Developing a Simulation Program for Dynamic Behavior Prediction of Bottoming System of Gas Turbine Combined Cycle

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Long Abstract

Introduction

The gas turbine combined cycle (GTCC) is primarily used to cope with peak electirc load. Accordingly, it experiences frequent unsteady operations such as start-up, shut-down and load change. In particular, rapid start-up is becominng the most important requirement from GTCC users. All of such fast and freqent changes in operation have a negative influence on the lifetime of the bottoming cycle as well as the gas turbine becasue of an higher thermal stress of critical components. Therefore, a dynamic simulation is a very important function in designing GTCC plants, and many studies have been conducted. Some examples are a thermal stress analysis of the drum during start-up[1], dynamic behavior simulation of the supercritical HRSG with an once through type evaporator[2], and cold start-up simulation[3]. A program which is able to simulate dynamic behavior is required for these researches. We are developing an in-house dynamic simulator of the GTCC bottoming cycle which can be used to simulate various transient operations such as start-up and load changes in both the design and operation phases.

Method and Result

In this study, we developed a simulaiton program based on MATLAB[4], and used an object oriented programming method to modularize each component. This method has advantages in program adaptability and maintenance, and the resulting program can be used to simulate various configurations of the bottoming cycle. Main components of the bottoming cycle are a heat recovery steam generator (HRSG), which consists of an economizer, evaporator and superheater, condenser, steam turbine and pump. Each heat exchanger element of the HRSG and the condenser consists of cold side, metal and hot side, each of which is divided into many segments. Governing equations of all components are energy conservation equations and convective heat transfer equations, and were solved by the Newton-Raphson method. The dependence of heat transfer coefficient upon fluid mass flow rate was adopted. In the steam drum, water and steam phases were modeled separately. A quasi steady assumption was applied (i.e. thermal inertia was ignored) to the steam turbine and pump. The Stoldola's ellipse law was used to model the off-design operation of the steam turbine. A component map, described as a volume flow, pressure head, efficiency and rotating speed, was used to model the pump.

Firstly, steady solutions after a certain transient operation were compared with results from commercial steady state codes such as GateCycle and AspenPlus [5,6] and good agreements were observed, which verified the fundamental modeling of the program. Then, various dynamic operations due to changes in gas turbine exhaust conditions were simulated using the program. A sample result of a single pressure bottoming cycle is exemplified in Fig. 1. The simulation was performed for the case where gas turbine exhaust flow rate was decreased about 10% linearly. In this example, drum level control by feed water modulation was used but turbiune control was not adopted. Physically sound trends of all operating parameters were observed. Dynamic simulation of a triple pressure bottoming cycle including a full steam turine control, which is the main target of the simulation, is being performed and the results will be presented in the final version of this paper.

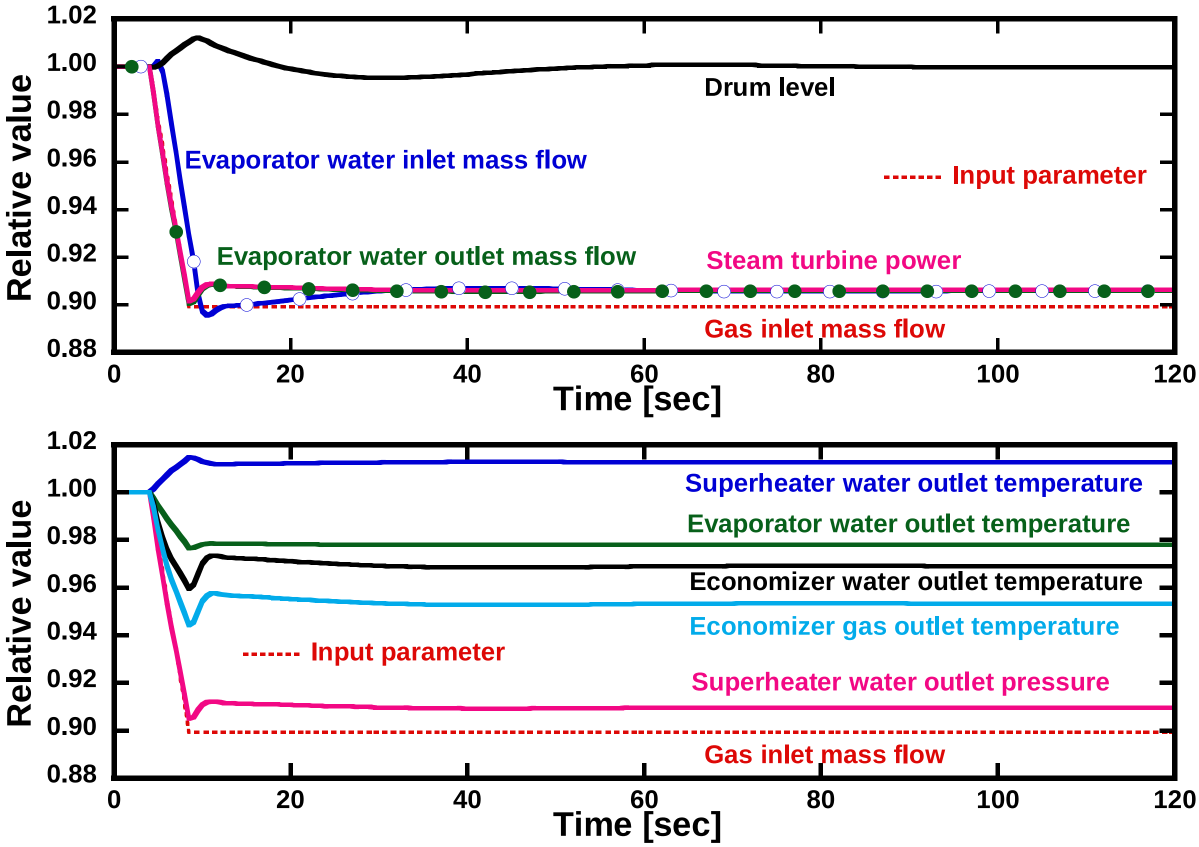

Figure 1. Dynamic simulation results of a single pressure bottoming cycle

References

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