FUTURE PROOFING YOUR BATTERY ENERGY STORAGE SYSTEM

Using galvanically isolated DC:DC converters to insure the long-term viability of your next battery energy storage system project

Abstract

This white paper discusses specific augmentation and safety enhancing strategies for how you can leverage galvanically isolated DC:DC converters to improve the safety and performance of your battery energy storage assets on both day one and over the life of the project

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Future Proofing Your Battery Energy Storage System

With large scale energy storage growing rapidly, this white paper explains steps you can take to assure the long-term viability of your battery energy storage system, whether it is standalone or closely coupled with solar or other clean energy sources of generation

Author's Note: This white paper includes several embedded links to dive deeper into some of the technical points it raises. We have done this because we do not want to overwhelm you with too much information but also want to make sure you have access to more information at your fingertips should you wish.

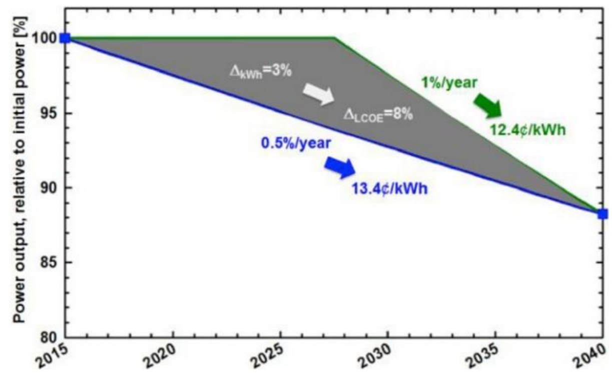
Introduction

Battery energy storage systems (BESS) on the grid are growing at an incredible rate. In 2020, 1.2 gigawatts of BESS were installed in the U.S. alone, with the industry projecting that number to grow to 100 GW by 2030. According to the U.S. Energy Administration, over 90% of the battery energy storage installations being deployed today utilize lithium ion-based battery chemistries. Lithium-based batteries are the most frequently deployed batteries due to their cost, which continues to tumble rapidly, and their relative level of technological maturity. Lithium-ion battery chemistries come with some unique challenges that need to be addressed over the life of a BESS project, including safety and their propensity to degrade rapidly relative to other alternative energy assets like solar.

In this white paper, we will explain how Alencon's galvanically isolated DC:DC converter – the BOSS - can help address these challenges to assure the long-term viability of BESS projects on the grid, whether they are stand-alone, DC coupled to a renewable resource like solar or AC coupled to a renewable resource.

Future Proofing Challenge #1: Degradation

Unlike other tools in the renewable energy toolbox, BESS are not a source of power generation, but rather a source of capacity for the storage of energy. Renewable resources like solar and wind are generators of energy. Also, unlike these renewable sources of generation, lithium-ion based energy storage degrades much more rapidly over time, a phenomenon known as capacity loss or capacity fading. For comparison, a typical PV system's generation capacity will degrade less than 0.5% per year, which amounts to about 12% over the twenty-five-year life of a solar project. The capacity of a typical lithium-based battery will degrade about 20% in the first 10 years of a BESS project's life, though the precise amount of degradation is directly correlated to several factors including duration of discharge, depth of discharge and charge, temperature, charge/discharge cycles and other factors.



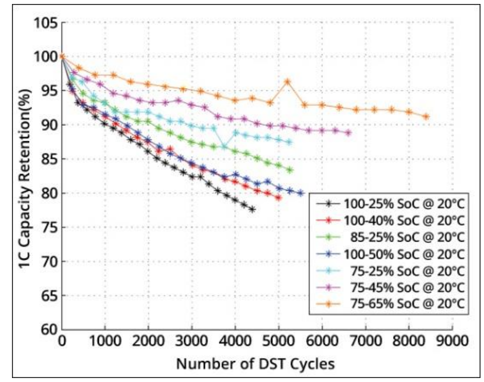


Figure 1: The diagram on the left (source: NREL) shows the typical degradation in generation of a PV plant, while the chart on the right show shows the degradation of a typical lithium-ion battery over time based on various cycling scenarios (Source: Battery University)

Future Proofing Solution #1: DC Augmentation

The known projected degradation of batteries means an augmentation plan is a critical part of any BESS project. Augmentation refers to the process of maintaining the capacity contracted for in the BESS over the life of the project. There are a variety of methods for augmentation planning, from oversizing batteries from the outset of project (oversizing), to adding additional inverters with more batteries connected to them (inverter-based augmentation) to adding additional battery racks to a DC bus (DC augmentation.)

