EFFECTIVE CONTAINMENT

OF VERY HIGH-DENSITY ENERGY STORAGE DEVICES UNDER EXPLOSION AND FIRE

Safety @ SCALE

PRESENTATION OUTLINE

I. **Premise and Threat Assessment Examples**

II. **Threat Assessment at Scale of an Energy Storage Device**
   a. **Definition of Energy at Scale**
   b. **Issues in Performing an Accurate Threat Assessment at Scale**
   c. **Proposed Tasks to Develop Needed Technical Information**

I. **Proposed Blueprint for Action**

P R E M I S E

Effective safety at a utility-size energy storage site can result only from a threat assessment based on the corresponding long-duration energy at scale.

QUALITY OF THREAT ASSESSMENTS EXAMPLES

- **Projects Reflecting SATISFACTORY Threat Assessments**
  - **HVDC Terminal Substation – Converter Building**

QUALITY OF THREAT ASSESSMENTS EXAMPLES (CONTINUED)

- **Projects Reflecting SATISFACTORY Threat Assessments**

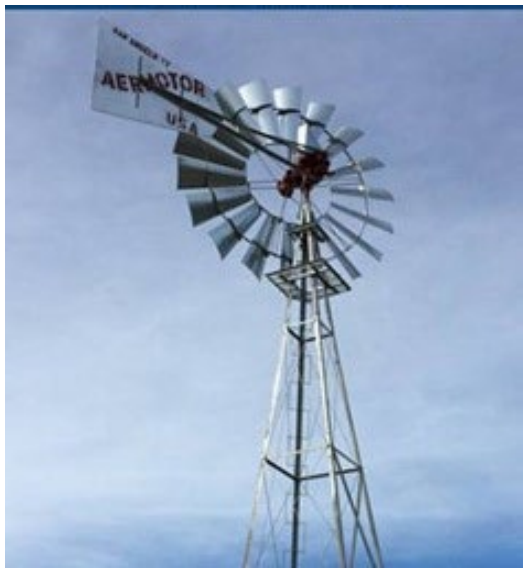
- **Modern Nuclear Reactor Containment Building**

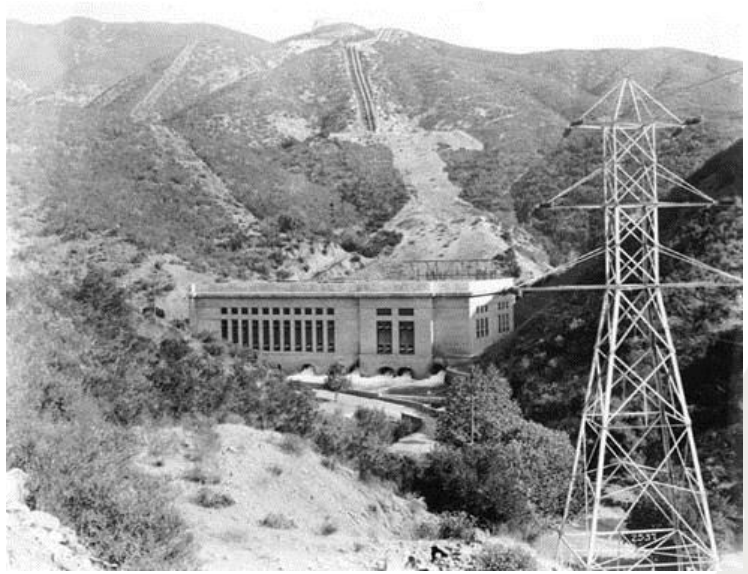
QUALITY OF THREAT ASSESSMENTS

(Examples Continued)

Projects Reflecting DEFICIENT Threat Assessment

- **Transmission Line Steel Towers**





QUALITY OF THREAT ASSESSMENTS EXAMPLES (CONTINUED)

- **Projects Reflecting DEFICIENT Threat Assessment**
  - **Fire Walls for Outdoor Power Transformers**

ENERGY STORAGE DEVICE CHARACTERIZATION

- **Quantification of the 'Energy at Scale'**

  The Energy at Scale of an energy storage device at a substation is equal to the sum of the ENERGY ratings of all interconnected conventional energy sources being displaced by the 'renewables-plus-storage' scheme, in addition to the maximum energy content of the device itself.

- **Duty Cycle Corresponding to the 'Energy at Scale'**

  Conventional generation is operated in a quasi-continuous duty cycle depending on the utility's scheduled maintenance intervals, which could typically be six months to a year. ALL loads must be served at ALL times, in addition to having energy reserves on demand to assure reliability, resiliency, and safety continuously.

ENERGY STORAGE DEVICE CHARACTERIZATION

Operational Conditions Under Which the Threat Assessment is to be Performed

1. **Prevention and suppression systems have fully failed**

2. **Containment of the explosion and fire is the only safety measure remaining**

BASIS*

FOR A THREAT ASSESSMENT AT SCALE

*** (To Be Developed)**

NEEDED: Codes, Standards, Test Protocols, and Test Facilities

1. **Revise the relevant codes, to categorize a utility-scale energy storage application according to the type and volume of fuel**, risk factors, use, and site conditions. Define and include a thermal resistance rating for the containment construction.**

   ****Test data AT SCALE for various types of energy sources will be needed here.**
2. **Develop safety criteria compatible with the full energy scale of the storage device under consideration.**
3. **Develop and disseminate representative standards and test protocols.**
4. **Develop facilities with the capabilities to test per the codes and standards.**

CONTAINMENT TESTING KEY POINTS

- **Develop criteria for the test specimen.**
- **Follow the time versus temperature curve that corresponds to a fire of the energy storage device under total failure.**
- **Apply the highest anticipated ‘replacement’ energy when performing the thermal resistance rating test of a containment system.**

CONTAINMENT TESTING KEY POINTS

(Continued)

- **Instrument the test facilities to measure all parameters to be evaluated, including: transient and steady state temperatures, heat flux, thermal radiation, and explosion shock waves.**

- **Simulate the explosion and fire suppression effects such as: thermal shock; contaminants generated and their dispersion; flooding; high pressures; and damage from water or other extinguishing materials.**

- **For practical reasons, tests for explosion and for fire exposure might need to be performed separately.**

RECOMMENDED BLUEPRINT FOR ACTION

Main Attributes

1. **BIG and BOLD**
2. **NOW and FAST**
3. **COLLECTIVE**

SAFETY @ SCALE

IN CONCLUSION

I. Take the <u>first</u> step now:

A. Develop codes and standards applicable to AT SCALE energy storage.

B. Perform an explosion and fire threat assessment AT SCALE on a representative long duration energy storage device.

II. To Be Determined (Contingent on I. above)

THANK YOU