# E-Safety Advanced Training H55-44494-55006

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# Reminders

## Electrical threats

- None of our sense organ warns us when we get near conductive components under voltage.
- A human is unable to perceive threats posed by electric current !
- A human is unable to: smell, taste, feel, hear, see electric current !

# Definition of High Voltage

- All voltages above 60 V are considered as high voltages. Any equipment working above that limit is considered a risk and shall not be touched or manipulated without specific precautions. These items shall be marked as such by dedicated placards:

# Definition of high voltage

- In the case of cables, they shall be orange and wear the “High Voltage” marking as well as the rated voltage.

# Definition of “High Current”

- According to Swiss law, all currents that could potentially endanger life, are considered  high currents. Even if the voltage is low, major risks remain due to short-circuit or overheating of supplied parts.

# Effects of current on human body

**Décharges électriques et effets sur le corps humain**

| | Alternating Current (AC) | | Direct Current (DC) | |
|---|---|---|---|---|
| | Current intensity (guide values) | Effect on people | Current intensity (guide values) | Effect on people |
|  | Up to 1 mA | **Threshold of perception.** The current is very weakly felt | Up to 2 mA | **Threshold of perception.** The current is very weakly felt |
|  | 5 mA | **Electrification, tingling.** It is still possible to let go of the conductive, 5 to 10 mA are felt as painful. | Up to 2 mA | **Pain threshold,** without cramps severe pain in the joints and a warm sensation when switching on and off. |
|  | 15 mA | **Threshold of muscular tetanization.** The non-leaching threshold has probably been exceeded. Possible respiratory disorders. | From to 2 mA | **Lethal threshold.** Fatal effect: ventricular fibrillation or cardiac arrest possible from 100 mA depending on the duration of exposure.<br><br>**Threshold of muscular tetanization**. Cramps, letting go only possible after a few seconds or minutes, especially from 300 mA. |
|  | 50 mA | **Threshold of danger.** Ventilatory paralysis, possibly cardiac arrest or venous fibrillation after a few moments. Determining time factor | | |
|  | Dès 80 mA | **Lethal threshold.** Fatal effect: ventricular fibrillation, cardiac arrest, respiratory arrest probable after 0,3 to 1 s. | | |

CFST 6281.F

# Work under voltage

- Definition: Work under voltage is defined as each activity for which a protection for people or things is needed.
- Always read the dedicated E-Hazard card before performing any task. All information can be found in the document FHA-43759-49110 E-Safety H55.

# Protection objectives

- Protection against currents flowing through the body (shocks)
- Protection against arcs (heat, glare)
- Protection against secondary damage (fall, fire…)

# Work methods

- Three work methods are listed in the directives of the Federal Office:
  - Method 1: Work on disconnected high current installations. It shall always be preferred when possible.
  - Method 2: Work in the vicinity of under voltage elements (i.e. electrically live components).
  - Method 3: Work directly on under voltage elements.

# Method 1

## Work on disconnected high current installations.

- Always work according to the 5+5 vital rules.


1. Disconnect
2. Insure against re-connecting
3. Verify the absence of tension
4. Grounding and short-circuit
5. protect against surrounding parts that remain under tension

