Testimony of Joseph H. Rowley

Professional Qualifications

Mr. Rowley's experience in the power industry spans from 1980 to present. He held various engineering positions at SDG&E from 1980 to 1990. In various management positions at the IID Power Department from 1990 to 1998 he was responsible for power generation, engineering, system planning, and grid operations. He was Director of project development at Sempra U.S. Gas & Power (USGP) from 1998 to 2001, and Vice President at Sempra USGP from 2001 to 2014. Mr. Rowley has since consulted on large scale power projects and Battery Energy Storage System (BESS) projects in particular.

Mr. Rowley was the developer of IID's El Centro Unit 2 Repowering (115 MW) and Sempra's Elk Hills Power (550 MW), Mesquite Power (1,250 MW), and Palomar Energy (550 MW), all gas-fired combined cycle projects. Mr. Rowley was the developer of Sempra's Mesquite Solar (700 MW) and had hands-on supervisory responsibilities for Sempra's Copper Mountain Solar (458 MW), Energia Sierra Juarez Wind (600 MW), and Auwahi Wind project (21 MW plus 5 MWh BESS).

Mr. Rowley teaches a twice yearly seminar on large scale power project siting, including an emphasis on BESS siting, to engineering and physics students at California State University at San Marcos. He has a B.S. degree in Chemical Engineering and is a registered Professional Engineer in Mechanical Engineering.

Issues that Affect BESS Siting

1. **The BESS industry's nascent state calls for caution**. The BESS industry did not exist prior to 2011, and it did not exist in significant quantity prior to 2018 (see the EPRI Failure Incident Database graph, attached. EPRI, the Electric Power Research Institute, is the electric utility industry's collective R&D organization). Consequently, the BESS industry has little actual operating experience and no long term experience. Because codes and standards are developed and revised in response to actual operating experience and mishaps, codes and standards for BESS (e.g., NFPA 855, UL 9540 and UL 9540A) are currently in their infancy. Because codes and standards are also revised in response to technology changes, and BESS technology is evolving rapidly, BESS codes and standards are behind and playing catch up. All of this means that the BESS industry presents circumstances that call for caution on the part of public agencies that review project siting.

2. **BESS facilities are industrial in nature**. Large scale BESS facilities pose industrial risk, and a fire at a BESS facility is an industrial accident. This risk is due to the fact that BESS facilities do not store electricity, but rather they convert electricity to chemical energy, and then store chemical energy. Thus, in terms of risks and potential impacts, BESS facilities are more akin to other forms of chemical energy storage (such as liquid fuel storage) than to electrical facilities such as power substations. A significant difference is that other forms of chemical energy storage (such as liquid fuel) are not subject to spontaneous thermal runaway, whereas lithium-ion BESS facilities are subject to this problem.

3. **Thermal runaway: an inherent risk of lithium-ion BESS**. Thermal runaway is an out-of-control chemical chain reaction between various materials inside lithium-ion batteries. The chemical reaction produces heat, which accelerates the chemical reaction producing more heat, and the process spirals onward. Thermal runaway does not require oxygen, as the chemicals and materials necessary to the reaction are inside the battery; cutting off air does not stop or slow the chemical reaction. Thermal runaway converts the battery materials into a gaseous plume that contains toxic chemicals such as hydrogen fluoride, carbon monoxide, hydrogen cyanide, hydrogen chloride, fluorinated particulates, and heavy metals.

4. **Thermal runaway typically results in a secondary, air-fed fire**. The flames seen at BESS fires are not thermal runaway, but rather a secondary, air-fed fire consuming available container systems and materials, including both plastic and metal. While the secondary fire may be extinguished by conventional methods (e.g., water or chemical agent), this has no predictable, positive effect on the underlying thermal runaway, which typically continues unabated until the available battery materials are completed consumed. Because a large number of BESS fires have occurred, firefighting agencies have had opportunity to review each other's experience and evolve their tactics. Rather than trying to extinguish the secondary fire, the generally adopted approach is to cool nearby BESS structures with water to prevent propagation, evacuate downwind populations, and wait for the fire and underlying thermal runaway to burn itself out.

