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ScienceDirect

Energy Procedia 127 (2017) 20–28

Energy Procedia

www.elsevier.com/locate/procedia

International Youth Nuclear Congress 2016, IYNC2016, 24-30 July 2016, Hangzhou, China

Tornado Hazard Assessment for a Nuclear Power Plant in China

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Abstract

Tornado is one of the most hazardous external natural events which should be taken into account in the siting, design and safety evaluation of nuclear power plants. The tornado hazard has been assessed for a nuclear power plant located in the Southeast China in this paper. Using the original Fujita scale and grading by a number of experts, intensities of the tornado segments have been determined. The design-basis tornado wind speed, parameters and missiles generated have been evaluated following the methodology listed in the Chinese Nuclear Safety Guide HAD101/10. The results show that the overall cumulative frequency and intensity of tornadoes in the site area is not in a logarithm-linear relationship. The expected annual tornado occurrence frequencies of various F scales have been estimated by fitting higher intensity samples. The resulting wind speed corresponding to an exceedance frequency of 10^{-7} per year seems to be sensitive to the fitting samples. Considering the uncertainties, the intensity and frequency of tornadoes in the survey area, the ultimate design-basis tornado wind speed is taken to be 70.4 m/s, which is the lower limit wind speed of F3 scale. Moreover current problems in tornado hazard assessment in China are discussed.

Peer-review under responsibility of the organizing committee of IYNC2016

Keywords: design-basis tornado wind speed; Fujita scale; event-intensity relationship; Rankine combined vortex model; missile

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1876-6102
Peer-review under responsibility of the organizing committee of IYNC2016
10.1016/j.egypro.2017.08.091

1. Introduction

Tornadoes are generally described as violently rotating columns of air, usually associated with a thunderstorm. They are one of the most hazardous severe weather phenomena, causing significant to catastrophic damage to man-made structures, vegetations as well as human injuries and fatalities. Thus they should be taken into account in the siting, design and safety evaluation of nuclear power plants and other important infrastructures.

Wind speeds associated with tornadoes are rarely measured by meteorological instruments because of the relatively small spatial extent and short time duration of a tornado at a certain location. Intensity of tornadoes is commonly measured by the Fujita scale [1], which classifies tornado intensity in six F scale classes from F0 to F5 based on the damages caused by the tornado. Most significant tornadoes (F2 and greater) are related to supercell thunderstorms [2], and are accompanied by hailstorms, thunderstorms, rainstorms, and other violent convective weather systems [3]. Other factors such as topography and underlying surface also play an important role in the generation of tornadoes. In China, most of the significant tornadoes (greater than F2) occurred in the eastern plain and coastal areas, coincident with the convective system-prone areas [3], where all of the nuclear power plants in operation and in construction and most of the planning ones are located. According to IAEA and Chinese nuclear safety guides [4-7], information over as long a period of time as possible should be collected to determine whether there is a potential for the occurrence of tornadoes in the region. If the possibility of tornadoes in the region is confirmed, a detailed investigation should be performed to obtain suitable data for the evaluation of a design basis tornado.

United States is the country where tornadoes occur most frequently in the world. Detailed tornado information including the location, path length, width, and maximum damage rating for every tornado segment is documented by the National Weather Service. Such data have been used to determine tornado strike probabilities and maximum wind speeds for use in nuclear power plant design [8]. In 2007, the National Weather Service of US has adopted the enhanced Fujita (EF) scale in place of the original Fujita (F) scale to improve the accuracy and precision of damage surveys. To reflect the changes, U.S. Nuclear Regulatory Commission updated regulatory guide 1.76 in 2007 [9], in which the contiguous United States is divided into three tornado intensity regions, and the design-basis tornado wind speeds at the 10^{-7} per year probability level are given for the three regions. The regulatory guide has facilitated the licensees and applicants in selecting the design-basis tornado and design-basis tornado-generated missiles for a nuclear power plant. However, no tornado database is available in China. The historical tornado records are scattered in some books, reports, newspapers, and also appear on internet after 2000 [3,10]. Tornado hazard assessment for a nuclear power plant is usually evaluated on a case-by-case basis using the principles in the Chinese Nuclear Safety Guide HAD101/10 [7]. In this paper, the method and process of tornado hazard assessment for a nuclear power plant site in Southeast China is described. Moreover the uncertainties and current problems are discussed.

2. Data acquisition

The location of the nuclear power plant in study is shown in Fig.1. The site is located in the middle of the coast of Fujian Province, which is in the southeast of China. According to the requirement of Chinese Nuclear Safety Guide HAD101/10 [7], a climatically homogeneous region should be selected for the development of tornado inventories. Considering these requirements, a typical area used to evaluate the design-basis tornado is a three-degree latitude and longitude box centered at the site, which is illustrated in Fig.1. The land survey area is 41,743 km^2. Tornado information was obtained from Collections of Meteorological Hazards in China [11], Annals of Meteorological Hazards [12], and other relevant books and reports, such as China Climate Impact Assessment [13], monthly reports of meteorological observation, local chronicles, et al. Due to the rapid development and popularity of internet since 2000, tornado videos, photos and onsite interviews have been widely reported on various meteorological websites and the government portal websites, which can be used as the supplement of tornado information. For most of the tornado records, only the locations, dates and damages were reported. Little information about tornado segment length, width, and area was available. From 1959 to 2012, a total of 103 tornado segments were collected.