Oversizing can be a highly problematic approach to augmentation because it means spending more money on day one of a project. According to sources as varied *Bloomberg New Energy Finance* to the *Energy Storage Association* to Elon Musk, battery prices are poised to drop by as much as 50% in the years to come. Thus, oversizing a project on day one to accommodate for capacity loss may not be a great financial decision. Essentially, oversizing assumes you are making an investment in an asset today whose value you know will tumble rapidly in the years to come.

Inverter based augmentation is another technically effective, though potentially commercially flawed approach. In this approach, you add another container of batteries with its own inverter to a BESS project when it is time to augment degraded batteries. This approach can be problematic because it is “lumpy” – it locks you into a certain sized augmentation block. Additionally, it might be altogether unfeasible depending on the grid interconnect agreement of a project. Alternative energy projects are constrained by their AC interconnect. As such, adding additional AC capacity to a BESS project, particularly one coupled to solar, may simply be a non-starter from a contractual perspective.

The Alencon BOSS supports the third method of augmentation – rack level DC-based augmentation. Historically, some BESS integrators have argued this approach renders systems unsafe due to differences in internal resistance between old and new battery racks.

Battery rack-based augmentation without a BOSS does indeed render a system unsafe to operate. According to a white paper from Wartsila published a few years ago, as batteries age and degrade, their internal resistance increases. When new batteries are installed in parallel with old batteries without a BOSS, the new batteries will operate at higher currents than the old batteries. These higher currents will exceed the current limitation of the conductors, over current protection devices, switches, and contactors in the power path. However, when battery racks are added with an Alencon BOSS between them and the DC bus, the BOSS can precisely control the current in and out of the new racks to ensure safe, continued operation even over many augmentation cycles over the course of many years.

Furthermore, the BOSS can safely [map a different voltage range new battery to the existing DC bus] thus giving system owners the freedom of mixing different types of batteries on a single BESS. As battery racks evolve, their charge/discharge voltages change. As is generally the trend in the alternative energy field, these voltages are tending to go up. Thus, the Alencon BOSS gives system owners the freedom to be technology agnostic for changing market conditions as they consider their future augmentation options.

Some Specific Approaches to DC Augmentation

Depending on how you have designed your BESS, there can be a variety of methods by which you can use the BOSS to realize your DC augmentation strategy.

Method 1: Rack Level Augmentation

In the rack level approach to DC augmentation, individual battery racks are simply installed in a battery container with battery racks with BOSS units already installed on them. This approach can be most sensible and cost effective for DC coupled Solar + Storage deployments where DC:DC converters are already installed in a battery centric manner. [Click here] to learn more about [battery centric and PV centric approaches to DC coupling].