5. **BESS fire suppression systems are not reliably effective**. BESS systems manufacturers have tried various suppression strategies (using water or "clean agents" such as Novec 1230), but without reliable success at stopping thermal runaway, and their various efforts continue. If a reliably effective solution (i.e., suppression material and system design) for interrupting thermal runaway is determined, such a solution would likely be reflected in future iterations of BESS codes and standards.

6. **Container spacing is the only proven means of reliably preventing fire propagation**. NFPA 855 Annex G states a preferred separation distance between containers of 20 feet. To prevent fire propagation between container-like structures containing combustible material, NFPA 80A calculations indicate a minimum separation distance of about 9 feet. In a published bulletin (attached), the industrial insurer AIG states that "based on industry experience AIG has adopted a minimum of 10 feet between units to minimize fire spread." AIG further states that "UL9540A is a very useful testing method to evaluate thermal runaway propagation but it does not guarantee that a fire will not spread when certain environmental conditions are present. Only adequate spacing will do this."

7. **BESS fires may continue for days**. Experience indicates that it can take 24 hours to a couple of weeks for the available battery materials to be consumed by thermal runaway and fire, depending on the degree to which the various battery groups comprising a facility are segregated (i.e., containers vs. warehouse, distance between containers, etc.). The event duration results in a large quantity of firefighting water which has almost certainly intersected the toxic plume to some degree. Because toxic chemicals will be, to an unknown degree, dissolved or entrained in the firefighting water, the water should be retained and tested before

being released to drainage or treated to render it non-toxic. The recent Escondido BESS fire (September 5-6, 2024) lasted for about 24 hours, during which time one or two water hose streams flowed continuously (see the attached photos). These efforts limited the fire to the consumption of one BESS container out of twenty-four, which are spaced about 8 feet apart. The Otay Mesa BESS fire (May 15-June 1, 2024) lasted much longer due to lesser segregation of batteries, so much more water was used.

8. **Offsite Impacts**. As for all industrial facilities that present the potential for airborne release of toxic chemicals, proposed lithium-ion BESS facilities should prepare an analysis of potential offsite impacts, often referred to as an Offsite Consequences Analysis (OCA). To be worthwhile, an OCA must evaluate credible, worst-case scenarios. For a BESS facility, this means consumption of the entirety of the battery materials contained in a single structure (e.g., container), assuming adjacent structures are sufficiently distant to prevent propagation. An OCA uses plume dispersion modeling to estimate downwind concentrations of toxins, and it compares those estimates with Acute Exposure Level Guidelines (AEGL). AEGL-1 is the appropriate threshold for evaluation, which is the concentration that produces "notable discomfort, irritation, or certain asymptomatic non-sensory effects," per USEPA.

9. **Risk of thermal runaway is proportional to BESS facility size**. Because BESS facilities are modular, the risk of thermal runaway is proportional to facility size. BESS are modular at every level, including individual battery cells, battery racks, and containers (including container systems). So regardless of the triggering event (e.g., battery cell manufacturing flaw, short circuit or ground fault, failure of a container's thermal management system, etc.), the size of the BESS facility (expressed in megawatt-hours, MWh) reflects the number of potential points of failure, and thus the probability of failure. For example, as compared with a 100 MWh BESS, a 200 MWh BESS has twice as many battery cells, twice as many electrical terminations, twice as many thermal management systems, etc., and thus twice the failure rate for the overall facility.

10. **Threshold temperature for thermal runaway**. One of the ways that thermal runaway can be initiated is by exceedance of a battery cell's thermal runaway threshold temperature. The threshold temperature depends on the specific type of lithium-ion battery. For example, the threshold for LFP (lithium iron phosphate) batteries is around 270^{o}C, for NMC (nickel manganese cobalt) batteries it is around 210^{o}C, and for NCA (nickel cobalt aluminum oxide) batteries it is around 150^{o}C. Lithium-ion batteries are about 90% efficient, which means they are about 10% inefficient, and this inefficiency is manifest as heat. Failure to entirely and continuous expel this heat from the battery cells and container (the job of each container's thermal management system) results in elevated temperature and potential thermal runaway. However, it is noteworthy that any specific technology's threshold temperature becomes irrelevant if the triggering event is an electrical arc (which may be produced by a short circuit or ground fault), as such events produce temperatures in the thousands of degrees Celsius.

