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[Technical Report]

Geological Safety Evaluation and Monitoring of Nuclear Facility Sites in South Korea

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The Korean Peninsula, located at the southeastern tip of the Eurasian Plate, is known to be tectonically stable, and no critical evidence has yet been found that would override the safety design of nuclear facilities in South Korea. Because a nuclear power plant, like other major social overhead capital facilities, could cause great damage to both the environment and society through an unexpected tectonic event, even one of extremely low probability, like the Fukushima accident, a defense-in-depth safety approach is required in geological and geotechnical site safety evaluation for nuclear projects. This paper introduces the regulatory procedures that are in place to confirm nuclear site safety and site monitoring (e.g., earthquakes and groundwater) systems applied to nuclear facilities in order to reduce inherent uncertainties within the site safety review of geological and seismological issues related with a NPP project.

Key words: site monitoring, nuclear facility, site safety, fault, geology

Introduction

The Korean Peninsula is known to have been tectonically stable for at least several hundred years, and no critical evidence has yet been found that would override the safety design for Korea's nuclear facilities, such as nuclear power plants (NPPs) and radioactive waste repositories. However, several recent studies of faults in the southeastern part of the Korean Peninsula have reported evidence of seismicity during the Quaternary (Ryoo et al., 2002; KIGAM, 2006; Chang and Chang, 2009; Kim and Chang, 2009; Kim et al., 2011). Also, several moderate earthquakes have occurred in the past 10 years, including the earthquake offshore of Uljin (M5.2, 29 May 2004) and the Odaesan Earthquake (M4.8, 20 January 2007).

Natural phenomena resulting from tectonic processes are uncertain and often unpredictable. One of the most extreme examples of such uncertainty was the accident at the Fukushima Daiichi NPP site in Japan. Therefore, it is important to quantify the characteristics and predicted future behavior of nuclear facility sites in a conservative manner in accordance with regulatory requirements and technical standards (NSSC, 2012a, 2012b, 2012c & 2012d).

The purpose of this paper is to introduce the regulatory criteria and procedures that are in place in Korea to confirm nuclear site safety and the site monitoring systems applied to nuclear facility sites in Korea (Lee, 2011; Cho et al., 2012).

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Safety evaluation of nuclear facility sites

There are four NPP sites in South Korea. Twenty-three commercial nuclear reactors are in operation after a series of safety reviews and operational permission being granted by the Nuclear Safety and Security Commission (NSSC) and the Korea Institute of Nuclear Safety (KINS) (hereafter the Regulatory body). Five reactors are under construction and/or safety reviews for operation (NSSC, 2012b). The major purposes of undertaking a safety evaluation/review of a nuclear facility site and monitoring it are to collect design input data and to verify the acceptability of the proposed site (Lee 2011; NSSC 2012a, 2012b, 2012c, & 2012d). A period of about 10 years is generally needed to commence the commercial operation of a nuclear power plant after applying to the government for a potential site (Fig. 1). An applicant should conduct a stepwise safety assessment, including performing a preliminary site survey for several proposed sites, conducting a detailed site survey and site design for one selected site, excavating and grading the site's foundation after receiving a construction permit from the regulatory body, and, if needed, establishing and operating a proper site monitoring system (Fig. 1). Subsequently, the regulatory body verifies the acceptability of the site by undertaking a safety review of the site characteristics report (SCR) incorporated in a safety analysis report prepared by the applicant, and by making a step-by-step preoperational inspection of the site's foundations (Fig. 1; NSSC, 2012b & 2012c). Safety issues identified during the safety review or preoperational inspection should be clearly resolved before final permission is granted for the commercial operation of the NPP (Fig. 1). The overall licensing process and regulatory requirements and technical standards are presented in Figures 1 and 2, respectively (NSSC, 2012c).

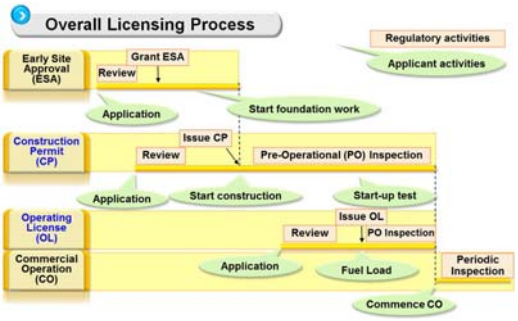

Fig. 1. Schematic flowchart showing the licensing process for a nuclear power plant site in Korea.