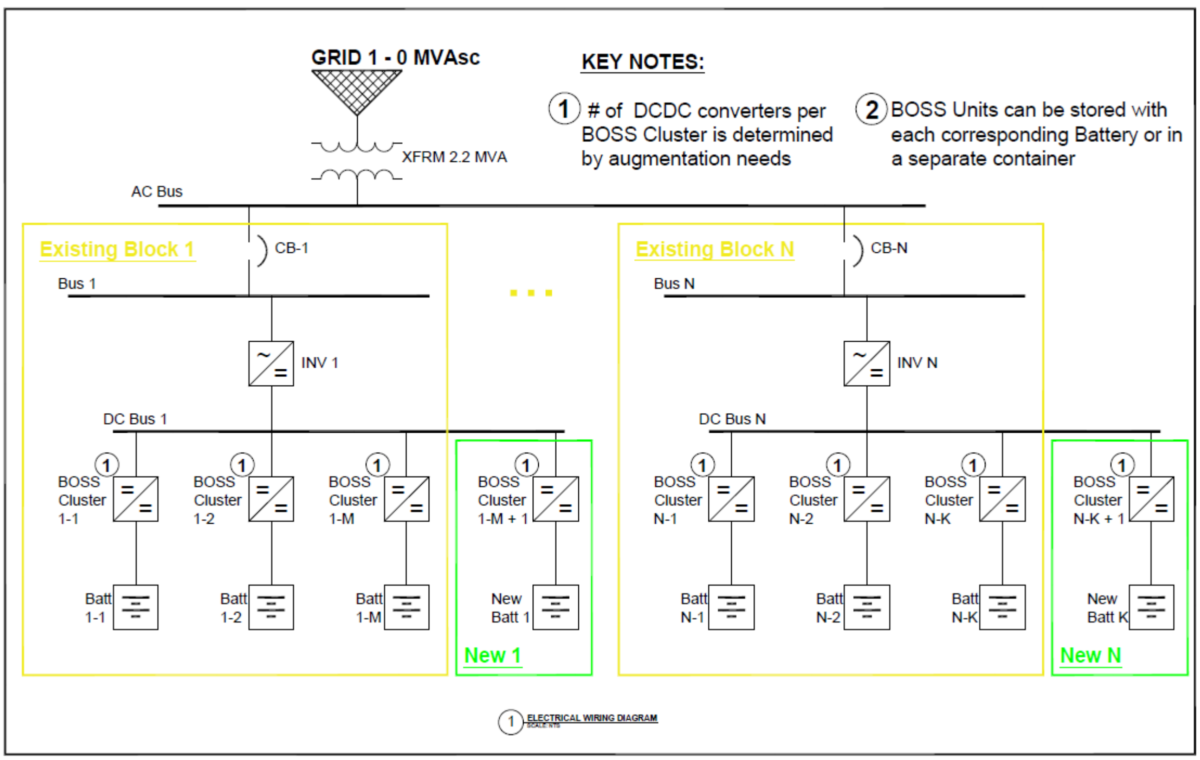


Figure 2: The diagram shows the rack level DC augmentation strategy where a BOSS or some number of BOSS units based on the total current that needs to be managed based on the C rate of the system and electrical specifications of the battery rack.

Method 2: Container Level Augmentation

In the container level approach to DC augmentation, BOSS units are used to facilitate the installation of an entire BESS container. In this approach, the unique properties of the [BOSS BOX] can even be leveraged to allow the BOSS units to appear as a monolithic block on one side of the system while siphoning off the amount of energy each older BESS container needs to maintain a given level of capacity.