11. **Cutting-edge vs. proven technology**. Historically, the power industry has relied upon proven technology rather than cutting-edge technology, such as in the case of combustion turbines, steam power cycles, generators, transformers, etc. This risk-averse ethos began to change as

non-utilities entered the power industry, and further changed with large scale solar development. Newer solar technology tends to be cheaper, and because solar facilities are modular, the risk of failure of any one component leaves the remainder of the facility unaffected, making the consequences small. Unfortunately, in some respects this thinking has carried over to BESS development. For example, the BESS industry strives for ever-higher energy density because this yields a cheaper result, although battery instability increases with energy density. As always, developers must make choices between cost and reliability. The problem is that (unlike solar facilities) the consequences of a BESS failure are not small, because BESS fires pose substantial risk, including risk to third parties.

12. **Noise**. About 10% of the energy stored by a BESS facility is lost as heat. Each container's cooling system (part of the container's thermal management system) must entirely and continuously expel this heat to promote battery life and avoid thermal runaway. So the cooling system is not merely cooling the interior of a container, but rather it is an essential part of the process of safely and reliably converting electricity to chemical energy, storing chemical energy, and later re-converting chemical energy back to electricity. As such the cooling system is substantial in size, and its fans generate considerable noise.

13. **Large scale BESS should be sited with industrial surroundings**. The problematic nature of thermal runaway calls for caution on part of public agencies that review proposed BESS site locations. Especially at this early stage of the BESS industry, large scale BESS facilities should be located in an industrial setting. The potential release of airborne toxic chemicals is not special to BESS facilities, but rather it is an aspect of many types of industrial operations. This is one of the reasons for co-locating industrial facilities via zoning, because each such facility should have an emergency response plan in place, and associated employee training, that can be activated regardless of whether the airborne toxic release has occurred onsite or at another industrial site in the vicinity. Codes and standards for BESS (e.g., NFPA 855, UL 9540, and UL 9540A) render BESS suitable for location in an industrial setting.

<u>Siting Issues Specific to the Proposed Rancho Viejo Project</u>

A. The proposed BESS component is not planned for an industrial setting. Instead, the site is surrounded by wildland (grasslands) and a proposed solar field, with single-family residential neighborhoods being the closest developed property. How grasslands and a BESS facility will interact is unknown, due to industry inexperience. A grasslands fire may be problematic for a BESS facility (e.g., dense smoke may disrupt BESS cooling system operation), and conversely, a BESS fire may spread to grasslands.

B. An OCA (Offsite Consequences Analysis) for the proposed BESS component has not been prepared for the proposed BESS component, i.e., no attempt has been made to assess offsite impacts of the plume resulting from a battery fire. Because the containers are proposed to be set in pairs only 3.5 feet apart, plume dispersion modeling should assume that <u>two</u> containers are completely consumed in a battery fire event (irrespective of UL 9540A test results).

