Design Feature of Ex-core Nuclear Instrumentation System (ENIS) for SMART

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1. Introduction

SMART (System-integrated Modular Advanced Reactor) is an integral type pressurized water reactor which has an integral reactor coolant system configuration that eliminates the need of large pipes for the connection of the major components. The top-tier requirements for SMART design are the enhancement of safety and the improvement of commercial competitiveness. For the safety enhancement, SMART has adopted the inherent and passive safety, simplified safety system, and advanced MMIS (Man-Machine Interface System). For the economic enhancement, SMART has implemented the system simplification and the component modularization. According to the top-tier requirements, SMART MMIS should include the followings: 1) to meet all current regulatory and industry requirements; 2) to improve plant safety and availability; 3) to improve the cost effectiveness of nuclear power generation. This paper introduces the neutron detector features such as functions, configuration and interfaces of the SMART ex-core nuclear instrumentations.

2. Detector Locations

Due to the integral type of SMART reactor, there are some limitations regarding reactor detectors locations. Ex-core detectors are installed inside the Reactor pressure vessel (RPV) because the neutron flux level is expected very low at outside of the RPV as shown in fig.1.

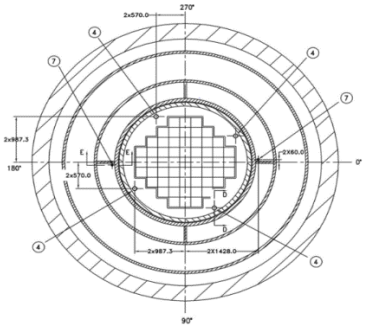

Fig. 1 Ex-core detector location in SMART (wide range and alternative source range)

In Fig. 1, ④ represents the wide range ex-core detector guide tube in Core Shroud Assembly and ⑦ is Alternate source range ex-core detector guide tube in Flow Mixing Head Assembly. During refueling time the closure head of SMART is totally removed, therefore all detectors installed period will be also removed. Hence Alternate source range detector are installed instead of previous path inside the RPV and take a place to monitor the leakage of the neutron only during refueling time as shown in fig. 2.

ENIS in SMART are sharing the detector between safety and non-safety system with specific isolation devices. Furthermore, the safety channel of ENIS in SMART provides the analogue signals to the Boron Dilution Shutdown Actuation System (BDSAS) for the source range neutron flux signal.

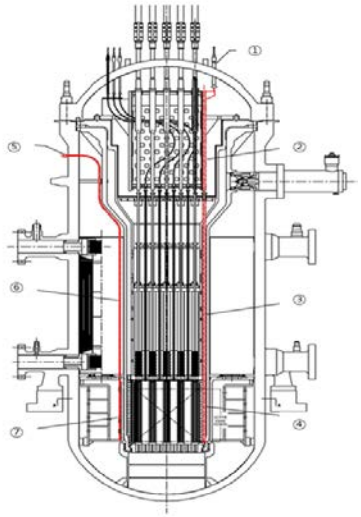

Fig. 2 Vertical Mounting passage of ex-core detector assemblies in SMART

In Fig. 2, ①Wide range ex-core detector nozzle in Reactor Closure Head Assembly ②Wide range ex-core detector guide tube in ICI support structure area ③Wide range ex-core detector guide tube in Upper Guide Structure Assembly. ④ Wide range ex-core detector guide tube in Core Shroud Assembly, ⑤Alternate source range Ex-core detector Nozzle in Reactor Pressure Vessel Assembly ⑥Alternate source range ex-core detector guide tube in Core Support Barrel

Assembly. ⑦ Alternate source range ex-core detector guide tube in Flow Mixing Head Assembly

3. SMART ENIS Features

3.1. Configuration

ENIS includes the guarded fission chambers for wide range signals which are located around the reactor core and the unguarded fission chambers for alternative source range which are located outside the Core Support Barrel Assembly (CSBA) inside the RPV as shown in fig.1 .Preamplifiers are located outside the RPV for each channel where applicable and the signal processing module is located in the electrical equipment room. Neutron flux is continuously monitored from source levels through full power level. The ENIS provides the signal outputs for the reactor protection, reactor control and information display.

Four (4) safety channel detectors are installed to provide neutron flux signals from source range to power range for protection including startup and control operations. Independent two (2) alternate source range channel detectors are installed for monitoring during refueling periods only.

Two control channels receive the signal output from the safety channel signal process module and provide the neutron flux information of 0 to 200 %FP (Full power) to the Power Control System (POCS). Each control channel consists of a signal processing unit. These control channels provide the linear power and the rate of change of power signals. The output signals of the safety channel preamplifiers are transmitted to control channels through the specific isolation devices as shown in fig. 3

Two startup channels receive the signal output from the safety channel signal process module as same as the control channel and provide the source level neutron flux information to plant operators during the reactor startup. Each startup channel consists of a signal processing unit. These startup channels provide the measured value of CPS (Count per second), the rate of change of power, and audible count rate. The output signals of the safety channel preamplifiers are transmitted to startup channels through the specific isolation devices.

Two alternate source range channels provide the source level neutron flux information to plant operators during reactor refueling periods. Each alternate source range channel consists of an unguarded fission chamber, a preamplifier, and a signal processing unit which contains a power supply and test circuitry. These channels provide the measured value of CPS, the rate of change of power, and audible count rate.

