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Electrically propelled road vehicles — Test specification for electric propulsion components —

Part 1: General test conditions and definitions

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Foreword

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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).

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This document was prepared by Technical Committee ISO/TC 22, *Road vehicles*, Subcommittee SC 37, *Electrically propelled vehicles*.

A list of all parts in the ISO 21782 series can be found on the ISO website.

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.

Introduction

Until now, there was no international standardized test procedure for the motor system including motors, inverters DC/DC converters and their combinations for electric propulsion systems of electrically propelled road vehicles available. There are some International Standards for industrial use which consider the steady/constant running of motors and inverters but don't consider the dynamic operation (acceleration/deceleration).

The ISO 21782 series was prepared aiming at the reproducibility of test results which will enable to compare and evaluate fairly the performance and reliability of electric propulsion system components such as the motor system (the motor, inverter, DC/DC converter and their combinations).

The overview of the ISO 21782 series is in Tables 1 to 4 shown below.

Table 1 — Contents of Part 1: general test conditions and definitions

Item of Part 1	Description
Introduction	Background and purpose of the ISO 21782 series
Terms and definitions	Terms to use in the ISO 21782 series
Abbreviated terms	Abbreviated terms to use in the ISO 21782 series
General test conditions	Definition of general condition; — Operating point — Current, voltage and power — DC input voltage — Temperature and humidity — Measurement accuracy

Table 2 — Contents of Part 2: performance testing of the motor system

Item of Part 2	Description	Motor	Inverter	Chopper	Motor system
Measurement of total loss and total efficiency	This test measures total loss and total efficiency between the input power of inverter and the output power of the motor.				5.1
Temperature rise test	This test investigates the temperature rise characteristics of each part of the motor system within the specified range.				5.2
Torque characteristic test	This test measures the torque characteristics specified in the specifications of the motor system.				5.3
Torque ripple test	This test measures the torque ripple of the motor.				5.4

Table 3 — Contents of Part 3: performance testing of the motor and the inverter

Item of Part 3	Description	Motor	Inverter	Chopper	Motor system
Measurement of loss and efficiency	This test measures loss and efficiency between the input power and the output power.	5.1.1	5.2.1	5.3.1	
	This test measures conversion rate between the input power and the output power.		5.2.1	5.3.1	

Table 3 *(continued)*

Item of Part 3	Description	Motor	Inverter	Chopper	Motor system
Temperature rise test	This test investigates the temperature rise characteristics of each part of the component within the specified range.	5.1.2	5.2.2	5.3.2	
Torque characteristic test	This test measures the torque characteristics specified in the specifications of the motor.	5.1.3			
Cogging torque test	This test measures the cogging torque of the permanent magnetic motor.	5.1.4			

Table 4 — Contents of Part 6: operating load testing of the motor and the inverter

Item of Part 6	Description	Motor	Inverter	Chopper	Motor system
Operation endurance tests of motor	Cyclic test of high acceleration/deceleration endurance	4.1.1			
	Cyclic test of torque pattern endurance including maximum torque	4.1.2			
	Over speed test	4.1.3			
Operation endurance tests of inverter	Cyclic test of output current pattern endurance including maximum current		4.2.1		
Breakdown strength verification test	Contents of this test are mainly spin test, data acquisition of mechanical strength of the motor.	4.3.1			

Electrically propelled road vehicles — Test specification for electric propulsion components —

Part 1: General test conditions and definitions

1 Scope

This document specifies the test procedures for performance and operating load for voltage class B electric propulsion components (motor, inverter, DC/DC converter) and their combinations (motor system) of electrically propelled road vehicles.

This document specifies the terms and definitions used in the ISO 21782 series and general test conditions.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

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

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

— ISO Online browsing platform: available at http://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1
chopper
DC electronic *power converter* (3.18) without an intermediate AC link giving a variable output voltage by varying the periods of conduction and non-conduction in an adjustable ratio

[SOURCE: IEC 60050-811:2017, 811-19-11, modified — The phrase "electronic power DC convertor" was modified to DC electronic power converter.]