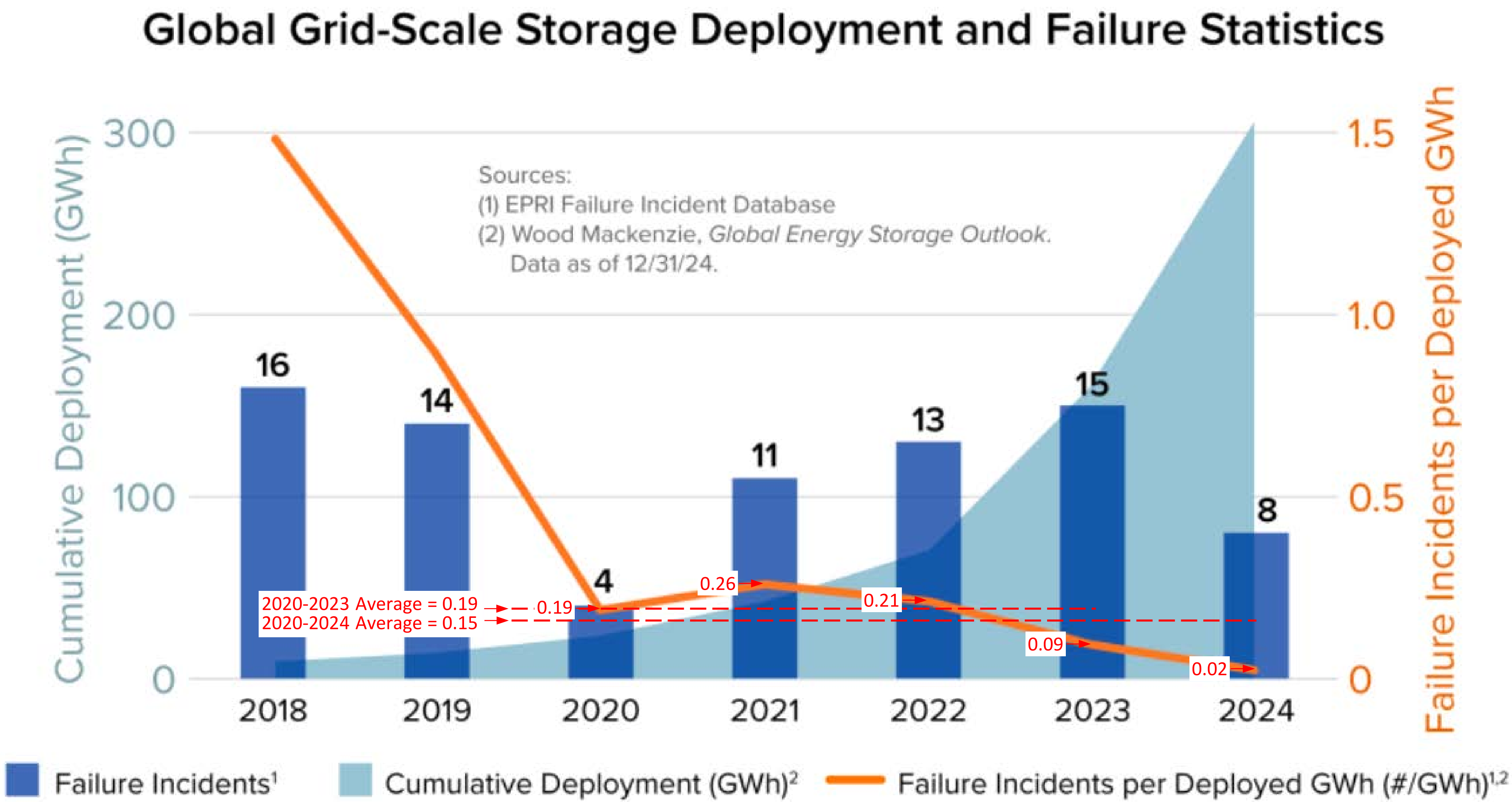
C. The proposed FK-5-1-12 fire suppressant is the generic name for Novec 1230, a chemical agent (fully-fluorinated ethyl isopropyl ketone) invented and produced by 3M. In its product data sheet, 3M explicitly states that this suppressant "cannot stop thermal runaway once initiated." The only reliable solution determined through experience to date is physical separation, which confines the event to a limited quantity of battery material. Because the proposed design has containers paired only 3.5 feet apart, emergency response plans should assume two containers will be consumed by fire (irrespective of UL9540A test results).

D. The proposed 30,000 gallon water tank is inadequate for addressing a BESS fire. It should be assumed that one or two hose streams will be needed for 48 hours, which assumes the fire will take 24 hours to consecutively work its way through each of two paired containers. At 200 gallons/minute per hose, and an average of 1.5 hoses in use over 48 hours, that equates to about 900,000 gallons. Alternatively, a water pipeline from a municipal source would need to convey at least 400 gallons/minute at adequate pressure.

