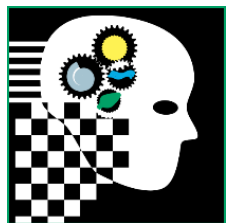


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BATTERY PROTECTION SYSTEM (BPS)

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SUMMARY

This Presentation will cover:

- From End to Beginning what teams need for BPS from end product to starting design
- What you need for Scutineering
- What you need for Vehicle Design Report (VDR)
- What you need from the regulations
- Approaches to proper design of BPS

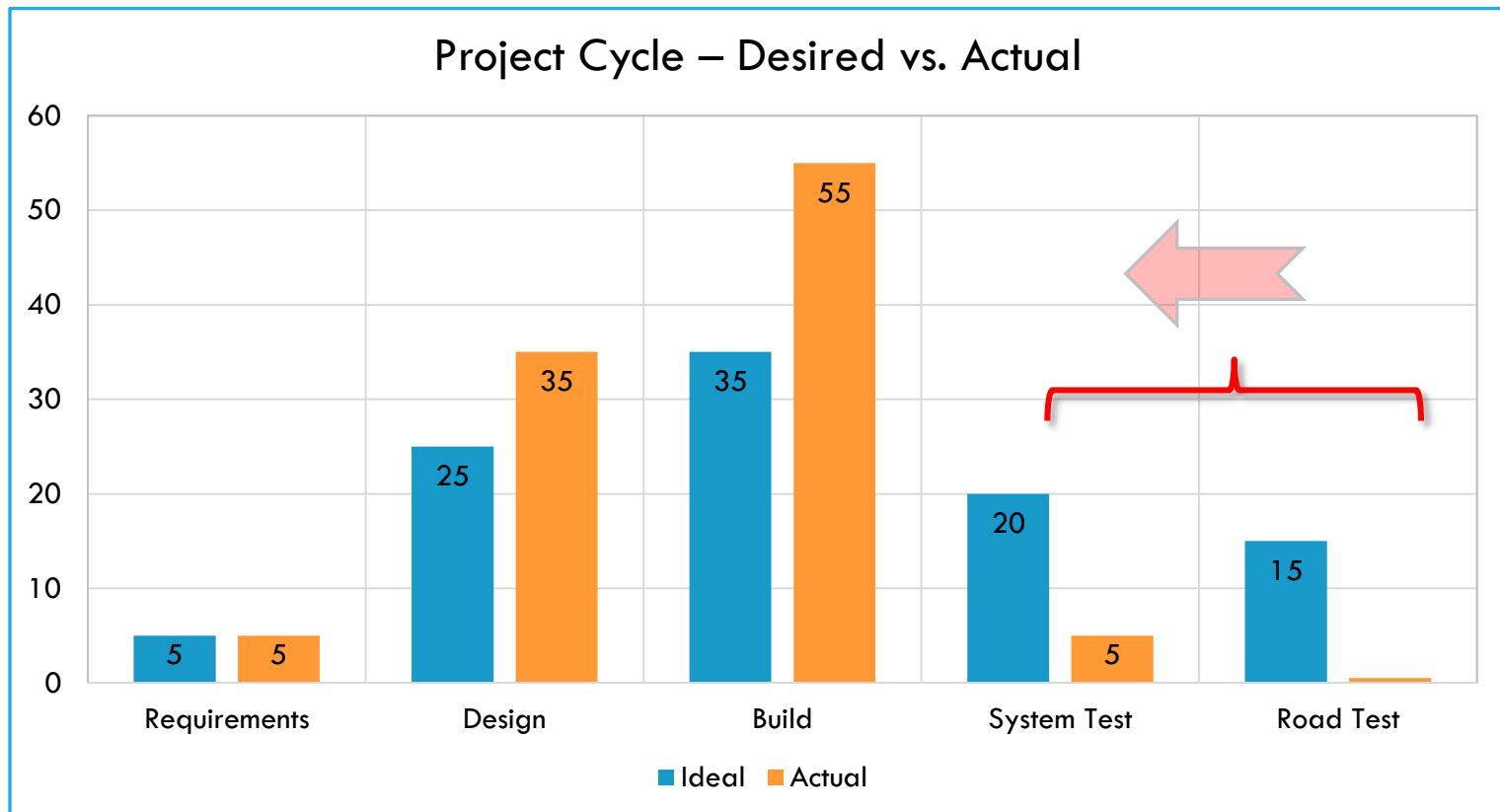
This Presentation will not cover:

- Battery Safety
- Component Selection for Fuse and Main Power Switch

HOW ARE WE GOING TO GET THERE?

