Methodology for a Seismic Qualification Review and a Seismic PSR of CANDU Reactors in Korea

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1. Introduction

According to the enforcement decree of the Korean Atomic Energy Act, a periodic safety review (PSR) shall be performed for operational nuclear power plants every 10 years. The scope of the PSR for nuclear power plants in Korea is based on 11 safety factors recommended by the IAEA, including a review of the seismic qualification of equipment in nuclear power plants. The following units have undergone a PSR: Kori unit 1, which began in May 2000; Wolsong unit 1, Kori units 2, 3, and 4; Yonggwang units 1, 2, 3, and 4; Ulchin units 1 and 2. At present, Wolsong unit 2 is being reviewed by the regulatory body and the PSRs of Ulchin units 3 and 4 and Wolsong units 3 and 4 have commenced. Most nuclear power plants in Korea are pressurized water reactor (PWR), and Wolsong units 1 to 4 are pressurized heavy water reactors (PHWRs) of the Canadian deuterium uranium (CANDU). A considerable amount of PWR experience has been gained through PSRs. This paper introduces methodology for seismic qualification reviews and seismic PSRs for CANDU reactors [1].

2. Seismic Classification

The systems and components that perform a safety function during or following an earthquake are classified in terms of the seismic level. These classifications are used to determine the magnitude of the loading on each component and the seismic category is used to identify the function of each component [2].

2.1 Seismic Levels

The following two levels of earthquake are defined as design envelopes for achieving safety objectives:

a. Design basis earthquake (DBE)
   A DBE means an engineering representation of the potentially severe effects of earthquakes applicable to the site, where there is a sufficiently low probability that these effects will be exceeded during the life time of the plant; this phenomenon is the same as an SSE of a PWR.
b. Site design earthquake (SDE)
   A SDE means an engineering representation of the effects at the site of a set of possible earthquakes with an occurrence rate, based on historical records, not greater than 0.01 per year; this phenomenon is the same as an OBE of a PWR.

2.2 Seismic Category

Two categories, “A” and “B”, are used in design to establish the extent to which components must remain operational during and after an earthquake.

a. Category “A” Components
   These components must retain their pressure boundary integrity or structural integrity or passive function and are not required to change state during and after an earthquake.
b. Category “B” Components
   These components must retain their pressure boundary integrity and remain operable during and after an earthquake.

3. Seismic Qualification

3.1 SSCs Requiring Seismic Qualification

The structures, systems and components (SSCs) that are required to perform a safety-related function during and after an earthquake are seismically qualified for one of two levels of earthquake (a DBE or an SDE) and one of two seismic categories (Category A or B) [3].

3.2 Seismic Qualification Program

The seismic qualification program of safety-related SSCs is based on the following Canadian National Standards:

a. CAN3-N289.1-M80 General requirements for seismic qualification of CANDU NPPs
b. CAN3-N289.2-M81 Ground motion determination for seismic qualification of CANDU NPPs
c. CAN3-N289.3-M81 Design procedures for seismic qualification of CANDU NPPs
d. CAN3-N289.4-M86 Testing procedures for seismic qualification of CANDU NPPs

These standards are also referred to in the Canadian National Standards and the ASME Boiler and Pressure Vessels Codes.

3.3 Seismic Qualification Criteria

The extent to which each system and component remains operational is established by means of the seismic categories of the individual components of each system.

A seismic category defines the following two requirements of a component:

a. the detailed functional requirement of the component to meet the safety function;

b. the requirement to perform during an earthquake or after an earthquake or both.

In section 2.2, the Category A components are qualified mainly by analysis or, if the analysis is insufficient, by a combination of analysis and testing. The Category B components are mostly qualified by tests, with a demonstration of the required functional operability. When considered appropriate, the qualification may be accomplished by a combination of analysis and testing. Specific safety-related systems that are necessary for an orderly shutdown of the reactor, for maintenance of the reactor in a safety shutdown state for an indefinite period, and for the removal of decay heat from the fuel for an indefinite period are designed and constructed to withstand the specified earthquake. The supports of pressure-retaining components that are within the ASME code boundary satisfy the requirements of subsection NF of ASME III [3].

