

ED-290

GUIDANCE ON HIGH VOLTAGE DEFINITION AND CONSIDERATION FOR PERSONAL SAFETY

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CHAPTER 1

INTRODUCTION

1.1 PURPOSE AND SCOPE

This document contains guidance for definition of “High Voltage” and electrical hazards on VTOL and consideration on personal safety.

Compliance with this standard is recommended as one means of assuring that the HV system will perform its intended function(s) safely under all conditions normally encountered in foreseeable routine aeronautical operation.

They may also have additional functions for which other MOPS or ETSOs may be applicable or, it may contain additional functions not defined by any MOPS or ETSO and, non ETSO function guidance may be applicable.

As clarified on section 1.5.3 below, voltage levels above 1500VDC or 1000VAC are not expected on VTOL application for now and require specific safety considerations. Therefore, those higher voltage levels are not in the scope of this document.

1.2 APPLICATIONS

Any regulatory application of this document in whole or in part is the sole responsibility of appropriate government agencies.

As the measured values of equipment performance characteristics may be a function of the method of measurement, standard test conditions and methods of test are recommended in this document.

1.3 DESCRIPTION OF EQUIPMENT/FUNCTION

N/A

1.4 ASSUMPTIONS

N/A

1.5 DEFINITIONS AND ABBREVIATIONS

AC: Alternate Current

CS: Certification Specifications

DC: Direct Current

E-LV: Extra Low Voltage

EASA: European Union Aviation Safety Agency

HV: High Voltage

IAW: In Accordance With

IEC: International Electrotechnical Commission

IT: Isol -Terre (isolated ground) grounding system

LV: Low Voltage

N/A: not applicable

PPE: Personal Protective Equipment

RMS: Root Mean Square

SEVL: Safety Extra-Low Voltage

VAT: Voltage Absence Tester

VTOL: Vertical Take Off and Landing

Purpose of this chapter is to give definition of what is call “High voltage” and provide a proposal to classify voltage levels that can be used on VTOL.

Voltage levels are defined in the industry according to the impact of contact or proximity of persons with electrical installation/equipment.

Regarding the electric shock consequences to people, the voltage levels may be classified as follows:

1.5.1

EXTRA LOW VOLTAGE

The Safety Extra-Low Voltage (SELV) is a voltage (RMS) threshold which ensures high level of protection of health and safety of persons against dangerous electric shock by contact or proximity. That means no harm is expected to be caused by a possible exposition to the voltage source. However, high energy low voltage sources can still generate sparks and arcs during short circuit events and must be handled with the applicable caution.

There are various standards that define Safety Extra-Low Voltage. The main ones are the following:

The International Electrotechnical Commission (IEC), the UK IET BS 7671:2008 and the NF C18-150 define a maximum voltage of 50Vac (RMS) or 120Vdc.

The demonstration of this voltage threshold definition is the following one:

The human body is a conductor and its impedance depends on many parameters (on current path, on touch voltage, duration of current flow, frequency, degree of moisture of the skin, surface area of contact, pressure exerted and temperature). By consequence the relationship between current and voltage is not linear. However, to ease this analysis we could assume it is mainly driven by the wet/dry environment and represented by body path resistance:

- **Dry skin:** $R=5000\Omega$
- **Wet Skin:** $R=2500\Omega$
- **Immersed skin:** $R=1200\Omega$

The dry skin (as defined in IEC 60479-1) represents the condition of the skin with regards to humidity of a living person at rest under normal indoor environmental conditions. The wet skin is the condition of the skin being exposed for 1 minute to water from public water supplies (non-salted), but not completely submerged. Those two skin resistances are relevant to VTOL application and are the ones which are going to be considered by this document.

The effects and the danger on the human body depend mainly on the magnitude and duration of the current flow as shown on [Figure 1-1](#) for AC and [Figure 1-2](#) for DC, extract from IEC 60479-1, defining four zones of current-magnitude/time-duration, in each of which the pathophysiological effects are described below.