# Method 1

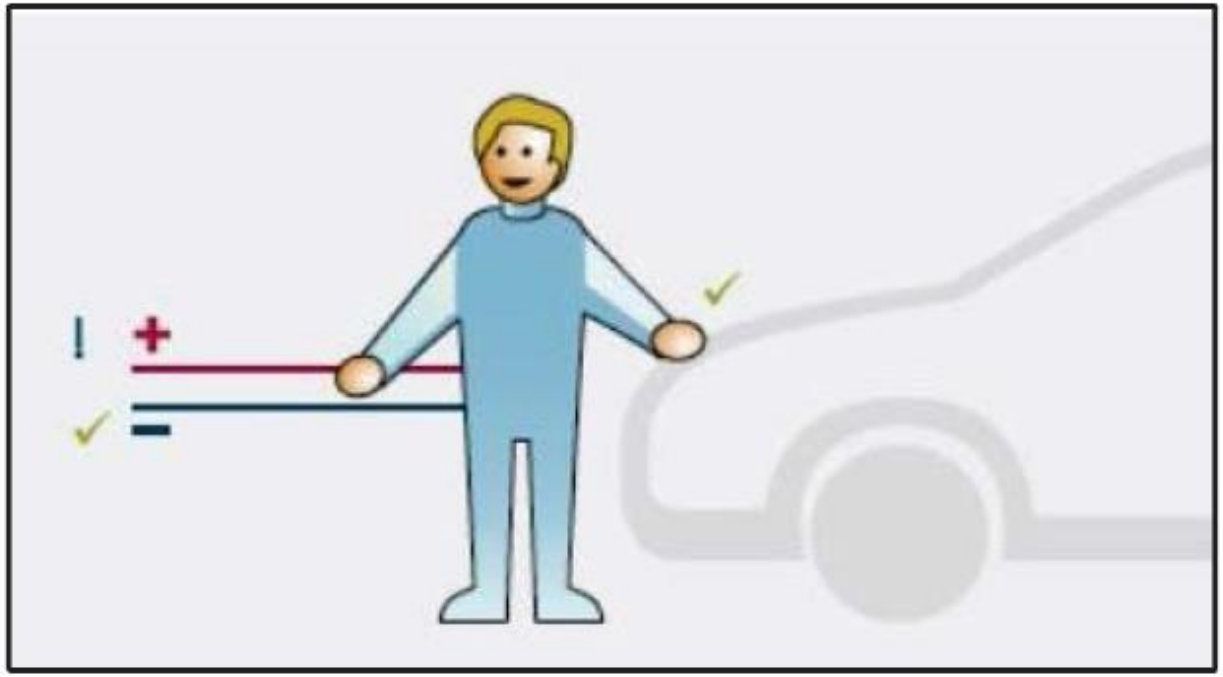
## Galvanic isolation

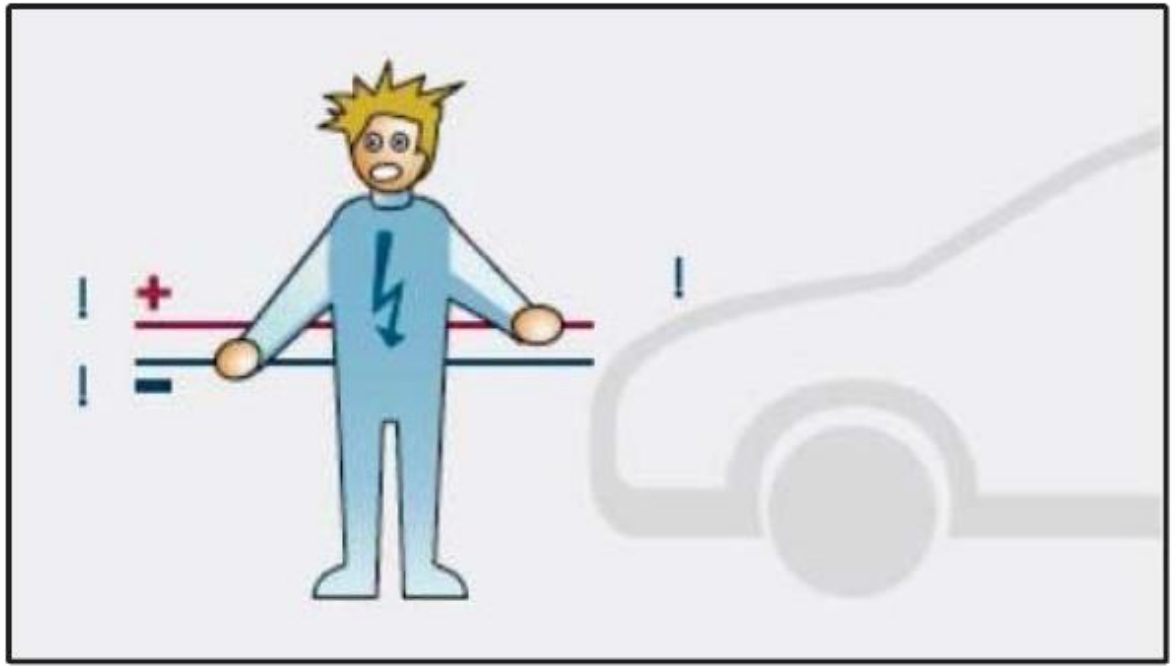
- Definition: **Galvanic isolation** is a principle of isolating functional sections of electric systems to prevent current flow; no direct conduction path is permitted.
- According to standards, the minimum acceptable value is:
  - $R \geq 500\ \Omega/V$
- For a 700 V battery -> 500 * 700 = 350 kΩ
- To ensure some margin, the value retained is:
  - $R_{min} \geq 500\ k\Omega$ (Only valid for P02)

# Method 1

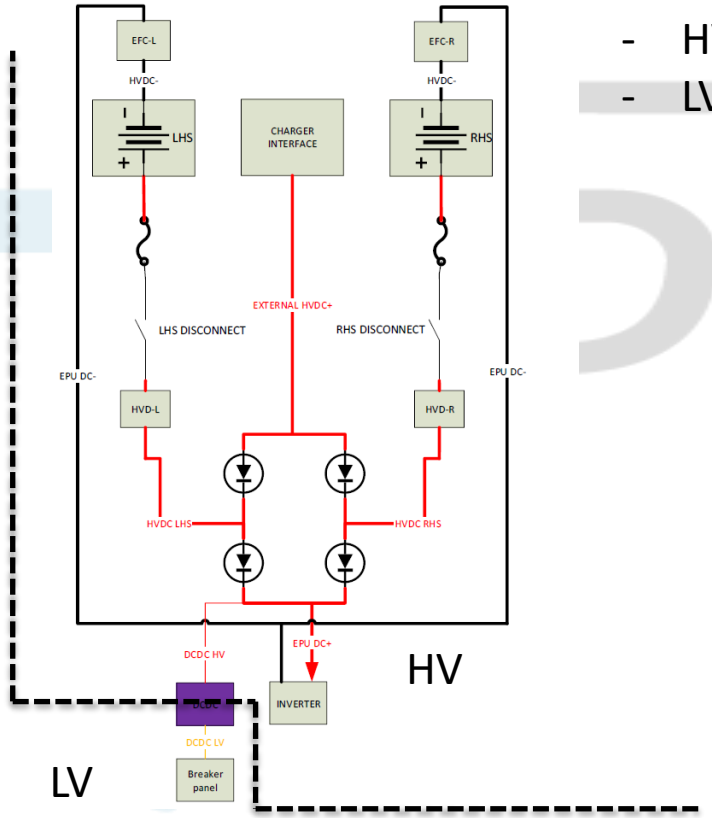
## Galvanic isolation

- The HV-system is galvanically separated from the vehicle´s body. The current will only flow through a human body if the person concerned touches two points within the HV-system that have different potentials – in such case the current circuit gets closed.





