Application Note:

High Voltage Batteries
Combining Methods and Equipment

Author(s):
Liam O'Brien
Michael Miller

***DISCLAIMER**: It is important to carefully read and follow all local code, manufacturer's instructions, and safety guidelines. Sol-Ark LLC disclaims all liability for any personal injury, property damage, or other damage that may result from mis-applying the information in this document.*

Copyright 2024 © Sol-Ark LLC

1. Overview

The Sol-Ark 30K and 60K C&I inverters feature dual high voltage (HV) battery inputs with each input terminal supporting up to 50A continuous current. When using both terminals the system can support up to 100A of total charge/discharge capacity.

These two terminals also allow for the connection of up to two HV batteries without the need of an external combiner solution (see Fig. 1-C). In the event more than two batteries need to be installed per inverter (Fig. 1-A and B) appropriate overcurrent protection and combining equipment is required.

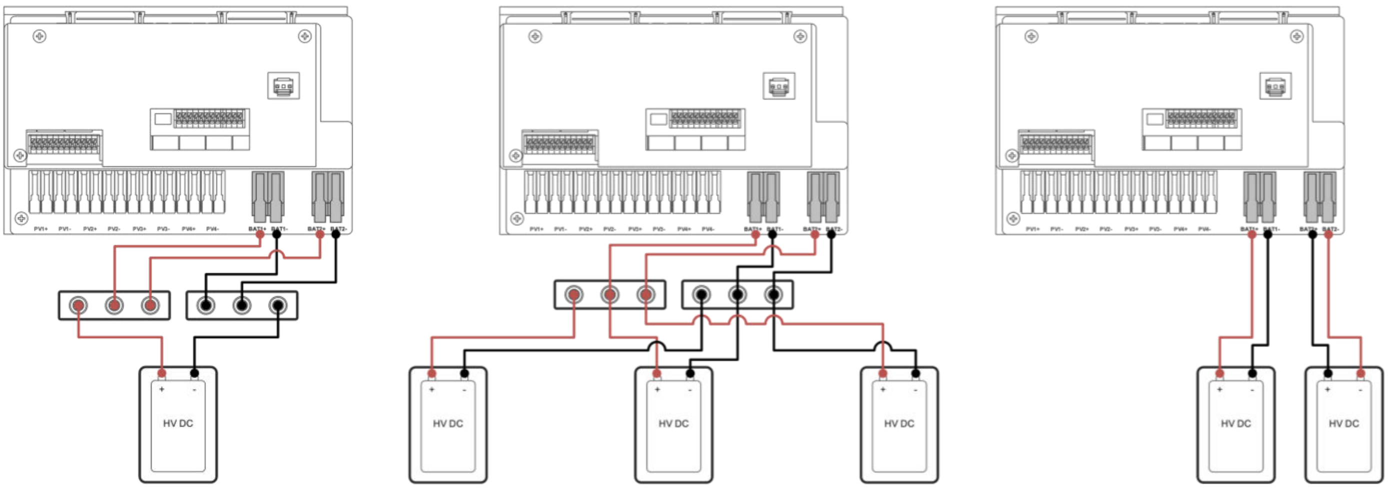

Figure 1 Battery Connection Configurations

a) single battery (1C/battery) *b) multi battery bank* *c) dual battery 0.5C/battery*

It is important to note that to maintain a warranty compliant 0.5C charge and discharge profile when operating the 30K or 60K inverter at its maximum charge/discharge rating of 100A a minimum of 2 batteries units is required.

Exception: When using the 30K inverter with the L3 HVR-60 battery only one battery unit is required

While the 30K-3P-208V and 60K-3P-480V support a wide voltage operating range, the continuous inverter output power is only achieved using a minimum of **300VDC** input on the 30K model and **600VDC** on the 60K.

Operating Voltage Range	
30K-3P-208V	160-500Vdc
60K-3P-480V	160-800Vdc
Min. Input Voltage at Rated Power	
30K-3P-208V	300Vdc
60K-3P-480V	600Vdc

2. Safety and Code Compliance

To ensure safe and NEC compliant operation, properly rated disconnecting means, overcurrent protection devices (OCPDs) and combiners suitable for HV battery banks must be utilized.

