BS ISO 12384:2010

BSI Standards Publication

Aerospace — Requirements for digital equipment for measurements of aircraft electrical power characteristics

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National foreword

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The UK participation in its preparation was entrusted to Technical Committee ACE/6, Aerospace avionic electrical and fibre optic technology.

A list of organizations represented on this committee can be obtained on request to its secretary.

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ISBN 978 0 580 66536 3

ICS 49.060

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This British Standard was published under the authority of the Standards Policy and Strategy Committee on 31 December 2010.

Amendments issued since publication

Date	Text affected

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BS ISO 12384:2010

INTERNATIONAL STANDARD

ISO 12384

First edition
2010-11-15

Aerospace — Requirements for digital equipment for measurements of aircraft electrical power characteristics

Constructions aérospatiales — Exigences relatives aux équipements numériques de mesure des caractéristiques de puissance électrique à bord des aéronefs

Reference number
ISO 12384:2010(E)

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Foreword

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The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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.

ISO 12384 was prepared by Technical Committee ISO/TC 20, *Aircraft and space vehicles*, Subcommittee SC 1, *Aerospace electrical requirements*.

ISO 12384 is closely allied with ISO 1540 and references from one to the other are freely used, particularly from ISO 12384 to ISO 1540. The proper use of this International Standard through referencing the applicable specific digital measurement methods should simplify the preparation of specifications and help to expedite the purchase and acceptance of the digital measuring equipment.

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Introduction

Various types of digital measuring equipment for electrical power characteristics are applied to the aircraft electrical system. There is no International Standard for digital measuring equipment for electrical power characteristics in the aerospace industry. The purpose of this International Standard is to explain, establish and standardize specific methods for digital measurements of the aircraft electrical system. The intended use of this International Standard is to define how to measure parameters of electrical characteristics in aircraft electrical power systems. The specific measurement methods are included here, while the terminology and general methods of digital measurement and signal processing are also presented. The requirements of digital measuring equipment are verified by testing of the aircraft electrical system.

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Aerospace — Requirements for digital equipment for measurements of aircraft electrical power characteristics

1 Scope

This International Standard specifies the requirements for digital measuring methods and digital measuring equipment for aircraft electrical power characteristics, including accuracy, algorithms and digital measuring equipment. The measuring equipment should be applied mainly for the use of laboratory or rig tests.

This International Standard can be applied to digital measuring equipment which is involved in the measurement of power electrical characteristics of the power supply system, power distributing systems and the utilization of equipment in aircrafts.

2 Normative references

The following referenced documents are indispensable for the application 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, *Aerospace — Characteristics of aircraft electrical systems*

ISO 7137, *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 the following apply.

3.1
sampling frequency
reciprocal of sampling interval time

3.2
sampling time
total of sampling interval time

4 Symbols

Symbols used by this International Standard are listed in Table 1.

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Table 1 — Symbols and definitions

Symbol	Unit	Definition
F_P		power factor
F_C		crest factor
f	Hz	steady state frequency
f_m	Hz	frequency modulation
I	A	steady state a.c. current
i_j	A	instantaneous value of a.c. current
j		sampling serial, $j = 1,2,3, \ldots n$
F_d	%	a.c. voltage distortion factor
n		total number of sampling points during the steady state time
N		cycle numbers during T_W
T		sampling period
T_w	s	time of a period not to exceed one second
T_θ	s	difference in time between the fundamental components of any two normalized phase voltages taken at consecutive zero crossings traced in the negative to positive direction
t_θ	s	difference in time between the fundamental components of any two phase voltages taken at consecutive zero crossings traced in the negative to positive direction
U	V	steady state phase voltage
U_A, U_B, U_C	V	phase A, B and C steady state voltage
U_d	V	distortion of a.c. voltage
U_Adc	V	d.c. component of a.c. voltage
U_j	V	rms value corresponding to the j^th cycle
U_P	V	peak value of a.c. voltage for each cycle
U_rm	V	voltage ripple
U_m	V	voltage modulation
U_n		n^th harmonic rms value of current or voltage
U_dc	V	steady state d.c. voltage
U_f	V	rms value of fundamental component of a.c. voltage
U_ε	V	voltage imbalance
U_D	V	rms value of a.c. distortion voltage
D_TH	%	total harmonic distortion
u_j	V	instantaneous value of a.c. voltage
$u_{\mathrm{D}j}$	V	instantaneous value of a.c. distortion voltage
u_dmax	V	maximum value of cyclic variation in relation to the mean level of d.c. voltage during steady state operation
u_dmin	V	minimum value of cyclic variation in relation to the mean level of d.c. voltage during steady state operation
u_dcj	V	instantaneous value of d.c. voltage
U_Ddc	V	distortion of the d.c. voltage
F_ddc	%	d.c. voltage distortion factor
Δt	s	sampling interval time
θ	°	phase voltage displacement

