**Shutdown systems**

**shutdown circuit**

* EV 6.1.1 The shutdown circuit directly carries the power driving the **AIR**s and the **pre-charge circuitry**.
* EV 6.1.2 The shutdown circuit is defined as a series connection of at least two **master switch**es, three **shutdown button**s, the **BOTS**, the **IMD**, the **inertia switch**, the **BSPD**, all required **interlocks** and the **AMS**. Picture on p.86.
* EV 6.1.3 All parts of the shutdown circuit must be on the **high-side connection** of the AIR coils and the pre-charge circuitry.
* EV 6.1.5 If the shutdown circuit is opened, **the TS must be shutdown** by opening all AIRs and the voltage in the TS must drop to below 60 VDC and 25 VACRMS in less than five seconds. All accumulator current flow must stop immediately. The action of opening the AIRs may be delayed by ≤250 ms to signal the action to the motor controllers and reduce the TS current before the AIRs are opened. The AIR supply must be abruptly switched off before reaching the minimum AIR supply voltage.
* EV 6.1.6 If the shutdown circuit is opened by the AMS or the IMD, it has to be latched open by a non-programmable logic that can only be manually reset by a person at the vehicle who is not the driver.
* EV 6.1.7 All circuits that are part of the shutdown circuit must be designed in a way, that in the de-energized/disconnected state they open the shutdown circuit.
* EV 6.1.8 It must be possible to demonstrate that all features of the shutdown circuit function correctly. This includes all interlocks.
* EV 6.1.9 Every system that is required to or is able to open the shutdown circuit must have its own, non-programmable, power stage to achieve this. The respective power stages must be designed to be able to carry the shutdown circuit current, e.g. AIR inrush currents, and such that a failure cannot result in electrical power being fed back into the electrical shutdown circuit.
* EV 6.1.10 The **shutdown buttons**, the **BOTS**, the **TSMS** and all **interlocks** must not act through any power stage.
* EV 6.1.11 All signals influencing the shutdown circuit are SCSs.
* EV 7.2.1 When charging, the charging shutdown circuit consists of at least the charger shutdown button, see EV 7.1.6, the IMD and the AMS.
* EV 7.2.2 If the shutdown circuit is opened the **charging system must remain disabled** and the **shutdown circuit opened** until it is manually reset.
* EV 7.2.4 All signals influencing the charger shutdown circuit are SCS, see T 11.9.

**TSMS**

* EV 6.1.4 The Tractive System Master Switch (TSMS) must be the last switch before the AIRs except for pre-charge circuitry and hardwired interlocks.
* EV 6.2.1 An TSMS must be part of the shutdown circuit.
* EV 6.2.2 The TSMS must be fitted with a “**lockout/tagout**” capability to prevent accidental activation of the TS. The ESO must ensure that it is locked in the off position whenever work is done on the vehicle or no ESO is present.
* EV 6.2.3 The TSMS must be mounted in the middle of a completely **orange circular area of ≥50 mm** diameter placed on a **high contrast background**.
* EV 6.2.4 The TSMS must be marked with “**TS**” and a **symbol** according to “ISO 7010-W012” (triangle with black lightning bolt on yellow background).

**IMD**

* EV 6.3.1 Every vehicle must have an IMD installed in the TS system.
* EV 6.3.2 The IMD must be a **Bender A-ISOMETER® iso-F1 IR155-3203** or **-3204** or **equivalent IMD approved** for automotive use. Equivalency may be approved by the officials based on the following criteria: **robustness** to vibration, **operating temperature** range, **IP rating**, **availability** of a direct output, **a self-test** facility and must not be powered by the system which is monitored.
* EV 6.3.3 The response value of the IMD must be set to ≥**500 Ω/V**, related to the maximum TS voltage.
* EV 6.3.4 The IMD must be connected on the **vehicle side** of the AIRs.
* EV 6.3.5 One IMD chassis ground measurement line must be connected to the **grounded accumulator container**. The other chassis ground measurement line must be connected to the **main hoop**. Each connection must use a separate conductor, rated for at least maximum TS voltage. An open circuit in any of this ground measurement connections must result in an opened shutdown circuit.
* EV 6.3.6 In case of an insulation failure or an IMD failure, the IMD must open the shutdown circuit. This must be done without the influence of any programmable logic.
* EV 6.3.7 If the IMD opens the shutdown circuit a red indicator light in the cockpit that is easily visible from inside and outside the cockpit even in bright sunlight and clearly marked with the lettering “IMD” must light. It must stay illuminated until the error state has been manually reset. Signals controlling this indicator are SCS, see T 11.9.
* EV 7.1.7 When charging the accumulator, an IMD as described in EV 6.3 must be active and must be able to shut down the charger. Either the charger must incorporate an active IMD or an active IMD must be within the accumulator. Other than stated in EV 6.3, the second chassis ground measurement line must be connected to the casing of the charger instead of the main hoop.
* EV 7.1.8 An IMD indicator light as defined in EV 6.3.7 must be available during charging.

**Chargers**

* EV 7.1.1 Only chargers presented and sealed at technical inspection are allowed. All connections of the charger(s) must be insulated and covered. No open connections are allowed.
* EV 7.1.2 **Exposed conductive** parts and the **TS accumulator** container must be connected to protective earth (PE).
* EV 7.1.3 All chargers must either be accredited to a recognized standard e.g. CE, or when built by the team, must comply with all electrical requirements for the vehicle **TS**, e.g. EV 4.3, EV 3.1 and EV 4.2.
* EV 7.1.4 **TS** charging leads must be orange.
* EV 7.1.5 When charging, the **AMS** must be live and must be able to turn off the charger in the event that a fault is detected.
* EV 7.1.6 The charger must include a push type emergency stop button which has a minimum diameter of **24 mm** and must be clearly labeled.
* EV 7.1.9 The charger must include TSMPs as described in EV 4.7. Other than stated, the TSMPs must be connected to the **TS** output of the charger.

**TS Accumulator HAND CART**

* EV 8.1.1 A hand cart(s) must be used for **transporting the TS accumulator** container(s) around the competition site.
* EV 8.1.2 The hand cart must have at least **four wheels**.
* EV 8.1.3 The hand cart must have a **brake which is always on** and only released if someone pushes the handle, or similar.
* EV 8.1.4 The brake must be capable of safely stopping the fully loaded hand cart.
* EV 8.1.5 The hand cart must be able to carry the load of the TS accumulator container(s).
* EV 8.1.6 The TS accumulator container(s) must be **mechanically fixed** to the hand cart to enable a safe transportation.
* EV 8.1.7 The TS accumulator container(s) must be protected from **vibrations** and **shocks** during normal operation of the cart, e.g. by the use of air tires.
* EV 8.1.8 The label on the TS accumulator container or an additional label according to EV 5.3.8 must be clearly visible if the TS accumulator container is on the hand cart.
* EV 8.1.9 The overall floor space used by the fully loaded hand cart must not exceed 1200 mm x 800 mm. If the accumulator container is larger than the allowed floor space, exceptions may be approved by the officials prior to the competition.

**ESF**

* EV 9.1.1 Prior to the competition, all teams must submit clearly structured documentation of their entire electrical system (including control and TS) called the **ESF**.