# Grounding of LV and HV




2 areas:

- HV, connection to LV GND in DCDC
- LV, aircraft frame

# Method 2

## Work close to under voltage elements

- All works for which it is necessary to enter the vicinity area of the under voltage elements with body parts, tools or other objects without touching under voltage elements directly.

# Method 2

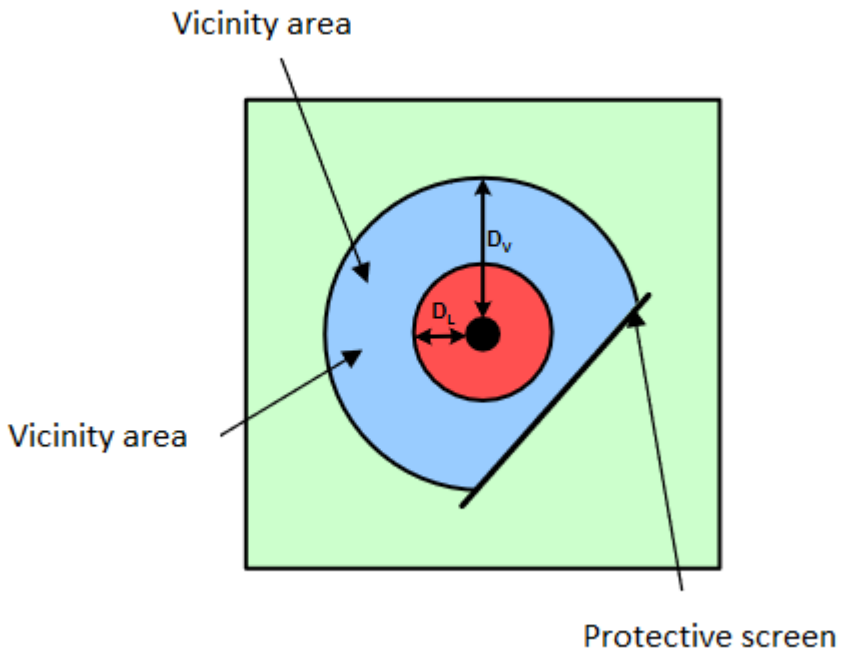
## Safety means

- Protection dispositive, barrier, envelope or insulating panel inside the area, the voltage rating shall be sufficient for the voltage of the system. At H55: Min 1000 V
- Protection with sufficient safety distance and surveillance preventing contacts in case of quick and unintentional critical movements.
- Protection for non-electric work (protective shoes, gloves…)

# Method 2

## Safety distances

- $D_L$ = 0.8 m
- $D_V$ = 0.8 + safety distance



# Method 3

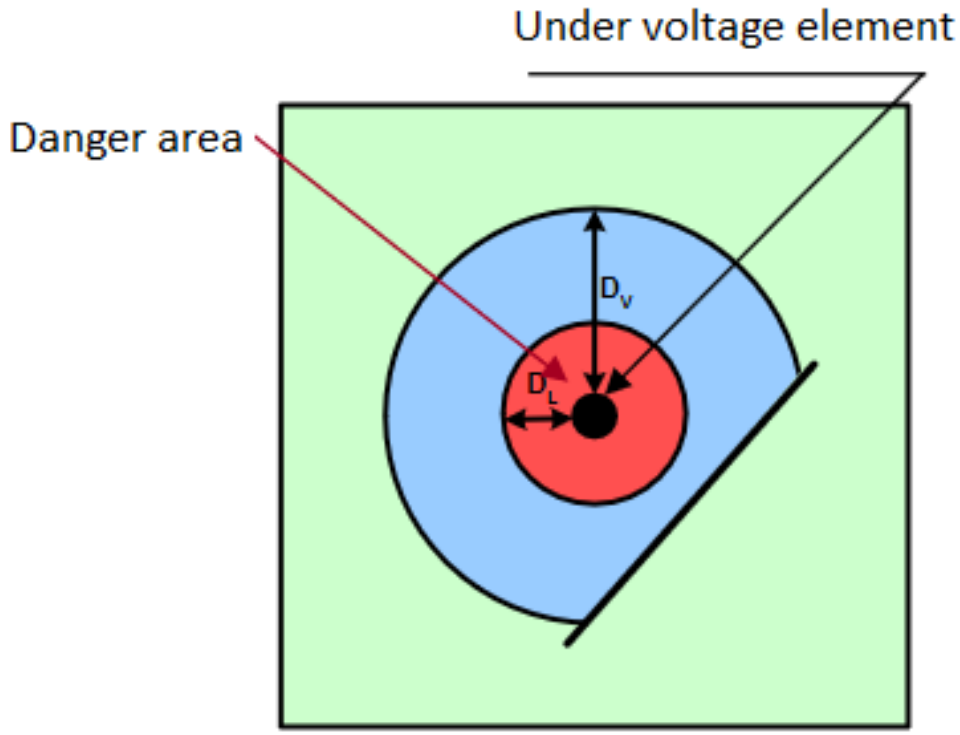
## Work directly on under voltage elements

- During the assembly of the batteries, it is impossible to disconnect the voltage source as the battery elements are sources. The responsible workers deliberately enters in contact with elements under voltage with body parts, equipment or tools AND enters the danger area.

