Design Features of Instrumentation and Control Systems for Sodium Integral Effect Test Loop for Safety Simulation and Assessment

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1. Introduction

Sodium integral effect test loop for safety simulation and assessment is a test facility for evaluating the transient behavior of prototype reactor under Design Basis Event (DBE) conditions and verify and validate (V&V) the safety analysis codes and other thermal-hydraulic codes [1-3].

In general, instrumentation systems and control systems are closely related with each other, and thus these systems are coupled for measurement and control of process variables. For the test facility, instrumentation systems have been designed to obtain physical parameters such as temperature, pressure, and flow rate used for understanding of thermal-hydraulic characteristics. Also, control systems have been designed to control components such as electromagnetic pumps, heaters, valves required for test in the test facility. In this paper, we have provided design features for the instrumentation and control systems of the test facility.

2. Design Features

In this section, overview of test facility and design features of instrumentation and control systems are described.

2.1 Overview of Test Facility

Fig. 1 shows overall arrangement of the test facility. The test facility consists of main systems, auxiliary systems, and instrument & control systems. The main systems consist of an Electric Core Simulator System (ECSS), a Model Primary Heat Transfer System (M-PHTS) including Model sodium-to-sodium Decay Heat eXchanger (M-DHX), two Model Intermediate Heat Transport Systems (M-IHTS) including four Model Intermediate Heat eXchangers (M-IHX) and two Ultimate Heat eXchangers (UHX), and four Model Decay Heat Removal Systems (M-DHRS) including two Model helical-coil type sodium-to-Air Heat eXchangers (M-AHX) and two Model Finned-tube type sodium-to-air Heat eXchangers (M-FHX). The auxiliary systems consist of a Sodium Purification System (SPS), a Sodium Charge/Drain System (SCDS), and Gas Supply Systems (GSS) etc.

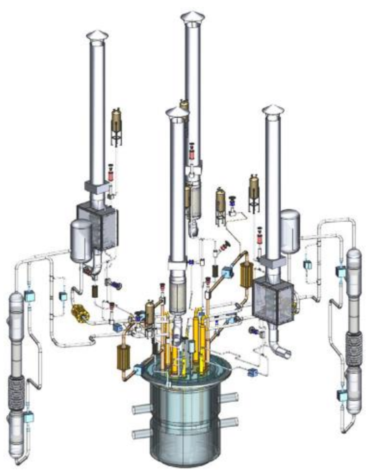

Fig. 1. The arrangement of the test facility

Fig. 2 shows configuration of control & monitoring systems of the facility. Control & monitoring systems control overall systems for achieving required test condition and monitor physical parameters such as temperature, flow rate, pressure, level etc., and save and analyze those data. Control & monitoring systems provide network redundancy to avoid network failure as shown in Fig. 2. If one network becomes unavailable then the network is switched to the other network, and thus continuous communication could be guaranteed. Furthermore, controller redundancy is also provided to avoid controller failure. If one controller becomes

