GM DRAFT

Post-Crash Electrical Safety

This part specifies electrical safety requirements for electric vehicles, hybrid vehicles and fuel cell vehicles following vehicle crash test(s). The crash test(s) to be used for purposes of evaluating compliance to these requirements are those specified within existing regulations of the contracting parties.

1 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

electrical isolation
the electrical resistance between the vehicle high-voltage source and any vehicle conductive structure.

energy storage system
the components comprising, but not limited to, the vehicle's high-voltage battery system or capacitor system. These include, but are not limited to, the battery or capacitor modules, interconnects, venting systems, battery or capacitor restraint devices, and energy storage boxes or containers that hold the individual battery or capacitor modules.

high-voltage source
any item that produces voltage levels equal to or greater than 30 VAC or 60 VDC.

protection degree
protection provided by an enclosure related to the contact with live parts by a test probe, such as a test finger (IPXXB), a test rod (IPXXC), or a test wire (IPXXD) as defined in ISO 20653

rechargeable energy storage system (RESS)
system that stores energy for delivery of electric energy and which is rechargeable

VAC
volts of alternating current (AC).

VDC
volts of direct current (DC).

2 Requirements

During and after the specified crash test(s), fuel cell vehicles to which this standard applies shall meet the performance requirements specified in paragraphs 2.1 through 2.3. Each vehicle to which this standard applies must be capable of meeting the requirements of any applicable single barrier crash/static rollover test sequence, without alteration of the vehicle during the test sequence. A particular vehicle need not meet further test requirements after having been subjected to a single barrier crash/static rollover test sequence.

[2.1 Electrolyte spillage from propulsion batteries

Not more than 5.0 liters of electrolyte from propulsion batteries shall spill outside the passenger compartment, and no visible trace of electrolyte shall spill into the passenger compartment. Spillage is measured from the time the vehicle ceases motion after a barrier impact test until 30 minutes thereafter, and throughout any static rollover after a barrier impact test.]

[2.2 Battery retention

Battery modules located inside the passenger compartment must remain in the location in which they are installed. No part of any battery system component that is located outside the passenger compartment shall enter the passenger compartment during the test procedures of S6 of this standard, as determined by visual inspection.]

[2.3 Electrical Safety

Within 5 seconds of the vehicle coming to rest after each crash test, electrical safety shall be provided as follows:

(a) For AC high-voltage systems, at least one of the following criteria shall be met:

- (1) Electrical isolation between any high-voltage source and the vehicle chassis electricity-conducting structure greater than or equal to [500] ohms/nominal volt; or
- (2) Voltage of the bus equal to or less than 30 VAC; or
- (3) Energy on the bus less than 0.2 Joules; or
- (4) The AC high-voltage bus is fully enclosed and isolated within a physical barrier that provides protection class IPXXB.

(b) For DC high-voltage systems, at least one of the following criteria shall be met:

- (1) Electrical isolation between any high-voltage source and the vehicle chassis electricity-conducting structure greater than or equal to [100] ohms/nominal volt; or
- (2) Voltage of the bus equal to or less than 60 VDC; or
- (3) Energy on the bus less than 0.2 Joules; or
- (4) The DC high-voltage bus is fully enclosed and isolated within a physical enclosure or barrier that provides protection class IPXXB.]

3 Test Conditions

The test conditions specified in paragraphs 3.1 and 3.2 shall be used. Where a range is specified, the vehicle must be capable of meeting the requirements at all points within the range.

3.1 RESS ~~Battery~~ state of charge

The ~~battery system~~ RESS is at the level specified in the following paragraph (a), (b), or (c), as appropriate:

(a) At the maximum state of charge recommended by the manufacturer, as stated in the vehicle operator's manual or on a label that is permanently affixed to the vehicle;

(b) If the manufacturer has made no recommendation, at a state of charge of not less than 95 percent of the maximum capacity of the ~~battery system~~ RESS; or

(c) If the ~~batteries~~ RESS are rechargeable only by an energy source on the vehicle, at any state of charge within the normal operating voltage, as defined by the vehicle manufacturer.

[3.2 Vehicle conditions

The switch or device that provides power from the ~~propulsion batteries~~ RESS to the propulsion motor(s) is in the activated position or the ready-to-drive position.

3.2.1 The parking brake is disengaged and the transmission, if any, is in the neutral position. [In a test conducted under S6.3, the parking brake is set.

3.2.2 Tires are inflated to the manufacturer's specifications.

3.2.3 The vehicle is loaded as specified in the crash test protocols of the contracting parties, including necessary test dummies, restrained only by means that are installed in the vehicle for protection at its seating position.]

