Critical Issues in NPH Categorization and Limit State Selection of Structures, Systems, and Components

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Steps of an ideal Natural Phenomena Hazards (NPHs) design process

The design of structures, systems, and Components (SSCs) in the Department of Energy (DOE) nuclear facilities for major Natural Phenomena Hazards (NPHs) is performed, in an ideal case, following these steps:

- **Step 1: Systematic safety and hazard evaluation using STD-3009 & STD-1189 to determine the unmitgated dose consequences of failure of the SSCs on collocated workers and the public. This step also includes defining what constitutes failure (e.g., for seismic design, determination of a Limit State associated with SSC failure)**
- **Step 2: Determination of NPH design category (NDC) of SSCs based on Step 1 results**

Steps of an ideal Natural Phenomena Hazards (NPHs) design process (cont'd)

- **Step 3: Selection of a probabilistic target performance goal (PG), defined as the annual probability of non-exceedance (i.e., inverse of the frequency of failure per year), for each NDC such that the product of PG and the severity of the SSC failure consequence qualitatively approaches the same value for all NDCs. Thus, a Seismic Design Category 3 (SDC-3) SSC is designed such that it's PG is very low compared to that of an SDC-1 SSC, because it's failure consequences are much higher than those for an SDC-1 SSC.**
- **Step 4: Selection of a design method and criteria for each NDC and for each NPH, and estimate a factor, called risk reduction factor (Rp), for each combination of NDC & NPH that is equal to the ratio of the NPH exceedance frequency (hereafter called Hd) and PG (i.e., Rp = Hd/PG). Thus, RR is a measure of conservatism that is inherent in the SSC design method and criteria.**

Steps of an ideal Natural Phenomena Hazards (NPHs) design process (cont'd)

- **Step 5: NPH site characterization to obtain data necessary to perform a probabilistic NPH assessment (PNA)**
- **Step 6: PNA to develop hazard curves that plots one or more hazard parameter (e.g., peak ground acceleration) against return period**
- **Step 7: Determination of Hd (Hd = Rp x PG)**
- **Step 8: Determination of NPH demand based on the hazard curve for Hd**
- **Step 9: Designing the SSC for the calculated NPH demand using the design method and criteria for which Rp value was estimated.**

The purpose of this presentation is to critically examine and discuss a few selected issues associated with these NPH design process steps and raise questions

In the context of the steps described, the issues to be discussed are:

- **The use of annualized versus cumulative risk in NPH design of SSCs**
- **Failure of only one SSC at a time to compare against permissible dose criteria**
- **The rationale for using the number of workers, collocated workers, and public that may get adversely-affected in determining NPH design category**
- **Potential impact of SSC down time resulting from one type of NPH event on the selection of NDC for another type of NPH.**
- **Selection of Limit States or deformation limits for SSCs that have only indirect safety functions**
- **Design rules to ensure that an SSC Limit States or deformation limits are not exceeded**

The use of annualized versus cumulative risk in NPH design of SSCs

- **The current method of NPH design, e.g., in the selection of design basis return period, does not have the ability to differentiate between two facilities having two different projected service life span, even though the total probability of a member of the public to be adversely affected by the failure of a safety related SSC in a facility is a direct function of the number of years the member is exposed to the risk.**
- **Currently DOE and NRC permits some relief arbitrarily for certain situations**
- **Why does the current method use one year as the basis, not one decade, or one month?**

Currently, in determining NPH design category, the failure of only one SSC at a time is considered for comparison against permissible dose criteria

- **Except for the common- cause failure considerations, the current method does not seem to consider the combined adverse effect of multiple SSC failure.**
- **Does the consideration of common- cause failure scenarios effectively account for potential multiple SSC failure?**
- **Doesn’t the common- cause failure account for only identical SSCs?**

Consideration of the number of adversely-affected workers, collocated workers, and public in determining NPH design category

- **Currently we do not consider these, but IBC, UBC, and ASCE 7 have been doing the number of building occupants for a long time.**
- **Why should the DOE criteria not differentiate between two facilities, one in the middle of a very thinly populated desert and the other in the middle of a city?**

Potential impact of SSC down time resulting from one type of NPH event on the selection of NDC for another type of NPH.

- **It is possible for an SSC to be, say SDC-3, but say, WDC-1 because it does not have any wind hazard related safety function. Then when a WDC-1 level wind occurs and the SSC may be marginally damaged and cannot perform it's safety function. Hence, the facility should remain in a shutdown condition until the SSC is repaired or replaced. If this shutdown period is not restricted to a very small period, the facility would remain vulnerable to a seismic event for which it has a safety function, and the safety function may be applicable to shutdown mode also.**
- **This is why it may be desirable to require this SSC to be designated WDC-3 based on its SDC. And the same for other similar situations.**

Selection of Limit States or deformation limits for SSCs that have only indirect safety functions

- **Say the failure of SSC XX, which by itself does not have any safety function, can adversely affect the safety function of SSC YY, an SDC-3 SSC. Then, SSC XX is also required to be assigned SDC-3 designation, Also, the Limit State designation for SSC XX must be such that, during an SDC-3 level seismic event, it does not get deformed to a level that it adversely affects the safety function of SSC YY. And that may require SSC XXX to be designed to even Limit State D. It is noteworthy because, from the old concept of "two-over-one" situations, oftentime there is a tendency to assume that since SSC XX does not have a direct safety function, it is OK to design it to Limit State A.**

Design rules to ensure that an SSC Limit States or deformation limits are not exceeded

- **For building components it is well recognized that ASCE 43-05 establishes the design rules to ensure that an SSC Limit States are not exceeded**
- **But for non-seismic NPH design, for which ASCE 43-05 and Limit States are not applicable, it is important to ensure that the design rules used have deformation limits that are consistent with the safety function of the SSC.**
- **For seismic design of non-building components, even though not widely used, the criteria and guidelines given in ANS 2.26 and ASCE 43-05 would also ensure meeting the Limit State designation.**
- **For non-seismic NPH design of non-building components, compliance with SSC safety functions are not always straightforward, and so needs special attention.**