Transactions of the Korean Nuclear Society Autumn Meeting
Jeju, Korea, October 21-22, 2010

The Design of Automatic Seismic Trip System for the Nuclear Power Plants

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1. Introduction

Over twenty (20) years, we are experiencing horrible earthquakes. The magnitude of earthquake is larger and larger and the fatality numbers are greater. The effect of earthquake is considered as a potential risk factor for the safety of the operating Nuclear Power Plants (NPPs). This is the reason why we are going to install the Automatic Seismic Trip System (ASTS) in the operating NPPs.

The nuclear facilities were damaged by a severe earthquake of magnitude 6.8 that occurred in vicinity of Kashiwazaki-Kariwa NPPs in July 2007. It is the first remarkable occurrence that the NPPs were scrammed by the severe earthquake that exceeds design limits required for warranting the safety of NPP. From the lessons learned from Japanese case, Korean Goverment has raised the necessity of countermeasure for the seismic incidents.

This paper provides system requirements and technical backgrounds for designing ASTS.

2. ASTS configuration

ASTS continuously monitors seismic levels and automatically generates a reactor trip signal when the measurements of seismic levels exceed the preset value.

As shown in Figure 1, ASTS consists of four (4) sensor modules including seismic sensor, signal conditioning enclosure and protection guard, one (1) trip logic cabinet, and two (2) actuation devices.

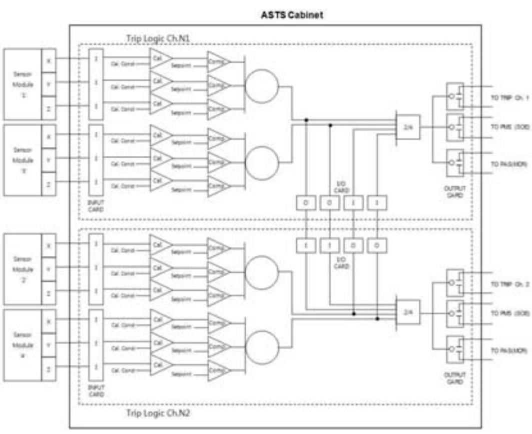

Figure 1. Functional Configuration of ASTS

In designing ASTS, the standardized design method is applied. ASTS is fully digitalized system that has two (2) redundant channels for the function of;

- Bistable Logic
- Local Coincidence Logic
- Initiation Circuitry

2.1 Design of Sensor Module

The sensor module that consists of seismic sensor, signal conditioning enclosure and protection guard is designed to satisfy Seismic Category I requirements defined in USNRC Regulatory Guide 1.29[1] and ANSI/ANS 2.2[2]. The seismic sensor is a triaxial accelerometer that consists of three accelerometers mounted orthogonally on an internal deck plate. The dynamic range of the device is 1000:1 zero to peak with a flat frequency response over the range of 0.1 to 50 Hz. Damping is selected between 55% and 70% of critical damping and velocity proportional. The signal conditioning enclosure is composed of low pass filter to reject frequencies over 10 Hz, bipolar-unipolar converter to translate a bipolar seismic signal into a unipolar seismic signal, voltage to current converter and enclosure as shown in Figure 2.

The seismic sensor is designed to be installed on the concrete base of the auxiliary building floor. The location of seismic sensors is considered to be detectable at the multiple seismic sensors. The protection guard is installed to protect signal conditioning enclosure from external physical impact.

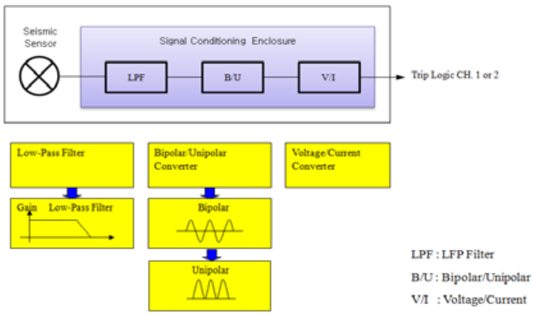

Figure 2. Typical Seismic Sensor Module Block Diagram

2.2 Design of ASTS Cabinet

ASTS Cabinet is a two-channel non-safety related system that consists of bistable logic, coincidence logic, trip initiation and other function. The hardware of ASTS Cabinet consists of digital equipment, uninterruptible power supply, maintenance and test panel, and other equipment as shown in Figure 3.