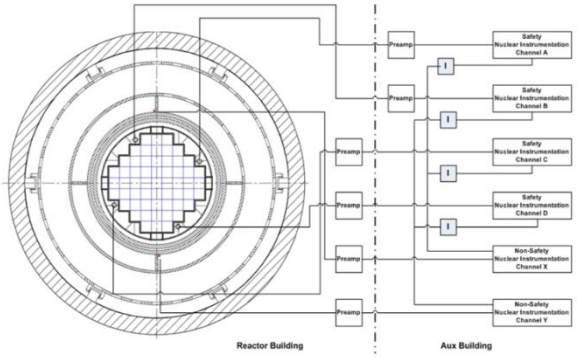

Fig. 3 Block Diagram of Ex-core Nuclear Instrumentation System in SMART

3.2 Interfaces

The safety channels of ENIS in SMART provides the analog and contact signals to the Reactor protection system for a High Logarithmic Power Trip, Variable Overpower Trip , high logarithmic power level bypass, and SMART Core Protection System /CRA Withdrawal Prohibit Bypass. It's also provides analog and contact signals to the SMART Core Protection System for a High Local Power Density Trip, Low Departure from Nucleate Boiling Ratio Trip, and SMART Core Protection System Bypass Permissive.

The safety channel of ENIS provides the analogue signals to the BDSAS (Boron Dilution Shutdown Actuation System) for the Rate of change of logarithmic power level. Furthermore, it provides an indication signals to the AIS, IPS and PAM (Post-Accident Monitoring) and ICCMS (Inadequate Core Cooling Monitoring System) at the MCR (Main Control Room) for logarithmic power level, linear power level rate of change of linear power level, and logarithmic power level of the safety channels, A and B at the RSR (Remote Shutdown Room) . See fig. 4.

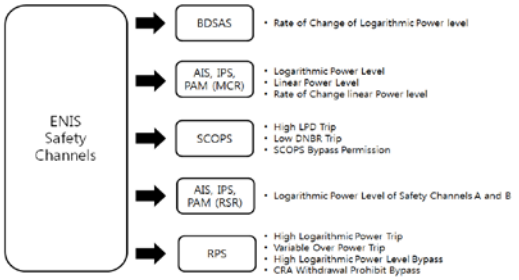

Fig. 4 ENIS Safety Channel Interfaces in SMART

The startup control channel ENIS in SMART provides the indication signals to the AIS and IPS at the MCR for the Source range neutron flux, Audible count rate with a form of tone bursts per count rate ascension.

The control channel ENIS provide the indication signals to the AIS and IPS at the MCR for linear power level, and Rate of change of power. See fig. 5.

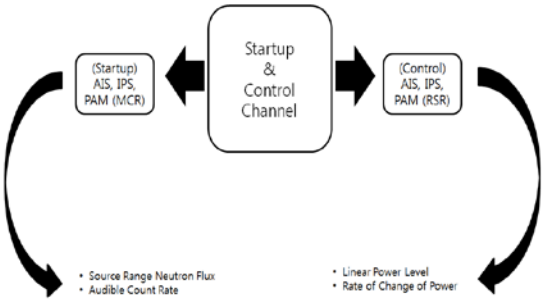

Fig. 5 ENIS Startup and Control Channel Interfaces in SMART

The alternative source range channel of ENIS in SMART provides the indication to the AIS and IPS at the MCR for the following functions which are Alternate source range neutron flux during the refueling periods and Audible count rate with a form of tone bursts per count rate ascension, The alternative source range channel of ENIS also provide the alarm signals to the AIS and IPS at the MCR for The energizing status of the alternate source range channel. See fig. 6.

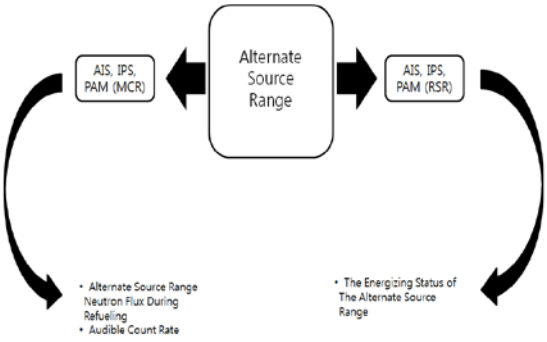

Fig. 6 ENIS Alternate source Channel Interfaces in SMART

4. Conclusion

Four main characteristics in SMART ENIS are considered in this paper which are; first is the location of ENIS, second is the alternate source range detector has different location and path which only use during refueling time, third detector for safety and non-safety are sharing though specific isolation devices and finally the Boron Dilution Shutdown Actuation System (BDSAS) for the source range neutron flux signal.

5. References

[1] IAEA Nuclear Energy Series No. NP-T-3.19, Instrumentation and Control Systems for Advanced Small modular Reactors

[2] "The Development of Ex-core Neutron Monitoring System for Integral Reactor", KAERI/TR-2873/2004, Korea Atomic Energy Research Institute, 2004.

[3] IEEE Std. 603, IEEE Standard Criteria for Safety Systems for Nuclear Power Generating Stations, 2009