# Method 3

## Work directly on under voltage elements

All people entering the safety area (blue area) are automatically subject to work method 2.



# Method 3

## Work directly on under voltage elements

- To limit the risks, different assembly phases shall be defined:
  - Phase 1: Battery modules in series ≤ 14. The residual voltage should not exceed 60V. Prior to assembly, each module shall be checked and the voltage inferior to 3.6 V.
  - Phase 2: 14 < Battery modules in series ≤ 27. The residual voltage should not exceed 100V. Prior to assembly, each module shall be checked and the voltage inferior to 3.6 V.
  - Phase 3: Battery modules in series ≥ 27. Final assembly step of the battery pack.
  - DANGER: For phases 2 and 3, electric shocks can have deadly issues.

# Method 3

## Protective equipment

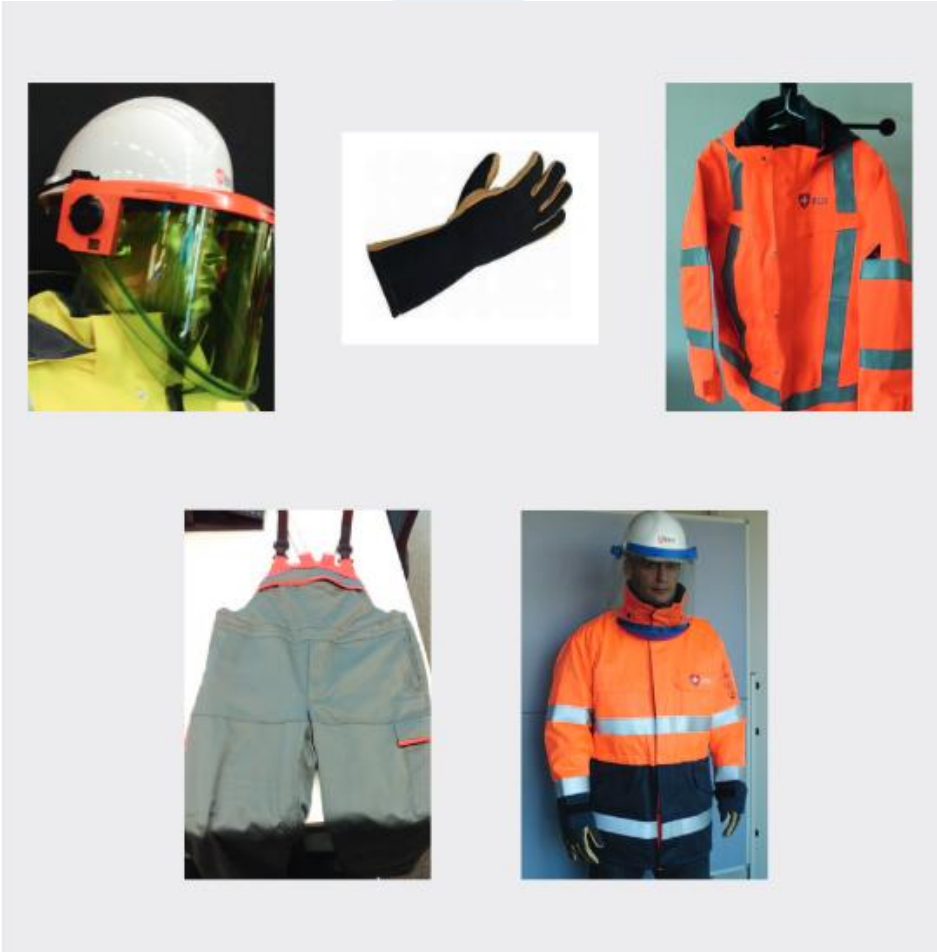
- Phase 1: Protective glasses, safety shoes, 100% cotton clothes (no ring, necklace…)
- Phase 2: Protective glasses, safety shoes, 100% cotton clothes, insulating gloves (no ring, necklace…)
- Phase 3: Protective helmet with visor, safety shoes, protective clothes cat.1 according to EN 61482-1-2, insulating gloves (no ring, necklace…)
- DANGER: For phases 2 and 3, electric shocks can have deadly issues.