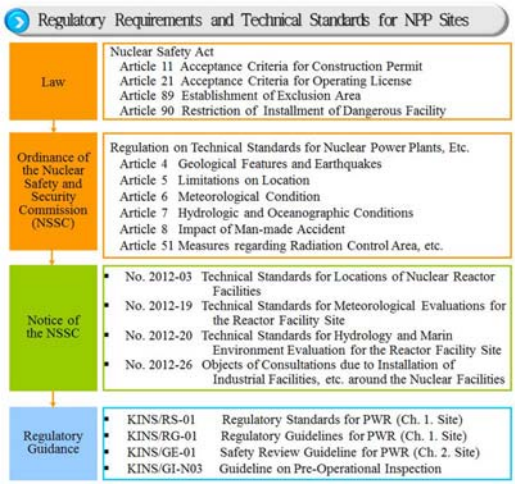

Fig. 2. Schematic flowchart showing the list of regulatory requirements and technical standards applied to nuclear power plant site selection and site evaluation in Korea.

Site monitoring for nuclear facilities

General purposes of site monitoring are to collect site-specific quantitative data from the site, to confirm and characterize the site based on the data, and to identify anomalous signals in order to prepare for a possible emergency caused by natural hazards (Fig. 3; Fig. 8.7 of BOSAI, 2007; Lee, 2011). In Korea, there are a fault monitoring system around a capable fault near Shin-Wolsong nuclear power plant site (EFMS) and a site monitoring system for Kyungju low/intermediate level radioactive waste repository (LILRWR). Korea Institute of Nuclear Safety, as a nuclear regulator, operates a nuclear site monitoring center to receive and analyze the log data from the two monitoring facilities.

Fault monitoring System near a Nuclear Power Plant

The Eupcheon Fault with a NNE-SSW trend and a SE dip direction, discovered at a construction site near the Wolsong NPP site in 1997, was defined as a capable fault at the safety review stage for the construction permit of the

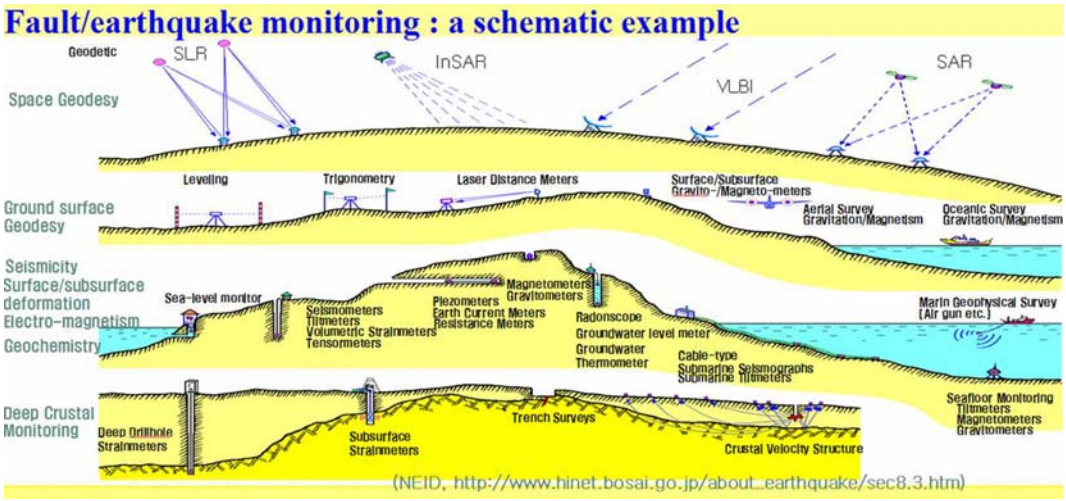

Fig. 3. A schematic diagram showing an example of fault/earthquake monitoring activities, adopted from the National Research Institute for Earth Science and Disaster Prevention (NIED) website (Modified from Fig. 8.7 of BOSAI, 2007).