4 Test Procedures

This section describes test procedures that may be used to determine electrical voltage, isolation and energy levels between the fuel cell vehicle high voltage systems and the vehicle conducting structure. Alternative test and analysis methods may also be used to demonstrate compliance to the electrical safety requirements of paragraph 2.3. For example, megohmmeter measurements are an appropriate alternative to the procedure described below for measuring electrical isolation. Well established calculation methods also exist to determine electrical energy on high voltage buses.

The following procedures should be performed before and after each of the specified crash tests.

4.1 Test setup and equipment

The (R)ESS shall be charged in accordance with 3.1.

The high voltage system shall be connected to the vehicle propulsion system, and the vehicle ignition shall be in the 'on' (high voltage system energized) position.

If a high voltage disconnect function is used and the disconnect function is integral to the ~~energy source / storage device(s)~~ RESS, measurements are taken downstream of the device performing the disconnect function.

If a high voltage disconnect function is used and the disconnect function is not integral to the ~~energy source / storage device(s)~~ RESS, measure the voltage upstream of the device performing the disconnect function.

The voltmeter used in this test shall measure DC values and have an internal resistance of at least 10 ~~million~~ mega ohm~~s~~.

NOTE: Meter resistance is neglected in the calculation of electrical isolation in that which follows.

[4.2 Test sequence

Figure 1 illustrates the procedural sequence to evaluate compliance to the electrical safety requirements of paragraph 2.3.

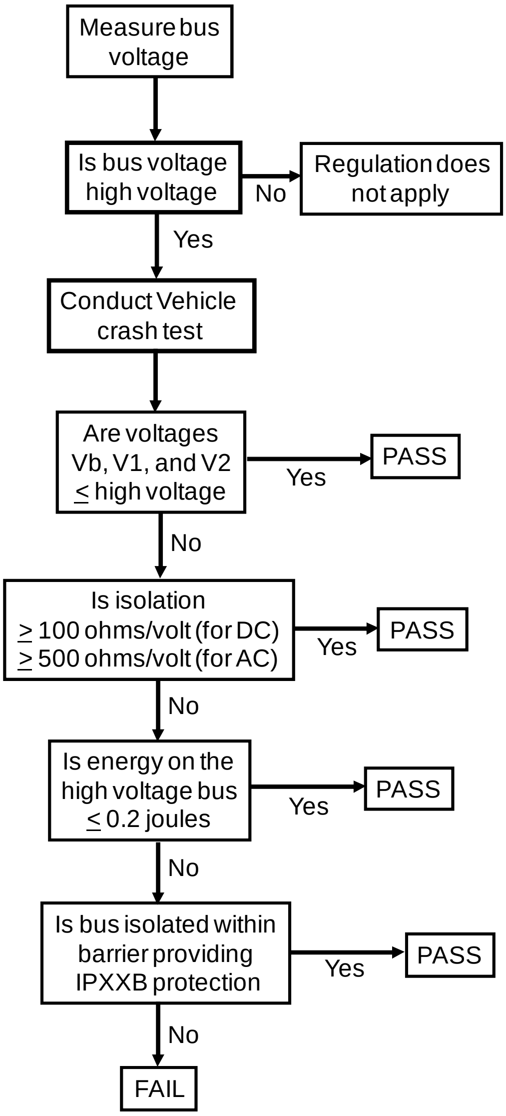


Figure 1 – Test sequence for electrical safety]

4.3 Bus voltage

The following instructions may be used if voltage is measured.

Prior to the vehicle crash test measure and record the high voltage bus voltage (Vb) (see Figure 1.1). If Vb is high voltage, conduct the specified vehicle crash test. After the crash test, determine the high voltage bus voltages (Vb, V1, V2) (see Figure 1.1). If the Energy Storage Device Assembly is designed to be isolated with respect to vehicle chassis, measure the voltage V3 between any conductive portions of the assembly and vehicle chassis.