# General Protective means

- Safety shall be ensured at all times. To prevent all risks:
  - Personal Protective Equipment shall be worn if indicated
  - Danger areas shall be marked
  - Personnel shall be specifically trained
  - Isolated tools shall be used
  - Access shall be restricted
  - Tasks must be clearly defined

# Personal Protective Equipment (PPE)

## EN 61482-1-2

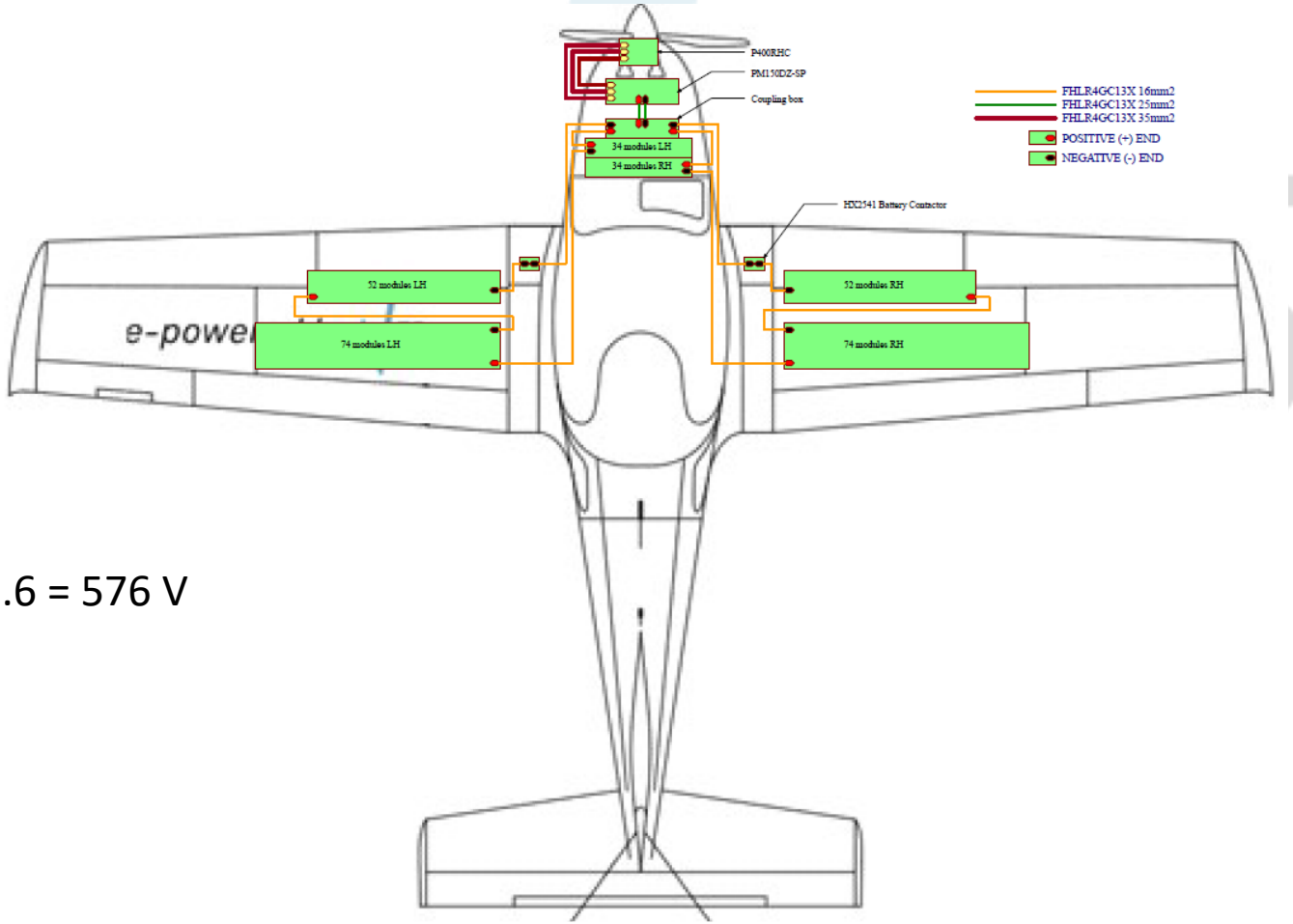
# Danger areas

- Danger areas shall be clearly indicated, and unauthorized personnel shall be prohibited at all times.

