PEER
Reviewers Guide

Formula Hybrid
IEEE
Pre-Event Electrical Review

INTRODUCTION

Thank you for volunteering to help out a team of student engineers by performing a Pre-Event Electrical Review of their race vehicle prior to the 2015 Formula Hybrid competition.

The PEER program was initiated this year in an effort to improve the percentage of student-built race vehicles that arrive at the competition ready to pass the safety inspections.

This Guide has been created to assist you to prepare for and conduct the Electrical Review.

Note: We are not asking you to perform a safety inspection, nor are we asking you to "sign off" on anything. As an experienced electrical engineer, we are asking you to look over a student-built electric-powered vehicle. The purpose of this is to help the student team be better prepared to pass our official safety inspections, which take place after the vehicles arrive at the competition in April.

What this also means is, that if you tell the team that something looks OK to you, the team cannot then protest the ruling of an inspector at the competition by saying that their reviewer said it was OK. (It may be helpful to remind the team of this periodically.)

One thing that you will discover during your interactions with the students, is that only a minority of them will be pursuing EE degrees. The majority will be mechanical engineers. Therefore you may have to tailor your responses and advice accordingly. (The historical EE/ME ratio continues to be a mystery to us, and suggestions for how to improve this are appreciated.)

We sincerely appreciate your volunteering your time and engineering skills to help out your team of student engineers, and we will provide as much support from our end as we can. Please feel free to contact us at any time and for any reason. Our contact information can be found at the end of this document.

Finally, in the likely event that you develop an attachment to your team and wish to accompany them to the competition, please let us know. We'll provide you with credentials along with lunch tickets and an invitation to Tuesday night's VIP reception.

Either way, we would like to show our appreciation by sending you a Formula Hybrid/IEEE "Official" shirt. Let us know your size and we'll get one off to you.

BEFORE YOU VISIT THE TEAM

The Formula Hybrid rules can be downloaded from: http://www.formula-hybrid.org > *Students* > *Rules and Deadlines.* Please read section **A1** for an overview, and familiarize yourself with the contents of section **EV**.

We do not expect you to become rules experts, but you should know where to find things.

PRELIMINARY VEHICLE REVIEW

One requirement of the Formula Hybrid competition is that prior to the event, each team must submit an Electrical Systems Form (ESF) and a Failure Modes Effects Analysis (FMEA) . For 2015, these are due by March 18th.

We will forward both submissions from your team as soon as we have them so that you have time to familiarize yourself with their vehicle. This should also give you some insight into the relative strengths and professionalism of your team.

As you look through these forms, please make notes and convey any concerns to us and/or the team as appropriate.

Giving the team time to correct problems before your visit will further help them be prepared.

ELECTRICAL SYSTEMS FORM (ESF)

The ESF is an extensive document with a great deal of information in it. The students fill in a template that we provide. Please look it over and make notes regarding errors or inconsistencies. Contact us if you have any questions or for assistance. If there are errors or inconsistencies, you should send it back to the team for corrections.

Note: The ESF must be complete and accurate before the team will be allowed to present their vehicle for inspection at the competition.

FMEA

The FMEA should be treated in the same manner as the ESF. Note that this may be the first time that many of the students will have seen an FMEA, so again, your feedback to the team will be very helpful to them.

VISITING THE FORMULA HYBRID TEAM

Your visit to the team should be thought of as both an electrical review of their vehicle and an educational session.

Remember that the goal is to help the teams arrive at the competition with a vehicle that is ready to pass our electrical safety inspections.

A secondary goal is to point out issues that in your opinion, might lessen a team's likelihood of completing all the dynamic (on-track) events.

What this means is, in addition to performing a formal electrical review, you should feel free to give the teams any advice you feel is appropriate in order to help them become better engineers and project managers. The only limitations that we impose on professional assistance can be found in the Formula Hybrid rules, sections **A7.1** through **A7.4.**

We stand ready to provide real-time support from seasoned Formula Hybrid electrical inspectors (via Skype or equivalent) during all or part of your review. They will have rules at hand and can provide information as you need it.

It will be helpful to us if you could email photographs of areas of the vehicle that concern you. When the vehicles arrive at the competition, our inspectors will review these photos to see how well teams have addressed issues that you have pointed out to them.

THE REVIEW PROCESS

The review should be a "non-energized" review, meaning that the high voltage system (TSV) should remain off during the review.

Unless the accumulator devices can be proven to contain no more than 30V (sum total) the accumulator containers should remain closed. (You can ask the team to provide photographs or engineering drawings of the container contents, or uncharged containers may be reviewed.)

EQUIPMENT

It is recommended that you bring the following to the review:

1. A copy of the 2015 Formula Hybrid Rules (Rules supersede any wording in this document)
2. Flashlight or Headlamp
3. Safety Glasses (Team members are required to wear safety glasses when working on the vehicle and you should set an example for them. See section **D10.7**)
4. Small, non-conductive rod (˜1/4" dia. x 8" -- To see around wires without touching them with your fingers.)
5. A Camera (a smartphone is fine) to photograph areas of concern.