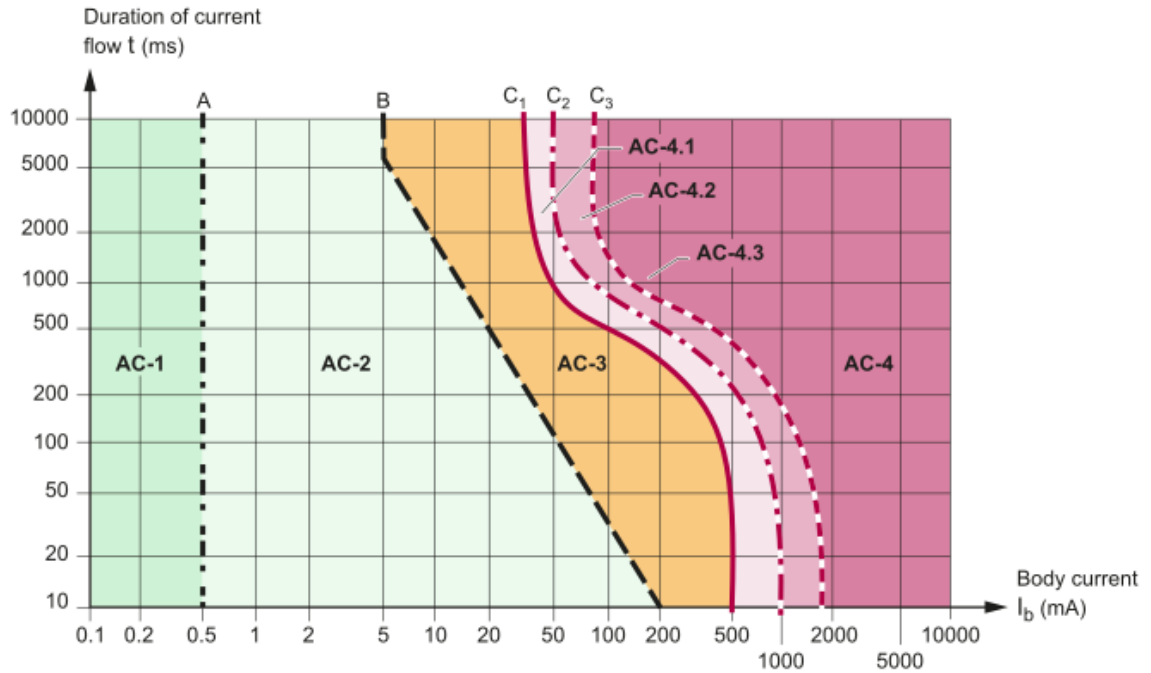


FIGURE 1-1: ZONES TIME/CURRENT OF EFFECTS OF AC CURRENT ON HUMAN BODY WHEN PASSING FROM LEFT HAND TO FEET

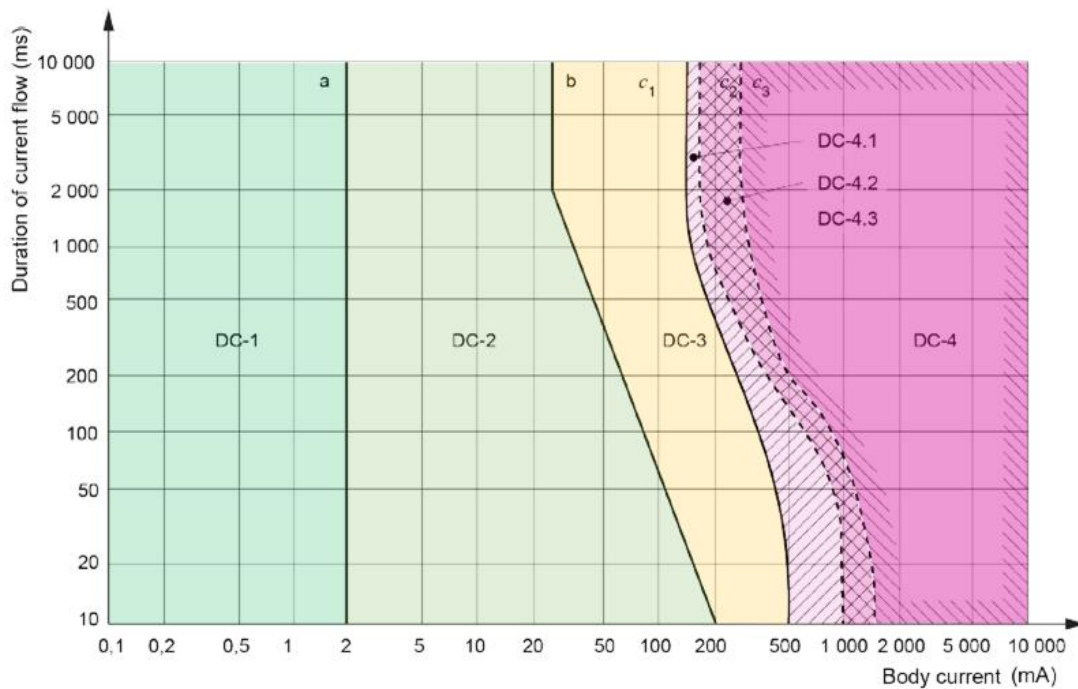


FIGURE 1-2: ZONES TIME/CURRENT OF EFFECTS OF DC CURRENT ON HUMAN BODY WHEN PASSING FROM LEFT HAND TO FEET

AC-1 and DC-1 zones: Imperceptible

AC-2 and DC-2 zones: Perceptible

AC-3 and DC-3 zones: Reversible effects: muscular contraction

AC-4 and DC-4 zones: Possibility of irreversible effects

AC-4.1 and DC-4.1 zones: Up to 5% probability of heart fibrillation

AC-4.2 and DC-4.2 zones: Up to 50% probability of heart fibrillation

AC-4.3 and DC-4.2 zones: More than 50% probability of heart fibrillation

A curve: Threshold of perception of current

B curve: Threshold of muscular reactions

C₁ curve: Ventricular fibrillation unlikely to happen

C₂ curve: Threshold of 5% probability of ventricular fibrillation

C₃ curve: Threshold of 50% probability of ventricular fibrillation

It is important to highlight that, for the AC circuits, the current levels specified are considered applicable for frequencies from 15 Hz to 100 Hz. Although higher frequencies are expected on the propulsion system (from PWM, for instance), it is expected that the engines are not running during maintenance and other ground operation and that, when running the surrounding is not supposed to be accessed. For the impact of higher frequencies, IEC 60474-2 is a reference to be used.

As per curve B of [Figure 1-1](#) and [Figure 1-2](#), above 5mA AC (RMS) and 27mA DC there is a human safety risk. However, 10mA AC (RMS) and 25mA DC are the values being considered by above regulations to determine the Extra Low Voltage threshold on any visible and accessible active part taking into account above resistances:

TABLE 1-1 EXTRA LOW VOLTAGE THRESHOLD