Shin-Wolsong NPP (Choi et al., 2012). Closest distance between the fault and the NPP is about 3 km. After a detailed investigation, including trenching and drilling, a geophysical survey both along and across the fault trace, and a probabilistic seismic hazard analysis, it was concluded that the Eupcheon Fault is a capable fault by definition, but the size of the impact expected from the fault would not affect the safety of the nearby NPPs (Choi et al., 2012). The regulatory body, however, required the applicant to install and operate a fault monitoring system around the Eupcheon Fault for the period of operation of the Shin-Wolsong NPP (Lee, 2011; Cho et al., 2012). As a result, the Eupcheon Fault monitoring system (EFMS) was installed in 2010 and is now in operation after a one-year test period (Cho et al. 2012). The EFMS consists of an in situ measuring unit that includes strainmeters (>5 × 10 – 10), creepmeters (± 0.025 mm, ± 1°C), a GPS (± 5 mm), borehole seismometers (62.2 V/m/s), groundwater-level meters (± 0.05 cm, ± 0.05°C), a data transmission unit, and an integral operating unit (database, data processor, and operating/alert system) (Cho et al., 2012). However, the signals currently recorded by the EFMS are yet to be filtered from noise produced by tides, temperature changes, and seasonal effects (Lee, 2011; Cho et al., 2012). It is expected that a long-term monitoring data should provide a site-specific tectonic characteristics of the site and hence reduce the uncertainties inherent the safety evaluation of the fault and the site.

Site monitoring for a low/intermediate level radioactive waste repository

A radioactive waste repository must be isolated from the environment until the radioactivity of the contained waste is reduced to natural levels (NSSC, 2012a & 2012d). This may take hundreds or thousands of years, depending on the characteristics of the materials in the repository. Therefore, site monitoring during the operational period is just as important as the safety evaluation or the installation of engineering structures. One LILRWR is under construction at a location adjacent to the Wolsong NPP site in Kyungju, Korea. The major purposes of site monitoring at the LILRWR are to: (1) confirm site models and design input data developed during the site characterization stage before permits are given for construction and operation; (2) provide early detection and warning based on any anomalous signals or unexpected leakages of radioactive materials or accidents; and (3) collect site-specific baseline data useful for long-term predictions of changes in site condition and stability, in the diffusion rate of the source materials kept in the repository, and in the regional stress field. The regulatory rules and technical standards for site monitoring require the ability to establish specific plans for

preoperational, operational, and postclosure site monitoring and to describe these in the site characterization report (SCR) (NSSC, 2012a). The aspects monitored are hydrology (surface water, groundwater, and seawater), geochemistry, meteorology, seismicity, faulting, geo-engineering (the stability of slopes, tunnels, and silos), site-boundary surveillance, population, and human activities. KORAD, the utility of the Kyungju LILRWR has officially been operating its site monitoring system including the operating system, SIMONS since September 2014 after installation and test operation for the last several years.

Integrated nuclear site monitoring system in Korea

The Korea Institute of Nuclear Safety has operated an earthquake monitoring center (EMC) to monitor earthquakes recorded at seismic stations on four Korean NPP sites, and has been reporting the records to the Korean government and related organizations since 1998 (KINS 2012a). To collect and monitor real-time environmental indicators at the nuclear facility sites, KINS established a centralized nuclear facility site-monitoring center (tentatively called "NSMC") at its headquarters in Daejeon, South Korea, in 2010 (KINS, 2012b). NSMC currently receives data from the EFMS, and will also receive data from the LILRWR site-monitoring system as it starts operating in 2014, as well as other types of signals (such as groundwater level and sea level) measured at various nuclear facility sites in Korea. The data accumulated from the nuclear site monitoring should provide a foundation for establishing site-specific characteristics of and technical standards for nuclear sites in South Korea.

Concluding Remarks

Site safety evaluation should be carried out to ensure the site suitability and to establish a set of design input data for the construction and operation of nuclear facilities in South Korea, and all the proposed sites have been thoroughly evaluated and accepted for nuclear facility sites in accordance with regulatory requirements and technical standards. Sometimes, however, even when the safety of the nuclear facility sites is already confirmed during the safety review by the regulatory body, additional safety function, like site monitoring system, may be required in order to reduce the uncertainties inherent in characterizing the natural phenomena.

South Korea operates a fault monitoring system around a small capable fault near a nuclear power plant and a site monitoring system for hydrology, geochemistry, meteorology, seismicity, faulting, and geo-engineering (the stability of tunnels and silos) at the LILRWR site in Kyung-Ju area. Main purposes of the site monitoring for the nuclear facilities in Korea are to reduce inherent uncertainties during the site safety analysis for the lack of clear evidences or relevant data and to monitor possible tectonic/non-tectonic hazards that could affect the safety of the facilities. All the measured signals being sent to the centralized site-monitoring center Korea Institute of Nuclear Safety from these monitoring systems at each nuclear site will be analyzed and accumulated, and hence they should provide a foundation in establishing a site-specific characteristics and regulatory criteria for Korean nuclear sites after a long-term site monitoring.

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