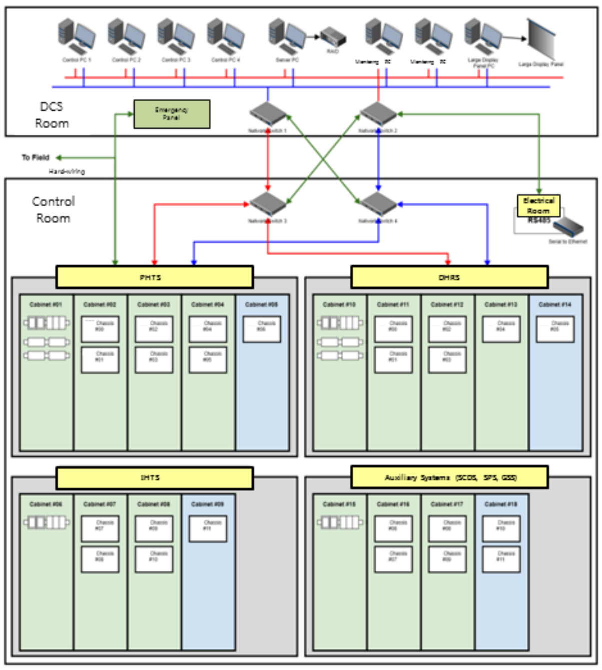

Fig. 2. Configuration of control & monitoring systems

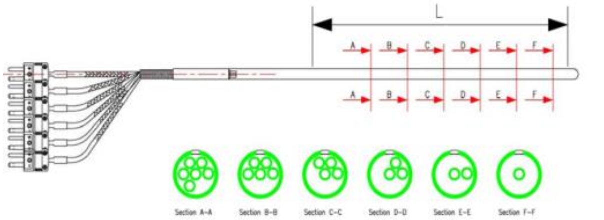

Fig. 3. Multipoint thermocouple for measurement of sodium temperature of hot pool and cold pool

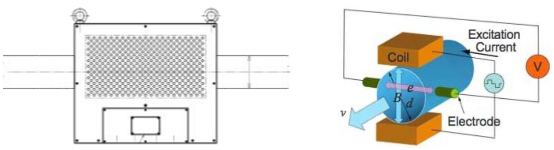

Fig. 4. Electromagnetic flow meter for measurement of sodium flow rate of M-PHTS, M-IHTS, and M-DHRS

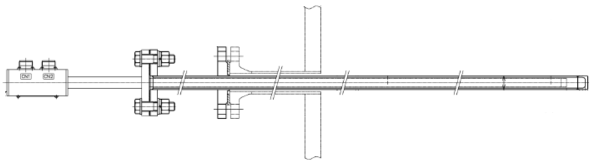

Fig. 5. Inductive type level meter for measurement of sodium level of tanks

unavailable then the controller is switched to the other controller, and thus continuous control and monitoring are available.

2.2 Design Features of Instrumentation Systems

Instrumentation systems consist of sensors which measure physical parameters such as temperature, flow rate, pressure, level, and local panels. Temperatures of sodium side are measured by K-type thermocouples. Multipoint thermocouples which can measure six points for each are used for measurement of sodium temperature of hot pool and cold pool as shown in Fig. 3. Electromagnetic flow meters are used for measurement of sodium flow rate of the M-PHTS, M-IHTS, and M-DHRS as shown in Fig. 4. Thermal mass flow meters are used for measurement of air flow rate of shell side of heat exchangers such as UHX, M-AHX, and M-FHX. NaK filled pressure transducers are used for measurement of differential pressure at sodium side, and pressure transmitters are used for measurement of static pressure and differential pressure at air side. Inductive type level meters are used for measurement of sodium level of tanks as shown in Fig. 5, and also level switches are added for guaranteeing diversity of level measurement.

2.3 Design Features of Control Systems

Control systems consist of measurement signals from

Table I: Minimum sampling speed for input signals

	Range	Sampling Speed (Hz)
Temperature	~ mV	2
Pressure	4 ~ 20 mA	10
Flow rate	4 ~ 20 mA	10
Power	4 ~ 20 mA	10
Control Valve	4 ~ 20 mA	10
On/Off Valve	Contact	2
Pump	4 ~ 20 mA	10

Table II: Minimum sampling speed for output signals

	Range	Sampling Speed (Hz)
Heater	4 ~ 20 mA	10
Control Valve	4 ~ 20 mA	10
On/Off Valve	Contact	2
Pump	4 ~ 20 mA	10

instrumentation systems and Distributed Control Systems (DCS) in which control logic for heaters, electromagnetic pumps, valves, and blowers of the test facility is implemented. All the signals including analog input (AI), analog output (AO), digital input (DI), and digital output (DO) are collected through DCS. The range of AI & AO signals is from 4 mA to 20 mA, while DI & DO signals are either zero or one. Signal from the sensors such as flow meter and pressure transmitter which have continuous measurements of process variables is AI signal. Signal from the sensors such as level switch and limit switch which have discrete measurements of process variables is DI signal. Signal from DCS for control of the components which have continuous process output such as heater, electromagnetic pump, and pressure control valve is AO signal, while signal from DCS for control of the components which have discrete process output such as on/off valve is DO signal.