Per the National Electrical Code (2023 Ed) **Article 706.15(A)** ESS systems are required to have a disconnecting means:

> *"Means shall be provided to disconnect the ESS from all wiring systems, including other power systems, utilization equipment, and its associated premises wiring."*

This section also describes the allowable location of said disconnecting means:

- *"(1) Located within the ESS*
- *(2) Located within sight and within 3 m (10 ft) from the ESS*
- *(3) Where not located within sight of the ESS, the disconnecting means, or the enclosure providing access to the disconnecting means, shall be capable of being locked in accordance with 110.25"*

As shown below, all models of the L3 LimitLess Lithium series BESS would comply with this requirement due to the inclusion of an integral, dual-pole, lockable disconnect (Fig. 2) within the Battery Management Unit (BMU). This device disconnects both the positive and negative battery output conductors of the battery system.

OFF ON

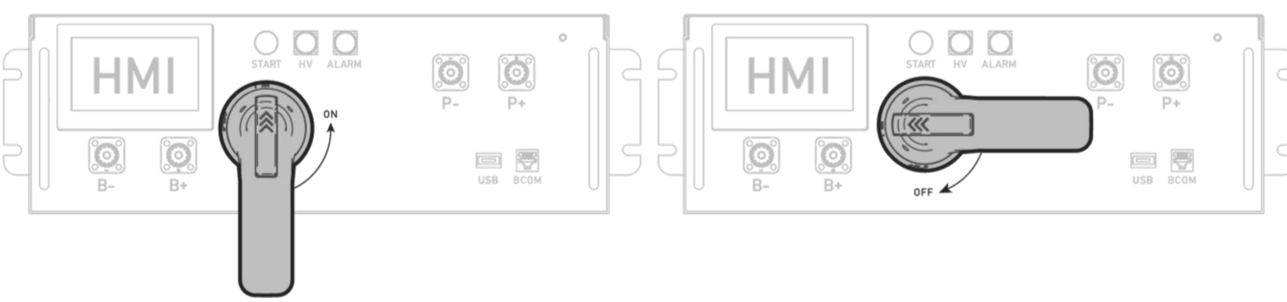

Figure 2 DC Disconnect Operation on the L3 HV BMU

L3 Series Equipment Overview

L3 HV - Indoor Series	
Models:	L3-HV-40 and L3 HV-60
OCPD:	160A Fuse Battery Management Unit (BMU)
Disconnect:	200A rated dual pole disconnect switch. (integrated into the BMU)

L3 HVR - Outdoor Series	
Models:	L3 HVR-60
OCPD:	160A fuse integrated into the BMU
Disconnect:	200A rated dual pole disconnect switch. (integrated into the BMU)

Other Battery Partners

Battery OCPD and disconnect switch configurations are highly product dependent and other battery providers may have their own disconnect requirements which are outside the scope of this application note.

Additional External Disconnects

While both the L3 HV and L3 HVR batteries include a built-in disconnecting means, additional disconnects could be required depending on the exact installation conditions of your project or local jurisdictional requirements. When utilizing external disconnects it is important to select a device carefully as many standard electrical safety switches, fuses, and breakers are not rated to interrupt a high voltage DC source. Proper device listing is directly called out in Art. 706.31(C) of the 2023 NEC as shown:

> *"Overcurrent protective devices, either fuses or circuit breakers, used in any dc portion of an ESS shall be* ***listed for dc and shall have the appropriate voltage, current, and interrupting ratings for the application****."*

Looking at an equipment example, in Fig. 3 this Square D 60A safety switch is only rated for 250Vdc, which is below the operating range of even the L3 HV-40 (500Vdc max). Many pieces of equipment rated for 600Vac are rated lower when used in DC applications, they might also have a lower maximum operating current or fault current (SCCR or AIC) compared to their AC duty rating. Because of this, it is important to consult the product cutsheet or reach out to the equipment manufacturer directly to confirm the suitability of the equipment selected.

