Li-ion Tamer®
Improved monitoring for lithium-ion battery health & safety

SUPDET ESS Design Challenge
November 30th, 2018
Overview

What is off-gas monitoring?
- Stages of a Battery Failure
- Early Warning Data & Thermal Runaway Prevention
- Implementation Method

Case Study
- Assumptions
- Layouts, Detection and Mitigations
- Logic flowchart
- Sample video

Wrap-up
What is off-gas?

**Definition:**
- The event in which the cell case vents due to a rise in internal pressure of the cell.

**Why is it Unique?**
- Gas generation in lead acid vs. lithium ion batteries
- Can be used for incipient fault detection

**UL 9540A Language**
6.2.5 The temperature at which the cell case vents due to internal pressure rise shall be documented.

6.2.6 The temperature at the onset of thermal runaway shall be documented.
What is off-gas?

UL 9540A Language

6.2.5 The temperature at which the cell case vents due to internal pressure rise shall be documented.

6.2.6 The temperature at the onset of thermal runaway shall be documented.

Off-gas is a unique event within the stages of a battery
Anatomy of a battery failure

Battery Failure Stages

- **Stage 1: Abuse factor**
  - Thermal, electrical, or mechanical abuse

- **Stage 2: Off-gas generation**
  - Occurs regardless of cell form-factor

- **Stage 3: Smoke generation**
  - Catastrophic failure is imminent

- **Stage 4: Fire generation**
  - Likelihood of propagation drastically increases
Battery Failure Detection (overheat)

Li-ion Tamer® detects off-gas prior to thermal runaway

Smoke Detector provides no early warning of failure
Battery Failure Detection (overheat)

Battery Fault Detection

- Off-gas is precursor to battery failure
- Detection of off-gas can provide early warning
- Advanced safety diagnostic for battery systems

Battery Fault Mitigation

- Off-gas monitoring can enable mitigation
- Isolate from charge/load when off-gas occurs
- Enables thermal runaway prevention
Battery Failure Detection (overcharge)

Test #1 conditions
- Third-party data (DNV-GL)
- 100% SOC, constrained
- Overcharged at 50A (0.8C)
- 63 Ah Pouch Cell Type
- FTIR data gathered during failure (plus H\textsubscript{2} and LEL monitors)

Remarks
- Low-level off-gassing occurs early, prior to thermal runaway
Battery Failure (overcharge)

Test #1 conditions

- Third-party data (DNV-GL)
- 100% SOC, constrained
- Overcharged at 50A (0.8C)
- 63 Ah Pouch Cell Type
- FTIR data gathered during failure (plus $H_2$ and LEL monitors)

Remarks

- Low-level off-gassing occurs early, prior to thermal runaway
- $H_2$, HCl, and HF generated during thermal runaway
- LEL monitor does not alarm
Battery Failure Detection (overcharge)

Test #1 conditions
- Third-party data (DNV-GL)
- 100% SOC, constrained
- Overcharged at 50A (0.8C)
- 63 Ah Pouch Cell Type
- FTIR data gathered during failure (plus H₂ and LEL monitors)

Remarks
- Low-level off-gassing occurs early, prior to thermal runaway
- H₂, HCl, and HF generated during thermal runaway
- LEL monitor does not alarm
- Li-ion Tamer correlates to first FTIR off-gas signatures

Li-ion Tamer provides 6.4 minutes of early warning prior to
Battery Failure (overcharge & mitigation)

**Test #2 conditions**
- Third-party data (DNV-GL)
- 100% SOC, constrained
- Overcharged at 50A (0.8C)
- 63 Ah Pouch Cell Type
- Charge is stopped at Li-ion Tamer indication
Battery Failure (overcharge & mitigation)

Test #2 conditions
- Third-party data (DNV-GL)
- 100% SOC, constrained
- Overcharged at 50A (0.8C)
- 63 Ah Pouch Cell Type
- Charge is stopped at Li-ion Tamer indication

Remarks
- Li-ion Tamer correlates to first FTIR off-gas signatures
- Thermal runaway of cell is avoided by removing charge at Li-ion Tamer indication

Li-ion Tamer is able to stop thermal runaway before it gets severe.
Case Study

Energy Storage System
- 1.6 MWh system
- 40 x 40 kWh racks
- 48,000 prismatic NMC cells

Objective:
- Fire protection concepts
- Minimizing loss
- Preventing re-ignition hazards
Assumptions

- Racks are built of air-cooled modules with flow plenum with cabinet
- Ventilation system is provided for combustible concentration reduction in accordance with NFPA 68 per NFPA 855 4.12.1
- Rack is equipped with E-Stop with remote connection to open contactor (e.g. LG Chem SR22C)
Design Concept

Layout

- One gas detector per battery cabinet – single cell fault detection for 1,200 cells
- Network of reference sensors to provide differential gas measurement within the battery racks
- Off-gas signal connections:
  - Contactor to isolate the rack from change/load
  - Ventilation to remove flammable gases and initiate draw for heavy venting during thermal runaway
Design Concept

Why mitigate with off-gas detection?

- Gas generation in lithium-ion batteries is fundamentally different than lead-acid.
- Detection and suppression designs must reflect these differences.

1. Isolate from charge and load
   - Initial stages of battery failure
   - Isolate cell to prevent thermal runaway
   - Removes 2.5% of storage capacity
   - SME can investigate fault
Design Concept

Why mitigate with off-gas detection?

2. Initiate ventilation ASAP
   - Lead acid paradigm dominates codes, standards, and best practices
   - Gas generation rates and large scale fire testing
   - Annex notes on NFPA 855 Section 4.12
   - Fire suppression initiated using:
     - Smoke & Heat
     - Off-gas and Smoke
Design Concept

Off-gas Monitoring at Rack X

- No change
  - NO: OG Detected?
    - YES: Clean Agent Released?
      - NO: Wait period
      - YES: Open Emergency Ventilation
        - NO: Close Em. Vent when gas clears
        - YES: Alert personnel on-site
          - Monitor trending temps, faults, etc
    - NO: Open Contactor at Battery Rack
IoT solutions can provide additional situational awareness of the energy storage system
Li-ion Tamer is a subdivision of Nexceris, LLC. We are located in Columbus, Ohio, USA. Our company is ISO 9001:2015 certified.

We design safety solutions for lithium-ion batteries. Our solutions are product and service oriented. Our global customer base is growing every day.
Why Li-ion Tamer?

Sensor capability
- MEMS Sensors
- IoT Connectivity
- Machine learning

Battery proficiency
- Failure expertise
- Health monitoring
- Smart algorithms