Environment	Vac (RMS)	Vdc
Dry	50	125
Wet	25	62.5
Immerged	12	30

The Low Voltage Directive (LVD) (2014/35/EU) applies from 50Vac (RMS) or 75Vdc. The Low Voltage by the European directive defines indirectly the Safety Extra-Low Voltage threshold with a major voltage difference for the direct current.

However, the Safety Extra-Low Voltage defined by the above regulation can be touched with a current of 10mA without any physiologic effect only for **1.8s** and with severe physiologic effect after **4.5min** (not shown on above figures). Above 1.8s shock and muscular contractions will happen.

Below 5mA for the AC circuits, it is considered that there will be no permanent safety effect. This value is the **one recommended** to define the maximum voltage to ensure high level of protection of health and safety of persons.

TABLE 1-2: VOLTAGE LEVEL FOR NO PERMANENT SAFETY EFFECT

Environment	Vac (RMS)	Vdc
Dry	25	60
Wet	12,5	30
Immerged	6	15

By consequence the maximum Extra Low Voltage which ensures the highest level of protection of health and safety of persons is 25Vac (RMS) or 60Vdc. Above this voltage the following electrical hazards can occur.

14Vdc and 28Vdc electrical network as defined in aeronautics standards should be considered as Extra Low voltage.

1.5.2 LOW VOLTAGE

Low voltage regulation:

The Low Voltage (LV) is a voltage range which can lead to harmful or dangerous electric shock by contact or proximity and needs to be correctly protected for the health and safety of persons. As for the Safety Extra-Low Voltage, there are various standards that define Low voltage. The main ones are the following:

The International Electrotechnical Commission (IEC), the UK IET BS 7671:2008 and the NF C18-150 define a voltage range from 50Vac (RMS) to 1000Vac (RMS) or from 120Vdc to 1500Vdc.