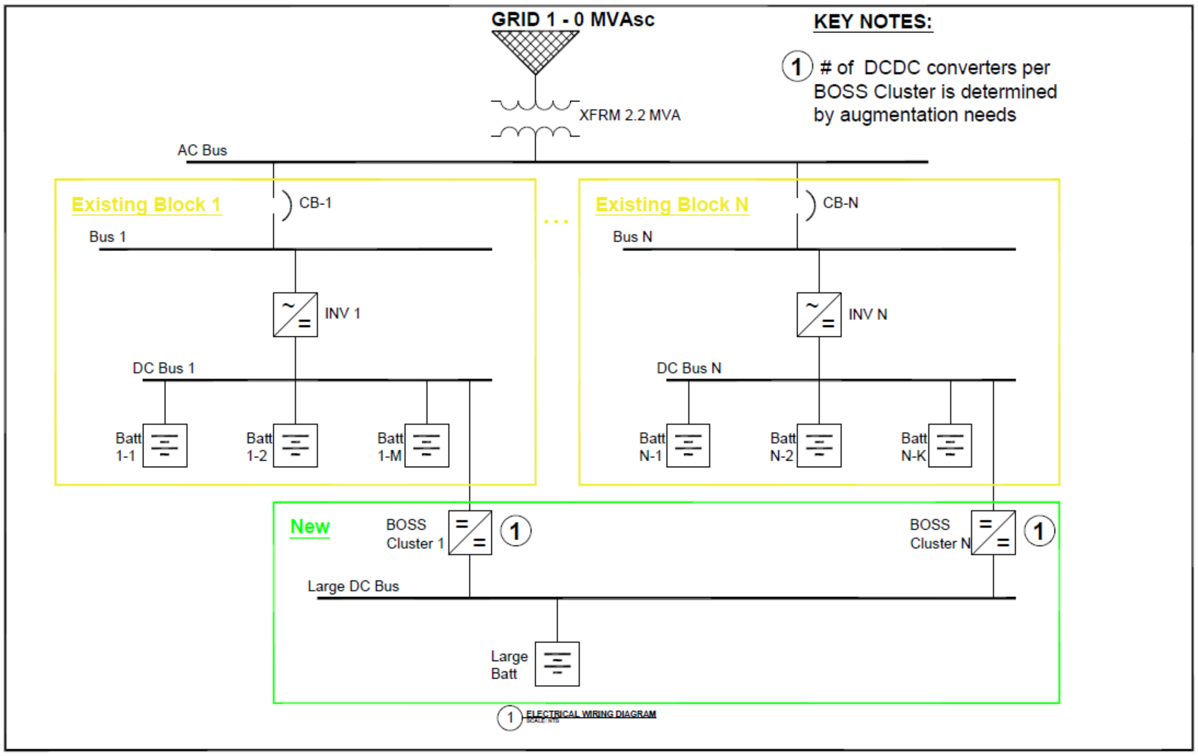


Figure 3: The diagram shows a container level augmentation, where a new BESS container can be installed and have energy delivered to individual containers that need additional storage capacity.

Method 3: Container/Rack Level Augmentation

In the container/rack level approach to DC augmentation, the appropriate number of BOSS units can be dedicated to each rack in a newly installed BESS container, where each rack in that new container can be assigned to the DC bus of each battery container on-site.

