Design of Safety Related Control Panels for HANARO Fuel Test Loop

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1. Introduction

FTL (Fuel Test Loop) is a test facility which could conduct fuel irradiation test at HANARO reactor [1]. The maximum 3 pins of PWR or CANDU type fuels can be tested in the IR1 irradiation hole of HANARO under the commercial power plant operating conditions. The control system for FTL operation is divided into the safety control system and the non-safety control system [2]. The safety control system is composed of the safety related control panels such as the protection panels, the safety control panels, and the safety indicator panel. The safety related control panels are used for controlling of the safety related FTL process systems and shutdown the HANARO reactor against the abnormal operating conditions. The non-safety control system consisted of the PLC system controls the non-safety related process systems. In this paper, a detailed design of the safety related control panels is introduced.

2. HANARO Fuel Test Loop

The FTL is composed of an IPS (In-Pile test Section) and an OPS (Out Pile system). Fig. 1 shows the schematic diagram of the FTL.

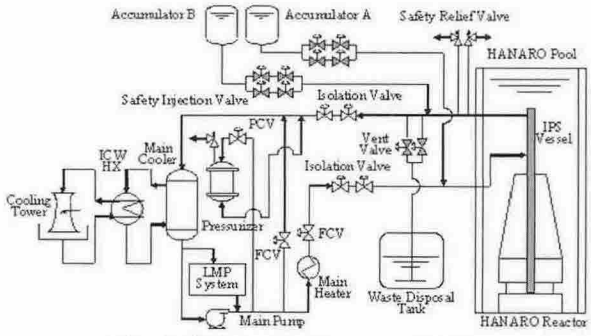

Fig. 1. Schematic diagram of FTL.

The IPS is to be loaded into the IR-1 position in the HANARO core. This implies that the environment around the IPS is subjected to a high neutron flux (Thermal neutron flux : 1.2×10^{14} n/cm^2·sec, Fast neutron flux : 1.6×10^{14} n/cm^2·sec). The IPS can accommodate up to 3 pins of PWR or CANDU type fuels and has instruments such as thermocouple, LVDT and SPND to measure the fuel performances during the test.

The OPS contains pressurizer, cooler, pump, heater and purification system which are necessary to maintain the proper fluid conditions. In addition, the OPS contains a engineered safety system that could safely shutdown both HANARO and the FTL if an accident occurs. The FTL simulates the irradiation conditions of the commercial power plants such as pressure, temperature and neutron flux levels to conduct for the irradiation and thermo hydraulic tests. The FTL coolant is supplied to the IPS at the required temperature, pressure and flow conditions that are consistent with the test fuel. The nuclear heat added within the IPS is removed by the main circulating water cooler. The main circulating pump provides the motive power to circulate the FTL coolant within the loop. After pump discharge, an in-line heater provides the capability to increase temperature for startup and for positive temperature control. A pressurizer is provided to establish and maintain the coolant pressure to the test fuel type. A purification and de-gasification system is provided to maintain the coolant inventory and the chemistry conditions. The emergency cooling system is provided to maintain the experimental fuel cooling in the event of the anticipated operational occurrence or the design basis accidents. The maximum operating conditions of the FTL are summarized in Table 1.

Table. 1. Maximum operating condition

Parameter	PWR type	CANDU
Flow	1.60 kg/sec	1.63 kg/sec
IPS inlet temp.	300 °C	277 °C
IPS outlet pressure	15.5 MPa	10.0 MPa
IPS outlet temp.	312 °C	290 °C
Heat generation	112 kW	116 kW

The application fields of the FTL are as follows.

· Nuclear fuel irradiation behavior test at the operating condition of the commercial power plant.
· Fuel burn-up and mechanical integrity verification.
· Irradiation data generation for the analysis model (PWR fuel, CANDU fuel and metal fuel).
· Technical improvement of design and fabrication for the advanced fuel development.
· Fuel rod irradiation test for performance verification.

