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**Aircraft — Auto-transformer  
rectifier units (ATRU) — General  
requirements**

*Aéronefs — Autotransformateurs redresseurs (ATRU) — Exigences  
générales*

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## Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see [www.iso.org/directives](http://www.iso.org/directives)).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see [www.iso.org/patents](http://www.iso.org/patents)).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see [www.iso.org/iso/foreword.html](http://www.iso.org/iso/foreword.html).

This document was prepared by Technical Committee ISO/TC 20, *Aircraft and space vehicles*, Subcommittee SC 1, *Aerospace electrical requirements*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at [www.iso.org/members.html](http://www.iso.org/members.html).

## Introduction

This document provides general requirements for auto-transformer rectifier units (ATRU) installed in aircrafts.

ATRU can convert electrical power from alternating current (AC) to direct current (DC) by using multipulse phase shifting auto-transformers to provide cancellation of certain harmonic currents.

ATRU have been shown to be the most cost-effective harmonic solution in aviation industry with minimum mass, simpler structure and higher reliability, compared with conventional harmonic suppression devices. ATRU are emerging among aircraft application, especially in more electrical aircraft and all electrical aircraft power supply system.

There are no International Standards on ATRU, and standardization is needed for aircraft electrical systems. This document provides the basis for manufacturers and users that develop and utilize ATRU installed in aircrafts.

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# Aircraft — Auto-transformer rectifier units (ATRU) — General requirements

## 1 Scope

This document specifies the general requirements and test methods for auto-transformer rectifier units (ATRU) for use in aircraft electrical systems.

This document is mainly applicable to ATRUs of 18-pulse and 24-pulse types.

## 2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 1540:2006, *Aerospace — Characteristics of aircraft electrical systems*

ISO 7137:1995, *Aircraft — Environmental conditions and test procedures for airborne equipment*

## 3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 1540 and ISO 7137 apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <https://www.electropedia.org/>

## 4 General requirements

### 4.1 Specification sheets

The individual item requirements shall be as specified in an applicable specification sheet. In the event of any conflict between the requirements of this document and the specification sheet, the latter shall govern.

### 4.2 Materials

#### 4.2.1 Selection of materials

The materials used shall enable the ATRU to meet all of the operational and environmental performance requirements of this document and the applicable specification sheet.

The materials used shall pass the requested certification in accordance with the applicable specification sheet.

#### 4.2.2 Metal materials

All metals used in ATRUs construction shall be processed and protected to resist corrosion. The use of magnesium is prohibited unless specifically approved for each application by the qualifying activity.

Dissimilar metals should not be used in intimate contact with each other. If really necessary to be used in contact with each other, dissimilar metals shall be protected against electrolytic corrosion in accordance with the applicable specification sheet.

#### 4.2.3 Non-metal materials

Non-metal materials, including plastics, ceramics, fabrics, and protective finishes, shall:

- be moisture-resistant;
- be fungus-proofing;
- be resistant for salt spray environment;
- be flame-resistant;
- not support combustion;
- be non-toxic when exposed to flame as well as when used under all operating and environmental conditions herein.

### 4.3 Design and construction

#### 4.3.1 General mechanical and electrical design

The ATRU shall be constructed with parts and materials to provide the specified performance, reliability and service life under all environmental and operating conditions specified herein. Dielectrics used for electrical isolation shall be adequate to prevent breakdown under all specified environmental conditions for the life of the equipment.

#### 4.3.2 Electrical design

##### 4.3.2.1 Derating design

Derating shall be implemented for the ATRU design by reducing the level of stress for components used in the ATRU, including electrical, thermal and mechanical stresses on components.

##### 4.3.2.2 Electric connections

Electric connections of the ATRU, including terminals, connectors and wires, shall be designed to give protection against short-circuit, reverse polarity, incorrect installation, electrical contact with people or other unrelated conductors, and to conform with the following requirements.

- a) Electrical wiring shall be neat and stable, meeting the requirements of the applicable specification sheet.
- b) Where terminals are used for connection to the ATRU, they shall be of the stud-type and shall be so designed that the current is conducted by means of surface-to-surface contact, and not through the stud threads. All studs shall be steel and corrosion-resistant.
- c) The mark and preventative measures of incorrect wiring shall be provided in electrical connection of the ATRU.
- d) Grounding shall be designed to metallic shell surfaces of the ATRU according to the requirements of the applicable specification sheet.
- e) The equipment structure shall not be used as a current path except for electromagnetic (radio noise) shielding.