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5 Measurement requirements for the aircraft electric power characteristics

5.1 General rules, measurement states and the admissible errors of the measurement results

5.1.1 General

The electric power characteristics measurement shall be implemented in accordance with the definitions of ISO 1540 and the requirements of this International Standard.

5.1.2 Measurement states

5.1.2.1 Steady state

The measurement of steady state parameters shall be processed only when negligible changes in electrical parameters appear. For example, no load state, rated load state, etc.

5.1.2.2 Transient state

The measurement of transient state parameters shall be processed in the transient state. Momentary variations of a characteristic from its steady state limits, and back to its steady state limits may occur as a result of a system disturbance. For example, apply the load immediately, switch from one load to another load, power bus or power source switching, building up and shut down power source, etc. The whole transient procedure should be tested.

5.1.3 Admissible errors of the measurement results

5.1.3.1 Steady state characteristics

When measuring voltages and currents within the range of waveform characteristics allowed in ISO 1540**,** the steady state measurement error shall meet the following requirements:

a) voltage:

   1) steady state a.c. and d.c. voltage: in the range of measurement, the absolute error of readings shall be in the range of ±0,5 %;

   2) D.C. component of the a.c. voltage: the absolute error of readings shall be in the range of ±10 %;

b) current:

   1) steady state a.c. current: in the range of measurement, the absolute error of readings shall be in the range of ±1 %;

   2) steady state d.c. current: in the range of measurement, the absolute error of readings shall be in the range of ±0,8 %;

c) frequency:

   the a.c. system: in the range of measurement, the absolute error of readings shall be in the range of ±0,1 % of the nominal frequency;

d) phase difference:

   in the condition that the voltage phase difference is in the range of 110°~130°, the absolute error of readings shall be in the range between ±0,2°;

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e) amplitude of distortion spectrum:

the absolute error shall be in the range between ±5% of limited value.

5.1.3.2 Transient characteristics

Measurement error of the transient characteristics should meet the following requirements:

a) voltage:

1) a.c. voltage: in the range of measurement, the absolute error of readings shall be in the range of ±1,0 % of the specified maximum transient a.c. voltage;

2) d.c. voltage: in the range of measurement, the absolute error of readings shall be in the range of ±1,0 % of the specified maximum transient d.c. voltage;

3) d.c. content of the a.c. voltage: absolute error of readings shall be in the range of ±10 % of the specified maximum transient d.c content voltage;

b) current:

1) a.c. current: in the range of measurement, the absolute error of readings shall be in the range of ±2 % of the specified maximum transient a.c. current;

2) d.c. current: in the range of measurement, the absolute error of readings shall be in the range of ±2 % of the specified maximum transient d.c. current;

c) frequency:

in the range of measurement, the absolute error of readings shall be in the range of ±0,2 % of the specified maximum frequency.

5.2 Measurement of constant frequency (CF) a.c. power system characteristics

5.2.1 Steady state characteristics

5.2.1.1 Phase voltage

The measurement of the phase voltage should be processed according to the following:

a) sampling frequency on each phase voltage not less than 72 kHz;

b) the three phase voltages sampled at the same time;

c) sampling time over a period not to exceed one second.