# Electricity damages on human body

# Dangerous components

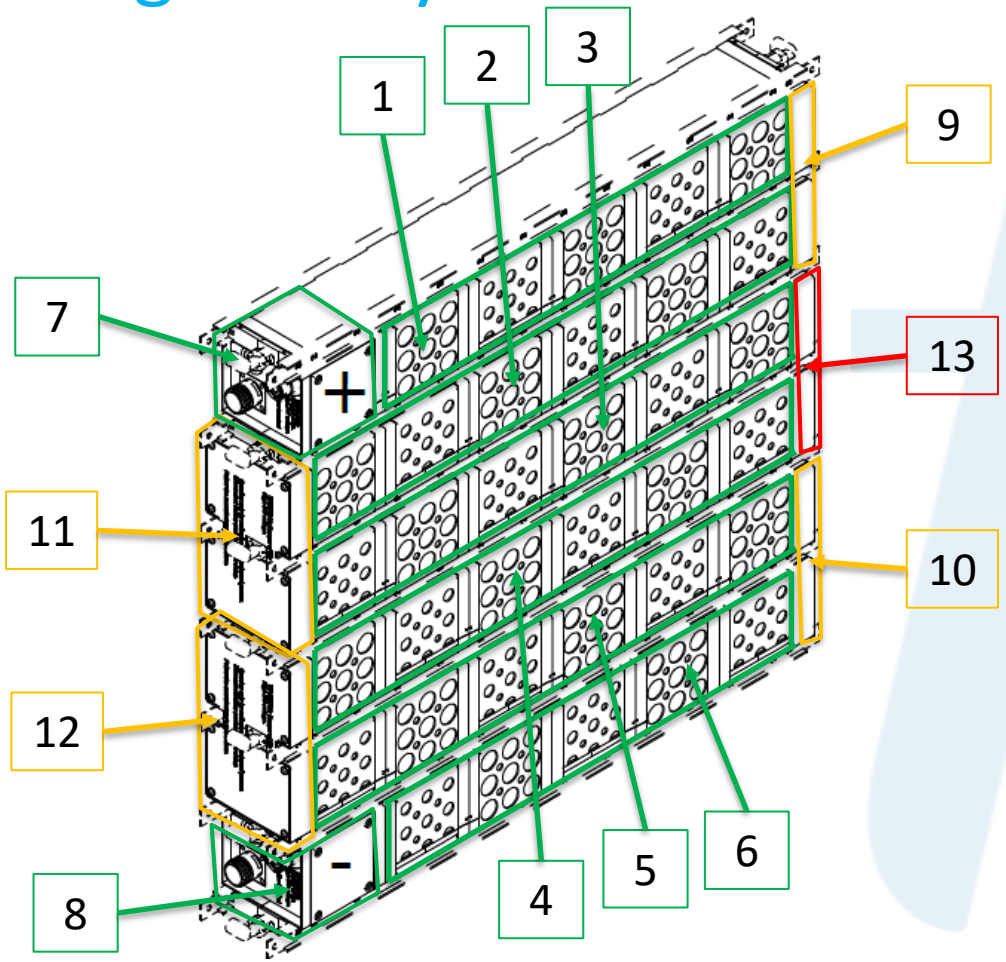
## Aircraft HV overview




Nominal Voltage : 160 * 3.6 = 576 V

# Dangerous components

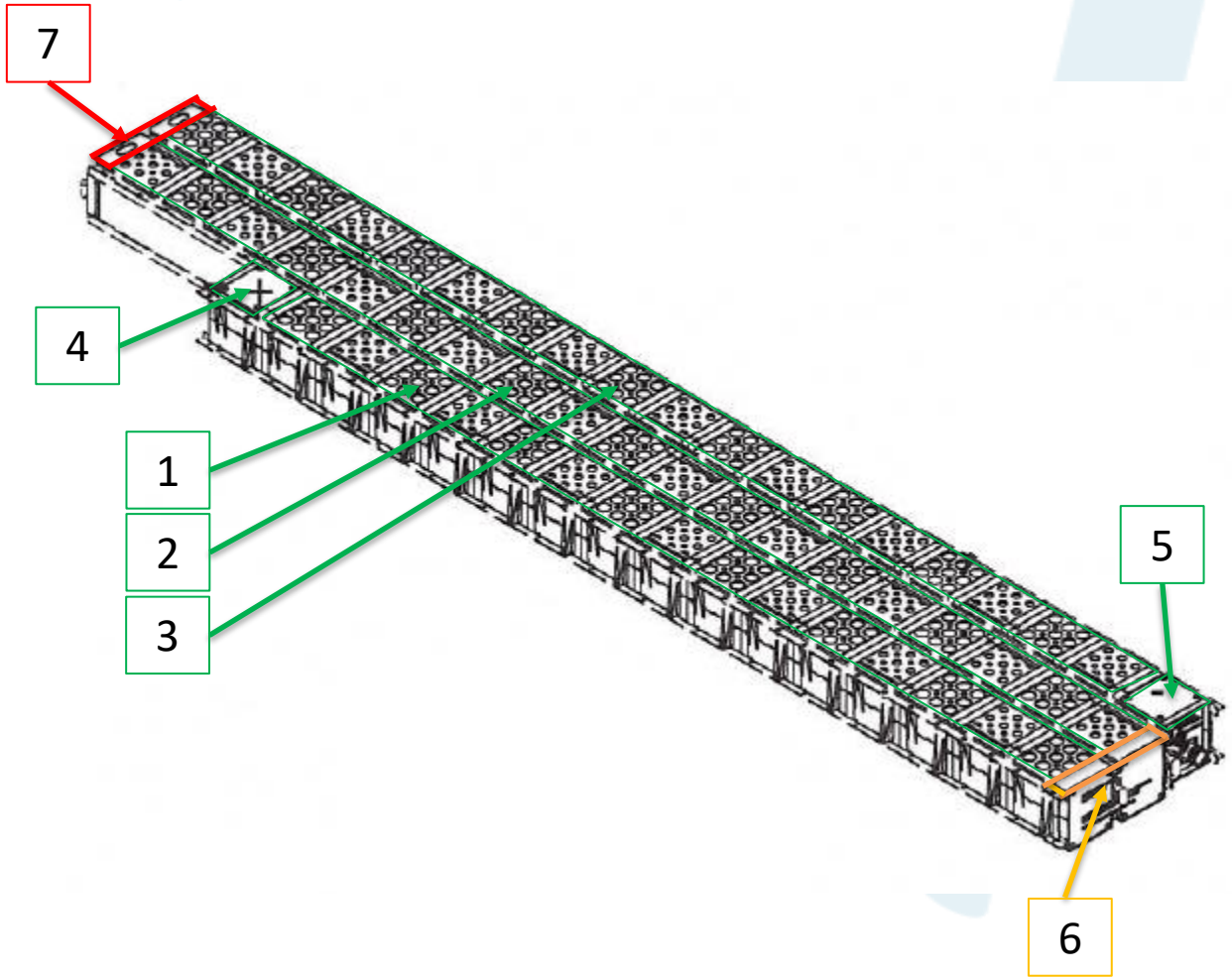
## Wing Battery Pack 74 modules




1: 5 BM = 18 V
2: 6 BM = 21.6 V
3: 6 BM = 21.6 V
4: 6 BM = 21.6 V
5: 6 BM = 21.6 V
6: 5 BM = 18 V
9: 11 BM = 39.6 V
10: 11 BM = 39.6 V
11: 17 BM = 39.6 V
12: 17 BM = 39.6 V