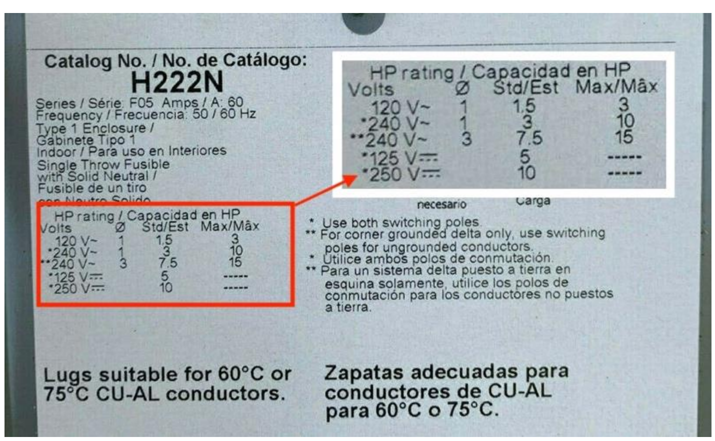

Figure 3 Safety Switch Rating Label - Detail

Figure 4 Fuse Rating Label showing a 125Vdc rating.

In addition, it is important to verify the UL listings of the equipment you are planning to use to see if they are listed or recognized to the appropriate standards for that product class.

As an example, circuit breakers must be listed as either UL489 or UL 1077 devices. UL489 listed breakers are allowed to protect feeders or multiple branch circuit devices—consider a main breaker in a panel board as an example—in contrast, UL 1077 devices are only acceptable for providing supplementary protection where there is generally already a UL489 branch circuit protection device ahead of it (think of a resettable fuse in an HVAC unit). As a rough guideline, you can only use UL 1077 listed breakers to protect circuits inside equipment which ***does not supply*** circuits that exit that equipment. Therefore, you would be required to use UL 489 listed breaker to protect the DC conductors leaving each battery cabinet or rack.

3. Limiting Battery Fault Current

When sizing overcurrent protection devices (fuses or breakers) it is also important to consider the fault current rating (kAIC), in addition to the trip rating (A), of the devices used.

As designed, each L3 HV or HVR battery unit has a fault current contribution of 4200Adc/1.47ms. This means that each parallel unit combined on the DC side increases the fault current contribution of the total system. This is important because most bus bars or power distribution blocks per UL508 Table SB4.1 have a Short Circuit Current Rating (SCCR) of **10kA** unless otherwise listed and marked.

Table SB4.1
Assumed maximum short circuit current rating for unmarked components
Table SB4.1 revised, effective date to be determined

Component	Short circuit current rating, kA
Bus bars	10
Circuit breaker (including GFCI type)	5
Current meters	a
Current shunt	10
Fuseholder	10

Figure 5 UL508 Table SB4.1

This means that with more than two L3 HV or HVR units in parallel, you would need to install an appropriate current-limiting overcurrent protection device on each battery output circuit to limit the available fault current present at the bus bar to ensure safe operation. According to the NEC Art. 100, current-limiting fuses are defined as the following:

A device that, when interrupting currents in its current-limiting range, reduces the current flowing in the faulted circuit to a magnitude substantially less than that obtainable in the same circuit if the device were replaced with a solid conductor having comparable impedance.

This means that a current-limiting fuse must open rapidly and without self-destructing, within one-half cycle or ~8ms, when subjected to a low-impedance fault such as a short circuit. To select an appropriate device, the fault current let through potential of fuses or breakers can be found by examining the product manufacturers Time v Current Curves, often called a *trip curve* in the industry.

