IMPROVING THE SAFETY OF LARGE-SCALE LITHIUM ION ENERGY STORAGE SYSTEMS

Lessons learned from a number of large-scale ESS fires in South Korea

Abstract
This white paper unpacks a recent investigation by the Korean government into 23 large scale ESS fires and explains how Alencon’s BOSS unit can prevent such mishaps from occurring in the future.
White Paper: Safety Lessons from Large Scale Energy Storage System Fires

Contents
Introduction .................................................................................................................................................. 2
How the Alencon BOSS can Help .................................................................................................................. 3
How Large Scale ESS are Constructed........................................................................................................... 3
Charging and Discharging the ESS – Container vs. Rack Level................................................................. 3
More Lessons from the Korean ESS Investigation ...................................................................................... 5
How the Alencon BOSS Make ESS’s Much Safer....................................................................................... 5
Why Addressing the Lithium Ion ESS Safety Issue is so Critical................................................................. 6

Figure 1: A large-scale lithium ion ESS fire in Korea being put out by first responders. Given the large amount of energy stored by these systems, fires created when they fail can be particularly dangerous and hard to contain.................................................................................................................. 2

Figure 2: The building blocks that make up ESS construction. .................................................................. 3

Figure 3: An electrical schematic of a DC coupled PV with ESS Monolithic Charger. In such a configuration, all racks are placed in parallel, generating a very high level of fault current and an inability to detect faults at the battery rack level................................................................................................................. 4

Figure 4: Alencon’s BOSS provides galvanic isolation to LI battery racks which offers many safety benefits including being able to detect harmful faults before they occur ................................................................................. 4
Introduction

By now, it is well understood that large scale energy storage is the key to allowing us to achieve our clean energy utilization goals in the effort to fight back against climate change. Energy storage helps us overcome the biggest drawback to renewable sources of generation like solar – the issue of intermittency. Pairing renewables with storage creates the opportunity to turn clean sources of generation into truly dispatchable energy resources.

Large scale lithium ion batteries can store a huge amount of energy and make it available on demand. However, the revolutionary benefit these batteries provide comes with a major public safety drawback: large scale lithium ion batteries can catch fire and even explode if not deployed safely. Such fires can be massive and particularly difficult to contain for first responders.

Figure 1: A large-scale lithium ion ESS fire in Korea being put out by first responders. Given the large amount of energy stored by these systems, fires created when they fail can be particularly dangerous and hard to contain.

One less well-known fact is that as of 2019, South Korea is the world leader in megawatt hours of large-scale lithium-ion energy storage systems (ESS) deployed. That deployment experience has also meant South Korea has seen a number of fires and other mishaps of large-scale storage systems, giving them more data points to study in improving safety going forward. In June of 2019, the Korean government issued a report on the conclusions its fire investigation committee drew regarding the root cause of the 23 energy storage system fires that have occurred there since August of 2017.

In their report, Korean officials stated:

“Systems were not able to properly protect against electrical hazards due to ground faults or short circuits. The short circuit current allowed the failures cascade to the bus bar which resulted in fires inside the ESS”.

Figure 1: A large-scale lithium ion ESS fire in Korea being put out by first responders. Given the large amount of energy stored by these systems, fires created when they fail can be particularly dangerous and hard to contain.
All the failed systems studied were charged/discharged by a monolithic power converter that required all of the battery racks in the ESS to be connected in parallel on the same DC-bus.

How the Alencon BOSS can Help
Here at Alencon, we build a unique DC-DC optimizer known as the Bi-Directional Optimizer for Storage Systems – the BOSS - which has been specifically designed to address the exact safety shortcomings in large scale lithium-ion ESS found by the Korean government in their investigations. The BOSS is a galvanically isolated DC-DC converter that charges each rack in a large scale ESS separately and thus eliminates the need for a common bus bar and can prevent the catastrophic failures observed in Korea and elsewhere by detecting ground faults and short circuits before they happen.

How Large Scale ESS are Constructed
Large scale ESS are made up of a series of smaller building blocks. Lithium ion cells are assembled into modules and modules are then stacked into racks placed into battery storage containers, which form the ESS (See Figure 2 below). Each module can store 10 to 15 KWh of energy at about 50 VDC. Each rack stores about 350 KWh via the serial connection of up to 24 modules. An ESS container can store upwards of 6 MWh energy. The modules have built-in electronics called a battery management system (BMS). The BMS is interfaced with the energy management system (EMS), which monitors the state of a battery rack and controls the power management system (PMS) that contains fuses and disconnects.

Figure 2: The building blocks that make up ESS construction.

Charging and Discharging the ESS – Container vs. Rack Level
Large scale ESS solve the intermittency problem of renewables by charging during times of oversupply of energy, such as when a PV plant with a DC overbuild in overproducing and discharging when the renewable resource is unavailable, such as at night, in the case of solar.