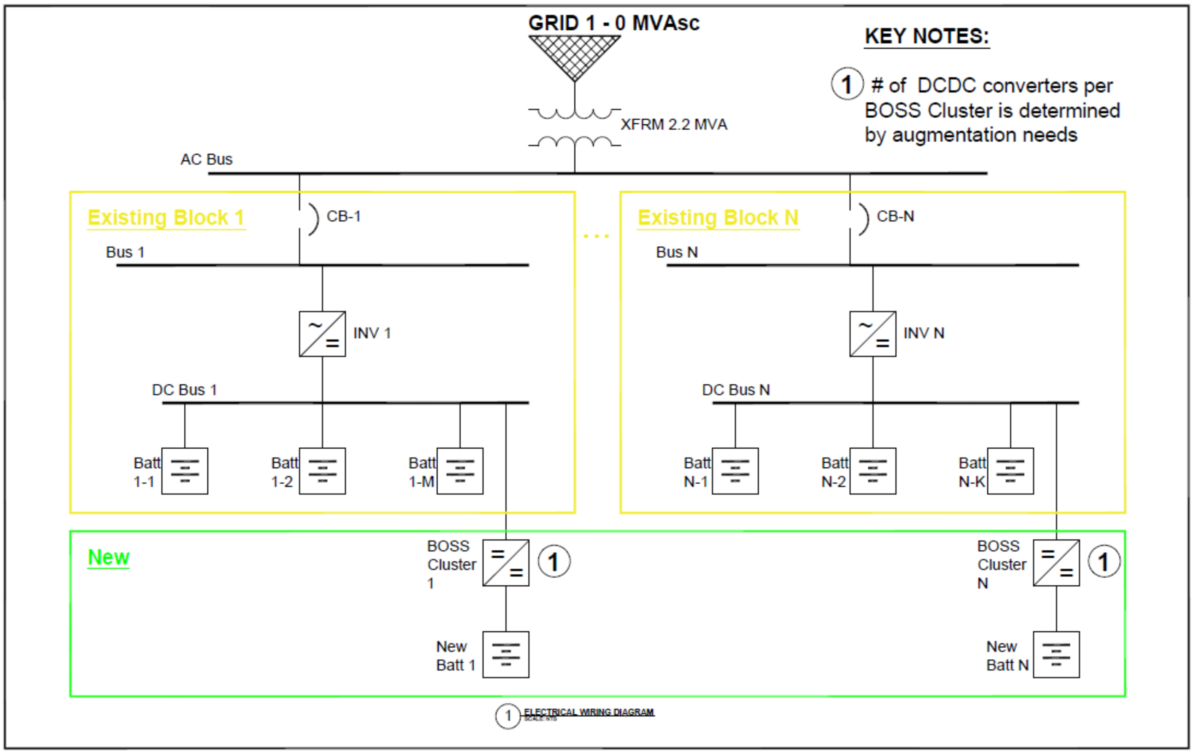


Figure 4: The diagram shows a container/rack level augmentation, where a new BESS container can be installed and have individual racks within the container assigned to different containers on site.

Future Proofing Challenge #2: System Safety

The safety challenges presented by large scale BESS have been well documented. Safety incidents started in South Korea, which lead the pack in deploying large scale battery systems. More recently, we saw from battery fire incidents in both United States and England that battery fires are not solely a Korean phenomenon. Much of the reaction to these incidents have focused on safety systems for fire fighters and other first responders, i.e. reactive measures to make firefighting safer and easier when these mishaps do occur. In this paper, we will discuss preventive measures that can be taken to assure these mishaps do not occur in the first place. As the saying goes, an ounce of prevention is worth a pound of cure.

Future Proofing Solution #2: DC Isolation

The Alencon BOSS can provide individual, galvanically isolated DC-DC converters for each rack of batteries. This means that each battery rack is isolated with 2,750 volts of isolation from each other both on the negative and positive terminals of the battery. Therefore, if one of the racks fails, no other rack can collapse upon it and cause a fault current. Even when two racks short together in one point, no short current will occur. If somehow the output of a BOSS unit is shorted, only the current from one rack will flow. This current will be interrupted by properly sized fuses on the BOSS's output. The BOSS provides unprecedented protection against lithium-ion battery fault currents.

Additionally, by isolating batteries, the BOSS allows battery racks to float, just as their manufacturers and designers intended them to. Battery manufacturers specifically want batteries to float because this means it takes two leakages to ground to cause a ground fault.

The BOSS's Leak Locator ™

Whenever a floating electrical system produces voltage from a series of modules, it is possible to both detect and locate a first leak to ground (e.g. ground fault). The most common example of such a system is a battery rack where battery modules are connected in series.

Various mechanical or chemical failures can cause a leakage path to ground. The Alencon Leak Locator monitors the magnitude (in megaohms) of the leak and identifies to its location as as depicted in Figure 5 below.

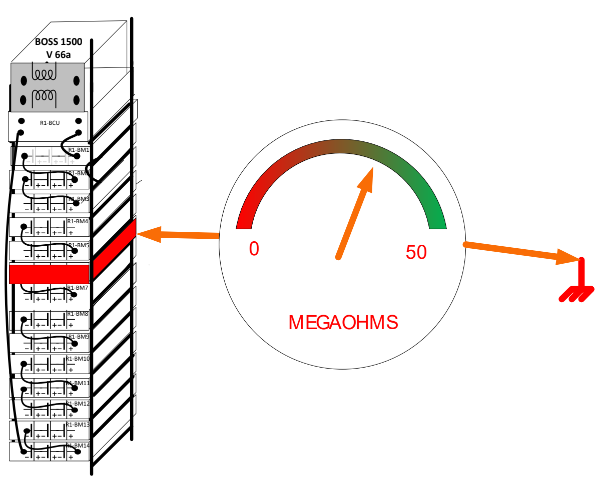


Figure 5: The BOSS' Leak Locator™ identifies the location and severity of a single ground leak.

