Notes on multi-unit battery chargers and charging—Formula Hybrid 2010

The Formula Hybrid rules about battery chargers apply straightforwardly to a single unit that derives power from the 120 VAC line voltage on one side and delivers it to a HV battery bank on the other side. There are two variations on this configuration for which the following clarification of the rules may be helpful. The two special situations are:

1. Lower voltage chargers connected to fewer cells in series, used to simultaneously or sequentially charge subsets of the full battery bank.
2. Chargers with dc input voltage, which is then supplied by a separate power supply which in turn gets power from the 120 VAC line.

If your charging plan includes either of these, we recommend reading the following guidelines carefully and submitting your charging system design to the rules committee for approval in advance of the event.

For reference the rules on charging are:

> **4.9 Charging Equipment**
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> Any external equipment such as chargers that are to be electrically connected to high-voltage system of the car must be maintained in safe working condition. High-voltage chargers and/or power supplies must be marked with appropriate high-voltage stickers.
>
> Provisions for charging must follow the same rules as other high-voltage wiring: no exposed connections, proper strain relief, etc. The accumulator enclosure must remain closed during charging.
>
> All chargers must be UL (Underwriters Laboratories) listed. Any waivers of this requirement require approval in advance, based on documentation of the safe design and construction of the system, including galvanic isolation between the input and output of the charger.
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> When the vehicle is charging from external sources:
>
> • The vehicle must be de-energized as much as possible while still allowing charging.
>
> • No other activities (including any mechanical or electrical work) shall be allowed.
>
> • At least one member of the team with knowledge of the vehicles electrical system and charging process must be present throughout the charging process.

Notes on charging in smaller groups of cells:

- If the overall battery bank remains connected in series during charging of lower-voltage sub-strings, the system has a high voltage overall, and all the connections are considered high-voltage, even if the voltage of the sub-string is under 30 V.
- If the series connections are broken for charging sub-strings, it is possible that the system then becomes a low-voltage system. This would allow avoiding the stringent “no exposed connections” rules for high voltage, though the connections must still be adequately guarded to prevent short circuits, for example if a wrench were dropped across them. In addition, a plan for safely making and breaking the connections when setting up for charging or reconnecting for running the vehicle will be needed. Safety in this operation could be achieved by various means. This could include an automatic system or a written procedure detailing the step-by-step process and safety equipment used during the process.
- The requirement that “the accumulator enclosure must remain closed during charging” means that you’ll need a plan to make multiple connections while keeping it closed. Whether these

connections may be exposed or not depends on whether the battery bank is broken into strings under 30 V. Note that the batteries must remain inside the closed enclosure—having it closed doesn't accomplish anything if the batteries are elsewhere!

Notes on charging with dc-to-dc chargers fed from separate ac-to-dc power supplies:

- Both the dc-to-dc charger and the ac-to-dc power supply need to be UL listed. As with a single-unit charger, "Any waivers of this requirement require approval in advance, based on documentation of the safe design and construction of the system." In this case, documentation that must be submitted should include your overall charging plan as well as the individual units. Note that UL recognized is not the same as UL listed. UL recognized means that it's a useful component that might be safe in a properly engineered system, but it's still up to you to engineer that system (and submit documentation to the rules committee showing that you have done so). For example a UL recognized power supply might have exposed high-voltage connections that you need to enclose.
- Galvanic isolation is necessary between the ac input and the dc output of the ac-to-dc power supply. The dc-to-dc charger may or may not need galvanic isolation:
    - If the sub-strings are charged simultaneously, in series, the dc-to-dc chargers need galvanic isolation.
    - If the sub-strings are charged sequentially, while still connected in series (just one set at a time), the dc-to-dc charger might not need galvanic isolation, but in that case both its inputs and its outputs would be considered high voltage.
    - If the sub-strings are disconnected from each other and are low-voltage, the dc-to-dc chargers do not need isolation.

- Chargers or power supplies with outputs or inputs under 30 V might not be designed to support HV on those connections relative to their cases, ground connections (if any), controls, or communications ports. In such cases where they have HV on those connections (for example, if the outputs of the chargers are connected battery sub-strings while the batteries are connected in series), documentation of their ability to support that voltage is required.
- The overall system may need to be mounted in an enclosure in addition to the enclosure of each component in order to safely meet requirements for avoiding exposed high-voltage connections.
- Exposed metal such as cases or enclosures must be grounded to the third prong of the ac power supply system.