13: 34 BM = 122.4 V
500 A < Isc < 1 kA

# Dangerous components

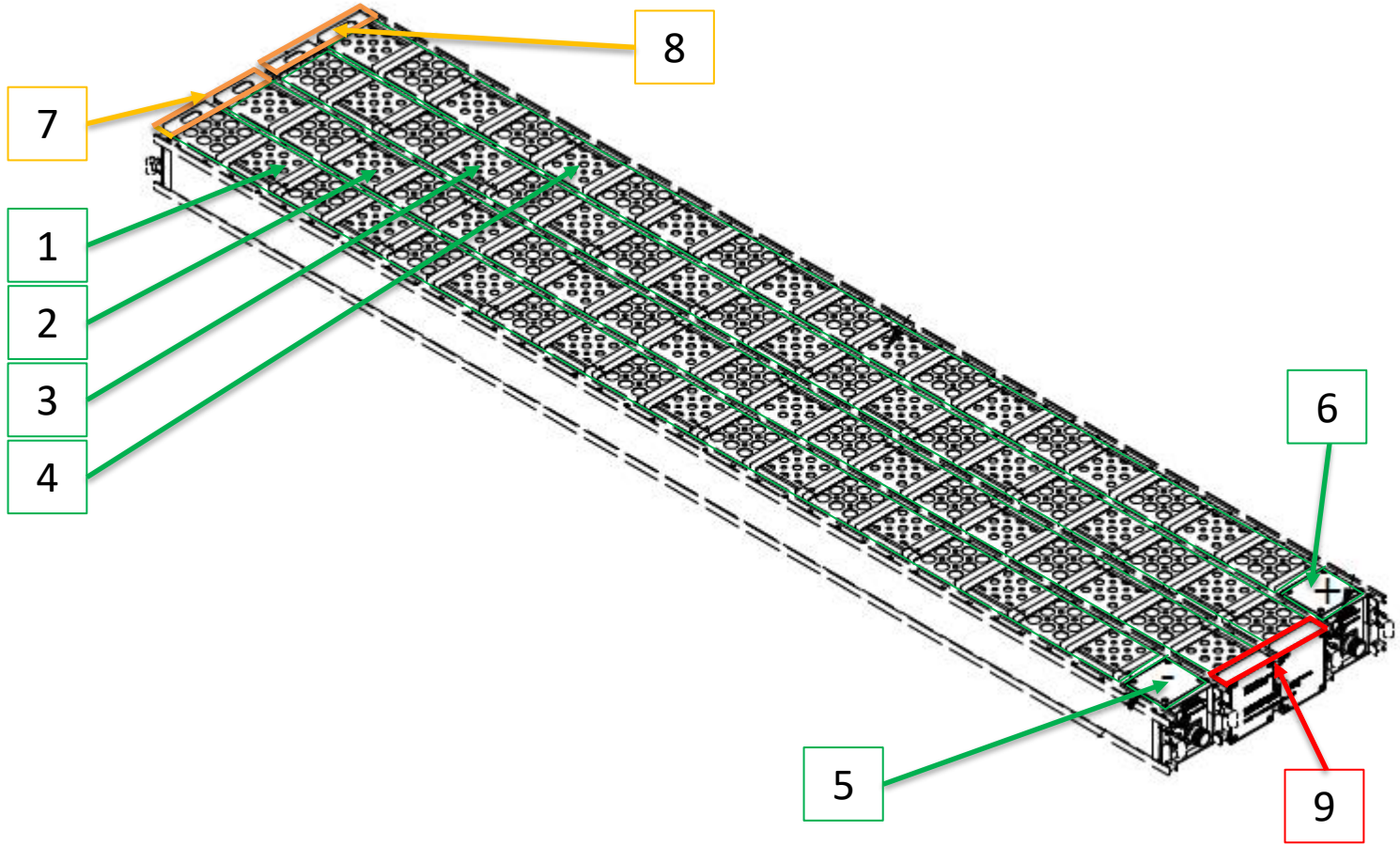
## Wing Battery Pack 52 modules




1: 15 BM = 54 V
2: 19 BM = 68.4 V
3: 18 BM = 64.8 V
6: 34 BM = 122.4 V
7: 52 BM = 187.2 V
500 A < Isc < 1 kA

# Dangerous components

## Wing Battery Pack 74 modules




1: 18 BM = 64.8 V
2: 19 BM = 68.4 V
3: 19 BM = 68.4 V
4: 18 BM = 64.8 V
7: 37 BM = 133.2 V
8: 37 BM = 133.2 V
9: 74 BM = 266.4 V
500 A < Isc < 1 kA