Calculate the steady state phase voltage according to Equation (1):

$$U = \sqrt{\frac{1}{T_\mathrm{W}} \sum_{j=1}^{n} u_j^2 \Delta t} \qquad (1)$$

where

U is steady state phase voltage, V;

T_W is the time of a period not to exceed one second, s;

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n is the number of samples;

j is sample serial, $j = 1, 2, 3 \ldots n$;

u_j is the instantaneous value of a.c. voltage, V;

Δt is the sampling interval time, s.

5.2.1.2 Phase voltage imbalance

The measurement of the voltage imbalance should be processed according to the following requirements:

a) calculate the steady state a.c. voltage U_A, U_B, U_C according to 5.2.1.1;

b) substitute the U_A, U_B, U_C into Equation (2) to calculate the phase voltage imbalance.

$$U_\varepsilon = \max\left[\left|U_\text{A} - U_\text{B}\right|, \left|U_\text{B} - U_\text{C}\right|, \left|U_\text{C} - U_\text{A}\right|\right] \quad (2)$$

where

U_ε is phase voltage imbalance, V.

5.2.1.3 Phase voltage modulation

Each phase voltage should be sampled at the frequency of more than 72 kHz. The sampling time should be at least one second. Calculate the positive peak voltage of each phase in every cycle, denoted as $U_{\text{PA}j}$, $U_{\text{PB}j}$, $U_{\text{PC}j}$ (j = 1,2,3, ..., n) and find out the maximum value and minimum value from these series:

$$U_{\text{PA}j,\text{max}}; U_{\text{PA}j,\text{min}}; U_{\text{PB}j,\text{max}}; U_{\text{PB}j,\text{min}}; U_{\text{PC}j,\text{max}}; U_{\text{PC}j,\text{min}}$$

Substitute them into Equation (3) to calculate the phase voltage modulation:

$$U_\text{m} = \max\left[U_{\text{PA}j,\text{max}} - U_{\text{PA}j,\text{min}}, U_{\text{PB}j,\text{max}} - U_{\text{PB}j,\text{min}}, U_{\text{PC}j,\text{max}} - U_{\text{PC}j,\text{min}}\right] \quad (3)$$

where

U_m is voltage modulation, V.

According to the positive peak voltage of every cycle in each phase, the cyclic or random variation of a.c. peak voltage can be obtained by computing the amplitude of the components at individual frequencies by the Fourier transformation, then plotting the frequency characteristics of voltage modulation.

5.2.1.4 Phase voltage displacement

Each phase voltage shall be sampled at the same time. The sampling time should be over a period not to exceed one second. The difference period among the three phases should not be more than one cycle of a fundamental component, finding the positive zero-crossing of the fundamental component wave of each phase and the period between the consecutive positive zero-crossing. Calculate the angle between the fundamental components of the two phase voltage according to Equation (4) which is the phase voltage displacement.

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$$\theta = \frac{t_\theta}{T_\theta} \cdot 360° \quad (4)$$

where

θ is the phase voltage displacement (electrical angle difference between the two fundamental component waves), (the unit is electrical angle);

t_θ is the period between the two consecutive positive zero-crossings of the fundamental component wave, s;

T_θ is the period between the consecutive positive zero-crossing of the normalized phase voltage fundamental component wave (cycle), s.

Measure the phase difference of fundamental components of any two phase voltages.

5.2.1.5 A.C. voltage distortion factor

Sample the distorting a.c. voltage with proper sampling frequency. The sampling time should be over a one second period. Calculate the a.c. voltage U according to Equation (1) and U_f. Then the a.c. voltage distortion factor can be obtained by using Equation (5).

$$F_\mathrm{d}(\%) = 100 \times \frac{\sqrt{\left(U^2 - U_\mathrm{f}^2\right)}}{U_\mathrm{f}} \quad (5)$$

where

F_d is the a.c. voltage distortion factor;

U is the steady state phase voltage, V;

U_f is the rms value of fundamental component, V.