3.2
conversion rate
ratio of output base wave power or output DC power to input DC power

3.3
DC link inductor
component boosted by the *chopper* (3.1) circuit, a magnetic energy storage and released in response to actuation of the switching element

3.4
efficiency
ratio of output power to input power

3.5
induction motor
IM
AC electric motor in which the electric rotor current needed to produce torque is obtained by electromagnetic induction from the magnetic field of the stator winding

EXAMPLE Asynchronous motor.

3.6
inverter
electric energy converter that changes direct electric current to single-phase or polyphase alternating currents

[SOURCE: IEC 60050-151:2001, 151-13-46]

3.7
maximum current for duration of t_0
$I_{t=t0}$
maximum current defined for the time frame t_0 which can be constantly achieved for t_0 seconds starting from the steady state condition of room temperature (RT) and the nominal cooling conditions until the *inverter* (3.6), *chopper* (3.1) reaches the defined maximum temperature limit

3.8
maximum operating speed
upper limit revolution speed for the torque-motor speed characteristics

3.9
maximum power for duration of t_0
$P_{t=t0}$
maximum power defined for the time frame t_0 which can be constantly achieved for t_0 seconds starting from the steady state condition of RT and the nominal cooling conditions until the motor, *inverter* (3.6) and *chopper* (3.1) reaches the defined maximum temperature limit

3.10
maximum speed
n_m
highest defined speed which can maintain maximum power

Note 1 to entry: Maximum speed can be limited by control software or supplier's definitions.

3.11
motor system
electric propulsion system for electrically propelled road vehicle comprising a combination of components such as motor, *inverter* (3.6) and if necessary, DC/DC converter

3.12
maximum torque for duration of t_0
$M_{t=t0}$
highest torque defined for the time frame t_0 which can be constantly achieved for t_0 seconds until the power limitation at higher speed starting from the steady state condition of RT and the nominal cooling conditions until the motor reaches the defined maximum temperature limit

3.13
maximum voltage for unlimited operating capability
highest value of OS1

Note 1 to entry: See ISO/PAS 19295 about OS1.

3.14
minimum voltage for unlimited operating capability
lowest value of OS1

Note 1 to entry: See ISO/PAS 19295 about OS1.

3.15
no-load induced electromotive force
E_0
voltage generated in the armature when the motor is rotated at the *rated speed* (3.21) as a power generator while the terminal of the synchronous motor is opened

3.16
operating load test
test method that take into account the deterioration due to the operation of the device itself

3.17
output frequency
frequency of the *inverter* (3.6) output current

3.18
power converter
device that converts electric energy from DC to AC or from AC to DC

EXAMPLE AC frequency conversion, DC power conversion, etc.

3.19
permanent magnet motor
PM
motor using permanent magnets for the field magnetic poles

3.20
rated frequency
f_r
output frequency (3.17) at the operating point corresponding to the *rated speed* (3.21) of the combined motor

3.21
rated speed
n_r
intersection of the *maximum torque for duration of* t_0 (3.12) and iso-power line

3.22
rated voltage
u_r
central value of OS1

Note 1 to entry: See ISO/PAS 19295 about OS1.