- f) The terminal block shall be so designed that it can be removed and replaced on the ATRU without the necessity of rebrazing or soldering. Barriers affording a positive separation of leads and terminals shall be provided on the terminal block. Durable, reusable and non-conductive terminal covers shall be provided. Terminal designations shall be durably, legibly and prominently marked on the terminal block.

#### 4.3.2.3 Adjustments

No adjustments or alignments shall be required during installation or during the life of the ATRU.

#### 4.3.2.4 Static discharge protection and control

The ATRU shall be designed to provide static discharge protection for electronic devices during assembly and handling. Static discharge protection and control shall conform to the applicable specification sheet.

#### 4.3.3 Mechanical design

##### 4.3.3.1 Screw thread standard

Screw threads of mechanical connections and fasteners in the ATRU shall conform to the requirements of the applicable specification sheet.

##### 4.3.3.2 Loosening prevention

Effective anti-loosening measures should be taken for fasteners, such as stud bolts and nuts, used in the ATRU.

##### 4.3.3.3 Ventilation openings

All ventilation openings shall be designed to prevent passage of foreign objects. Their structural form and size shall conform to the requirements of the applicable specification sheet.

##### 4.3.3.4 Operating position

The ATRU shall operate in any position, unless otherwise specified in the applicable specification sheet.

##### 4.3.3.5 Assembly and disassembly

The ATRU shall be assembled and disassembled with bolts and nuts, unless otherwise specified in the applicable specification sheet.

##### 4.3.3.6 Cooling

###### 4.3.3.6.1 Natural cooling

The ATRU is cooled by modular heat sink. When the radiator is exposed, the insulation failure and excessive temperature rise of the exposed radiator should be effectively prevented.

###### 4.3.3.6.2 Internally mounted fan cooling

An internally mounted, integral cooling fan may be used for ATRUs. Explosion-proof fan should be selected for cooling fan.

#### 4.3.3.6.3 Forced-air or forced-fluid cooling

Pressure drop through forced-air or forced-fluid cooled ATRUs shall not exceed the values specified in the applicable specification sheet.

For forced-air or forced-fluid cooled ATRUs, the direction of air and fluid flow shall be as required by the applicable specification sheet and depicted by an arrow that is visible on the ATRU exterior.

#### 4.3.3.7 Installation

The aircraft manufacturer should allow a clearance of at least 25 mm at each end of the ATRU in addition to the maximum dimensions shown on the applicable specification sheet for installation and ventilation.

#### 4.4 Size and mass

The dimensions and mass shall include the dimensions and mass of all auxiliary apparatus of the ATRU and shall meet the requirements of the applicable specification sheet.

#### 4.5 Colour

The ATRU shall be finished as identified in the applicable specification sheet. Colouring has no influence on performance of the ATRU.

#### 4.6 Processing quality and appearance quality

##### 4.6.1 Processing quality

The machined parts shall be free of burrs and sharp edges. The metal castings shall be free from blisters, looseness, cracks and other defects. The welds shall be clean and free of void-welding. The riveting shall be firm. The fasteners shall not be loose. There shall not be floating solder, metal fragments or other unwanted materials inside the ATRU.

Each ATRU and its parts and components shall be inspected as required by the applicable specification sheet.

##### 4.6.2 Appearance quality

The appearance of ATRUs shall be free from defects such as cracks, crushing, scratches, deformation, rust and paint peeling.

#### 4.7 Markings

##### 4.7.1 Components and parts

Unless otherwise specified, the ATRU parts and components shall be marked in accordance with the applicable specification sheet.

##### 4.7.2 Nameplate of ATRUs

The marking and nameplate of each ATRU shall be as required by the applicable specification sheet and drawings.

## 4.8 Performance

### 4.8.1 Input power

#### 4.8.1.1 Steady-state input power

The ATRU shall meet the requirements specified herein or the applicable specification sheet when it applies to an aircraft electrical system and supplied with normal or abnormal steady-state AC power as defined in ISO 1540.

#### 4.8.1.2 Transient input power

##### 4.8.1.2.1 Input voltage spikes

When AC input power (constant frequency or variable frequency) voltage spikes of the ATRU are within the limitations specified in ISO 1540:2006, Figure 9, the ATRU shall not be damaged and shall meet the requirements specified in [4.8.2.1.1](#).