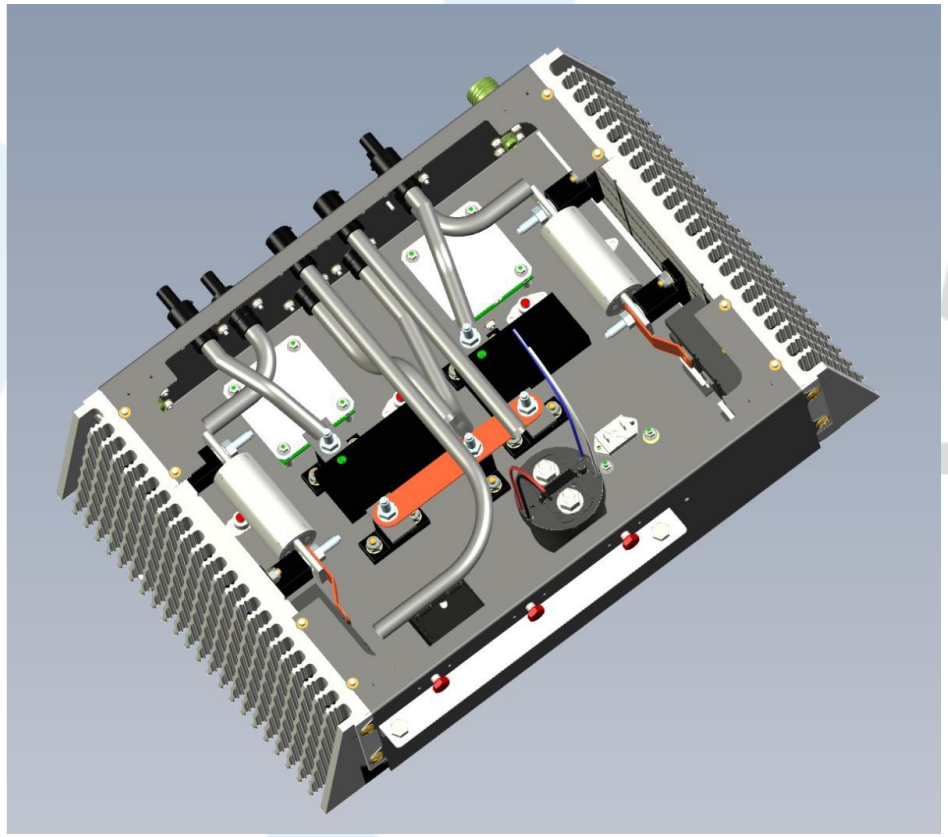
# Dangerous components

## Inverter


High power electronics are equipped with large capacitors. They can remain dangerous even after disconnection.

# Dangerous components

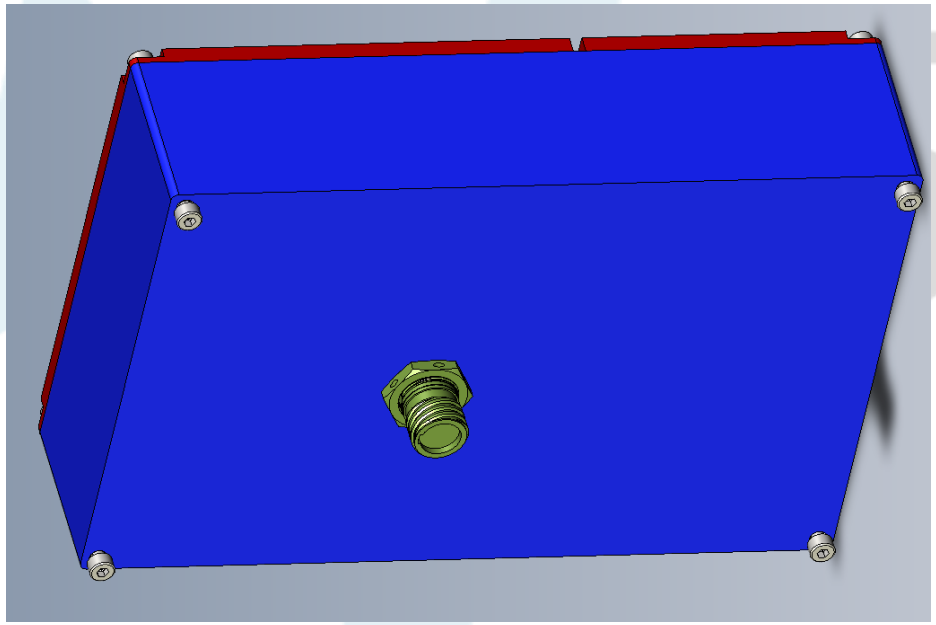
## Coupling Box



Some components can have multiple power sources !

# Dangerous components

## DCDC



# Dangerous components

## Electric Motor

# Dangerous components

## Charger plug

# Dangerous components

## Charger