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Istituto Superiore per la Protezione e la Ricerca Ambientale

Sistema Nazionale per la Protezione dell'Ambiente

Seveso sites and battery energy storage systems - Situation in Italy and risk assessment issues

Some thoughts on the possible risks associated with the use of BESS, in particular in industrial parks or in establishments already subject to the Seveso directive

Introduction

- Battery Energy Storage System (BESS) refers to an electrochemical device that can convert electrical energy into chemical energy or vice versa, depending on its operating mode: charge or discharge.
- The recent operational experience of BESS with lithium ions highlights a series of accidents which are also particularly significant in terms of effects (typically fires and explosions caused by thermal run-away) which severely re-propose the need for structured analyzes of these emerging risks.
- It is therefore necessary, for the operators of these increasingly numerous installations, to evaluate all the dangers given the presence, real or foreseen, of dangerous substances which it is reasonable to foresee that they could be generated, in the event of loss of control of the processes.
- In fact, in addition to the aforementioned effects, it is absolutely not possible to exclude during the actual accident phase also the development of toxic and flammable dispersions and during the response management phase the need to manage the water deriving from firefighting actions .

Introduction

Introduction

- Thermal runaway occurs when the amount of heat being generated by the battery reaction exceeds the batteries' ability to dissipate heat. Thermal runaway in a battery cell can result in fire, explosion, and toxic gases.
  - The most common initiating events that cause short circuit and thermal runaway include the following:
  - Manufacturing defects in the cells,
  - Overcharging (e.g., inverter failure),
  - Overheating (e.g. cooling system failure), and
  - Mechanical abuse (e.g., seismic event or impact)

Introduction

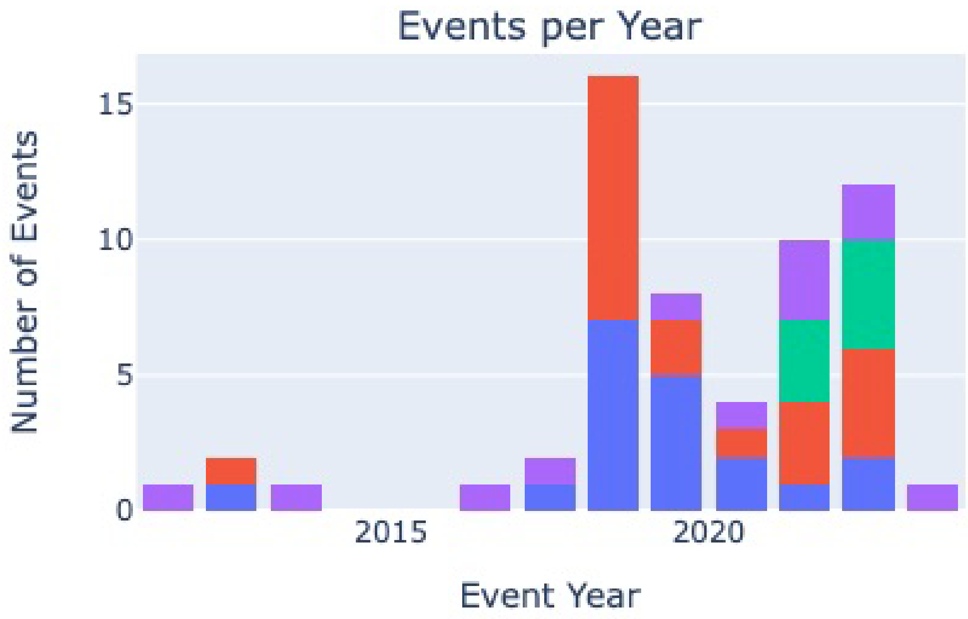
- For lithium ion battery cells, the vented battery gas mix is flammable and typically consist of the following:
  - Carbon Dioxide (CO_2)
  - Carbon Monoxide (CO)
  - Hydrogen (H_2), and
  - Hydrocarbons (C_xH_x).
- The mixture of these gases can be ignited when exposed to an ignition source.