There are essentially two ways to charge or discharge the battery racks in an ESS. You can either parallel all of the racks on the same DC-bus or do so one rack at a time. So called “monolithic” chargers require all the racks to be placed in parallel and thus charge and discharge all the racks in the ESS at once. An electrical schematic of such an approach is shown in Figure 3 below in the context of a DC coupled Solar + ESS. In such a topology, all racks are placed in parallel which of course leads to much higher fault current contributions (in parallel, current adds up…and as any electrician will tell you, current kills!)
Figure 3: An electrical schematic of a DC coupled PV with ESS Monolithic Charger. In such a configuration, all racks are placed in parallel, generating a very high level of fault current and an inability to detect faults at the battery rack level.

In a rack level-based charging scheme using the Alencon BOSS, as shown in Figure 4 below, each rack can be controlled individually and thus does not require all the racks to be placed in parallel, thus significantly reducing the fault current contribution of the ESS.

Figure 4: Alencon’s BOSS provides galvanic isolation to Li battery racks which offers many safety benefits including being able to detect harmful faults before they occur.

You can learn more about rack level vs monolithic charging as it pertains to fault current contribution from the article located at https://alenconsystems.com/learning/minimizing-fault-currents-large-scale-storage-deployments/
More Lessons from the Korean ESS Investigation
The Korean government’s report highlighted two interesting conclusions about the causes of these fires:

1. **Insufficient battery protection systems against electric shock:** Systems were not able to properly protect against electrical hazards due to ground faults or short circuits. When large electrical surges were imposed on the battery system the fuse was not able to quickly interrupt the current which led to catastrophic failure of the contactors. The short circuit current allowed the failures to cascade to the bus bar which resulted in fires inside the ESS. This failure mode was confirmed by the committee during their fire accident investigation.

2. **ESS System Integration:** The integrated protection and management systems were found to be insufficient with the ESS. It was confirmed by the committee that gaps in the integration of the battery management system (BMS), energy management system (EMS), and power management system (PMS) can result in conditions that lead to fire. Integration issues included inadequate information sharing between systems, system operating sequence, and checking for abnormalities of the batteries after PCS maintenance or troubleshooting.

How the Alencon BOSS Make ESS’s Much Safer
The Alencon BOSS combines two unique approaches to significantly increase the safety of lithium ion ESS to avoid fires and other safety mishaps. As stated above, the Alencon BOSS charges and discharges each rack in the ESS individually, thus reducing overall fault current potential. Perhaps more importantly however, thanks to its patented Galvanic Isolation approach, the BOSS also isolates each rack and can thus detect faults at the rack level **BEFORE THEY OCCUR.**

Talk to any major lithium ion battery manufacturer and they will tell that their racks should be floating, as opposed to grounded. Battery manufactures make this recommendation for safety reasons. By allowing racks to float, two faults are then needed to cause a safety issue. When using Alencon’s BOSS in an ESS, the racks are not only isolated from one another, but also isolated from ground. As the battery racks in the ESS are floating, the BOSS monitors the resistance from their positive and negative terminals to ground. Should any cell get damaged and short to a grounded case, the loss of isolation will be immediately detected by the BOSS and the entire battery rack safely removed from the battery container by the PMS. This allows for the dangerous sorts of faults found in the systems studied by the Korean government to be detected much earlier, before fault conditions occur and tragedy strikes.

The BOSS’s approach is simply far safer than the reactionary approach required when using a monolithic charger. To make matters worse than just increasing fault current contribution, the monolithic DC-DC converters typically being deployed today are **not galvanically isolated,** a particularly problematic approach when pairing batteries and PV on the same DC bus in a technique known as “DC Coupling.” As such, non-isolated, monolithic DC-DC units basically have to rely on very large fuses and contactors to react when danger strikes. These are the exact devices that the Koreans found to fail in their investigations.

In short, a major takeaway from the ESS fires observed in Korea is this: A rack of prevention, is better than a container of cure. The Alencon BOSS is just such a preventive measure.
Why Addressing the Lithium Ion ESS Safety Issue is so Critical

Here at Alencon, our company is motto is “Passionate about Power.” Well, if there was ever an issue in the power industry to be passionate about, it’s this one. The issue of preventing lithium ion ESS fires transcends just safety (which is more than enough to be passionate about in its own right!) but rather our chances at achieving a clean energy future and combatting climate change.

“If these fires continue to occur, it doesn’t bode well for the industry in the short term and the storage market will almost certainly slow down,” said Ravi Manghani, an analyst at Wood Mackenzie Power & Renewables, the leading media voice of authority on the renewables and storage industry.

And if the ability to store renewable power is curtailed, that doesn’t bode well for anyone, least of which is the planet.