Lithium Battery Care and Maintenance

The Warthog is equipped with a Lithium battery bank consisting of four 118Ah 12.8V batteries connected in a 4S1P configuration, and a single BMS control unit.

The main function of the BMS is:

- Protect the individual modules from being over charged or over discharged
- Protect the modules from operating outside of their acceptable temperature range
- Provide status information to higher level systems via a CAN interface
- Provide independent system management without a higher level control system
- Provide status, warning and error messages from each of the modules connected to the battery power system
- Control the charging operation
- Perform module to module balancing of the system, the battery module will control cell balancing within itself

There is a main power contactor which is controlled by the BMS unit, and is placed in such a way that it controls all power to the system. Upon turning on the main disconnect switch:

1. The BMS powers up first and begins communicating with all of the battery modules in the system
2. If they are all present and have no errors the BMS will close the main contactor and allow the Warthog to power up as normal, this process can take a few seconds before the main contactor closes
    a. If all the modules are not present, the system State of Charge (SOC) is too low, or there are errors being reported by any of the modules in the system, the contactor will not close, and the system will not power up.
3. Similarly, if a user is in discharge mode (using the Warthog) and any errors are detected, or if the SOC falls to a cut off point, the contactor will open and remove power from the system to protect the modules
    a. It is not good practice to run the SOC to 0%. This will decrease the life of the battery module. In general, keeping the SOC to a minimum of 30-50% can increase the lifetime of the batteries
    b. As a note, the system SOC is identical to the module with the lowest SOC in the system, so if three modules are at 45% SOC, and one module is at 25%, then the SOC of the system is 25%, and the BMS will act accordingly cutting off power to protect the module with the lowest SOC. Cell balancing and proper charging techniques are important to maintaining good battery health.
4. The Warthog can be charged when the unit is powered and running, and can also be charged when the unit is not powered (main disconnect switch is open).
    a. The charger has been configured and wired in a way that the BMS is actually controlling the charger and can turn it off, and on, depending on the status of the charging cycle.
    b. Even though the unit can be charged while running, this process does not allow for proper cell balancing to occur. It will allow for bulk charge to occur to regain most of the charge in the system, however, repeatedly charging in this manner will allow each module to become out of balance with the other modules. If this

process if followed long enough the SOC values for each module can vary by a substantial amount. The larger the variation, the longer it will take to fully balance the system, therefore it is recommended (depending on use) that at least once every two to three weeks that the system be completely charged while the main disconnect switch is in the off position. Doing so will allow the BMS to go through an equalization phase where the charger is being turned on and off by the BMS to balance the voltages across each cell layer, in each module across the system.
        i. This is a very important step in maintain battery health, and getting the maximum lifetime out of the battery system
5. To allow for this level of control there are three contactors in the system:
    a. The main contactor for discharge of the system
    b. The charge contactor to connect to the output of the charger
    c. The charge control relay to turn the charger outputs on and off and control the cell balancing or equalization phase of the charge cycle
6. To charge the system
    a. Plug in the charger DC output cable (heavier gauge cable)
    b. Plug in the charger auxiliary control cable
    c. Plug the charger into AC power (directly to the wall outlet, no extension cords)
    d. This can be done with or without power on Warthog being on (however the note above applies, at least once every couple of weeks the charge process needs to be allowed to fully balance the system)
7. To disconnect the charger
    a. Unplug the charger from AC power
    b. Unplug the charger auxiliary cable
    c. Unplug the charger DC output cable (heavier gauge cable)

System Specifications

System voltage (nominal):	51.2 V (up to 59 V while charging)
System capacity:	118 Ah
System energy:	6.041 kWh
Continuous discharge current:	150 A
Peak discharge current (30 sec):	300 A
Discharge temperature range:	-10 °C to 50 °C
Charge temperature range:	0 °C to 45 °C