Proposal for Suppression, Detection, and Signaling Research for SUPDET® 2022

Extended Abstract

Title: Data Informed Fire-Ground Operations

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Background and Overview

Recent high profile battery Energy Storage System (ESS or BESS) failures have brought to light a significant gap in the industry: inadequate (or complete lack of) real-time data provided to First Responders on the scene of an ESS failure. Data Informed Fire-Ground Operations is a topic that specifically pertains to these unique and up-and-coming technologies. This extended abstract proposes a pathway to close current gaps in the requirements and performance of emergency alarms, notifications, and monitoring systems that are typically provided for an ESS. This is a classic application of smart fire protection and smart firefighting.

BESS Landscape and Data Sources

In the current BESS landscape, there are several useful sources of information available to first responders during a BESS failure to provide them with direction and guidance. The information that is available can be extracted from two independent sources: the Battery Management System (BMS) and the Automatic Fire Alarm and Detection system.

Understanding the Problem

Information and data from these sources, however, are not readily provided to First Responders (Fire Department and Emergency Personnel) during an ESS failure. Data informed fire-ground operations can be executed in real-time by providing the Incident Commander (IC) the relevant information about the interior conditions of an ESS. ESS fire events have demonstrated that they are relatively long duration events. This is reflected in the preliminary loss data that indicates that emergency responders responding to a ESS fire will be engaged for hours and days, and in a few cases even weeks.1

Every fire event of serious magnitude eventually requires manual intervention, e.g., fire department response. In some settings like maritime or remote locations (e.g., Antarctica), this

1 EPRI “BESS Failure Event Database”, Electric Power Research Institute, Website:
manual intervention may be limited to the internal personnel and resources. Regardless, there will almost always be a hand-off from the fixed built-in fire protection measures to the manual firefighting teams to take control, mitigate the hazard, and return the application to a safe setting.²

For most ESS applications this will likely be the local fire department responsible for the jurisdiction of the facility. Presently a serious gap exists in delivering critical data to the responding fire department that allows them to make effective real-time decisions on their fire ground operations. The focus of this paper is to identify and clarify this gap, as well as providing recommendations to address it.

**Battery Management Systems**

Currently, there are no standards that govern the construction or performance requirements for Battery Management Systems. With such variability within the industry on each individual manufacturer’s technology, design and architecture, the operation of these systems will greatly vary. This variability within the BESS landscape will unfortunately ensure that First Responders will have to adjust in their tactics for every potential BESS failure response. There will be no “one size fits all” approach and no “right answer” when responding to an ESS failure.

The current (and most widely adopted) installation codes and standards for BESS do not have prescriptive requirements that a system’s BMS operation is monitored in real time and available for First Responder’s use. The installation codes in New York City for outdoor battery ESS 3 RCNY 608-01, however, require BMS to continuously transmit data about a systems state of health to a remote, 24/7 manned area.³ 3 RCNY 608-01, more specifically Sub-section (i)(1), sets some performance expectations on the remote monitoring and reporting of the battery management system. Not only does 3 RCNY 608 require that the BMS is continuously monitored, but in the moment that it appears likely that a system has exceeded safe operation thresholds, a notification shall be made to the Department, as well as qualified fire mitigation personnel made immediately available to the Incident Commander.

A high degree of system reliability is needed, and expected, from the BMS to meet these aggressive, yet proactive performance requirements. Some of the current shortcomings with BMS are system reliability, integrity, and functional safety. The primary function a BMS is to monitor voltages, temperatures, state of charge, state of health, and other operational conditions from cells and modules within the system. Although the BMS is designed to automatically execute safety responses such as system shut-down and isolation when out-of-parameter conditions are met, they are typically not designed to be able to determine whether a fire is occurring⁴. Depending on system architecture, some BMS will lose communication after shut-down, creating a void with no data transmission. A potential solution to this issue is to design the BMS as a Safety Instrumented System (SIS) with a discrete Safety Integrity Level (SIL). An SIS is an instrumented system used to implement one or more safety instrumented functions (SIFs) and is characterized though discrete levels (1 through 4) with SIL 4 having the highest level of safety integrity and SIL 1 having the lowest⁵. It is noted that an SIS with a SIL 2 rating is consistent with the minimum reliability

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³ "3 RCNY 608-01, entitled Outdoor Stationary Storage Battery Systems" Website: https://www1.nyc.gov/assets/fdny/downloads/pdf/codes/3-rcny-608-01.pdf
⁴ 2020 NFPA 855 Appendix C Section C.7.1 Fire Detection
⁵ NFPA 69 (2019 Ed) Section 3.3.36 Safety Instrumented System (SIS)
expectations of many currently manufactured systems and components. SIL-2 typically represents a minimum reliability expectation of most fire protection systems and could be considered an appropriate minimum level of safety.\(^6\)