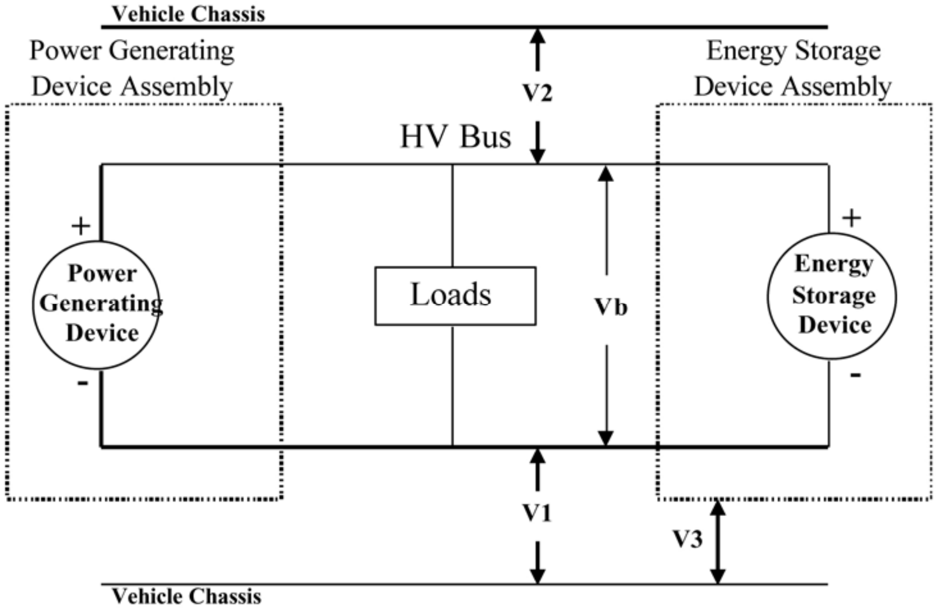


Figure 1.1 - Measurement of high voltage bus voltage

4.4 Electrical isolation

The following instructions may be used if isolation is measured.

Before the vehicle crash test, measure and record the high voltage bus voltage (Vb) (see Figure 1.1). Vb must be equal to or greater than the nominal operating voltage as defined by the vehicle manufacturer. [It is acceptable for vehicle manufacturer to elect to calculate or simulate this value instead of measuring this after the crash.]

Measure and record the voltage (V1) between the negative side of the high voltage bus and the vehicle chassis (see Figure 2.1):

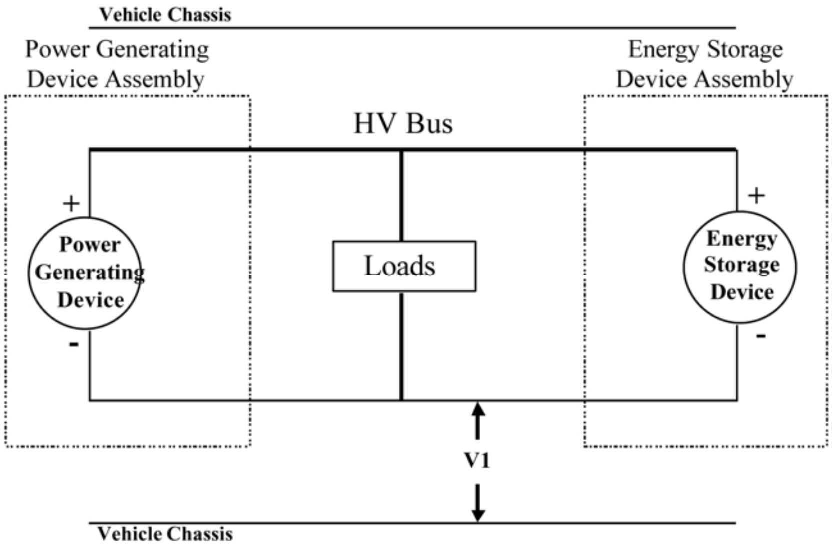


Figure 2.1 - Measurement of the voltage between the negative side of the high voltage bus and the vehicle chassis

Measure and record the voltage (V2) between the positive side of the high voltage bus and the vehicle chassis (see Figure 2.2):