Project Management

With a timeline, milestones, and strategies to stay on schedule



ON THE ROAD



The “Ideal” BPS:

- Will not need fault or require reset at any point along race.
- Will be protected from fault conditions by a separate BMS w/ coordination
 - Array limits shuts off before creating excess Over Voltage or Over Current Charge
 - Motor limits current and regen based on state of charge
 - Secondary alarming levels set prevent reaching BPS limits
- Vehicle has proper telemetry, data logging, and driver display for team to know state of charge and operating parameters
- Design is robust to electrical noise found from sources in and out of vehicle
- System has been tested and calibrated to have accurate measurement values over the entire operating ranges as a total system
- System is build to robust and reliable to vibration, elements, and users



SCRUTINEERING

What will you need:

- Working and tested system with the car chassis minus the canopy
- Scrutineering sheet filled out
- Need any harness and special tools to access sense leads, thermistor, and current sensor for test
- Have read the posted testing procedure
 - UV
 - OV
 - OC charge/discharge
 - OT charge/discharge
- Demonstrate a latching fault with manual clearing
- Have a means for locking firmware settings by covering programming or IC's



SCRUTINEERING CONT.

Common Problems:

- Showing up at appointed time
- Having Scrutineering sheet completed with all values
- Bringing the required test harness or tools
- Having the correct team members with expertise to describe and operate
- Having telemetry or displays to verify readings
- Documents to show specs and configuration
- Correct measurement coding to:
 - Latching fault so as not to reset if value brought back to operating range
 - Two tier measurement values for charge and discharge temperature ranges
- Having not planned how to test setting (No test points, leads, or harness)

DESIGN REPORT

How they are reviewed

- Read Electrical System Technical Report (Reg. 3.4.C)
- Read Battery Battery Tech Report (Reg. 3.4.D)
- Read Battery Protection Tech Report (Reg. 3.4.E)

Team	#_ Team Name	
ASC	2015	
Status	Rule	Notes
Green	3.4.E Battery Protection Tech Report: All batteries must be protected with technology appropriate to the chemistry used. Battery protection test report must be submitted to ASC Headquarters as part of the Vehicle Design Report by the date indicated in Reg. 3.2.A.2. The tech report must document the design approach used with respect to Reg. 5.4 including the following information:	
Green	3.4.E.1 Battery Approval Forms for each battery type	Document Received. (For future save as PDF) Electrical Review Complete
Yellow	3.4.E.2 Over temperature set points (charge and discharge if different) for each battery type	Battery allows Chrg(40)/DisChrg(60) <> Set(47). Must be lower of two or distinguish charge and discharge states.
Green	3.4.E.3 Under voltage set point for each battery type	2.7 = Set(2.7)
Green	3.4.E.4 Over voltage set point for each battery type	4.2 = Set(4.2)
Green	3.4.E.5 Over current set point for each battery type	32=ChrgSet(21) / 64=DisChrg(21)
Yellow	3.4.E.6 Block diagram for BPS for each battery type	Missing.
Yellow	3.4.E.7 Description of how the BPS will operate for each battery type.	Battery fan must be on anytime contactors powered. How is it powered? No mention of Aux pack and how the BPS powers up/down.
Green	3.4.E.8 How firmware or settings will be rendered static and un-modifiable after inspection (i.e. sealed in battery enclosure)	Sealed in battery box



DESIGN REPORT CONT.

Top Feedback Points

- Current Team Name, Number, and Contacts
- Inconsistencies between battery approval and tech reports
- Set point margins at absolute value of manufacturing spec
- Two tier temperature and current for charging and discharge
- Component location
- Communication dependencies
- Primary function of BPS
- Layers of protection
- Manufactured spec sheets for components or sub-systems are not a substitute for the system design report.
- How system starts
- Car must come to a complete stop before re-engaging the BPS
- After Isolation what steps are required to restart car
- Locking out changes



REGULATIONS (5.4)

5.4 Protection Circuitry

All batteries must have protection circuitry appropriate for the battery technology used.

