RIPB Framework – Application to Seismic Analysis and Design

Nilesh Chokshi

SMiRT-25, Charlotte NC

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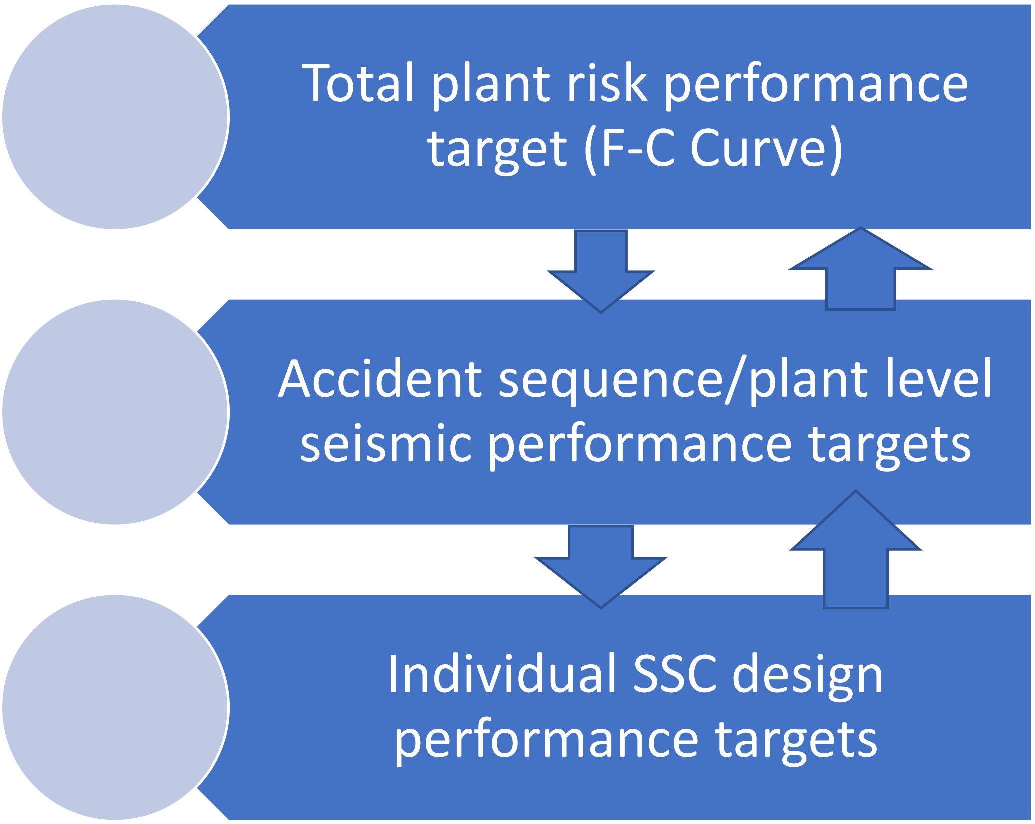
Basic Concept



An Iterative Process

Guiding Principles

- Integrate with the broader RIPB framework
- Build on existing RIPB approaches in structural/seismic engineering
- Design process still basically familiar “deterministic” process
- Utilize existing codes and standards to a maximum extent possible
- Update regulatory framework and guidance as necessary

Evolution to Performance-Based and Risk-Informed Seismic Design

DOE and consensus standards

DOE 1020-2002
Natural Phenomena Hazards Analysis and Design Criteria for DOE Facilities (updated in 2012)

ASCE 43-05
Establishes criteria for risk-informed performance-based seismic design (Reviewed in NUREG/CR-6926)

ASCE 43 Update (2018)

ASCE 4 Update (2016)
Seismic and structural analysis (consistent with ASCE 43)

ASCE 1 (Update) (2018)
Geotechnical analysis and design

1971 | 1973 | 1996 | 2002 | 2005 | 2007 | 2016-2021 | > 2021

GDCs

RG 1.60
Standardized seismic design response spectra

10CFR100.23
Requires addressing uncertainties in SSE estimates and permits use of PSHA

10CFR50 App. S
Relocated seismic engineering design criteria in Part 50

RG 1.165
PSHA guidance

RG 1.208
Performance-based approach for selecting site-specific earthquake ground motion

