope with a sudden change in demand as well as large loss of power generation efficiency by operating only by automatic operation of a thermal power plant. This paper explains those changing environments around thermal power plant and proposed two types of simulation-based approaches to challenge the issue of dynamic plant operation. As for the fluid flow dynamics in the complicated tubes in a coal-fired boiler, visualization of unbalanced flow was simulated, which is impossible in a physical boiler in the real world. As for the inlet/outlet flow behavior of the thermal power plant, visualization of behavior of the flows was simulated in a process-oriented manner, which is also impossible in a physical plant in the real world. Even though these models implemented in this study are still in the initial stage of the implementation, the result shows the feasibility of the simulation-based approach as a new direction to challenge the dynamic plant operation issue in order to cope with unpredictability in the power supply and/or demand and propose a simulation-based solution to handle adaptable plant operation.

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