NRC Regulations for Seismic Analysis and Design Applied to San Onofre Nuclear Generating Station

Christie Hale
Megan Williams

1. NRC History and Overview

2. Regulations for Seismic Hazards

3. San Onofre Geologic Siting Criteria and Seismic Design

4. NRC Post-Fukushima Actions

Overview

• Atomic Energy Commission
  – Atomic Energy Act of 1946
• Nuclear Regulatory Commission
  – Energy Reorganization Act of 1974

Power Plant and Regional Office Locations

Region I
Region II
Region III
Region IV
SONGS

How we Regulate

- Regulation and Compliance
- Support for Communities
- Nuclear Plant Licensing
- Reactor Performance Review
- Common Body of Knowledge
- Reactor Safety Standards
- Employee Engagement and Certification
- Performance Assessment
- Grid
- Safety
- Quality Assurance
- Safety
- NRC.gov
2. Regulations for Seismic Design

Applicable Regulations (pre-1997)

Design Bases Earthquakes (ground motions)
1. Safe Shutdown Earthquake (SSE)
   • based upon an evaluation of the maximum earthquake potential considering the regional and local geology and seismology
2. Operating Basis Earthquake (OBE)
   • could reasonably be expected to affect the plant site during the operating life of the plant

Changes to Regulations

• In the 80’s probabilistic seismic hazard analysis began replacing deterministic approach
• NRC Commission Policy Statement on Severe Accidents in 1985 recognized valuable insights from probabilistic risk assessment (PRAs)
• Individual Plant Examination for External Events (IPEEE) program undertaken in the 90s

Regulatory Guidance

Regulatory Guide 1.60 (1973)

Design Response Spectra for Seismic Design of Nuclear Power Plants
• Newmark method
• 14 strong motion recordings
• Anchored to SSE acceleration
Applicable Regulations (post-1997)

- 10 CFR 100.23 Geologic and Seismic Siting Criteria
- 10 CFR 50 Appendix S Earthquake Engineering Criteria for Nuclear Power Plants
  - uncertainties must be addressed through an appropriate analysis, such as a probabilistic seismic hazard analysis

Reassessment of Existing Plants

- When new hazard significant information comes available, the possible impact to safety of existing plants is reviewed by NRC staff
- Generic Issue program is the current program for assessment of new information

3. San Onofre Geologic Siting Criteria and Seismic Design

SONGS Basics

- Operator: Southern California Edison
- Type: Pressurized Water Reactor
- Design: Combustion Engineering
- Architect: Bechtel Power Corporation
- Power: 2200 Mw

SONGS Timeline

Unit 1
- Construction: 1964
- Full Power: 1968
- Decommissioning: 1992

Unit 2
- Construction: 1973
- Operating License: 1982

Unit 3
- Construction: 1973
- Operating License: 1982
Final Safety Analysis Report (FSAR)

- The principal document upon which the NRC bases its safety evaluation supporting the issuance of a license
- Describes the facility
- Presents the design bases and the limits on plant operation
- Provides a safety analysis of the structures, systems and components

Properties of Materials Underlying Site

- Excavated Terrace Deposits

SONGS Past Earthquakes

- Plot of Instrumental Epicenters M5.0 and greater, 200-mile Radius
- Compiled from CalTech Catalog, 1932-1980

SONGS Significant Faults

<table>
<thead>
<tr>
<th>Fault</th>
<th>Length (km)</th>
<th>Nearest Approach to Site (km)</th>
<th>Largest Historical Magnitude</th>
<th>Maximum Theoretical Magnitude</th>
<th>Maximum Site Bedrock Acceleration (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>San Andreas</td>
<td>965</td>
<td>92</td>
<td>8+</td>
<td>8+</td>
<td>0.2</td>
</tr>
<tr>
<td>San Jacinto</td>
<td>272</td>
<td>69</td>
<td>6.8</td>
<td>6</td>
<td>0.27</td>
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<tr>
<td>Whittier-Elsinore</td>
<td>233</td>
<td>37</td>
<td>5.1</td>
<td>7.75</td>
<td>0.32</td>
</tr>
<tr>
<td>Hypothesized Zone of Deformation</td>
<td>240</td>
<td>8</td>
<td>6.3*</td>
<td>7</td>
<td>SSE = 0.67</td>
</tr>
<tr>
<td>Palos Verdes</td>
<td>96</td>
<td>18</td>
<td>None</td>
<td>7</td>
<td>OBE = 0.33</td>
</tr>
</tbody>
</table>