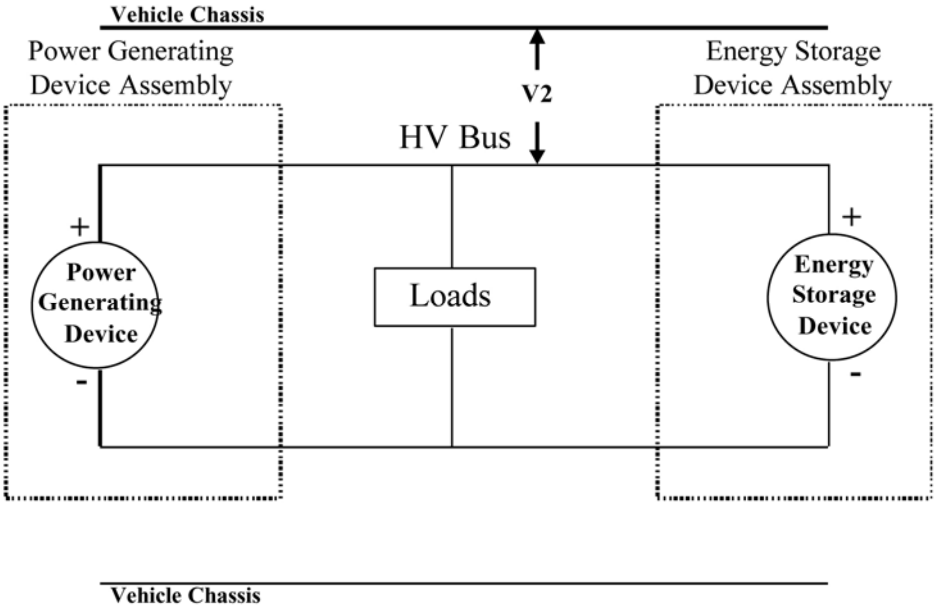


Figure 2.2 – Measurement of the voltage between the positive side of the high voltage bus and the vehicle chassis

If V1 is greater than or equal to V2, insert a standard known resistance (Ro) between the negative side of the high voltage bus and the vehicle chassis. With Ro installed, measure the voltage (V1') between the negative side of the high voltage bus and the vehicle chassis (see Figure 2.3). Calculate the electrical isolation (Ri) according to the formula shown. Divide this electrical isolation value (in ohms) by the nominal operating voltage of the high voltage bus (in volts).

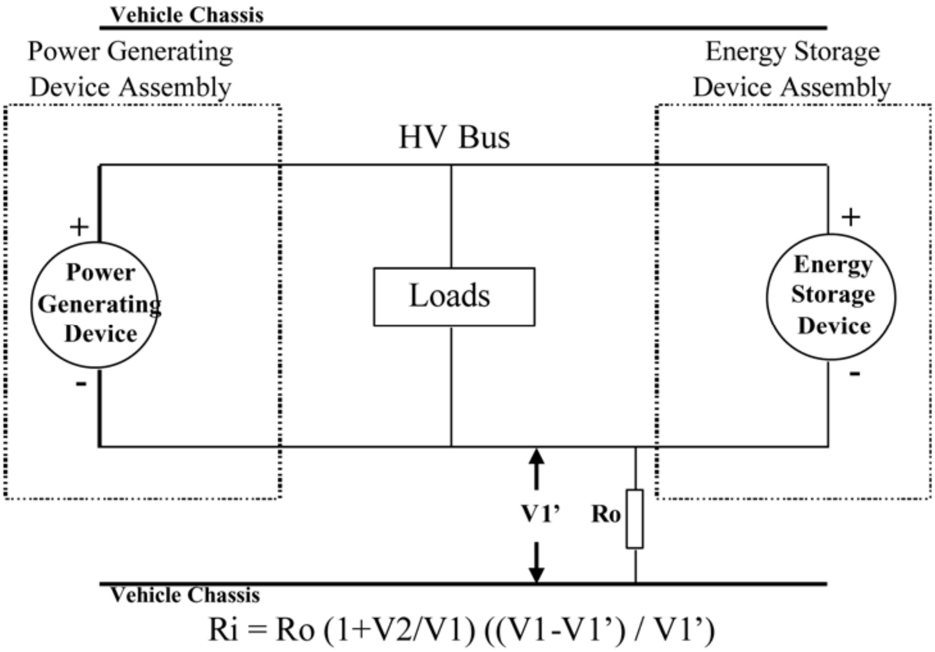
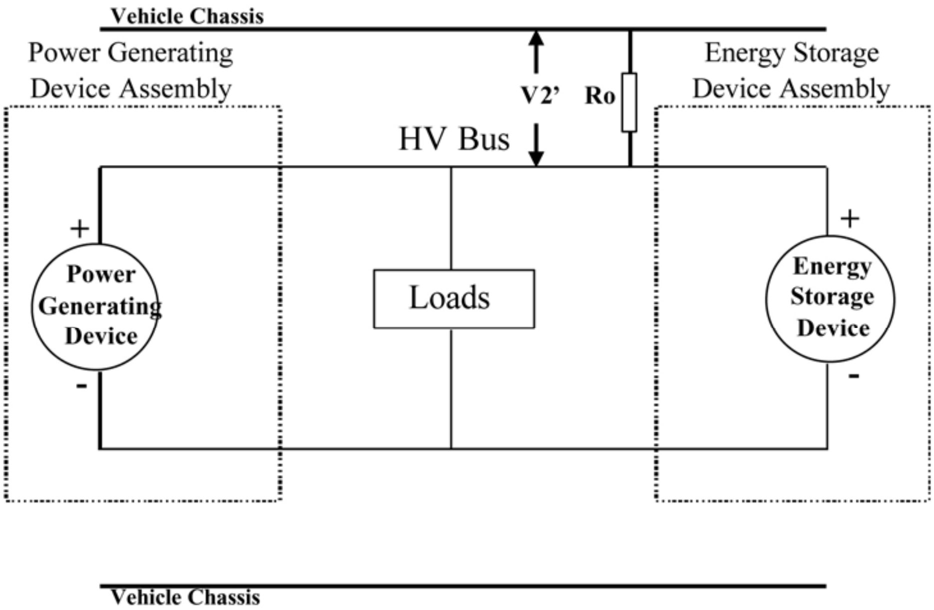


