TO: LFEV Team

FROM: Drew Jeffrey

DATE: 11 May 2014

SUBJECT: Fusing FEV Compliance Memo

ABSTRACT:

This memo details how the analysis requirements relating to the accumulator container have been met in our system's final design. This document outlines how requirements EV 3.6.4, EV 6.1.1, EV 6.1.2, EV 6.1.3, and EV 6.1.4 have or have not been met by the current design.

REQUIREMENTS:

EV 3.6.4 - All voltage sense wires to the AMS must be either protected by fuses as defined in ARTICLE EV6 or must be protected by resistors so that they cannot exceed their current carrying capacity in the event of a short circuit. Any fuse or resistor must be located as close as possible to the energy source. If any of these fuses are blown or if the connection to measure the cell voltage is interrupted in any other way then this must be detected by the AMS and must be reported as a critical voltage problem. If the AMS monitoring board is directly connected to the cell, it is acceptable to have a fuse integrated into the monitoring board.

> In the current battery pack, no fuses are contained in the voltage sense wires, so this requirement is currently not met.

EV 6.1.1 - All electrical systems (both tractive system and grounded low voltage system) must be appropriately fused.

> The battery pack currently contains a main 200 A fuse in the discharge tractive system path of the device. The only GLV circuitry within the pack pertains to the charging circuitry on the Pack Manager Breakout board which allows the charge relays to open and close and the charger to be detected. Two fuses on the main charging path protect these circuits.

EV 6.1.2 - The continuous current rating of a fuse must not be greater than the continuous current rating of any electrical component, for example wire, busbar, battery cell or other conductor that it protects.

The fuses protecting the battery cells have a maximum continuous current rating of 200A. The short circuit current of the cells is approximately 3.2V / 2mΩ = 1600A. The aluminum bars which consist of the discharge path have a cross-sectional area of approximately 322.6mm^2. By knowing the resistivity of aluminum and the cross-sectional area of our discharge path, we can calculate the time it takes for the aluminum bar to reach its melting point at a current greater than the fuse rating of 200A:

$$Time\ to\ Survive = C_p\left(T_{melting} - T_{ambient}\right)\left(\sigma * \left(\frac{A_{cs}}{I}\right)^2\right)$$

Where C_p is the specific heat capacity of aluminum (2.42e6 J/m^{3}K), T is in Kelvins (melting point of aluminum is 933.52 K, ambient temperature is 298 K), σ is the conductivity of aluminum (3.50e7 S/m), A_{cs} is the cross-sectional area of the bar, and I is the current that is being conducted in the bar. At a current of I = 201A, the aluminum bar will survive for 14000s. Since this is above the rated current of the fuse, the fuse will burn out long before the aluminum conductors will ever become in danger of being damaged, proving that the 200A fuse will protect the discharge path of the battery pack.

EV 6.1.3 - All fuses and fuse holders must be rated for the highest voltage in the systems they protect. Fuses used for DC must be rated for DC, and must carry a DC rating equal to or greater than the system voltage of the system in which they are used.

The discharge path fuse must be rated for at least 30VDC as this is the highest voltage expected within the accumulator container. The Zoro Tools G3475534 fuses and fuse holders used in the current pack are rated for up to 160VDC and 600VDC respectively, which is much higher than the necessary 30VDC. The charge fuses and their holders are rated for 500VDC and 250VDC respectively, which is more than the 30VDC system voltage.

EV 6.1.4 - All fuses must have an interrupt current rating which is higher than the theoretical short circuit current of the system that it protects.

The maximum short circuit current in the system is approximately 1600A as calculated above. The discharge fuse’s interrupt current rating is 50KA and the charge path fuses are rated for 20KA. These values are well above the 1600A theoretical short circuit limit in the system.