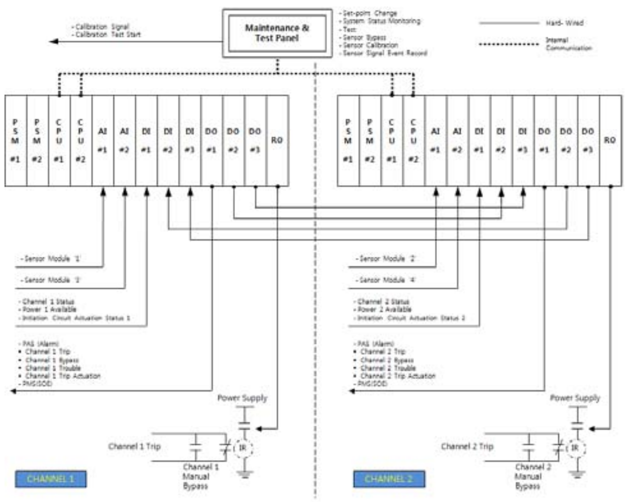

Figure 3. Typical ASTS Cabinet Block Diagram

To decrease the sampling distortion between the analog signal from sensor module and sampling frequency, the interval of sampling frequency of Analog Input Cards is shorter than 500 Hz (2ms) that is over two (2) times than minimum 200 Hz (5ms) defined in ANSI/ANS 2.2[2]. The Analog Input Card provides 16 bit resolution and is capable of sampling two (2) more sensor signals simultaneously. The processor module is designed to provide the provision for the integral diagnostic tests that continuously check status of the processor.

The bistable function determines the trip state by comparing the seismic level to the predefined trip setpoint. When the measured signal exceeds the setpoint, the edge triggering happens and the status is set to "0" by comparator actuation. In this case, the latch is engaged and kept the status for ten (10) seconds by the edge triggering.

The 2/4 coincidence logic generates a trip initiation signal whenever two out of four bistable output are in a tripped condition.

When one sensor module is bypassed during function check or system test period, the voting logic in the trip logic cabinet is changed from 2/4 to 2/3 to prevent unnecessary reactor trip. When channel bypass is initiated, the initiation circuit of the related channel does not make the trip signal.

3. Tip Initiation Circuitry

In PWR (Pressurized Water Reactor), the trip circuit breaker on the MG-Set (Motor-Generator-Set) is selected for the trip actuation device. This breaker cuts off the power to CEA Control System when ASTS trip logic is initiated as shown in Figure 4.

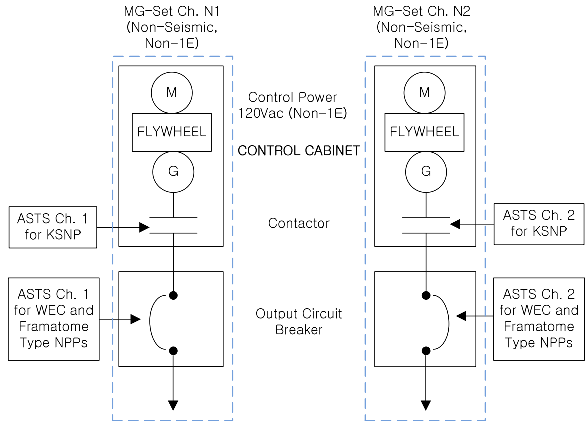

Figure 4. Trip Initiation Configuration in PWR

In case of PHWR (Pressurized Heavy Water Reactor), the reactor trip is initiated by the power cutting off from the VBPS (Vital Bus Power Supply System) to the SOR (Shut-off Rod) clutch bank coil as shown in Figure 5.

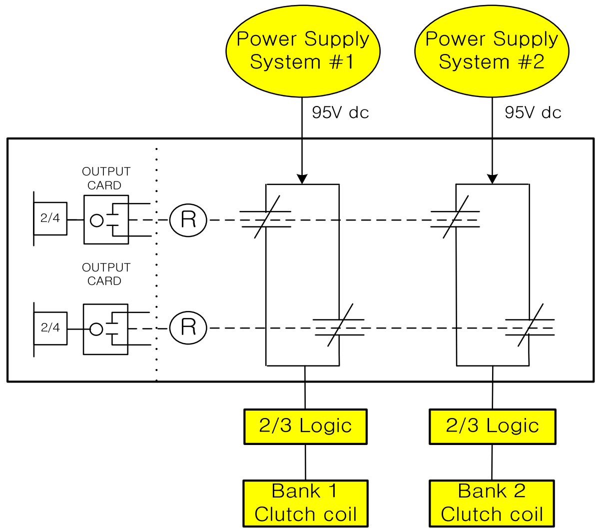

Figure 5. Trip Initiation Configuration in PHWR

4. Conclusion

The main purpose of ASTS is to provide proactive measure for the earthquake event. ASTS will be installed in all operating NPPs until the end of 2012. The characteristics of ASTS design are;

- Modular design
- Standardized design to fit the various reactor types.
- Safety and reliable design through diverse channel application

By the application of digitalized ASTS the system reliability and safety will be increased as well.

REFERENCES

[1] USNRC Reg. Guide 1.29, "Seismic Design Classification", 2007.
[2] ANSI/ANS 2.2, "Earthquake Instrumentation Criteria for Nuclear Power Plants", 2002.