Figure 2.3 – Voltage across resistor between negative side of the high voltage bus and vehicle chassis

If V2 is greater than V1, insert a standard known resistance (Ro) between the positive side of the high voltage bus and the vehicle chassis. With Ro installed, measure the voltage (V2') between the positive side of the high voltage bus and the vehicle chassis. (See Figure 2.4.)

Calculate the electrical isolation (Ri) according to the formula shown. Divide this electrical isolation value (in ohms) by the nominal operating voltage of the high voltage bus (in volts).



$$Ri = Ro\,(1+V1/V2)\,((V2-V2')\,/\,V2')$$

Figure 2.4 – Voltage across resistor between negative side of the high voltage bus and vehicle chassis

NOTE 1: The standard known resistance Ro (in ohms) should be approximately 500 times the nominal operating voltage of the vehicle (in volts). Ro is not required to be precisely this value since the equations are valid for any Ro; however, an Ro value in this range should provide good resolution for the voltage measurements.

NOTE 2: If the isolation resistance is calculated to be between 500 Ohms/V and 250 Ohms/V, additional calculations may be required to determine the location and number of ground faults and the resulting worst-case leakage current.

4.5 Electrical Energy

The following procedure may be used if energy is measured.

After the vehicle crash determine the high voltage bus energy (see Figure 3.1). Install switch S1 and known resistance Re. Close switch S1 and measure and record voltage Vb and current Ie. Integrate the product of these two measurements with respect to time to obtain total energy. ~~If the total energy is less than 0.20 Joules this constitutes a passing test result.~~

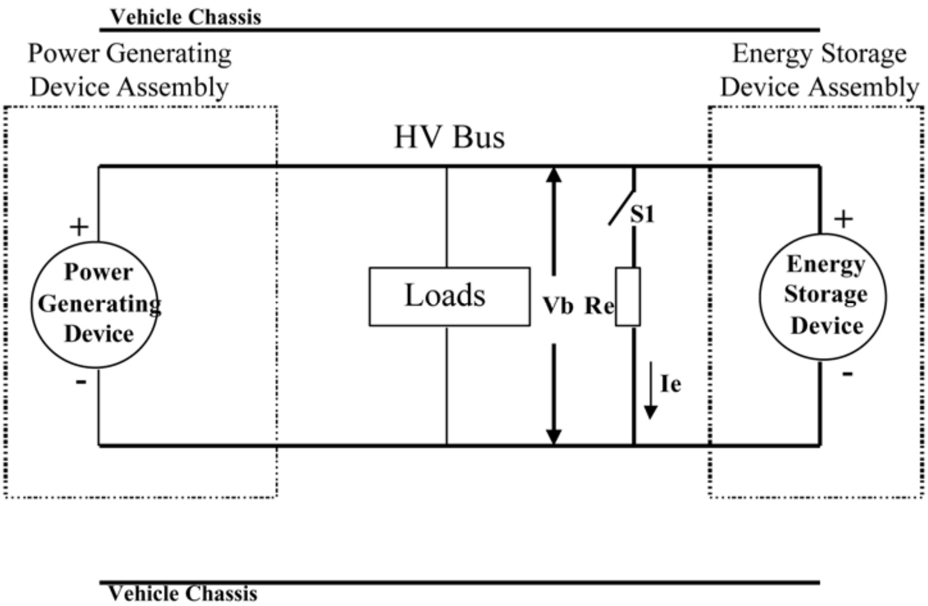


Figure 3.1 – Measurement of high voltage bus energy