E. The proposed BESS component does not appear to include a retention basin to sequester firefighting water. Such a retention basin would need to be sized for 900,000 gallons (at minimum) plus freeboard. To avoid reliance on transfer pumps, the retention basin would necessarily be located downhill from the BESS component. Unfortunately, as shown on the project drawings, an "Environmentally Sensitive Area" is located immediately downhill from the BESS (based on elevations determined via Google Earth). The effect of toxin-containing firefighting water on this "Environmentally Sensitive Area" is unknown.

F. The proposed NCA (nickel cobalt aluminum oxide) lithium-ion technology is relatively unproven in large scale BESS application. NCA batteries have a relatively low threshold for initiation of thermal runaway. Furthermore, as indicated by the proposed 8.1 MWh per container, the energy density of NCA technology is very high (5-6 MWh per container is more typical). Holding other variables constant, the risk of failure increases with higher energy density and lower thermal runaway threshold temperature.

G. There is a major discrepancy in the stated size of the proposed BESS component. Generally, the size is stated as 192 MWh. However, given the proposed 38 containers of 8.1 MWh each, the overall BESS component would store 307 MWh of chemical energy, a 60% increase. This means not only a 60% increase in the overall tonnage of battery materials stored onsite, but it also poses increased risk for a battery fire, because risk is proportional to facility size. Based on EPRI statistics, the average risk is about 1.5 failures each year per 1,000 MWh. At 192 MWh, the facility would have about an 86% chance of fire over a 30 year life. At 307 MWh, the facility would have about a 138% chance of fire over 30 years. However, EPRI's failure statistics are based on batteries with a worldwide fleet average age of only about 2 years. To what degree failure rates will increase due to increased fleet average battery age is unknown. Furthermore, the proposed NCA lithium-ion batteries may have a higher failure rate than the worldwide fleet, which is generally comprised of mostly NMC and some LFP batteries. The potentially higher failure rate of NCA batteries is due to their lower thermal runaway threshold temperature and higher energy density.



Values and notes in red have been added (J. H. Rowley 3-22-25).

Insight: Utility Battery Energy Storage Systems

Recognizing the Risk

With the push for more renewable energy and the need for battery energy storage systems (BESS), the number of installations has been significantly increasing globally. While the use of batteries is nothing new to the electric generation industry, the use of batteries within the electrical grid to support large electrical loads is. This quick expansion has led to added risk and questions about proper fire protection.

There are different types of battery cells available that can be found in a wide range of consumer product applications from mobile phones to electric vehicles. Lithium-ion batteries (LIBs) are currently the most common type used at large-scale power generation facilities to support electrical grid loads. And BESS is still a relatively new application. LIBs have many advantages including efficiency, long life expectancy, and relatively low maintenance. But disadvantages with this technology include significantly increased fire risk with difficulty in fire control and extinguishment once a fire has started.

Like all batteries, LIBs are chemical energy storage units that release their stored charge in the form of electrical energy through an electrochemical reaction. However, the design of the LIB is the reason fire hazards are extremely difficult to extinguish.

Thermal Runaway is the term used when a battery experiences a quickly escalating overheating event. This can lead to a catastrophic fire or explosion which then often quickly cascades to adjacent cells. These types of fires are difficult to put out and are extremely hazardous, producing toxic fumes along with the fire and the associated electrical hazards. This type of failure has been witnessed at multiple BESS facilities across the world with large associated property damage and business interruption costs.

As a result of a significant failure, in 2019, the National Fire Protection Association (NFPA) developed Standard 855 to address the fire protection of these systems. In this standard, the BESS test standard UL 9540A is recognized.

Controlling the Hazard

As these large BESS facilities continue to be built to support the growth of renewable energy, focus has increased on making safer and more reliable systems. The electrical industry knows that batteries are necessary and will play a key role in the future of the electrical grid.

There are many fire protection methods that include fire suppression systems, monitoring and control systems, and spacing between units. While both fire suppression and monitoring and control systems are useful mitigation measures, it has been proven that the only truly effective method is adequate spacing to prevent spread to adjacent units and containment to a single unit. While industry experience has shown that water-based fire suppression systems have even been the cause of thermal runaway due to inadvertent operations or leaks, gaseous fire suppression systems have proven to be ineffective for this type of chemical reaction fire.