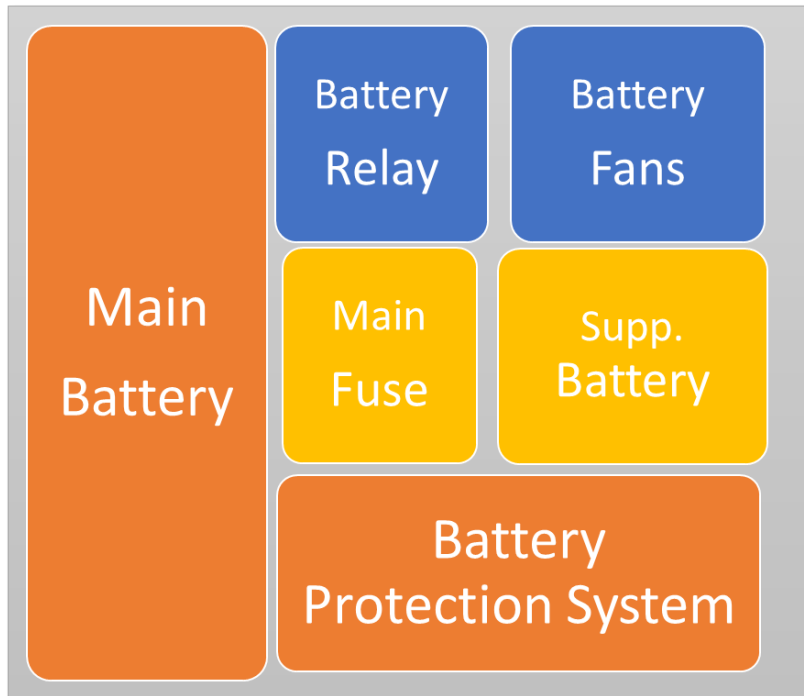
Proof is required at Scrutineering that the protection system is functional and meets manufacturer's specifications.

Testing procedures will be provided, and the protection system design should allow for such testing.

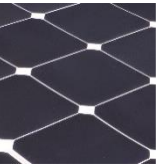
All measurement leads should be fused or current limited to less than 1 mA for non-isolatable sinks in the measurement circuitry.

All protection circuitry should be contained in the battery enclosures per Reg. 5.5.

BPS PHYSICAL LAYOUT



[In the Box]	Why?
Cells	Protection and ventilation
Battery Relay	Electrical Isolation (wet hand test)
Fans	Sealing and ducting
Main Fuse	Electrical Isolation
Supplemental Battery	<ul style="list-style-type: none"> • Temporary power for BPS • Power for Relay • Monitor it with BPS
Batt. Protection System (BPS)	No connectors No HV wire leads Sealed from damage / elements



REGULATIONS (5.4.A)

5.4.A.1 Cell: The smallest available source of energy in the battery pack as purchased from a manufacturer. A single electrochemical cell.

5.4.A.2 Module: The smallest easily removable group in a battery pack.

5.4.A.3 String: The smallest group of cells needed in a battery pack to provide the required voltage.

5.4.A.4 Protection Limit: The measured level determined to be adequate to protect from an event.

5.4.A.5 Active Protection: System in which measurements are constantly monitored and where actions are taken immediately without operator intervention. Any protection faults will latch such that a manual clearing process is required by the driver with the vehicle not in motion and only after faults have been verified clear by the protection system.

5.4.A.6 Passive Protection: System in which measurements are monitored by the driver and where action is driver controlled.



REGULATIONS (5.4.B)

5.4.B.1 Li-Based: All lithium based battery packs must have **active** protection such that

- over-voltage,
- over-temperature (for charge and discharge rating),
- over-current and
- under-voltage

cause the pack to electrically isolate the source or sink from the battery pack.

The level of protection measurement is required down to the module level at a minimum and may be required at a cell level depending on the cell manufacturer.

Fuses are not acceptable for over-current protection, but are required as per Reg. 5.6.



REGULATIONS (5.4.B) CONT.