5.2.1.6 Total harmonic distortion (current or voltage)

Sample the a.c. voltage or current waveform at a frequency of more than 200 KHz. The sampling time should be over a period of one second. Calculate the rms of fundamental component, and the n^th harmonic component of current or voltage. Then the total harmonic distortion can be obtained by using Equation (6).

$$D_\mathrm{TH}\left(\%\right) = 100 \times \frac{\sqrt{\sum_{2}^{n} U_n{}^2}}{U_\mathrm{f}} \quad (6)$$

where

U_f is the rms value of fundamental component of current or voltage;

U_n is the rms value of n^th harmonic component of current or voltage.

5.2.1.7 A.C. voltage distortion spectrum

Sample the distortion a.c. voltage with proper sampling frequency. The sampling time should be over a period of one second (which is the period of testing steady state voltage T_w); calculate the rms value of each frequency component, and plot the spectrum curve.

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5.2.1.8 Crest factor

Each phase voltage should be sampled at a frequency of more than 72 kHz. The sampling time should be over a one second period. Calculate the rms value of each cycle U_j ($j = 1, 2, 3, ..., n$) during the sampling time, getting the peak value of each cycle U_{Pj} ($j = 1, 2, 3, ... n$) and calculate the crest factor F_C of each cycle using Equation (7). Then find the extreme value from a series of F_C.

$$F_C = \frac{\left| U_{Pj} \right|}{U_j} \tag{7}$$

where

F_C is the crest factor;

U_{Pj} is the voltage peak value corresponding to the j^{th} cycle, V;

U_j is the rms value corresponding to the j^{th} cycle, V.

5.2.1.9 D.C. component of the a.c. voltage

After a.c. components have been filtered out, phase voltage should be sampled at the frequency of more than 72 kHz. The sampling time should be over a period not to exceed one second. Then calculate the d.c. component of the phase voltage according to Equation (8).

$$U_{Adc} = \frac{\sum_{j=1}^{n} u_j}{n} \tag{8}$$

where

U_{Adc} is the d.c. component of the a.c. voltage, V;

u_j is the instantaneous value of a.c. phase voltage, V;

j is the sampling serial, $j = 1, 2, 3, ..., n$;

n is the total number of sampling points during the steady state time.

5.2.1.10 Steady state frequency

The sampling time should be over a period not to exceed one second. Calculate steady state frequency according to Equation (9).

$$f \cdot \frac{N}{T_W} \tag{9}$$

where

f is steady state frequency, Hz;

n is the cycle numbers during T_W.

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5.2.1.11 Frequency modulation

Sample the phase voltage at a frequency of more than 72 kHz, compute the frequency of each cycle, and get the maximum frequency f_{max} and minimum frequency f_{min} in one minute, then calculate the frequency modulation.

$$f_m = f_{max} - f_{min} \tag{10}$$

where f_m is the frequency modulation, Hz.

According to the frequency of each cycle in one second, the frequency modulation amplitude can be obtained in different repetition rates. Plot the frequency modulation curve.

5.2.2 Transient characteristics

5.2.2.1 Voltage transients

Sample the transient wave of a.c. voltage at a frequency of more than 100 kHz. The sampling time should be more than 0,25 s. Calculate the RMS of each cycle by using Equation (1), and then plot normal transient voltage envelope.

Sample the transient voltage of over-load, under-load a.c. voltage at a frequency of more than 100 kHz. The sampling time should be more than 10 s. Calculate the RMS of each cycle by using Equation (1), and then plot abnormal transient voltage envelope.

5.2.2.2 D.C. content transients

Sample the transient wave of a.c. voltage at a frequency of more than 100 kHz. The sampling time should be more than 10 s. Calculate the average value of each cycle by using Equation (8), and then plot abnormal d.c. content transient envelope.