##### 4.8.1.2.2 Input power interruptions

When the duration of normal input power interruptions is within 200 ms, or the duration of abnormal input power interrupt is within 7 s (constant frequency or variable frequency), the ATRU shall not be damaged and shall not be required to demonstrate specific performance. After removal of the interruptions and restoration of input voltage specified in [4.8.1.1](#), the ATRU output voltage shall be automatically restored and shall meet the requirements specified in [4.8.2.1](#).

##### 4.8.1.2.3 Input frequency transients

When AC input power frequency transients (constant frequency), frequency step changes and rate of change of frequency (variable frequency) are within the limits specified in ISO 1540, the ATRU shall operate normally, without damage.

### 4.8.2 Output power

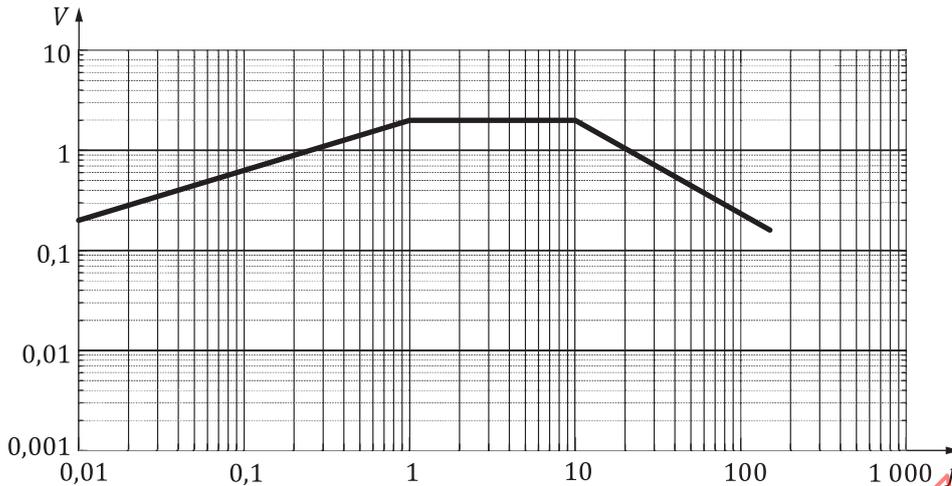
#### 4.8.2.1 Steady-state output voltage

##### 4.8.2.1.1 Normal steady-state output voltage

Unless otherwise specified in the applicable specification sheet, with the normal input power specified in [4.8.1.1](#) and the ATRU operating within full rated load, the output voltage characteristics of the ATRU shall have the following performance.

- a) The nominal steady-state DC output voltage of the two output terminals of ATRUs with respect to the neutral of the system shall be +135 V DC and -135 V DC, respectively.
- b) The output voltage shall remain between  $\pm 125$  V DC and  $\pm 160$  V DC.
- c) The output voltage differential mode ripple amplitude of the ATRU shall not exceed 16 V (peak-to-peak).
- d) Individual frequency components of the output voltage ripple of the ATRU shall not exceed the limits of [Figure 1](#).
- e) Output voltage distortion factor of the ATRU shall not exceed 3 % (measured with full load under resistive load).

The voltage values for  $\pm 270$  V DC system are the voltage ratio 270/135 times the values in a), b) and c).



AC ripple frequency limits	
Frequency (kHz)	Voltage ripple (V rms)
0,01	0,2
1,0	2,0
10,0	2,0
150,0	0,16

**Key**

*f* frequency (kHz)

*V* voltage ripple (V rms) of each frequency component

Multiply voltage ripple values in this figure by the voltage ratio 270/135 for a ±270 V DC system.

**Figure 1 — Frequency characteristics of ripple in DC output power**

**4.8.2.1.2 Abnormal steady-state output voltage**

Unless otherwise specified by the applicable specification sheet, with the limits of input AC three-phase abnormal voltage specified in 4.8.1.1 and the ATRU operating within full rated load, the output voltage characteristics of the ATRU shall have the following performance.