The Low Voltage Directive (LVD) (2014/35/EU) applies from 50Vac (RMS) to 1000Vac (RMS) or from 75Vdc to 1500Vdc.

Even though there defines different minimum voltages, they all agree on the same maximum voltages which is the threshold for the High Voltage.

The proposal for the Low Voltage range is to adapt for the minimum threshold defined for Extra Low voltage, but for the maximum threshold the value recommended to be applied is as per above regulations. By consequence the Low Voltage range proposal is from 25Vac (RMS) to 1000Vac (RMS) or from 60Vdc to 1500Vdc.

26Vac, 115Vac, 230Vac, 270Vdc or 540Vdc network defined according aeronautics standards should be considered as Low voltage.

1.5.3 HIGH VOLTAGE

High Voltage regulation:

As for the Low Voltage, there are various standards that define High voltage. However for the main ones they all agree with the same thresholds:

The International Electrotechnical Commission (IEC), the UK IET BS 7671:2008, the NF C18-150 and the Low Voltage Directive (LVD) (2014/35/EU) define a voltage range from 1000Vac (RMS) or from 1500Vdc

The High Voltage range threshold values recommended to be applied is as per above regulations. By consequence the High Voltage range is from 1000Vac (RMS) or from 1500Vdc.

1.5.4 INDUSTRIAL / AERONAUTIC VOLTAGE MATCHING

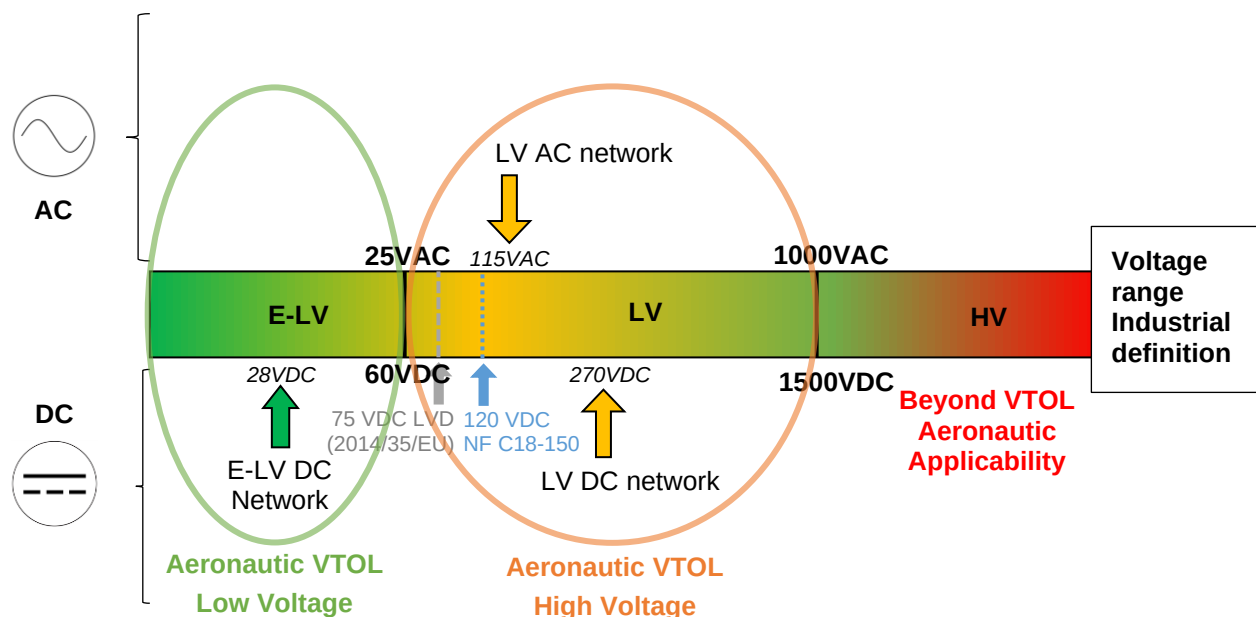


FIGURE 1-3: INDUSTRIAL/AERONAUTIC VOLTAGE RANGE CORRESPONDANCE

For consistency with legacy voltage standards existing in aeronautic domain the following voltage ranges will be proposed for the electric shock discussion in the current document:

- LOW VOLTAGE (LV) range: up to 60Vdc and 25Vac. 14Vdc, 28Vdc standards identified in DO160 or MIL-STD-704 or EN2282 are considered as “Low voltage”
- HIGH VOLTAGE (HV) range: above 60Vdc and 25Vac. 115Vac, 270Vdc, 540dc, ... are considered as “high voltage”. For HVdc higher than 1500Vdc and HVac higher than 1000Vac specific considerations may be proposed. Those higher voltage levels are not intended to be used for now on the VTOL industry and is out of scope of this document.

1.6 REFERENCES

N/A

1.7 RELATIONSHIP TO SC-VTOL

Whilst this standard was developed with a particular view to the European legal framework, namely the EASA Special Condition VTOL 01, it may be applied to support other regulatory frames.

As regards the EASA SC VTOL, this standard supports the showing of compliance with the following requirements and/or complements the following related Means of Compliance:

- VTOL.2320 (a)(2) Occupant physical environment
- VTOL.2340 (b) Design and construction information
- VTOL.2400 (c)(3) Lift/thrust system installation
- VTOL.2430 (a)(5) Lift/thrust system installation, energy storage and distribution
- VTOL.2430 (c)(3) Lift/thrust system installation, energy storage and distribution

1.8 RELATIONSHIP TO OTHER DOCUMENTS

N/A

CHAPTER 2

GENERAL REQUIREMENTS

2.1 GENERAL DESIGN REQUIREMENTS

The following EUROCAE Standards are available as general reference documents:

- Software: ED-12 and software documents suite, ED-109
- Hardware: ED-80
- System Safety Assessment: ED-79 and ED-135
- Security: ED-201, ED-202, ED-203, ED-204, ...

2.2 INSTALLED EQUIPMENT PERFORMANCE

This chapter is N/A for HV Systems installation assurance guidance.

2.3 AIRCRAFT OPERATIONAL PERFORMANCE CHARACTERISTICS

This chapter is N/A for HV Systems installation assurance guidance.

CHAPTER 3

MINIMUM PERFORMANCE REQUIREMENTS

This chapter addresses considerations for personal safety regarding installation of electrical system on VTOL. It is important to highlight that the local legislation is applicable, and the applicant is responsible to check consistency of the proposed considerations with its local regulations.

3.1 MARKING

Due to the criticality of hazard, a danger Risk Label is a means to help protecting the health and safety of persons, but is not a substitute for required protective measures to reduce or eliminate hazards which will be described in this document. For LV electrical installation/equipment, specific marking of voltage risk is not required at proximity of the active parts as long as barrier protection IP2X defined in EN60529 (see example in appendix 1) is fulfilled.

For device with different voltage level at the terminals, the highest voltage level have to be considered.

Example: in case of equipment with LV on its terminals and HV on others terminals, this equipment shall be considered HV, Risk label is required.

For HV electrical installation/equipment, even though barrier protection IP3X is required, due to the criticality (due to higher voltage and by consequence higher current) and novelty of the above hazards, danger risk labeling is required at the proximity of active parts.

For HV electrical installation/equipment, specific marking of voltage risk shall be displayed at proximity of the active parts.



Warning; Electricity

FIGURE 3-1: SYMBOL W012 IN ACCORDANCE WITH ISO 7010

3.2 ELECTRIC SHOCK PROTECTION

There are two main causes of electric shock hazard in case of contact with the skin:

- Indirect contact;
- Direct contact.

In case of conductive material applied on active conductor(s) via indirect or direct contact this could also lead to HV electric shock hazard, through the conductive material and then to the skin, but also to electrical fire, sparks, arc flash, explosion and toxic gases hazards due to the low resistance of the conductive material.

NOTE: *Distinction shall be made between normal operation and maintenance procedures:*

- *in normal operation (VTOL powered and operating), any person(s) who may be in contact or in proximity of an electrical installation/equipment without having a specific authorization/training, will be protected by indirect/direct contact protection.*
- *during maintenance procedures (troubleshooting, repair, change of cables, etc...), any authorized operator(s) who want have access to conductors which might be active, will be protected by specific procedure and having followed a proper training.*