There are two recommended practices currently in development from the Institute of Electrical and Electronics Engineers (IEEE) known as P286 and P2688 – Recommended Practice for Battery Management Systems and Energy Management Systems in Energy Storage Applications, respectively.\(^7\) Although these recommended practices are voluntary, application of these best practices can provide an avenue for technology-wide standardization and reliability of these critical systems, further achieving the goal of firefighter safety and preservation of life and property. The national installation codes and standards are anticipated to increase the robustness of the BMS in future revisions as well.

**Gaps:**

- The BMS is a tremendous source of information, but with no installation standards existing to governing them, system variability will exist within the industry.
- Although the BMS conducts numerous safety features, they are not required to be Safety Instrumented Systems. Systems will not be robust or reliable.
- Recommended practices by IEEE are currently in development, but they are voluntary.

**Automatic Fire Alarm and Detection**

Arguably, the most critical and reliable source of information that is provided to the First Responders during a failure event is transmitted via the Automatic Fire Alarm and Detection systems. The requirements to provide these systems, however, will vary based on the governing codes and standards for BESS depending on battery technology, installation size, and installation location. These codes and standards typically mandate smoke detection to be provided at a minimum, with an allowance for alternative detection technologies if tested and acceptable to the Authority Having Jurisdiction (AHJ). Contrary to the BMS, automatic Fire Alarm systems are extremely robust, reliable, and are required to meet strict performance criteria. This includes installation standards such as NFPA 72, UL listings, and performance criteria of fire protection and life safety systems. The shortcoming with these systems is that the information provided to the first responders from these systems will be binary: There is smoke detected/There is no smoke detected. Activation of a smoke detector will expeditiously notify the first responders of the alarm condition and addressable systems can provide further guidance - pin-pointing the specific detector and location that is in alarm. Other than that, the information will be static.

Novel detection technologies may be able to address these shortcomings. For example, addressable heat detectors can potentially transmit temperature thresholds to the Fire Alarm Control Panel and provide valuable guidance to the Incident Commander on trending temperatures. Addressable gas-detectors that are resistant to fouling in a soot filled off-gassing environment can provide gas concentration readouts and potential trends in the flammable atmosphere within an enclosure. The right (and reliable) data needs to be provided to the First Responders to afford them with tailored information to help them make informed decisions during fire-ground operations. The most

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\(^6\) NFPA 69 Appendix A.15.5.5.1.2(1)  
\(^7\) [https://www.osti.gov/servlets/purl/1639304](https://www.osti.gov/servlets/purl/1639304)
challenging and dangerous situation will be when there are no visible signs of failure and no information available\(^8\).

Gaps:

- Information provided by the Automatic Detection systems is binary – Smoke/No Smoke
- Codes and Standards do not always require Automatic Detection to be provided – depends on system size, location, AHJ, etc.
- Hostile environment during fire and failure could foul detectors and render them inoperable during critical events.

**Subject Matter Experts and Fire Mitigation Personnel – Translating Data to the IC**

In good practice, during an emergency resulting from a fire or damaged ESS, fire remediation personnel representing the system owner would be immediately notified and dispatched to assist the Fire Department. These representatives should be adequately trained and versed on the hazards associated with these systems and will remain on site until the event is over, the damaged system is removed from the premises, or if dismissed by the first responders.

3RCNY 608-01 requires that a Subject Matter Expert (also known as a Certificate of Fitness Holder) is made immediately available to the department for consultation during a failure event. They can be available for consultation over the phone but could be requested to respond in-person to the scene within two (2) hours. It is the responsibility of the Certificate of Fitness holder to be inherently familiar with the installation and emergency response procedures. The Certificate of Fitness holder should also have access to BMS data to translate the information to the Incident Commander, ensuring that they are receiving the proper information needed to make effective fireground decisions.

The need to provide knowledgeable and trained fire remediation personnel stems from the lessons learned in previous large-scale ESS fires. Having a well-trained response staff has been proven to be beneficial in many aspects and considered good practice. Not only will they be able to provide guidance to the first responders, but their thorough understanding of the system architecture can also potentially avoid unintentional damage to the ESS if the first responders begin aggressive firefighting tactics that may not be necessarily warranted.

