Site specific seismic hazard assessment – a case study of Guanyin offshore wind farm

場址特定地震危害度評估-以觀音離岸風力發電廠為例

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Outline

1. A case of offshore wind farm
2. Seismic Hazard Analysis
   ① The Earthquake Catalog
   ② Potential Seismic Sources
   ③ Ground Motion Prediction Equations
   ④ Seismic hazard Curves
3. Uniform Hazard Response Spectrum
4. Synthetic Earthquake Ground Motions
5. Site Specific Seismic Response Analyses
• WPD Taiwan Energy Co., Ltd. assess to participate in an Offshore Wind Farm project in Taoyuan County (GUA OWF).
Introduction - Seismic Hazard

- To estimate the hazard level of an earthquake for a specific area, one can perform seismic hazard analysis (SHA). Specially, the important structures such as: nuclear power plants, reservoirs, high-speed railway and so on.

- **DSHA** Deterministic

- **PSHA** Probabilistic

Procedure of PSHA

(revised from Cheng et. al, 2002)
Earthquakes and active faults related databases were incorporated into GIS, then the regional sources divided, and source models were selected. There are two models to estimate the recurrence rate of earthquakes. One is the Truncated-Exponential model, and the other is the Characteristic-Earthquake model.
Secondly, the analysis also considers the attenuation of seismic energy as it emanates from the earthquake hypocenter to the site. The attenuation of seismic energy is evaluated by empirical Ground Motion Prediction Equations (or GMPEs).
Thirdly, a logic tree was adopted to deal with the uncertainties of parameters in PSHA, such as: source type, GMPE, focal depth, earthquake magnitude distribution model, and fault geometry, finally, we can get ground motion hazard curves, uniform hazard response spectrum and deaggregation.
The Earthquake Catalog

Epicentral distribution of crustal earthquakes in 1991-2016

Epicentral distribution of mantle and subduction zone earthquakes in 1900-2016

Legend:
- Magnitude ($M_L$) 2-3, 3-4, 4-5, 5-6, 6-7, 7-8, 8-9
- Depth (km) <20, 20-35

EPICENTER MAP OF EARTHQUAKES IN TAIWAN
1900/01-2016/12 M ≥2
hypocenter depth ≤35 Km
Data source:
Seismological center of Center Weather Bureau

Taiwan Strait
Penghu Islands
Potential seismic sources in the vicinity of west Taiwan offshore wind farms may include (1) regional sources; (2) crustal faults sources; (3) subduction zone interface and (4) subduction zone intraslab earthquakes.
The information of active faults are referred to Central Geological Survey and National Central University (Lee, 1999; Cheng, 2002; Southern region water resources office, 2015).

Two subduction systems are nearby Taiwan.
The regional sources information are from Cheng et al. (2015). It uses the information on geomorphology, seismology, and geophysics. By the depth boundary of 35 km, regional sources were divided into “shallow regional sources (0~35km)” and “deep regional sources (35~200km)” , and there are 28 sources and 7 sources individually.
For the application of the PSHA, in addition to reliable seismogenic sources, another key factor is proper GMPEs. In this project, GMPEs by Lin et al. (2011) were used for crustal earthquakes, and those by Lin and Lee (2008) were used for subduction zone earthquakes.
Ground Motion Prediction Equations

Crustal earthquakes
*(Lin et al., 2011)*

\[ \ln(y_{ij}) = c_1 + c_2 M_i + c_3 \ln(R_{ij} + c_4 e^{c_5 M_i}) + \ln \varepsilon \]

where \( y \) represents the response acceleration for PGA or SA in g, \( i \) denotes the \( i \)th earthquake, \( j \) denotes the \( j \)th station recorded the \( i \)th earthquake, \( M \) is the moment magnitude, \( R \) represents the closest distance (in km) to the rupture surface, \( \varepsilon \) is a random error, and \( C_1 \) to \( C_5 \) are constants.

Subduction earthquakes
*(Lin and Lee, 2008)*

\[ \ln(y_{ij}) = c_1 + c_2 M_i + c_3 \ln(R_{ij} + c_4 e^{c_5 M_i}) + c_6 H_i + c_7 Z_t + \ln \varepsilon \]

where \( y \) represents the response acceleration for PGA or SA in g, \( M \) is the moment magnitude, \( R \) represents the hypocentral distance in kilometers, \( H \) represents the focal depth in kilometers, \( Z_t \) represents the subduction zone earthquake type (\( Z_t = 0 \) for interface earthquakes, whereas \( Z_t = 1 \) for intraslab earthquakes), \( \ln \varepsilon \) is a random error and \( C_1 \) to \( C_7 \) are constants.
The annual exceedance probability of a certain shaking level at a specific site can be evaluated by the probabilistic seismic hazard analysis (PSHA).
Seismic hazard curves

We can see the hazard contribution of different sources in various return period from the results of PGA. The horizontal dash line indicates the annual probability of exceedance in 1/475 representing 475-year return period, and it crosses over the total hazard curve at PGA of 0.19g.
Uniform hazard response spectra (UHRS) are computed or developed from the seismic hazard curves. For a given exceedance probability or return period, the ordinates are taken from the hazard curves for each spectral acceleration, and an “equal hazard” response spectrum is generated.
We use RSPMATCH program to produce the synthetic time histories, and the original accelerograms is from the Chi-chi earthquake record of the strong motion station in Xihu elementary school (TCU029) whose geological conditions are similar. Then, we adjust and iterate its time histories to match the design response spectrum in the frequency domain.

The synthetic accelerograms fitting the design response spectrum
1. We establish the soil profile model according to the drilling data.
2. Input motion, i.e., the time ground motion history, will be put at base of the soft soil profile to do the site specific response analysis with SHAKE program.
Synthetic and amplification acceleration time-histories in 475 year return period

The amplification and matched response spectrum

0.16g ➔ Pseudo-static Analysis  time-histories ➔ Dynamic Analysis
Thanks for your attention