Introduction

- When a lithium-ion battery cell has failed and starts on fire, the electrolyte becomes the main fuel. In this burning reaction, byproducts that are typically generated consist of the flammable gases explained above. Furthermore, fluorine will be liberated which comes from the lithium salt that dissolves in the electrolyte. When the hydrogen reacts with the fluorine, hydrogen fluoride gas (HF) can be formed. The HF gas production is directly proportional to the electrical energy stored in the cell or battery and can be conservatively estimated with 200 mg of HF/ Wh.

Introduction

- The BESS Failure Event Database (EPRI) provides an example where HF exposure resulted in several hospitalizations of first responders (i.e., the Neuhardenberg event). In addition, a lithium ion battery fire inside the battery room of a Norwegian ferry resulted in several hospitalizations due to the exposure to toxic chemicals



Introduction

- Some examples, excluding South Korea (29 events from 2018-2022)

Location	Capacity (MWh-MW)	Application	installation	Event date	System age (y)	status
US, CA Moss Landing	1,200-300	Solar Integr. (SI)	Power Plant	09-4-2021	0.8	
Australia, Moorabool	450-300	Grid Stability (GS)	Rural	07-30-2021	0	Construction/ commissioning
Germany Neuhardenberg	5-5	SI/ frequency reg. (FR)	Indoor/ hangar	07-18-2021	5	
China, Beijing	25- ?	SI+ other services	Mall	04-16-2021		Construction/ commissioning
France Perles-de-Castelet, Arège	0.5-0.5	Local demand mgt	substation	12-1-2020	0	testing
UK, Liverpool	10-20	FR	substation	09-15-2020	1.5	
US AZ, Surprise	2-2	Volt Reg, PQ, SI		04-19-2019	2	
SK,N.Geyongsang, Chilgok	3.7-?	SI	Mountains	05-04-2019	2.2	Charged, inactive
Australia, Brisbane		SI	Indoor, elevated floor	03-17-2020	6.7	
Belgium, Drogenbos	6(1;5)-4(1)	Test Center	Gas power plant	11-11-2017	0	

A possible approach on risk analysis

- There are various techniques that can be used to perform the hazard analysis. Most popular methods include quantitative risk assessment (e.g., with event trees), failure modes and effect analysis (FMEA), or the bowtie method.
- The bowtie hazard mitigation analysis identifies threats, hazards, and possible consequences. A bowtie diagram provides a visual representation of the mitigation features that are intended to prevent the undesired event and those mitigation features that prevent undesired consequences once that event has occurred. It should be noted that this is a consequence-based analysis, and the likelihood of the event is not considered.

A possible approach on risk analysis

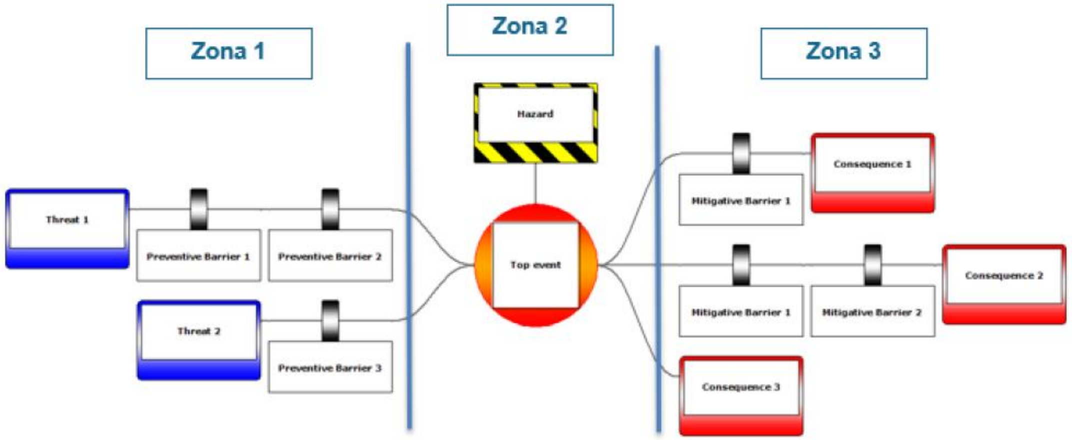
Required failure modes in hazard analysis.