4 Abbreviated terms

AC alternating current

ACL 3-phase inductance equivalent to the leakage inductance of motor

DC direct current

DUT device under test

EMF electromotive force

PWM pulse width modulation

RL ACL with series resistance equivalent to phase resistance of motor

RT room temperature

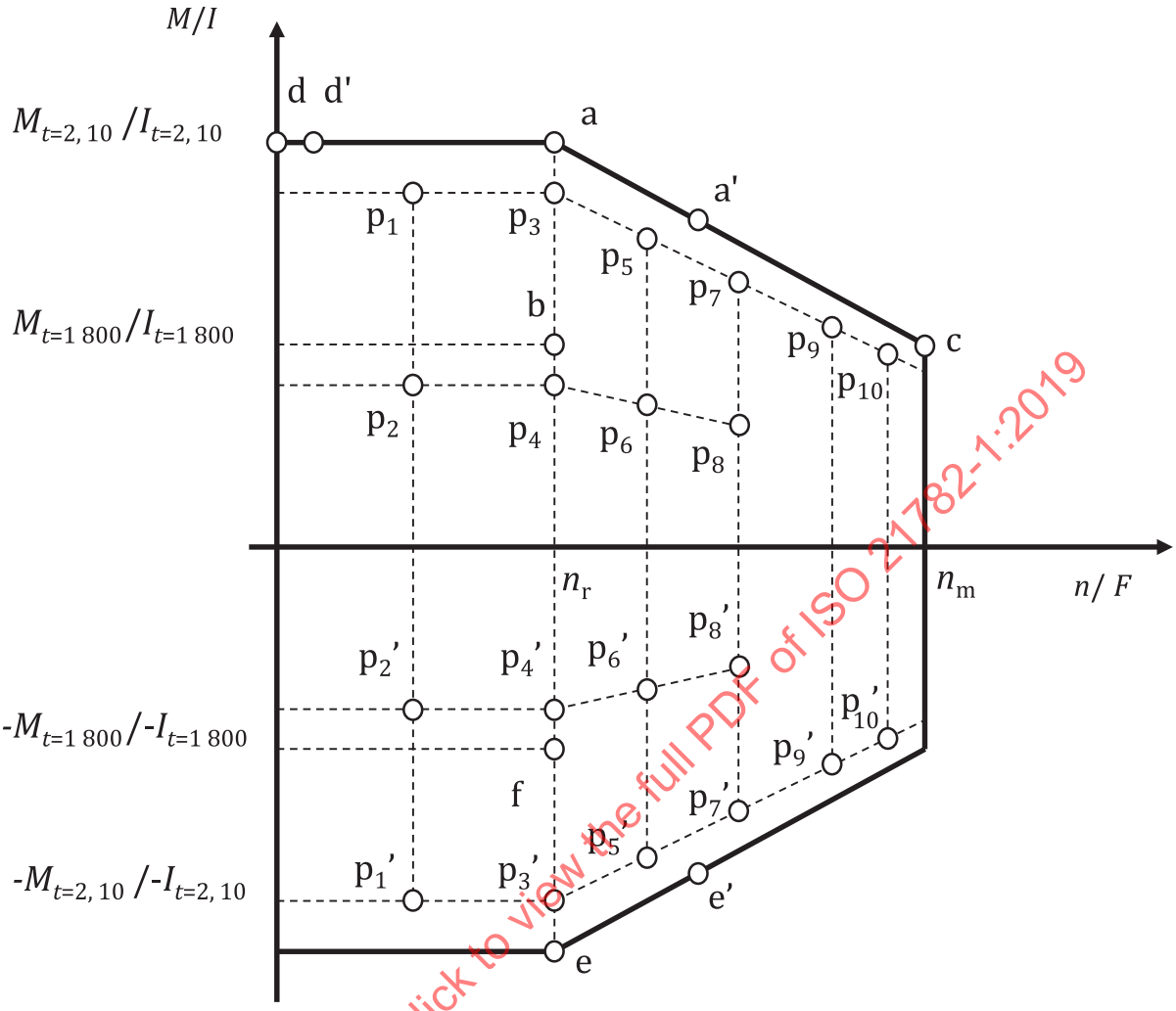
5 General test conditions

5.1 Operating points

Operating points as used in test are defined in Figure 1, Table 5 and 6.

t_0 shall be 2 s, 10 s or 1 800 s.

As an operation for t_0, also 30 s or 60 s may be chosen instead of 2 s and 10 s.



Key

n	motor speed (in min^{-1})
F	frequency (in Hz)
M	torque (in Nm)
I	current (in A)
$M_{t=2,\,10}/I_{t=2,\,10}$	maximum motoring torque/current duration for t_0=2, 10 (in Nm)/(in A)
$M_{t=1\,800}/I_{t=1\,800}$	maximum motoring torque/current duration for t_0=1 800 (in Nm)/(in A)
$-M_{t=2,\,10}/-I_{t=2,\,10}$	maximum regenerating torque/current duration for t_0=2, 10 (in Nm)/(in A)
$-M_{t=1\,800}/-I_{t=1\,800}$	maximum regenerating torque/current duration for t_0=1 800 (in Nm)/(in A)
n_m	maximum speed/frequency (in min^{-1})/(in Hz)
n_r	rated speed/frequency (in min^{-1})/(in Hz)
a, a', b, c, d, d', e, p_1–p_{10}	operating points as defined in Table 5
e', f, p_1'-p_{10}'	optional operating points as defined in Table 6