Gaps:

- Other than NYC, SMEs (or Fire Mitigation personnel) are not required to be on-scene expeditiously to assist the Incident Commander during a failure event.
- Clear and concise incident command guidelines need to be developed, to allow the SME to communicate efficiently with the Incident Commander and translate the information obtained from BESS data sources.

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\(^8\) NFPA 855 Appendix C Section C.4 Emergency Response to ESS Incidents
**Data Informed Fire-Ground Operations** Gathering, processing, and delivering the right data to the IC during an ESS failure is a classic application of smart firefighting and smart fire protection. Smart firefighting involves the utilization of a data rich environment in cyber-physical systems to enhance the tasks and activities of emergency responders\(^9\). For every application this involves the following three primary steps:

1) Gathering of Data (Communication)
2) Processing of Data (Computation)
3) Use of Data (Targeted Decision-Making)

An ESS is already a data rich environment, assuming the existence of an operational and properly designed BMS. Gathering and processing the data (steps 1 and 2) is already occurring throughout the ESS installation with numerous sensors. Of special note, the BMS is already collecting extensive real-time data that is used by technicians and facility engineers, but not the fire service. The primary gap is the failure to share this data for targeted decision making by the fire service incident commander, to make effective real-time fireground decisions.

This targeted data must be tailored precisely to what is needed by the fire service incident command. Just like a fighter pilot, too much data, incorrect data, or superfluous data can result in paralysis and be self-defeating. The data must address what is needed, to who needs it, when it is needed, the way it is needed, and nothing more. This should be similar to an annunciator panel that every fire service commander expects to see in the lobby of every high-rise building. They need to know what is happening inside the building, or for ESS within the cabinets, such as the precise location of the fire event. Of particular importance to the IC on a fire event, they need to know if the fire is growing and spreading, or if it is relatively contained and not spreading. For the fire service incident commander this translates directly to either offensive fire ground operations or defensive, i.e., are they losing control and must take rapid intervention, or the event steady state and they have time.

For the recent ESS fire events we have all witnessed, what do we expect the fire service to do when they show up? Lacking critical information, they will understandably default to a conservative or fail-safe approach. For example, if there is any question of possible fire spread on external cabinets, they will apply water until they are sure it is no longer needed. For long duration fire events like ESS that can result in very excessive water application unless there is clear indication that the hazard is mitigated, and water is no longer required. The BMS has this and other information that is valuable to the IC, to inform the IC when they can shut down exterior hose lines because the danger of fire spread has been mitigated. In summary, we don’t need to apply water for days on an ESS fire if it’s not required, but we can expect it if we don’t provide them with the situational awareness data they need to make their decisions.

**Summary Observations**

In summary, it is critical for real-time data to be provided to First Responders to facilitate Data Informed Fire-Ground Operations during a BESS failure. This real-time data fosters the ability for the Incident Commander to perform targeted decision-making during emergency operations.

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\(^9\) Grant C, Hamins A, Bryner N, Jones A, Koepke G, “Research Roadmap for Smart Fire Fighting”, NIST Special Publication 1191, Figure 1.3, page 9, May 2015
There are some fundamental data points that are recommended to be provided to the IC during a BESS failure event:

1. Fire Unit: Clearly delineate the system or area of concern that is under failure condition, most importantly, where it is located?
   a. Temperatures: how are the temperatures trending? Upwards, downwards, steady-state
   b. Flammable gas concentrations: what are the flammable gas concentrations within the unit?
   c. Active fire protection system and BMS status: Are explosion prevention systems operational and powered? Are protection systems like BMS receiving power?

2. Adjacent Units:
   a. Fire propagation: is there temperature rise occurring in adjacent units? Is fire spreading?
   b. Power: is power maintained in adjacent units (for operational purposes)?
   c. Active fire protection system and BMS status: Are explosion prevention systems operational and powered? Are protection systems like BMS receiving power?

*Note: Reach out to local responding FD to incorporate any information that they would like (or are expecting to see) if you are planning an installation.*

**The Path Forward**

What is the path forward to close the aforementioned gaps and create a BESS landscape that nurtures Data Informed Fire-Ground Operations?

- Develop and adopt BMS standards to create standardization across the industry.
- Construct resilient and reliable BMS as Safety Instrumented Systems with a minimum of SIL-2.
- Implement novel Automatic Detection technologies for BESS installations with addressable systems that can provide real-time data and trends to the First Responders.
- Bridge the gap between battery system manufacturers and first responders – create an open forum that will solidify what information would be most important, and how that information should be delivered.
- Adopt requirements for knowledgeable personnel that are intimately familiar with the installation and technology to be immediately available to the Incident Commander for consultation during a failure event.