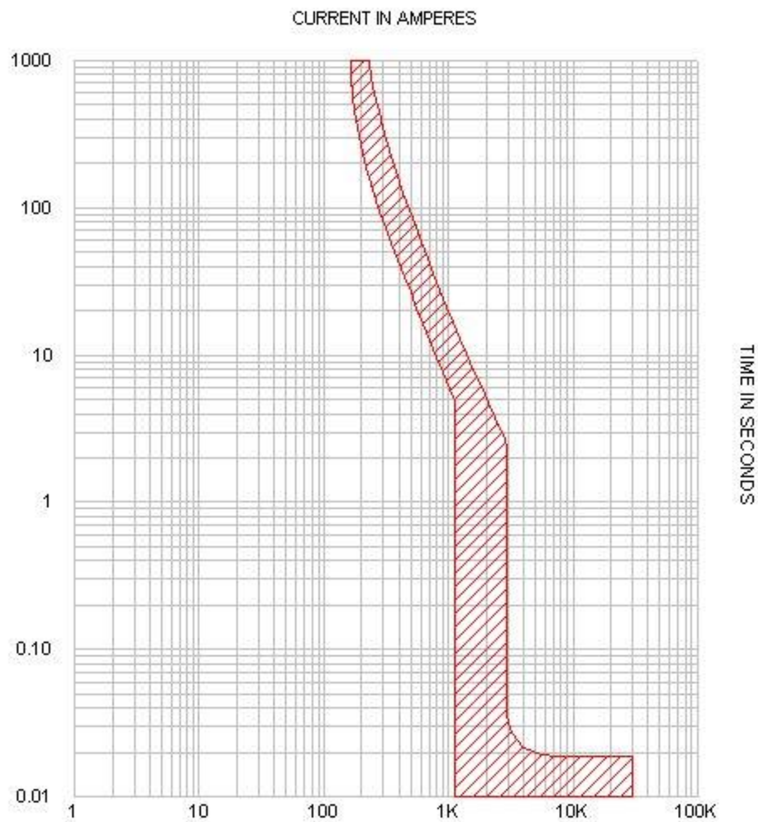

Figure 6 Illustrative Time vs Current Curve

As a rule of thumb, for a trip time on the order of 1-5ms most circuit breakers will allow a fault current let-through of 4-6 times the devices rated trip current. For example, assuming a 100A rated breaker this would represent 400-600A of fault current before the breaker opens to clear the fault condition.

Over-Current Protection Device (OCPD) Sizing

It is important to size the wiring and OCPD, connected to the battery output according to the anticipated current required from each battery at full load. To do so correctly requires taking into consideration NEC Art. 240 (Overcurrent Protection) and Art. 706.30, which applies specifically to energy storage systems.

Example – Single Inverter System

As your starting point, you must determine the maximum current value required for battery circuit, this is defined by Art. 706.30(A)(1) through (5). For the 30/60K inverters option (3) the Inverter Input Circuit Current would apply:

> *"The maximum current shall be the continuous inverter input current rating when the inverter is producing rated power at the lowest input voltage."*

As an example, using a 30K inverter paired with an L3 HV-40 battery operating at full power this value would be 93.75A (30,000W / 320V = 93.75A). However, since each inverter has two battery ports rated at only 50A you would require two separate circuits rated for half of this value (46.87A) to reach the total overall power input.

Per 706.30(B) for battery circuits, you are required to provide an OCPD sized 125% larger (unless listed for 100% use) than the current calculated by 706.30(A) or in this example 46.87A x 125% = 58.6A., this corresponds to a 60A OCPD per battery output based on Table 240.6(A).

Parallel Systems

It is important to note that as more batteries are added in parallel, the current required by each battery to the inverter decreases, this in turn can reduce the size of the OCPD and conductor required for each battery when operating under full load.

In a system consisting of 6 batteries and a single 30K inverter, the current required from each battery would be 1/6th of the total value (93.75A) or 15.6A. The required OCPD in this case would only be 20A after 125% upsizing. This reduction has the benefit of allowing for more equipment options, such as the fuses used for DC PV strings which typically range up to 30A.

4. Commercially Available Products

The following product recommendations are for informational purposes only. Before using any products mentioned, it is important to validate the products ratings as well as carefully read and follow the manufacturer's instructions and usage guidelines.

The product options presented below represent a starting point for combining and fusing battery circuits. While these offer a solid foundation, additional assembly or components may be required depending on your specific application/project needs.

600V Rated (30K Inverter ONLY)

Manufacturer	Model Number/Name	Category	Links
Edison	EPDB104, EPDB512	Power Distribution Block	Catalog
Edison	HPB Series	Power Distribution Block	Catalog
Midnite	MNPV6	Fused Combiner	Catalog

1000V Rated (60K or 30K)

Manufacturer	Model Number/Name	Category	Links
Littlefuse	LFXV15 Series	Fuse + Holder	Catalog
Midnite	MNTS	Midget Class Fuse Holder	Catalog
Littlefuse	SPF Series	Midget Class Fuses	Datasheet
Projoy	PEBS-S Series	Breaker	Catalog
Midnite	MNPV10-1000	Fused Combiner	Catalog
Midnite	MNPV4-1000	Fused Combiner	Catalog
ILSCO	LDAU-16-500	Power Distribution Block	Catalog