Study on Design Optimization of Severe Accident Monitoring Variables

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1. Introduction

The accident monitoring instrumentation system provides necessary information to operators during and following design basis events. The accident monitoring instrumentation system shall be designed to satisfy the requirements of IEEE Std. 497. IEEE Std. 497 provides variable selection, performance, design, qualification, and display criteria for accident monitoring.

Following the Fukushima accident in March 2011, IEEE Std. 497-2016[1] added a new kind of variables, Type F, which provides primary information to indicate fuel damage and the effects of fuel damage. IEC 63147:2017[2] also added Type F variables in addition to the existing Type A, B, C, D, and E variables.

Therefore, it is necessary to design for Type F variables in the latest nuclear power plants including small modular reactors. Type F variables will be implemented in the Qualified Indication and Alarm System - P (QIAS-P) that indicates Type A, B, and C variables for the latest large nuclear power plants, Shin-Hanul Nuclear Power Plant Units 3 and 4 (SHN 3&4). Type F variables have not yet been selected for small modular reactors, and research is needed to optimize design of those variables.

This paper summarizes design requirements for Type F variables and presents studies on design optimization of those variables for small modular reactors compared to large nuclear power plants.

2. Design Requirements for Type F Variables

This section describes the major design requirements and design impact for Type F variables according to IEEE Std. 497-2016.

2.1 Selection Criteria

Type F variables provides primary information to accident management personnel to indicate fuel damage and the effects of fuel damage. Type F variables should be selected as variables that need to execute Severe Accident Mitigation Guidelines (SAMGs) and to mitigate accidents postulated in a plant's severe accident analysis. According to these criteria, Type F variables shall be selected based on SMAG and severe accident analysis.

2.2 Performance Criteria

The ranges for Type F variables shall encompass those limits that would result from fuel damage and shall additionally have extended ranges. Therefore, the instrumentation range for Type F variables shall be sufficient to execute SAMGs by adding appropriate margin to the range derived from severe accident analysis. Also, the required operating time for Type F variable instrument channels shall be sufficient to execute SAMGs based on the longest severe accident duration in addition to any design basis event that may precede it.

2.3 Design Criteria

For Type F variables, a separate stand-alone power supply protected from common cause events shall be available. This stand-alone power supply shall be independent from the design basis power suppliers. Therefore, a separate stand-alone power is required to ensure continuous power supply when the design basis power fails for severe accident monitoring.

2.4 Qualification Criteria

The type testing shall be performed for Type F variable instrument channels under anticipated severe accident environmental conditions. If required test conditions are not reached due to limitation of test equipment, then a survivability analysis shall be performed for the anticipated severe accident conditions. According to these criteria, type testing results and survivability analysis reports shall be documented.

2.5 Display Criteria

Type F variables shall be uniquely identified as severe accident variables. If Type F variables were implemented in existing accident monitoring instrumentation systems, design changes are required to add identifiers to Type F variables or to collect those variables on one page of display. Otherwise, a dedicated display shall be added to indicate Type F variables.

Type F variables shall be displayed in locations used for command and control during implementation of the SAMGs. According to these criteria, Type F variables shall be displayed in technical support center (TSC) for command and in Main Control Room (MCR) for control.

3. Design of Type F Variables for APR1400

It is necessary to design Type F variables in existing accident monitoring instrumentation systems or new display equipment for SHN 3&4. Type F variables are being designed in the QIAS-P, which displays Type A, B, C variables for SHN 3&4.

There are two main reasons why Type F variables are displayed in the QIAS-P. The first reason is that all selected Type F variables are variables related safety and overlap with the most of the variables displayed in the QIAS-P. The second reason is that a mobile diesel generator was selected to satisfy the power supply requirements described in Section 2.3. A mobile diesel generator, which is a separate stand-alone power, is selectively connected to either safety division I or II according to the accident response strategy. Since the QIAS-P has been designed to two channels (A and B) considering single failure, there are no restrictions on connecting a mobile diesel generator.

These are the reasons why Type F variables are implemented in the QIAS-P. Additionally, QIAS-P has been designed to meet all design requirements for Type F variables described in Section 2.

4. Conclusions

Recently, interest in small modular reactors is growing. For small modular rectors, design for Type F variables is also required according to IEEE Std. 497-2016. However, implementing Type F variables in safety systems like large nuclear power plants should be reconsidered. Because Type F variables do not require designs that apply to safety systems such as single failure or common cause failure requirements. Furthermore, implementing Type F variables in safety systems may be a little inefficient and conservative design, taking into consideration cost effectiveness and maintenance for small modular reactors.

If most of the selected Type F variables are related to non-safety, it is necessary to consider implementing Type F variables in non-safety systems such as operator workstation for small modular reactors. To do this, a separate stand-alone power is required to satisfy the power supply requirements described in Section 2.3.

Type F variables have been not selected yet for small modular reactors. First, Type F variables is selected, and then the design optimization of those variables shall be performed. And accident monitoring instrumentation systems including Type F variables shall be designed to improve cost effectiveness and facilitate maintenance for small module reactors.

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REFERENCES

[1] IEEE Std. 497-2016, “IEEE Standard Criteria for Accident Monitoring Instrumentation for Nuclear Power Generating Stations”
[2] IEC 63147: 2017, “Criteria for Accident Monitoring Instrumentation for Nuclear Power Generating Stations”