The team should be able to provide a Digital Multimeter (DMM) in order to do continuity and ground bonding measurements.

SAFETY FIRST

Each team is required to have a "Rules and Safety Officer" (RSO) and your review should start by talking with the RSO.

Ensure that the team has the following safety equipment, and that it is in good condition: (**EV3.8.6**)

1. Insulated screw drivers
2. Multimeter with shrouded banana connectors and protected probe tips
3. Insulated wrenches, if screwed or bolted connections are used in the tractive system
4. Face shield which meets ANSI Z87.1-2003
5. HV insulating gloves (which are within 14 Months of the test date) and protective outer glove. (Note that Formula Hybrid allows an extra 2 months for test compliance.)
6. 2 HV insulating blankets of sufficient size to cover the vehicles accumulator(s)
7. Safety glasses with side shields (ANSI Z87.1-2003 compliant) for all team members.

Note: All electrical safety items must be rated for at least the maximum tractive system voltage.

If the team is missing any of the above, they should order equipment ASAP to have it in time for the competition. If you feel that ordering this equipment might place a hardship on the team, have them contact the organizers.

You should also discuss lock-out/tag out procedures with the RSO. (See **A6.4, EV8.3** and **Appendix F**)

CHARGING (EV8.2):

The charging equipment for the vehicle should be UL listed, or the RSO should present documented approval from the FH Rules committee for use of the team's charger. If the charger is not UL listed, and the team has not obtained approval from the FH Rules committee, the team should submit a support ticket ASAP.

1. Physically inspect the charger.
    a. Are there any exposed conductors?
    b. Do all connectors have proper strain relief?
2. Review the team's charging procedures with the RSO.
    a. Do they have a designated charging area?
    b. Does a knowledgeable team member stay with the vehicle during charging?
    c. Do they have warning signs to notify people High Voltage is in use?

DOCUMENTATION REVIEW:

You should have reviewed the team's ESF and FMEA prior to arrival, and may have already gone through a few iterations with the team to correct obvious errors or discrepancies.

This is now your opportunity to compare their documents to the actual vehicle.

SCHEMATIC:

1. What circuitry is located in which container in the vehicle? Do any of the containers contain both grounded low voltage (GLV) and tractive system voltage (TSV)? (See **EV4.1**)

2. Fusing
    a. Are fuses rated for DC?
    b. Are the DC voltage ratings of the fuses greater than the maximum voltage of the system they are protecting?
    c. Is there a fuse table for the GLV and TSV systems?
    d. Are wires sizes adequate based on the fuses chosen to protect them? (**EV6**)"
3. Locate the Accumulator Isolation Relays (AIRs). Are they directly controlled by the shutdown circuit (i.e. not using logic or microprocessors)?

   When the AIRs are open, is there any way for TSV to be present outside the accumulator container? (See **EV3.5**)
4. Are there Traction System Measuring Points (TSMPs)? Are they current limited or fused? (See **EV4.10**)
5. Locate the Tractive System Active Light (TSAL) Will it illuminate when the AIRs are energized? (See **EV4.4**)
6. Locate the Tractive System Voltage Present (TSVP) lights Are they directly controlled by voltage being present outside the accumulator container (i.e. not using logic or microprocessors)?

   If an isolated dc/dc converter is used to power the TSVPs, is the output ground referenced? (See **EV4.12**)

MASTER SWITCH/SAFETY LOCK OPERATION (SECTION EV5):

1. Does the team have a diagram showing the safety loop similar to **Figure 32** in the rules? Does it contain all the necessary components:
    a. Three Big Red Buttons (BRBs)
    b. Master Switches
    c. Brake over-travel switch
    d. Insulation Monitoring Device (IMD)
    e. Accumulator Monitoring System (AMS)
    f. Accumulator Isolation Relays (AIRs)
2. Can the team explain how it operates? Does it comply with the state diagram in **Figure 30** and **Table 17** of the rules?

   NOTE: A large part of the electrical inspection at the competition focuses on the safety loop and schematic, and a team that can explain both clearly and concisely will expedite the inspection process at the event.

FMEA

Quiz the team: Pick a few scenarios from the FMEA. Can they explain the failure mode and the expected vehicle response?

VEHICLE INSPECTION:

A majority of your review time will be spent looking at the actual vehicle. Depending on the preparedness of the team, the vehicle could be complete, or it could be in several pieces. In any event, this is your opportunity to work with the team to identify possible issues.

Before looking for specific rules infractions, take a few moments to get some general thoughts:

1. Does the wiring/conduit look neat and purposefully routed? Conversely, do you see any "rat nests" of wiring?
2. Are electrical compartments within the physical outline of the vehicle (including the underside)? Do they look solid and securely attached to the vehicle?

Ask the team to point out key elements to you, such as the accumulator, motors, motor controller, GLV battery, test points and safety circuit components.