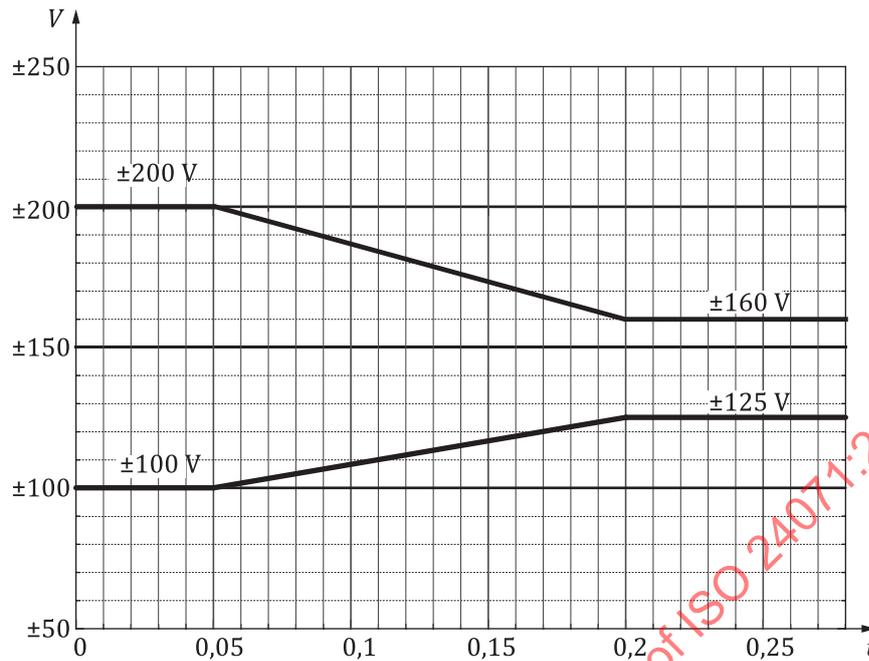
- a) The steady-state output voltage shall remain between ±120 V DC and ±178 V DC.
- b) The output voltage differential mode ripple amplitude of the ATRU shall not exceed 25 V (peak-to-peak).

After restoration of normal input voltage specified in 4.8.1.1, normal output voltage shall be automatically restored and meet the requirements of 4.8.2.1.1.

The voltage values for ±270 V DC system are the voltage ratio 270/135 times the values in a) and b).

**4.8.2.2 Output voltage transients**

When subjected to transient input voltages, or during the starting period at full rated load, or if the full rated load is applied and removed, the ATRU output shall remain within the limits of Figure 2.

**Key**

$t$  time from onset of transient (s)

$V$  DC voltage (V)

Multiply voltage values in this figure by the voltage ratio 270/135 for a  $\pm 270$  V DC system.

**Figure 2 — DC output power voltage transients**

**4.8.2.3 Output power interruptions**

The ATRU shall not be damaged and shall not be required to demonstrate specific performance during the power interruptions as specified in [4.8.1.2.2](#). The ATRU can return to normal operation after restoration of normal input voltage.

**4.8.3 Efficiency**

The efficiency of the ATRU shall meet the requirements of the specification sheet at minimum and full rated load.

**4.8.4 Overload**

The ATRU shall deliver overload current according to the requirements of the applicable specification sheet and shall maintain the output voltage as specified in the applicable specification sheet. Normal output voltage shall be automatically restored after removal of the overload and restoration of normal rated loading.

**4.8.5 Short circuit**

Unless otherwise specified, the ATRU shall deliver short circuit current in short circuit tests specified in the applicable specification sheet, without damage. Normal output voltage shall be automatically restored after removal of the short circuit and restoration of normal rated loading.

**4.8.6 Soft starting**

Soft-starting function should be used in order to limit excessive starting inrush current of the ATRU.

#### 4.8.7 Insulation resistance and dielectric strength

##### 4.8.7.1 Insulation resistance

The insulation resistance of the ATRU at the highest nominal operating temperature shall be in accordance with the requirements in [Table 1](#).

**Table 1 — Requirements on ATRU hot insulation resistance**

Test location	Test voltage (DC) V	Insulation resistance MΩ
Between the ATRU AC input terminals and the housing of the ATRU	500	≥ 10
Between the ATRU DC output terminals and the housing of the ATRU	500	≥ 10

##### 4.8.7.2 Dielectric strength

The cold insulation dielectric strength of the ATRU shall be in accordance with the requirements in [Table 2](#). The test location is specified in the applicable specification sheet.