The minimum sampling speed for input and output signals are shown in Table I and Table II, respectively. Especially, sampling speed of input and output signals for electromagnetic pump, electromagnetic flowmeter, and NaK filled pressure transducer in main systems including M-PHTS, M-IHTS, and M-DHRS is chosen to 100 Hz since fast response is required for achieving test requirements. Furthermore, the synchronization of time stamps with different sampling times is achieved in DCS and server system.

Electric core heater and line heater are required to be controlled in order to make required sodium temperature which satisfies test condition and prevent solidification of sodium. Proportional-Integral-Differential (PID) feedback control which is implemented in DCS is applied to heater control. AI signal from thermocouple is the input to PID feedback controller and the output of PID controller, which is AO signal, is sent to Thyristor Power Regulator (TPR) or Silicon-Controlled Rectifier (SCR) to adjust input power of heater within the range from 0 to 100 % as shown in Fig. 6. Electromagnetic pumps which provides

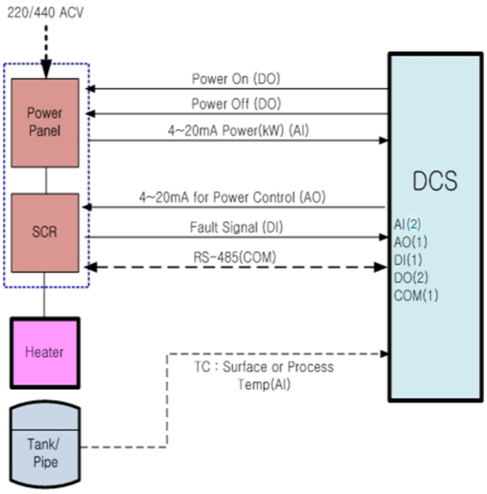

Fig. 6. Configuration of input & output signals for control of heater

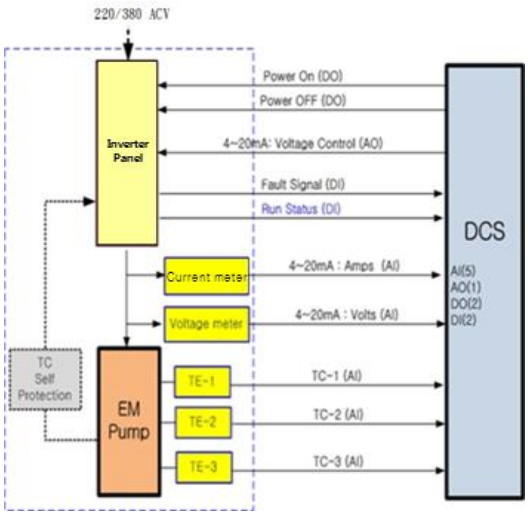

Fig. 7. Configuration of input & output signals for control of electromagnetic pump

required sodium flow rate are also controlled by PID feedback control. The output of PID feedback controller is sent to an inverter to adjust input power of the electromagnetic pump from 0 to 100% as shown in Fig. 7. The inverter which is a kind of variable voltage variable frequency (VVVF) controller is used to adjust input power of the electromagnetic pump from 0 to 100% by changing frequency from 0 to 60Hz. Blowers which provide air flow rate to shell side of UHX, M-AHX, and M-FHX are also controlled by PID feedback control. The output of PID feedback controller is sent to an inverter to adjust revolutions per minute (RPM) of the blower from 0 to 100% by changing frequency from 0 to 60Hz. All the controllable components such as heaters, electromagnetic pumps, pneumatic valves, and blower can be controlled and monitored at Human Machine Interface (HMI). Also, all the control logics such as on/off control and PID feedback control are implemented in DCS and control parameters can be adjusted in HMI.

3. Conclusions

In this paper, we have provided configurations and design features of instrumentation and control systems for sodium integral effect test loop for safety simulation and assessment. Instrumentation system is designed for measurement of physical parameters which describing thermal-hydraulic behaviors of fluid such as temperature, flow rate, and pressure etc. Furthermore, control system is designed for achieving required test condition through control of heaters, electromagnetic pumps, valves, and blowers etc.

4. Acknowledgement

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