The Alencon Leak Locator has been developed in compliance with the relevant safety standards for isolation monitoring devices. As such, it can also provide the financial benefit of eliminating the need to integrate additional third-party isolation monitoring devices (IMDs) into a BESS.

DC Coupling of Solar + Storage: An opportunity to be Future Proof from the Start

Of course, adding an additional piece of hardware like the BOSS into a BESS adds cost, a cost that needs to be weighed against the value of the safety and augmentation benefits described above. In the case DC coupled solar + storage systems, designing in a galvanically isolated, rack level DC coupled device like the BOSS into the system from day one can have the greatest bang for the buck. In DC coupled Solar + Storage systems, a DC:DC converter is a required piece of equipment to match the differing voltage levels of the battery and PV array connected on the same DC bus. The BOSS's high speed constant power control mode allows the inverter to find and track the solar maximum power point (MPPT). Thus, by using the BOSS, you can achieve the benefits of a DC coupled architecture while at the same time future proofing your BESS, all while doing so in a highly cost-effective manner.

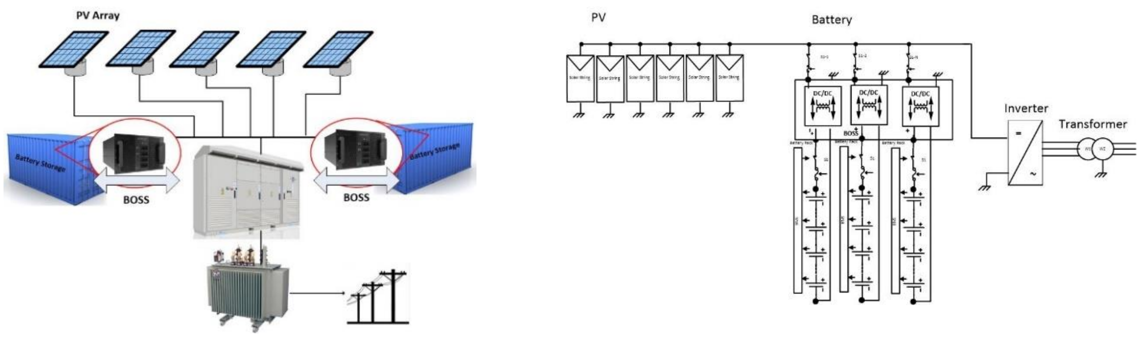


Figure 6: The drawings shown above provide more detailed schematics of a battery centric approach to DC coupling. On the left is an illustration of a BESS wired with bi-directional DC:DC optimizers connected to a DC bus where the DC bus is connected a grid tied inverter that is performing maximum power point tracking in the PV array. The schematic on the right shows how such a system would be wired.

How Future Proof is the BOSS?

All of this discussion of future "proof-ness" may have you asking yourself – well just how future proof is the BOSS? The BOSS is a highly rugged device by both design and manufacture. From a design perspective, the BOSS unit is designed to last well over 25 years without the need for replacement. This calculation is done based on mean time between failure (MTBF) analysis, which looks at the expected life of all the components in the device. Beyond just theory, here at Alencon, we also perform extensive accelerated life testing on our products in our state-of-the-art power electronics lab located in our suburban Philadelphia, Pennsylvania factory. We expose our products to extreme operating conditions in terms of power throughput, heat and temperature fluctuations (i.e. going from extreme low temperatures to extreme high temperatures) for weeks on end. We then correlate this modeling and lab endurance testing with field performance. By manufacturing our products in our U.S.-based factory, we can assure the highest level of quality and repeatability in each BOSS unit that we ship. We assure this by leveraging state of the art, high power testing methods during multiple steps in the production process.

Conclusion

Building safe battery energy systems that are cost effective and easy to maintain while being cost effective is a great way not only to future proof not just BESS but our renewable energy future.