5.4.B.2 Ni-Based: All nickel based battery packs must be protected from over-temperature and over-voltage. Active Protection is not required but recommended if Passive Protection is unavailable.

5.4.B.3 Pb-Acid: All lead based battery packs must be protected from over-voltage. A minimum of passive protection is recommended.

5.4.B.4 Supplemental: All supplemental batteries must have at a minimum Passive Protection for under voltage where charging occurs remote to the solar vehicle unless they are primary cells. Active Protection is required if charging is within the solar vehicle.

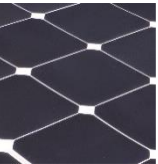
RELATED REGULATIONS



5.3.C Supplemental Batteries: Supplemental, replaceable batteries carried in the solar car may be used to power: main disconnect relay, radios, commercially available electronic panel meters with internal batteries, cell phones, driver ventilation fans (if solely used for driver ventilation), and the horn. Supplemental battery power may be used to **momentarily power the battery protection system as defined by Reg. 5.4 to verify safe battery parameters before energizing the main power switch.**

5.6.C Voltage Taps: All battery protection circuitry (BPS) measurement leads or voltage taps off the battery must be **fused or current limited to less than 1 mA** for non-isolatable sinks in the Battery Protection or measurement circuitry.

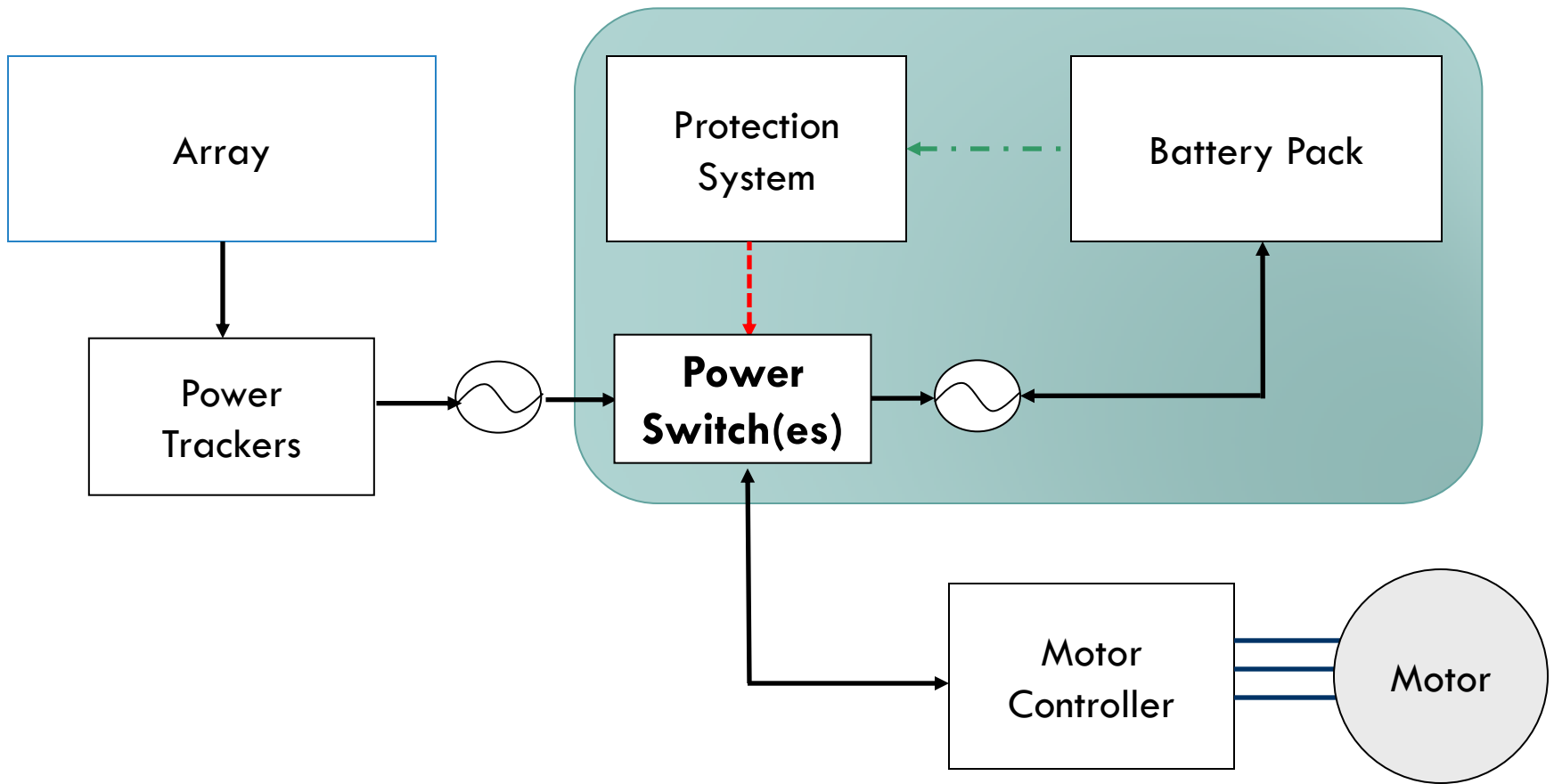
5.7.A Main Power Switch: The solar car must be equipped with a single throw manually operated, high current and DC-rated, multiple pole switch to quickly isolate the battery, motor, and array from each other and the electrical system of the vehicle. This switch must be capable of interrupting the maximum DC-rated voltage and the full load current. Relays or contactors used for this purpose must also be DC-Rated, normally open, and non-latching. Power for the relay may be supplied by Supplemental batteries per Reg. 5.3.C. MOSFETs or other solid state switches that could fail in a closed circuit state are not acceptable for power switches.