3. Design of Safety Related Control Panels

In this section, the detailed design of the safety related control panels which are composed of the protection panels, the safety control panels and the safety indicator panel are introduced. The protection panels are installed in the FTL I&C Room located at the first floor of reactor hall. The safety control panels and

the safety indicator panel are installed in the HANARO control room. Fig. 2 shows the logic diagram of the safety related control panels.

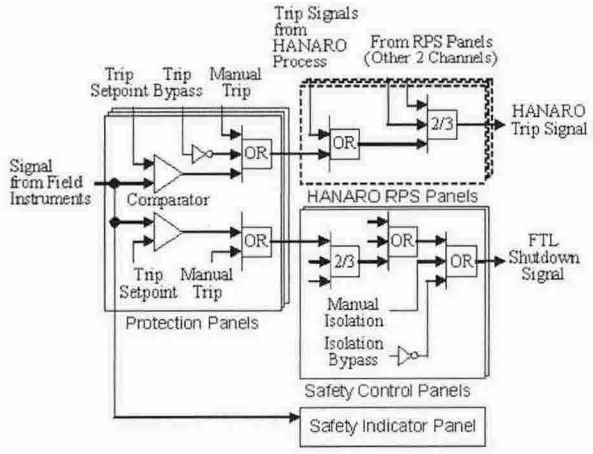

Fig. 2. Logic diagram of the safety related control panels.

The protection panels composed of three channels receive signals from the corresponding field instruments, and generate the HANARO trip signal and the FTL shutdown signal if the measurement signal is exceeded the trip setpoint. The HANARO trip signals from the protection panels are interfaced with the corresponding channels of the HANARO RPS (Reactor Protection System) panels which generates the reactor trip signal. The HANARO RPS panels have the '2 out-of 3' local coincidence logic for reliability. The reactor trip parameters are as follows:

- Low flow rate of IPS inlet main cooling water
- High flow rate of IPS inlet main cooling water
- High temperature of IPS outlet main cooling water
- Low pressure of inlet main cooling water
- High pressure of inlet main cooling water
- High-High pressure of IPS inner/outer vessel interspace gap.

The main purpose of the safety control panels is to supply the emergency cooling water to remove the heat from test fuels after reactor shutdown. The safety control panels are composed of independent two panels, and have some manual switches and relays in each panel for controlling of safety related process systems. The safety control panels receive the trip signals from the protection panels when the transient excursions of the process condition from the IPS main cooling water occurred to unacceptable set point levels as followings:

- Low-Low flow rate of IPS inlet main cooling water
- High flow rate of IPS inlet main cooling water
- High-High temperature of IPS outlet main cooling water
- Low-Low pressure of inlet main cooling water.

The '2 out-of 3' concept is also applied to the safety control panels to satisfy the reliability of overall plant. If the any of above input signals come from the protection panels, The safety control panels automatically send the output command signals to the following control device for safe cooling down the fuel temperature after HANARO shutdown.

- Close the IPS inlet/outlet main cooling water isolation valves.
- Open the accumulator discharge isolation valves.
- Open the emergency cooling water isolation valves.

The FTL safety indicator panel receives the following analog signals to supervise the vital process status in the HANARO control room together with the FTL control room.

- Pressure of IPS inlet main cooling water.
- Flow rate of IPS inlet main cooling water.
- Temperature of IPS outlet main cooling water.
- Pressure of IPS inner/outer vessel interspace gap.

The safety related control panels were designed with the safety regulation of the IEEE Standard-603 such as single failure criterion, redundancy, independency, diversity, fail-safe, manual initiation, channel check, channel bypass, etc. to ensure the system reliability [3].

3. Conclusion

A detailed design of the safety related control panels for FTL was introduced. The panels were designed with the safety regulation of the IEEE Standard-603. This paper can be applied to the design of the safety related control panels in the nuclear facilities.

REFERENCES

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