At this point, you should be able to take a closer look at the vehicle. Ask the team to remove any body panels or compartment covers to make wiring and components accessible. Below are some of the key things to look for on the vehicle:

1. Is there any TSV in the cockpit (either in conduit or exposed)?
2. Exposed/uninsulated TSV anywhere?

   Weak areas are often at the motor connections and transition between conduit and electrical components. Review **EV4.5 - TSV Insulation, wiring and conduit** for guidelines.
3. Are all the body parts/hardware/frame grounded (defined as <300 mOhms)? While the frame is usually well grounded (most are welded steel tubing) there are a lot of other ways where teams have problems meeting this rule (See **EV 4.3 - Grounding**)
   a. Some teams make their instrument panel out of non-conductive material (Plexiglas, etc.). If they use a standard toggle switch, the metal nut holding the switch to the panel is considered ungrounded.
   b. A metal panel connected to the frame using non-conductive hardware is considered ungrounded and must be connected to the frame with a ground strap.
   c. Check the driver harness attachment points
   d. Carbon fiber is very problematic, especially if the team did not incorporate a conductive mesh during fabrication. Multiple points of the carbon fiber should be tested to see if it is less than 5 Ohms to ground.
   e. Check that their grounding wires are at least 16 AWG, and that the connections are mechanically solid.
4. Is wiring inside the electrical enclosures neat and organized? Is it easy to inspect? Are appropriate electrical connections used?
5. If low voltage and tractive voltage are in the same container, are they properly segregated or mechanically separated? If an insulator is used to separate low voltage from tractive voltage, is it UL listed and rated for 150°C? If the team designed a circuit board with both low voltage and tractive voltage on it, are the traces properly separated (See **Table 16**)?

6. **Note:** Teams are sometimes confused about which wires fall in which category. It doesn't matter what the voltage is on a particular wire—it only matters whether it is galvanically connected in any way to one or the other system. A wire must be either a Ground Low Voltage wire or a Tractive Voltage wire (never both), as the two systems must be galvanically isolated. Ideally it would be apparent just from looking which wires were in which system, but if it's not, point at a wire and ask they team which system it is part of. They should be able to tell you immediately. If they can't, provide guidance on how the team can improve on wire routing and separation.
7. Check that bolted electrical connections (**EV4.5.11**):
    a. Do not have plastic in the stack-up. (So that pressure on the contacts is maintained even if they got hot enough that plastic would soften.)
    b. Do not have steel washers between the Cu (or Al) conductors.
    c. Fasteners are tight.

POUCH CELLS

NOTE: Examining the inside of the accumulator housing is optional, and should only be undertaken if you are certain that the voltages are below 30 VDC or you are comfortable working in the presence of potentially lethal voltages:

Bolted stack-ups: Are they tight? There should not be any plastic or any other deformable material in the stack-up as contact pressure could be lost if the plastic softens due to heat. Steel washers are acceptable in the stack up so long as they are not between (i.e. in the current flow path) of the conductors in the stack-up. (**EV4.5.11**)

NOTE: If the team has assembled their own battery using Lithium-Ion pouch cells, they should be able to produce considerable evidence of communications with the Formula Hybrid rules committee.

Our requirements for the use of pouch cells are extensive and teams that have not communicated with us may find passing the electrical tech inspection difficult.

FINAL COMMENTS

The term "professional standards" is scattered throughout the rules. You are the professional, and the team members will learn a lot from you as you point out items that do not meet this definition.

If you are unsure of anything, there is a team of experienced inspectors to help. Document those items which may remain unresolved through the review, and the seasoned inspectors will review them to provide further guidance.

Thank you!!

The Formula Hybrid Electrical Inspection Team

FORMULA HYBRID CONTACTS

Doug Fraser, Director
Skype: lotuar
Phone: (603) 646-3522
Cell: (603) 443-0012
Email: douglas.a.fraser@dartmouth.edu

Amy Keeler, Coordinating Manager
Skype: amy.e.keeler
Phone: (603) 646-6580
Cell: (406) 249-1066
Email: amy@formula-hybrid.org

Rob Wills, Chief Electrical Inspector
Skype:
Cell: (603) 801-4749
Email: rwills@citizenre.com

Michael Royce, Chief Mechanical Inspector
Email: mjr01@comcast.net

FORMULA HYBRID ELECTRICAL ACRONYMS

AIR	Accumulator Isolation Relay
AMS	Accumulator Management System
BRB	Big Red Buttons (Emergency shutdown switches)
ESF	Electrical System Form
EV	Electrical Vehicle
FMEA	Failure Modes and Effects Analysis
GLV	Grounded Low Voltage
GLVMS	Grounded Low Voltage Master Switch
HVD	High Voltage Disconnect
IMD	Insulation Monitoring Device
IMDT	Insulation Monitoring Device Test
IMT	Insulation Measurement Test
RSO	Rules Safety Officer
TSAL	Tractive System Active Light
TSMP	Tractive System Measuring Point
TSMS	Tractive System Master Switch
TSV	Tractive System Voltage (i.e. High Voltage)
TSVP	Tractive Voltage Present