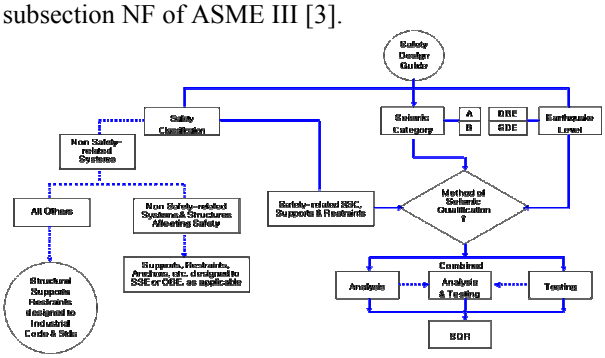

Fig. 1. Flow Chart of Seismic Qualification Process

3.4 Methods and Procedures of Qualification

The qualification and documentation procedures used meet the provisions of CAN-N289.3-M81 and CAN-N289.4-M86.

a. Qualification by Analysis
   Detailed finite element dynamic analysis with either a response spectrum method or a time history method is used for the seismic qualification of Category A components. When the structure can be modeled as a single degree of freedom system, a conservative method of equivalent 'static' coefficients is also used.
b. Qualification by Testing
   The procedures in CAN3-N289.4-M86 are used for the qualification tests. Test results that satisfy IEEE Standard 344 are acceptable. AECL accepts several test methods; the sine sweep test and the triaxial broadband random vibration test are two of the more frequently used methods.
c. Combined Analysis and Testing
   Any equipment that cannot be qualified in terms of a practical standard either by analysis or testing alone because of its size and complexity is qualified by a combination of analysis and testing in accordance with the procedures described in CAN3-N289.4-M86 or IEEE-344.

4. Seismic Periodic Safety Review

The objective of a seismic PSR is to determine whether the safety-related equipment of NPPs is qualified to perform its designated safety function throughout its installed service life under earthquakes. The items required for the seismic qualification of equipment are stipulated as follows in clause 19.2.3, 'Details of a PSR', of the enforcement regulations of the Korean Atomic Energy Act, and table 1 shows the status of a seismic PSR [4, 5]:

a. Master list and administrative procedures of qualified equipment
b. Method of equipment qualification and quality assurance
c. Analysis of the influence of equipment failure on the qualification
d. Monitoring of the environmental condition of qualified equipment
e. Physical condition and functionality of qualified equipment
f. Maintenance records of qualified equipment

Table 1: Status of a Seismic PSR

Items	Group Ⅰ	Group Ⅱ	Group Ⅲ	CANDU
Ref. Years	Before 1975	1975~1989	After 1989	PHWR
License Basis	Housner spectrum IEEE 344-71 SRP 3.7(r2): not applied	RG 1.60 IEEE 344-75 SRP 3.7(r2): not applied	RG 1.60 IEEE 344-87 SRP 3.7(r2): Applied	Canadian spectrum
NPPs	Kori 1 Kori 2	Kori 3,4 Yonggwang 1,2,3,4 Ulchin 1,2	Ulchin 3,4,5,6 Yonggwang 5,6	Wolsong 1 Wolsong 2,3,4
Seismic issues	USI A-46 USI A-40 USI A-17	USI A-40	updated license basis is owned	-
PSR status	Completely done	Completely done	U3,4: under processing U5,6/Y5,6 : to be performed	W1: life extension is under processing W2: under review W3,4: under processing

5. Conclusion

This paper introduces the overall methodology of a seismic qualification process and a seismic PSR for CANDU reactors in Korea. The evaluation results confirm that most of the CANDU reactors, except for Wolsong unit 1, meet the requirements of the evaluation standards, method and procedures. The life span of Wolsong unit 1 is expected to be extended and maintained in accordance with the requirements through a renewal of the license.

REFERENCES

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