American Solar Challenge

Battery Pack Development

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Background

- Typically, Solar Race Vehicles must be very efficient to be competitive and cannot spare energy to waste.
- Balancing either during charge or discharge consumes energy that could be used for raycing
- Creating a balanced pack is preferred to any form of balancing.
- It is from this perspective that this report is prepared.

How to Build a Pack
Starting Out

- First and foremost, understand all you can about the battery technology you choose, MSDS , Product design, Testing and performance details& Safety aspects.
- Different variants of 18650 cells have different limitations/failure modes as an example.
- Acquire “manufacturer’s” data sheets for any cell you expect to use.
- Submit it to ASC prior to Build for preliminary approval. URL & MSDS will be required for final pre-approval anyway
- Sharing this information early with ASC is the teams advantage.

How to Build a Pack
The Basics

- Let's say we are considering a pack of 400 cells to make weight.
- We want a current to drive the vehicle of 60 amps and each cell's Discharge Current is limited to 6 amps.
- We will need a minimum of 10 cells in parallel to acquire the needed discharge current.
- Likewise this means 40 @ Nom Voltage = Nom Pack Voltage
- Similarly, Charge current is limited to 3 amp/cell thus 30 amps will be pack charge limitation.
- Cells grouped in parallel are designated as Modules and are typically labelled as 10P40S; 10 cells in parallel, 40 modules in series
- Modules placed in Series to provide voltage is designated as a string/pack.

How to Build a Pack
What to Measure

- Before you even purchase a bunch of cells, a sample of 5 can tell you many things.
- Cell Impedance (think of this as: What potential in/out efficiency the battery pack will have). The lower the number, the better!
- The Less Variation in impedance, the better.
- Capacity is the other metric of importance, the same applies, the less variation, the better!
- Those cells with similar impedance will provide the pack with the most usable energy.

How to Build a Pack
Variation

- So now we know which cell we want and we have preliminary go ahead from ASC.
- We discuss with supplier the quantity we want and that they need to be from the same “Manufacturing Lot” Why, one might ask?: Those cells from common lot will have less variation than with cells from various lots.
- Why do we care about variation? Battery Packs **Hate** variation. If Cells vary in impedance, or capacity, they operate differently and result in an imbalanced pack.
- **Discussion!**

How to Build a Pack
Testing

- How might a team go about testing cells?
  - You may consider a tester with as many banks as can be afforded. Impedance being the primary measure, Capacity is secondary
  - Measure all cells for your metrics and match them as close as possible for each module.
  - A mismatched Module is very dangerous, one cell will not operate as the rest even though electrically they are paralleled.
  - The battery protection system can not detect it either. So make sure cells within a module are matched as closely as possible.

How to Build a Pack
Testing Cont.

- If you have a situation with a mismatched cell in the module, obviously, the paralleled cells will force the voltage and current to share.
- Chemically, the cell will not support the differences that result and the cell will either charge or discharge in the attempt to meet common voltages.
- Basically, the slope of voltage curve will force a weaker cell to go to a different SOC to meet common voltage.
- So understanding the Slope(impedance) of the cells lead to understanding the balance aspects.

DIscussion?

How to Build a Pack
Testing Cont.

- It is very likely, during testing that outliers or tails of the distribution will be found. These are the reason you test. Even if the Supplier claims to have already sorted for you, I would still measure each and every cell.
- Your measurement equipment should have 10 times the accuracy of what it is you are trying to measure.
- Impedances of 100 to 200 m-ohms, you'll need 10 m-ohms or better capability, likewise, Voltage differences or Millivolts meaning you'll need tenths of millivolts capability.
- Don't skimp on testing cells or the equipment, it'll cost you variation.

How to Build a Pack
Where to start assembly

- As you understand the performance aspects, don't forget thermal.
- When laying out which cells are used in modules, consider spacing adequate for the required airflow. If you intend to rayce in warm or hot environments, this is imperative.
- Modelling is valuable at this stage. A good thermal model will save a lot of energy.
- When laying out the Modules in Series in the pack, also consider the airflow and distribution with the goal of maintaining each and every cell at the same temperature.
- Cells that have temperature variation, will also have performance variation which reduces effective pack capacity.

How to Build a Pack
Module Testing

- So, now you have modules built, hopefully without damaging the cells in the process (overheating the terminal connections or something bad like that)
- Make sure that the connections can carry your current.
- No undue stress on the terminals, or package.
- Now we test modules. Impedance and capacity.
- This will certainly require different test equipment. This may even use a power light bar as a resistive load.
- Anyhow, capture equivalent testing results for each module and use it to match modules best you can.

How to Build a Pack
Pack Assembly

- Now that all modules are Characterized, assemble the most equally matched modules into a pack by stringing them together serially.
- Do not parallel Strings! This introduces other issues that are not easily protected with the BPS. If the BPS can not detect an issue, then it is dangerous to do, so do not parallel strings.
- Notice, more cells/modules will be needed to develop a Good rayce pack.
- The amount needed depends on the amount of variation in the cells you buy. So if you buy cells from a supplier who doesn't keep manufacturing lots together, this may require 3 packs worth to get a good pack.
- Not a pretty picture, but that's the cost of putting together a good pack.
- Cells/modules Charge and Discharge at slightly different voltages for a common SOC.
- Also when connecting modules in series, make sure the relative SOC is consistent between Modules not just the voltage.
- Not having a Consistent SOC between modules will cause Pack Imbalance right from the start.

How to Build a Pack
How Long will it take?

- Next Question is how much time will a pack build take?
- I wish I could provide an answer to that, but lets say it takes a good team 2 years of study and work to get a good pack.
- Yes, some have had successful packs with less work than I have listed, but those that have completed this level of work ended up raycing the same pack for three and sometimes more events.

How to Build a Pack
Before you Rayce

- When you finally get a pack built, everyone thinks its ready to put in the solar car and rayce it. Not quite.
- Next, you need to CHARACTERIZE the pack, so the team can predict some performance standing during the race day.
- To do this, may take a resistive based load and a controllable voltage power supply.
- You also now need to consider placement of sensors to detect worst case situations you are aware of (Temperature and Voltage) within your pack. The benefit of monitoring what are the worst cells, is that your pack will last vs degrade or even worse.

How to Build a Pack
Battery Cooling

- After placing the Pack of cells in the Battery Pack box and drawing a load on them, they will likely display a thermal imbalance. This should be understood by the team and compensated for by the battery ventilation.
- It is another goal of the team to keep the cells at the same temperature throughout the pack. This can only be done with adequate spacing, and airflow.
- Variation in temperature results in variation of cell performance.
- By no means should the pack be as small as possible, unless you don't want to rayce it in the summer, it will likely overheat.
- How you mount the cells in the battery pack is important: 1) for service should you need to replace one, 2) for service to measure it compared to the others 3) for vibration & containment 4) or mechanical abuse.

How to Build a Pack
What is Important

- A Balanced pack is better than high capacity pack.
- A thermally spaced cool pack is better than a lower air load consumption or a compact (dense) pack.
- It only takes **one** cell to take down a pack.
- So be considerate of those cell(s) and monitor them ahead of the event so know what to expect.

How to Build a Pack

- Ok! We spent Sixteen slides telling you how to build a pack.
- What you do with this information is up to you.
- How your vehicle performs will be predicted on how well you build a pack
- Those Not on the Battery Team will Agree!!!

QUESTIONS?

Team Discussion

Introduce your team and share your NEGATIVE Battery experience