RG 1.208 Update

New RGs
Performance-based seismic design criteria and analysis

SRP Revisions

Advanced Reactors
Performance-based guidance

Other hazards

ASCE 43-05
Seismic design criteria for structures, systems, and components in nuclear facilities

- A standard for the design of a new nuclear facility using performance targets for individual SSCs.
- The goal of the standard is to achieve the specified target levels at the component levels:
    - Less than about a 1% probability of unacceptable performance (limit state) for design basis earthquake (DBE) ground motion; and
    - Less than about a 10% probability of unacceptable performance for ground motions equal to 150% of the design basis ground motion.

ASCE 43-05
Seismic design criteria for structures, systems, and components in nuclear facilities

- Two key assumptions:

  The analysis procedures of ASCE Standard 4 predict seismic demands for the DBE shaking at the 80^{th} percentile nonexceedance probability; and

  The equations for design strength in materials standards ACI 349 and AISC N690 deliver capacities at the 98^{th} percentile exceedance probability.

ASCE 43-05
Seismic design criteria for structures, systems, and components in nuclear facilities

- The acceptable performance level (the target performance goal) is achieved by selecting the return period of the DBE shaking
- Limit state (LS) defines the required performance in terms of the limiting acceptable condition of the SSC.
- The limit state (or the design performance) is adjusted based on the ultimate safety function and risk significance of the component.

This approach allows to control conservatisms and safety margins in accordance with the risk significance of SSCs permitting more balanced design

ASCE 43 – Concept of Seismic Design Categories (SDC) and DBE

- ANS 2.26 provides guidance to assign categories for DOE facilities - SDC 5 is considered applicable to NPPs

	SDC Categories		
	3	4	5
Target Performance Goal (P_F)	1×10^{-4}	4×10^{-4}	1×10^{-5}
Probability Ratio (R_P)	4	10	10
Hazard exceedance probability (H_D) ($H_D = R_P \times P_F$)	4×10^{-4}	4×10^{-4}	1×10^{-4}
DBE Response spectra or time history	DF (or SF) x UHRS		

ASCE 43 – Limit States

Limit State	Structural Deformation Limits
A	Large permanent distortion, short of collapse
	Significant damage
B	Moderate permanent distortion
	Generally repairable damage
C	Limited permanent distortion
	Minimal damage
D	Essentially elastic behavior
	Negligible damage

Limit state D is used currently for safety related SSCs

Use of ASCE 43 for Advanced Reactors

- Explore assigning alternate DBEs and limit states to SSCs according to their risk significance
- An example of a potential process
  - **Perform the design selecting initial SDC and LS categories**
  - **Perform a seismic PRA**
  - **Identify the major accident sequences (similar to the concept of design basis sequence in addition to postulated design basis accidents)**
  - **Identify the actual "importance" of each SSC, (if different than the original classification)**
  - **Revise SDC and LS categories, to identify design solutions that use a risk categorization approach to provide more margin where needed, but that backs off where appropriate. Maintain defense-in-depth and other qualitative factors, such as balance between prevention and mitigation, over reliance on human actions, etc.**
  - **Revise the seismic PRA to assure that the final design meets all of the criteria..**

RIPB Approach in Current Use

- Design basis ground motion for new reactors is based on hazard exceedance probability of 1 x 10^{-4} (SDC 5) – Regulatory Guide 1.208. No ASCE 43 performance targets for SSCs are explicitly applied
- The performance target currently for new reactors is at the plant level vs. component level target in ASCE 43. Demonstration of seismic capacity of 1.67 x DBE (HCLPF capacity) is required using SPRA or SPRA based methods
- Full scope (external and internal hazards) Level 1+ plant-specific PRAs are completed before fuel loading

Next Steps

- Bridging the gap between Regulatory Guide 1.208 and an integrated, performance-based approach to seismic/structural analysis and design of SSCs important to safety
- Efforts are underway to establish links among the performance targets for the overall plant risk, seismic accident sequence and plant level, and individual SSCs according to the risk significance
- Adopt ASCE 43-05 approach to the proposed framework
- Update guidance as necessary