5.2.2.3 Transient frequency

Sample the normal a.c. frequency or over-frequency, under-frequency transient wave at a frequency of more than 100 kHz. The sampling time should not be less than 10 s. Calculate the frequency of each cycle, and then plot the normal a.c. frequency or over frequency, under-frequency transient envelope.

5.3 Measurement of variable frequency (VF) a.c. power system characteristics

The characteristics of the VF system should be measured according to the items in 5.2, but the sampling frequency should be increased according to the ratio of the VF system's high frequency to CF system's rating frequency.

5.4 Measurement of d.c. power system characteristics (28 V or 42 V system)

5.4.1 Steady state characteristics

5.4.1.1 Steady state d.c. voltage

Sample the instantaneous value of d.c. voltage at a frequency of more than 20 KHz. The sampling time should be over a one second period, calculating the steady state d.c. voltage using Equation (11).

$$U_{dc} = \frac{1}{n}\sum_{j=1}^{n} u_{dcj} \tag{11}$$

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where

U_{dc} is steady state d.c. voltage, V;

u_{dcj} is the instantaneous value of d.c. voltage, V;

j is the sampling serial, $j = 1, 2, 3, ..., n$;

n is the total number of sampling points.

5.4.1.2 D.C. distortion factor

Sample the ripple of the d.c. voltage at a frequency of more than 20 KHz. The sampling time should be near or equal to one second. Calculate the d.c. voltage distortion by using Equation (12):

$$U_{Ddc} = \sqrt{\frac{1}{T}\sum_{j=1}^{n} u_{Dj}^{2} \Delta t} \tag{12}$$

where

U_{Ddc} is the distortion of the d.c. voltage,V;

T is the sampling period (near or equal to 1s), s;

u_{Dj} is the instantaneous value of the a.c. voltage distortion wave, V;

j is the sampling serial, $j = 1, 2, 3, ... n$;

n is the total number of sampling points;

Δt is the sample interval time points, s.

By submitting the d.c. voltage distortion derived from Equation (12) and steady state d.c. voltage into Equation (13), the d.c. voltage distortion factor can be obtained.

$$F_{ddc}\ (\%) = 100 \times \frac{U_{Ddc}}{U_{dc}} \tag{13}$$

where

F_{ddc} is the d.c. voltage distortion coefficient;

U_{Ddc} is the d.c. voltage distortion, derived from Equation (13), V;

U_{dc} is the steady state d.c. voltage, V.

5.4.1.3 D.C. voltage distortion spectrum

According to 5.4.1.2, sampling the a.c. components of d.c. voltage wave and the sampling time should be less than one second. Individual frequency components of ripple are obtained by calculating the rms of each frequency component through the Fourier transformation. Then plot the spectrum curve.

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5.4.1.4 D.C. voltage ripple

Sample the d.c. voltage at a frequency of more than 20 kHz (eliminate the voltage spike and filter out the abnormal disturbance). The sampling time should be near or equal to one second. Find the maximum u_{dmax} and the minimum u_{dmin} from instantaneous cycle voltage. Calculate the d.c. voltage by using Equation (14):

$$U_{rm} = u_{dmax} - u_{dmin} \tag{14}$$

where U_{rm} is the d.c. voltage ripple, V.

5.4.2 Transient d.c. voltage

Sample d.c. voltage waveform at a frequency of more than 80 kHz. The sampling time should not be less than 0,25 s. Measure the instantaneous value of d.c. voltage. Plot the normal transient d.c. voltage envelope.

Sample d.c. voltage waveform at a frequency of more than 80 kHz. The sampling time should not be less than 10 s. Measure the instantaneous value of d.c. voltage. Plot the over-voltage and under-voltage abnormal transient envelope.

5.5 Measurement of current parameter

The measurement method and data processing principle of the CF system can use the corresponding measurement method of the voltage. The sampling frequency should not be less than 20 kHz. However, the sampling frequency should be increased when measuring the transient current, and when measuring the distortion of the current, the sampling frequency should be increased further.