Physical Layout

When designing a BESS, one of the most important aspects is the physical layout of the batteries. BESS can be installed in either both newly fabricated buildings designed specifically for this application or retrofitted buildings that before served other purposes. In either case indoor facilities have shown to be a significant risk and mitigating the spread of damage from a fire event extremely difficult. Industry experience has also shown that indoor facilities are not the best option when designing a large scale BESS.

Outdoor facilities are the prefered option when building a large scale BESS as there is usually adequate room to provide the required spacing, typically in rural locations. Where outdoor spacing cannot be extended, electrical capacity of the facility may need to be decreased (fewer batteries) which may make the project economically less attractive.

Adequate spacing of battery racks or containers won't prevent a fire, but will keep losses to a minimum. There is currently no industry standard for the correct spacing, but based on industry experience AIG has adopted a minimum of 10 ft (3.0 m) between units to minimize fire spread.

The UL9540A test method was established for evaluating thermal runaway propagation and is widely recognized thoughout the industry. The results of a UL9540A test will help the manufacturer develop installation guidelines, ventilation requirements, appropriate fire protection methods, and strategies for fire department. There is some confusion too as some test results used during UL9540A testing showed that in some cases adequate spacing can be less than 1 ft (0.3 m) for certain manufacturers. Industry experience has shown that this is not always the case. The UL9540A utilizes certain criteria such as wind speed. The reasoning behind this is that a higher wind speed would help to cool adjacent battery containers and will limit overall damage to these containers which is correct, but higher wind speeds in some cases will also aid the fire in jumping to adjacent containers. Therefore UL9540A is a very useful testing method to evaluate thermal runaway propagation but it does not guarantee that a fire will not spread when certain environmental conditions are present. Only adequate spacing will do this.

In outdoor facilities once a fire has begun at one container it can be assumed that this one container will be a complete loss and if adequate spacing between containers is used no other containers will be heavily damaged. The idea is to keep the damage contained to a single container.

The design of containerized units also needs to take into acount the location of explosion vents or other penetrations to ensure they are placed in a way that directs any hot gases away from surrounding equipment or buildings.

Battery Management Systems

Although not all fires can be mitigated it is still important to incorporate measures into the design that will help mitigate an event before a failure leads to a fire. Battery management systems play an important role in monitoring and controlling the BESS to make sure it is operating within the correct limits.

Battery management systems should monitor cell temperature, capacity, state of charge, voltage, and current while charging and discharging, and provide alarms and trip functions. Just like any other maintenance program or monitoring system the idea is to identify a concern in enough time to take action. Advanced battery monitor systems are able to collect and process a large amount of data that provides valuable information and determines the overall health of each cell.

Recommendations

Large-scale BESS facilities are being built at a fast pace with no signs of slowing down. As the industry continues to gain experience and technology advances mitigation strategies will also need to evolve. When designing BESS the most important consideration needs to be the physical layout and specifically the spacing of equipment. Spacing is the recommended way to limit the overall damage during a fire event. While battery monitoring systems and fire suppression systems are important, a battery fire is like no other fire the electrical industry has seen. Based on industry experience and past BESS failures, it is recommended to only design outdoor facilities with a minium of 10 ft. (3m) between containers.Spacing, Spacing, Spacing!

Resources / Standards

NFPA 855 Standard for the Installation of Stationary Energy Storage Systems

UL 9540A Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems

For more information, contact your local AIG Property Risk Engineer.

Escondido Substation BESS Fire
September 5, 2024

Escondido Substation BESS Fire – Particulate Plume
September 5, 2024

Escondido Substation BESS Fire – Propagation Suppression
September 5, 2024

Escondido Substation BESS Fire – Involved Container
September 5, 2024

Escondido Substation BESS Fire – News Coverage
September 5, 2024

Escondido Substation BESS Fire – Thermal Image
September 5, 2024