**Table 2 — Requirements on ATRU cold insulation dielectric strength**

Nominal voltage V	Test voltage		Test time min
	Voltage V rms	Frequency Hz	
115/200 (AC) or ±135 (DC)	1 500	50/60	1
230/400 (AC) or ±270 (DC)	2 000		

#### 4.8.8 Influence on the input power system

The influence of ATRU on the input power system shall meet the requirements specified in ISO 7137:1995, 3.2, unless otherwise specified.

#### 4.8.9 Electrical protection

Protection shall be available for failure modes of the ATRU which can result in overvoltage, overcurrent and short current, etc. Failure modes shall be as required by the applicable specification sheet. Protective circuitry can be inside the ATRU or in aircraft power supply system.

#### 4.9 Acoustical noise

Acoustical noise level requirements of the ATRU shall be as required by the applicable specification sheet.

#### 4.10 Reliability

The mean time between failures (MTBF) of the ATRU shall be as required by the applicable specification sheet.

#### 4.11 Maintainability

The mean time to repair (MTTR) of the ATRU shall be as required by the applicable specification sheet.

#### 4.12 Interchangeability

All parts having the same specifications and models shall be directly and completely interchangeable with respect to installation and performance.

### 5 Environmental conditions and test procedures

Unless otherwise specified, the environmental conditions and test procedures shall be in accordance with ISO 7137 and in accordance with the categories given in [Table 3](#).

Unless otherwise specified, the order of the environmental conditions test shall be according to the numbers of [Table 3](#).

**Table 3 — Environmental conditions and test procedures**

No.	Test	Procedure given in ISO 7137:1995	Category	Comment
1	Temperature and altitude	1.1	E1	Non-pressurized and non-controlled temperature locations at altitudes up to 21 300 m (70 000 ft)
2	Humidity	1.3	A	Standard humidity environment
3	Shock	2.1	A	Standard operational shocks
4	Vibration	2.2	S	Standard vibration test
5	Audio frequency conducted susceptibility	3.4	Z	For all types of electrical system
6	Induced signal susceptibility	3.5	B	Operation in systems where interference be controlled to a tolerable level
7	Radio frequency susceptibility (radiated and conducted)	3.6	S	The internal EMI environmental from aircraft equipment
8	Emission of radio frequency energy	3.7	B	Operation in systems where interference be controlled to a tolerable level
9	Waterproofness	1.5	W	subjected to falling water (generally the results of condensation)
10	Fluids susceptibility	1.6	F	
11	Sand and dust	1.7	D	Subjected to blowing dust
12	Fungus resistance	1.8	F	Subjected to severe fungus contamination
13	Salt spray	1.9	S	Subjected to a corrosive atmosphere
14	Magnetic effect	3.1	A	Measure distance > 0,3 m to ≤ 1 m to the ATRU
15	Lighting induced transient susceptibility	3.8	K	Installations in a moderate environment

## 6 Qualification inspection

### 6.1 General

The purpose of qualification inspection is to ensure that the design and performance of ATRUs meet the specifications of this document.

The examinations and tests listed in [Table 4](#) shall be conducted on the ATRU for qualification unless otherwise specified.