SONGS Design Response Spectra

- Safe Shutdown Earthquake (SSE)
- Horizontal
SONGS Floor Response Spectra

- Various Elevations

SSE, Horizontal, Containment Elev. 27’-7”
SSE, Horizontal, Containment Elev. 70’-3”

SONGS UFSAR Figures 37A-02, 37A-06

SONGS Damping Ratios

- (per Regulatory Guide 1.61)

<table>
<thead>
<tr>
<th>Type of Component</th>
<th>Operating Basis Earthquake</th>
<th>Design Basis Earthquake</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equipment &amp; large diameter piping systems,</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>pipe diameter greater than 30 inches</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Small diameter piping systems, diameter less</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>than or equal to 31 inches</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Welded steel structures</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Reinforced concrete</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Reinforced concrete structure</td>
<td>3</td>
<td>3</td>
</tr>
</tbody>
</table>

SONGS UFSAR Table 3.7-02

SONGS Seismic Design Classification

Seismic Category I
Those structures, components, and systems designed to remain functional if a safe shutdown earthquake ground motion occurs

Seismic Category II
Those structures, components, and systems whose limited damage could interrupt generation of power.

Seismic Category III
Those structures, components, and systems whose failure could inconvenience normal plant operation

SONGS UFSAR Section 3.2

SONGS Design Load Combinations

Example: containment

Operating Conditions

\[ D + L + T_A + F \]

Accident Conditions

\[ D + F + T_A + H_A + R + E' \]

\[ D = \text{dead load} \]
\[ L = \text{live load} \]
\[ T_A = \text{abnormal thermal loads} \]
\[ H_A = \text{abnormal pipe expansion} \]
\[ R = \text{pipe rupture and miscellaneous missile loads} \]
\[ F = \text{prestress load} \]
\[ E' = \text{design basis earthquake load} \]

SONGS UFSAR Section 3.8

Seismic Qualification of Equipment

Demonstrates equipment will function during and after an earthquake

Testing/Analysis

- Shake Tables
- Simulates in-service conditions
- Mathematical modeling to simulate operating capability

SONGS UFSAR Section 3.2

Seismic Instrumentation

Seismic Trip
Setpoint: 0.48g
2 out of 4 logic

Ye, SCE
4. NRC Post-Fukushima Actions

Fukushima Dai-ichi Accident

March 11, 2011 - Great Tohoku Earthquake/tsunami
M9, 45 feet waves; 6 nuclear power reactors extensively damaged
July 12, 2011 – Task force issued report
No imminent danger to continued operations in U.S.
12 Recommendations to enhance safety and emergency preparedness

1. Reevaluate seismic and flooding hazard under present-day methodology and guidance
March 12, 2012 – 50.54 (f) Letters Issued

- First regulatory requirements for 104 nuclear power plants
- Mandatory response to five attachments

Recommendation 2: Reevaluate and upgrade design-basis seismic and flooding protections of Structures, Systems, and Components

- Hazard Evaluation
- Update every 10 years
- Walkdowns

Recommendation 2.1 Hazard Evaluation: Seismic

SSHAC Objective: Create reproducible, stable estimates of probabilistic seismic hazard at a site (greater regulatory assurance)

- Evaluation – considering the data, models, and methods of the larger technical community
- Integration – building models that represent the center, body, and range of technically defensible interpretations

Recommendation 2.3 Walkdowns: Seismic

Identify and address vulnerabilities until longer term actions completed

Focus on degraded, nonconforming, or unanalyzed conditions

- Electric Power Research Institute (EPRI) guidance
- Reports due in 180 days (Nov 2012)
- Temporary instruction required Resident Inspectors to accompany licensee team and conduct independent review

Recommendation 2.1 Hazard Evaluation: Seismic

NRC Actions

- Perform a reevaluation of seismic hazards at their site using present-day requirements
  - Ground Motion Response Spectrum using a probabilistic approach
  - Compare reevaluated seismic hazard and current design basis and results will be:
    - No further risk
    - Seismic risk assessment
    - Probabilistic risk assessment (SPRA)
    - Margin assessment (SMA)

Staff approved methods
Recommendation 2.3 Walkdowns: Seismic

Potential Issues:
1. Go through licensing basis evaluation
2. If not easily dispositioned, added to Corrective Action Program
3. All open items at time of reporting go into CAP

NRC Actions

Contact the NRC

Thank You

References

1. SCE, San Onofre Nuclear Generating Station, Units 2 & 3, Updated Final Safety Analysis Report (UFSAR)