HAI TESTBED

Process Architecture

The process flow of the testbed was divided into four primary processes: the boiler process (P1), turbine process (P2), water treatment process (P3), and HIL simulation (P4) (Figure 1). The HIL simulation enhances the correlation between the three real-world processes at the signal level by simulating the thermal power and pumped-storage hydropower generation processes.

The boiler and turbine processes simulated the thermal power plant, while the water treatment process

simulated the pumped-storage hydropower plant.

Infinite Bus

Power Grid

Hardware-In-the-Loop Simulation

Model

(P4)

(P4e)

Steam Turbine

Pump-Storage

Power Generator

HydroPower Generator

Steam

Power

Power

Hydro

Turbine

Generator

Generator

Turbine

Model

Model

Model

Model

(P4a)

(P4b)

(P4d)

(P4c)

Virtual World

Real World

Return

Heat Transfer System

Motor

Main

Water Tank

(P1b)

System

Water Tank

(P1c)

(P2a)

(P3a)

Heating

Main

Water Tank

Feedwater

Feedwater

Water Tank

Rotor

Return

Feedwater

Water Tank

(P1d)

Pump

Pump

(P1a)

System

Pump

(P2b)

(P3b)

Heating

Cooling

System

Boiler Process

System

Turbine Process

Water-Treatment Process

(P1e)

(P1)

(P1f)

(P2)

(P3)

FIGURE 1. PROCESS FLOW DIAGRAM OF THE TESTBED.

P1: BOILER PROCESS

The boiler process involved water-to-water heat transfer at low pressures and moderate temperatures,

where the boiler pressure, temperature, and water level are controlled by the boiler process. The opening and closing rates of the main valve are also controlled according to the opening rate of the steam valve of the thermal power plant in the HIL simulator. The pressure and temperature of the main

pipe and the water level are transmitted to the HIL simulator in real-time to determine the amount of power generated.

Cool water in the main water tank (P1a) is pumped to the heat-transfer system (P1b) through a feedwater pump, subsequently providing water at a constant temperature and pressure to the return water tank (P1c). The heating system (P1e) transfers thermal energy through the water to the heat transfer system. The water temperature and pressure values are then converted into the current steam

temperature and pressure values for the steam-turbine power generator of the HIL simulator (P4a). Water flows from the return water tank (P1c) to the main water tank (P1a) at a constant flow rate, thereby maintaining constant water level in the return water tank. The water circulating to the main tank is not sufficiently cooled; therefore, the cooling system (P1f) additionally removes the thermal