**Table 4 — Qualification inspection**

No.	Inspection title (examination and test)	Requirement	Test method
1	Processing quality and appearance quality	<a href="#">4.3.1/4.3.3/4.6</a>	<a href="#">6.2.1</a>
2	Colour	<a href="#">4.5</a>	<a href="#">6.2.2</a>
3	Markings	<a href="#">4.7</a>	<a href="#">6.2.3</a>
4	Size and mass	<a href="#">4.4</a>	<a href="#">6.2.4</a>
5	Insulation resistance and dielectric strength	<a href="#">4.8.7</a>	<a href="#">6.2.5</a>
6	Normal steady-state input voltage	<a href="#">4.8.1.1</a>	<a href="#">6.2.6</a>
7	Abnormal steady-state input voltage	<a href="#">4.8.1.1</a>	<a href="#">6.2.7</a>
8	Input voltage spikes	<a href="#">4.8.1.2.1</a>	<a href="#">6.2.8</a>
9	Input power interruptions	<a href="#">4.8.1.2.2</a>	<a href="#">6.2.9</a>
10	Input frequency transients	<a href="#">4.8.1.2.3</a>	<a href="#">6.2.10</a>
11	Output voltage ripple	<a href="#">4.8.2.1.1/4.8.2.1.2</a>	<a href="#">6.2.11</a>
12	Output voltage frequency characteristics	<a href="#">4.8.2.1.1</a>	<a href="#">6.2.12</a>
13	Output voltage distortion factor	<a href="#">4.8.2.1.1</a>	<a href="#">6.2.13</a>
14	Output voltage transients	<a href="#">4.8.2.2</a>	<a href="#">6.2.14</a>
15	Output power interruptions	<a href="#">4.8.2.3</a>	<a href="#">6.2.15</a>
16	Efficiency	<a href="#">4.8.3</a>	<a href="#">6.2.16</a>
17	Overload	<a href="#">4.8.4</a>	<a href="#">6.2.17</a>
18	Short circuit	<a href="#">4.8.5</a>	<a href="#">6.2.18</a>
19	Soft starting	<a href="#">4.8.6</a>	<a href="#">6.2.19</a>
20	Influence on the input power system	<a href="#">4.8.8</a>	<a href="#">6.2.20</a>
21	Electrical protection	<a href="#">4.8.9</a>	<a href="#">6.2.21</a>
22	Acoustical noise	<a href="#">4.9</a>	<a href="#">6.2.22</a>
23	Reliability	<a href="#">4.10</a>	<a href="#">6.2.23</a>
24	Maintainability	<a href="#">4.11</a>	<a href="#">6.2.24</a>
25	Interchangeability	<a href="#">4.12</a>	<a href="#">6.2.25</a>

### 6.2 Methods of inspection

#### 6.2.1 Processing quality and appearance quality

Processing quality and appearance quality testing for ATRUs shall be conducted in accordance with the quality control documents, product drawings and process documents of the manufacturer. The conclusion of the test shall be in accordance with [4.3.1](#), [4.3.3](#) and [4.6](#), or as identified in the applicable specification sheet.

## 6.2.2 Colour

The colour of exposed surface of the ATRU shall be inspected according to the requirements of the purchaser or drawings. The testing results shall meet the requirements specified in [4.5](#).

## 6.2.3 Markings

Equipment, assemblies and parts shall be marked in accordance with the applicable specification sheet or drawings. The results shall meet the requirements specified in [4.7](#).

## 6.2.4 Size and mass

The outline dimensions and installation dimensions of the ATRU shall be measured by general measuring tools. The mass of the ATRU shall be measured by industrial weighing apparatus. The measurement results shall meet the requirements specified in [4.4](#).

## 6.2.5 Insulation resistance and dielectric strength

### 6.2.5.1 Insulation resistance

The insulation resistance is measured after the ATRU is heat stabilized at the highest nominal operating temperature. The test location and test voltage are specified in [Table 1](#) (see [4.8.7.1](#)). When testing, the test voltage shall last 1 min after reaching the specified value. The testing results shall meet the requirements specified in [4.8.7.1](#).

Before testing, the capacitor and semiconductor device between the tested parts shall be disconnected. It is not advisable to repeat the test between the same parts. If necessary, the subsequent tests shall keep the same polarity as the initial test.

### 6.2.5.2 Dielectric strength

The dielectric strength test shall be conducted under the cold condition of the ATRU. The inspection location, test voltage and test time are specified in [4.8.7.2](#). The testing results shall meet the requirements specified in [4.8.7.2](#).

The power of test power supply shall not be less than 0,5 kVA, and the sensitive semiconductor device in the circuit under test shall be disconnected before testing. When testing, the applied voltage is raised from 0 V to the specified value at a constant speed and should be maintained for 1 min. Then the test voltage is reduced to 0 V immediately, and the test power supply is disconnected. The test voltage rising and falling rates are maintained at about 500 V/s.

It is not advisable to repeat the test at the same location. If necessary, the test voltage shall be reduced by 15 %.

When it is difficult to conduct the tests on the whole equipment, the tests can be conducted before the assembly.

## 6.2.6 Normal steady-state input voltage

When the normal input voltage of the ATRU meets the requirements specified in [4.8.1.1](#), the steady-state output voltage shall be measured under the minimum load, 50 % of rated load and full rated load specified in the applicable specification sheet, the results shall meet the requirements specified in [4.8.2.1.1](#).

## 6.2.7 Abnormal steady-state input voltage

With the limits of input AC three-phase abnormal voltage specified in [4.8.1.1](#), the ATRU capability of starting and 30 min continuous operation shall be tested under full rated load at minimum and