Equipment Survivability Assessment in APR1400

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1. Introduction

In the case that severe accident can lead to core damage among beyond design basis accidents, although it will be very unlikely, it is reasonably assumed that a number of safety and non-safety related systems are damaged or inoperable.

An nuclear power plant must have available, at the very minimum, equipment and instrumentation necessary for ensuring that vital safety functions such as RCS inventory control, core heat removal, reactivity control and containment integrity are successfully being accomplished.

Equipment Survivability(ES) assessment is to evaluate the ability of equipment and instrumentation used during a severe accident to survive and deliver their intended functions in the harsh containment environments.

2. Regulatory Requirements

The regulatory requirements regarding equipment survivability assessment during severe accidents are as follows.

❍ 10CFR50.34(f)[1]
The equipment necessary for achieving and maintaining safe shutdown of the plant and maintaining containment integrity should perform its safety function during and after being exposed to the environmental conditions with the release of hydrogen generated by the equivalent of a 100% fuel-clad metal-water reaction including the environmental conditions created by activation of the hydrogen control system.

❍ SECY-90-016[2]
The mitigation features must be designed to operate in the severe accident environment over the time span for which they are needed.

❍ SECY-93-087[3]
The design features only provided for severe accident mitigation need not be subject to the environmental qualification requirements of 10CFR50.49, quality assurance requirements of 10CFR50 Appendix B and the redundancy and diversity requirements of 10CFR50 Appendix A, and equipment survivability of the features has to be considered based on the reasonable assurance against initiate events such as station blackout(SBO), and earthquake and severe accident environmental conditions such as pressure, temperature and radiation.

3. ES Assessment

3.1 Criteria

Based on the regulatory requirements described above, plant design should demonstrate that :

❍ Equipment, both electrical and mechanical, needed to prevent and mitigate the consequences of severe accidents is capable of performing its function for the time period needed in the best-estimate environmental conditions of the severe accident (e.g., pressure, temperature, radiation) in which the equipment is relied upon to function .

❍ Instrumentation needed to monitor plant conditions during a severe accident is capable of performing its function for the time period needed in the best-estimate environmental conditions of the severe accident (e.g., pressure, temperature, radiation) in which the instrumentation is relied upon to function.

3.2 Screening of equipment and instrumentation

There are several steps, as depicted in figure 1, to select the equipment and instrumentation within the scope of ES assessment.

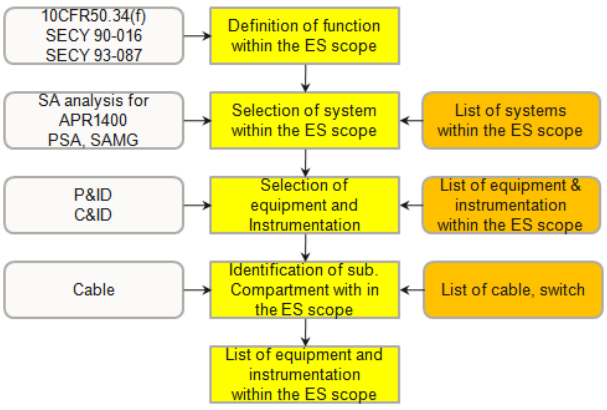

Fig. 1. Screening process diagram of equipment and instrumentation

First step is to define functions which are required regarding ES assessment in regulatory requirements. The following are the functions regarding ES.

- Reactor Safe Shutdown
- Severe Accident Mitigation and Containment Integrity Maintenance
- Severe Accident Monitoring

Second step is to identify systems that would perform the function described above. The remaining steps are to identify their sub-compartments such as equipment and instrumentations which perform the functions in the first step.

3.3 Environmental condition of ES assessment

The accident sequences are selected based on the most probable accident sequences from PSA results by considering dominant core damage frequency and sequences that can result in significant hydrogen generation and burning in containment. Then thermal-hydraulic responses of each accident sequence are calculated. Based on the thermal-hydraulic responses, the bounding thermal-hydraulic environment (i.e. compartment gas temperature) are determined, so called, ES curve, in other words, the severe accident environment. Especially, the thermal-hydraulic responses at 24 hours after core damage are used to determine the bounding thermal-hydraulic environment because the containment pressures and temperatures will start decreasing after 24 hours following the onset of core damage by the operations of the CSS(Containment Spray System) and ECSBS(Emergency Containment Spray Backup System). The equipment and instrumentation can perform their intended functions against initiating events induced by seismic event because they are designed to have Seismic Category I in APR1400.

3.4 Assurance of Survivability

There are several steps to reasonably ensure that selected equipment and instrumentation are operable in severe accident condition as follows:

- Comparison between the severe accident environment and the vender/ supplier EQ test data
- Comparison between the severe accident environment and the ES test condition
- Analytical approach: Thermal lag analysis, Qualified Life analysis
- Alternative Means: Relocations, Fire protection wrap, fire suppression device
- Multi-train design

First step is to compare between the severe accident environment and the vender/supplier EQ test data. For example, if the severe accident environment of equipment and instrumentation are not harsher than DBA EQ Test condition of them, the equipment and instrumentation are operable in the severe accident environment. Otherwise, then the next step is to compare between the severe accident environment and ES test data as in the first step. If it is impossible to ensure that equipment and instrumentation are operable in the severe accident environment by the first two steps, then there are other ways to ensure the survivability such as an analytical approach, alternative means, and multi-trains design.

4. Conclusion

In this paper, the outline of equipment survivability assessment for APR1400 was presented and is based on related regulatory requirement.

In reality, in design stage, severe accident conditions are incorporated into purchase specifications to make vender/supplier manufacture equipment and instrumentation which are reliable as much as they can operable during harsh environment. If it is impossible to manufacture such equipment or instrumentation due to the limit of costs or the manufacture technology, then designers adapt other ways such as analytical approach, alternative means, and multi-train design to meet the regulatory requirements of ES assessments.

REFERENCES

[1] USNRC, 10CFR50.34(f), Additional TMI-Related Requirements, Jun 12, 2009.
[2] USNRC, SECY-90-016, Evolutionary Light-Water Reactor Certification Issues and Their Relationship to Current Regulatory Requirements, Jan 12, 1990.
[3] USNRC, SECY 93-087, Policy Technical and Licensing Issues Pertaining to Evolutionary and Advanced Light Water Reactor Design, April 2 1993.