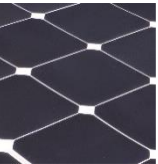


BPS SYSTEM OVERVIEW

- Primarily purpose is to protect batteries
 - Not the same as BMS
- Automatic monitoring and reaction
 - “Smart Fuse”
- Operates within manufactures specifications
 - Over Voltage(OV)
 - Over Temperature(OT)
 - Over Current(OC) for Charge and Discharge w/ OT
 - Under Voltage(UV)
- Complete and immediate isolation when faults
- Car must come to complete stop before reset

BPS SYSTEM DIAGRAM





BPS FAIL SAFE AND RELIABILITY

- **Fault Condition**
 - Cell failure
 - Loose Wire or Connectors
 - Harsh Environmental Conditions
 - BPS Self Diagnostics (watchdog, communications error)
- **User Error**
 - Coding Set Points
 - Incorrect setting on power trackers or motor controller
 - Lack of active monitoring (telemetry or driver readouts)
 - Regen Braking
- **Reliability**
 - Loose Wire
 - Bad Sensor or Measurement
 - Sensitivity to noise (EMI/RFI)
 - Hysteresis, Delay, Calibration
 - Sense Voltage Isolation (Galvanic, Optocouplers)

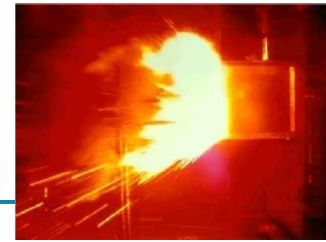


WHOLE SYSTEM PROTECTION

Disconnecting Motor Controller, DC/DC, or MPPT under load can cause secondary damage.

- Understand effects on system when an abrupt shut down occurs
- Braking Resistor, Clamping Diode, or Transient Stability Circuit on Main Bus
- Integrate Protection System to soft shut down all sources (BMS)
- Provide telemetry to detect and prevent conditions that result in faults
- When a fault occurs determine root cause before continuing
- Understand effects on system when an abrupt shut down occurs

RISKS



Risk compensation is a theory which suggests that people typically adjust their behavior in response to the perceived level of risk, becoming more careful where they sense greater risk and less careful if they feel more protected.

Safer Cars = More reckless drivers

In other words, don't underestimate the complexity of the engineering design necessary to not only meet, but exceed the regulation for the safest system you can produce.

Boeing, Tesla, and other companies still have difficulty taming all issues with larger resources of headcount, research, and testing.

The BPS is a critical safety component to your operating car! It is there to stop abuse to the batteries.

There is no performance gain not fully implementing to your manufactures specifications or not following the intent of the regulations

QUESTIONS?