The measurement method and data processing principle of the variant frequency a.c. system can be referred to the corresponding methods of the CF a.c. system. However, the sampling frequency should be increased according to 5.3.

5.6 Measurement of power transfer characteristics

Measure the period of the voltage and frequency between the zero and normal working limit when switching between power bus and power source. Inspect the waveform of the testing point according to the transient measurement method of the voltage and frequency. Calculate the transfer period between the waveforms.

5.7 Measurement of voltage spike characteristics

Test the utilization equipment according to the testing equipment and method regulated in ISO 7137. Determine the testing result according to the regulations in ISO 1540.

5.8 Measurement of power factor

Sample the a.c. voltage and current waveform at the same time. The sampling frequency should not be less than 72 kHz. The sampling time should be a period not exceeding one second. Calculate the steady state a.c. voltage U which has been stated in 5.2.1.2. Calculate the a.c. current U stated in 5.5, and calculate the power factor according to Equation (15).

$$F_P = \frac{1}{UIT_w} \sum_{j=1}^{n} u_j i_j \Delta t \tag{15}$$

where

F_P is the power factor when voltage and current distortion, θ doesn't equals to the difference angle of the u, i waveform;

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U is the steady state a.c. voltage (calculated according to 5.2.1.1), V;

I is the steady state a.c. current (calculated according to 5.5), A;

T_W is a period not to exceed one second, s;

j is the sample serial, $j = 1, 2, 3, \ldots n$;

u_j is the instantaneous value of a.c. voltage, V;

i_j is the instantaneous value of a.c. current, A;

Δt is the sampling interval time, s.

6 General requirements for the measuring equipment

6.1 Applicability

6.1.1 Efficiency

The measuring equipment shall be able to measure the characteristics of power supply according to Clause 5. The results shall be in accordance with the definition stated in ISO 1540.

6.1.2 Operating environment

The measuring equipment shall be able to work under the regulated environment (e.g. inner field, outfield, in the vehicle and airborne). The additional error shall not cause the measurement result to exceed the admissible errors stated in 5.1.3 when the environmental factors vary in the range of the regulated conditions.

6.2 Performance and functions

6.2.1 Accuracy

The accuracy of the measuring equipment shall comply with the requirements in 5.1.3.

6.2.2 Scope of the measuring equipment

The scope of the measuring equipment shall comply with the range of transient characteristic parameters stated in ISO 1540.

6.2.3 Measurement resolution

The measuring equipment shall be able to detect the 0,05 % variation of the maximum limited value stated in ISO 1540.

6.2.4 Input impedance

The variation of influence to the measured system caused by the measuring equipment input variation shall not exceed the range of limit in resolution of the measuring equipment.

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6.2.5 Sampling frequency range

According to the characteristics of the measured system, the sampling frequency should not be lower than 200 kHz (when measuring a.c. or d.c. voltage distortion factor and a.c. or d.c. voltage distortion spectrum); 100 kHz (measuring the a.c. transient characteristics); 80 kHz (measuring the d.c. transient characteristics); 72 kHz (measuring other characteristics of the a.c.); 20 kHz (when measuring d.c. voltage, the d.c. voltage ripple range and steady state current).

6.3 Electromagnetic compatibility

The measuring equipment should not produce electromagnetic disturbance to the equipment under test and the measuring equipment shall work well as long as the electromagnetic disturbance of the tested system does not exceed the regulation limit.

6.4 Human-machine interface project

Operation of the measurement system should be simple. Human-machine interface should be user-friendly. The operation mistake should not be able to cause damage to the measurements or measured system.

6.5 The regulation of select measuring equipment

6.5.1 The measurement regulation of the data process software

The data processing method of the measuring equipment software shall comply with the definition of the corresponding power supply characteristics stated in ISO 1540 and fulfill the regulation requirements in this International Standard.

6.5.2 Selecting requirement

The measuring equipment which has been calibrated and warranted by the calibrating and testing department of the country should be selected.

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Bibliography

[1] ISO 6858, *Aircraft — Ground support electrical supplies — General requirements*

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