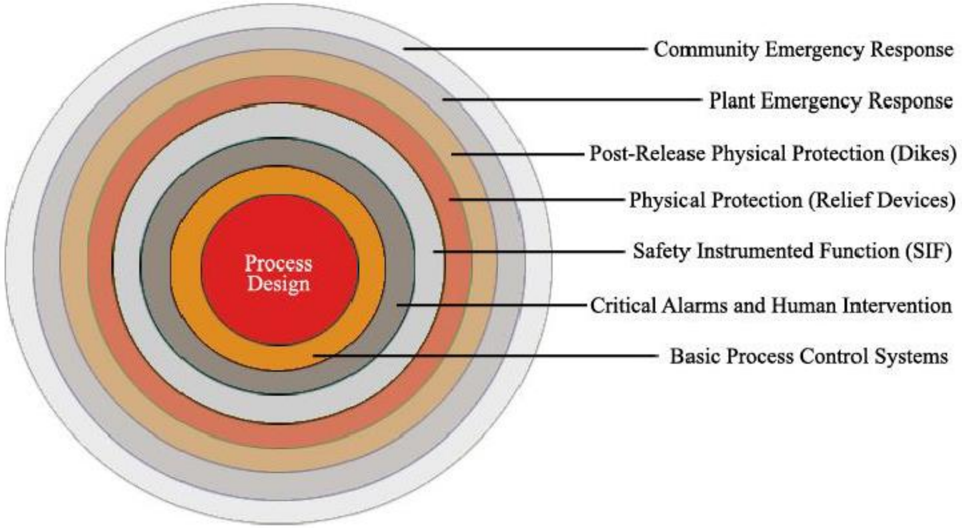
2020 NFPA 855	2021 IFC
• Thermal runaway condition in a single module, array, or unit • Failure of an energy storage management system • Failure of a required ventilation or exhaust system • Failure of a required smoke detection, fire detection, fire suppression, or gas detection system	• Thermal runaway condition in a single-battery storage rack, module, or array • Failure of any energy management system. • Failure of any required ventilation system • Voltage surges on the primary electric supply. • Short circuits on the load side of the stationary battery storage system. • Failure of the smoke detection, fire-extinguishing, or gas detection system. • Spill neutralization to being provided or failure of the secondary containment system

A possible approach on risk analysis

- These are the phases of the study conducted for a leading energy production company
  - Analysis of the reference documentation provided
  - Application of the Bow-Tie method for risk analysis, identifying the hazards, top events, causes, consequences and existing risk control measures
  - Application of Layer Of Protection Analysis for frequency quantification, using a semi-quantitative approach, of the results of the Bow-Tie analysis
  - Evaluation of the current risk, for comparison with the risk acceptability thresholds

A possible approach on risk analysis





Conclusions

- In brief, The following consequences were analysed:
  - Uncontrolled fire confined to a single BESS – Safety
  - Uncontrolled fire involving other BESS – Safety
  - Explosion and subsequent projection of fragments – Safety
  - Fire controlled by dry pipe activation and subsequent contamination - Environment
    - What about toxic release of HF?*
    - Quantification of hydrofluoric acid and other toxic off-gases emissions during the fire
    - In the absence of reliable information, rescuers-responders should be provided with the appropriate equipment.

* Journal of Loss Prevention in the Process Industries 81/2023

References

- Journal of Loss Prevention in the Process Industries 2023
- Application of the COMAH and Hazardous Substances Consents Regulations to Battery Energy Storage Systems (BESS) 2022
- Hazard Assessment of Battery Energy Storage Systems Atkins Ltd 2021
- BESS Failure Event Database
- CHEMICAL ENGINEERING TRANSACTIONS –AIDIC 2022

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Grazie