Figure 1 — Operating points

Table 5 — Definition of operating points

Operating point	**Motor speed** (in min^{-1}) **/frequency** (in Hz)	**Torque** (in Nm) **/current** (in A)	**Output power** (in W)
a	rated speed/frequency	$M_{t=2,\,10}/I_{t=2,\,10}$	$P_{t=2,\,10}$

Table 5 *(continued)*

Operating point	**Motor speed** (in min^{-1}) **/frequency** (in Hz)	**Torque** (in Nm) **/current** (in A)	**Output power** (in W)
a'	—	—	$P_{t=2,\,10}$ (if "a" is not maximum power)
b	rated speed/frequency	$M_{t=1\,800}/I_{t=1\,800}$	—
c	maximum speed/frequency	—	$P_{t=2,\,10}$
d	zero speed/frequency	$M_{t=2,\,10}/I_{t=2,\,10}$	—
d'	low speed/frequency	$M_{t=2,\,10}/I_{t=2,\,10}$	—
e	rated speed/frequency	$-M_{t=2,\,10}/\text{-}I_{t=2,\,10}$	—
f	rated speed/frequency	$-M_{t=1\,800}/\text{-}I_{t=1\,800}$	—
p_1	0,5 × rated speed/frequency	0,8 × $M_{t=2,\,10}/I_{t=2,\,10}$	—
p_2	0,5 × rated speed/frequency	0,4 × $M_{t=2,\,10}/I_{t=2,\,10}$	—
p_3	rated speed/frequency	0,8 × $M_{t=2,\,10}/I_{t=2,\,10}$	—
p_4	rated speed/frequency	0,4 × $M_{t=2,\,10}/I_{t=2,\,10}$	—
p_5	0,25 × (maximum speed/frequency – rated speed/frequency) + rated speed/frequency	—	0,8 × $P_{t=2,\,10}$
p_6	0,25 × (maximum speed/frequency – rated speed/frequency) + rated speed/frequency	—	0,4 × $P_{t=2,\,10}$
p_7	0,5 × (maximum speed/frequency – rated speed/frequency) + rated speed/frequency	—	0,8 × $P_{t=2,\,10}$
p_8	0,5 × (maximum speed/frequency – rated speed/frequency) + rated speed/frequency	—	0,4 × $P_{t=2,\,10}$
p_9	0,75 × (maximum speed/frequency – rated speed/frequency) + rated speed/frequency	—	0,8 × $P_{t=2,\,10}$
p_{10}	0,9 × (maximum speed/frequency – rated speed/frequency) + rated speed/frequency	—	0,8 × $P_{t=2,\,10}$

Table 6 — Definition of operating points: optional

Operating point	**Motor speed** (in min^{-1}) **/frequency** (in Hz)	**Torque** (in Nm) **/current** (in A)	**Output power** (in W)
e'	—	—	$\text{-}P_{t=2,\,10}$ (if "e" is not maximum power)
p_1'	0,5 × rated speed/frequency	0,8 × $-M_{t=2,\,10}/-I_{t=2,\,10}$	—
p_2'	0,5 × rated speed/frequency	0,4 × $-M_{t=2,\,10}/-I_{t=2,\,10}$	—
p_3'	rated speed/frequency	0,8 × $-M_{t=2,\,10}/-I_{t=2,\,10}$	—
p_4'	rated speed/frequency	0,4 × $-M_{t=2,\,10}/-I_{t=2,\,10}$	—
p_5'	0,25 × (maximum speed/frequency – rated speed/frequency) + rated speed/frequency	—	0,8 × $-P_{t=2,\,10}$
p_6'	0,25 × (maximum speed/frequency – rated speed/frequency) + rated speed/frequency	—	0,4 × $-P_{t=2,\,10}$

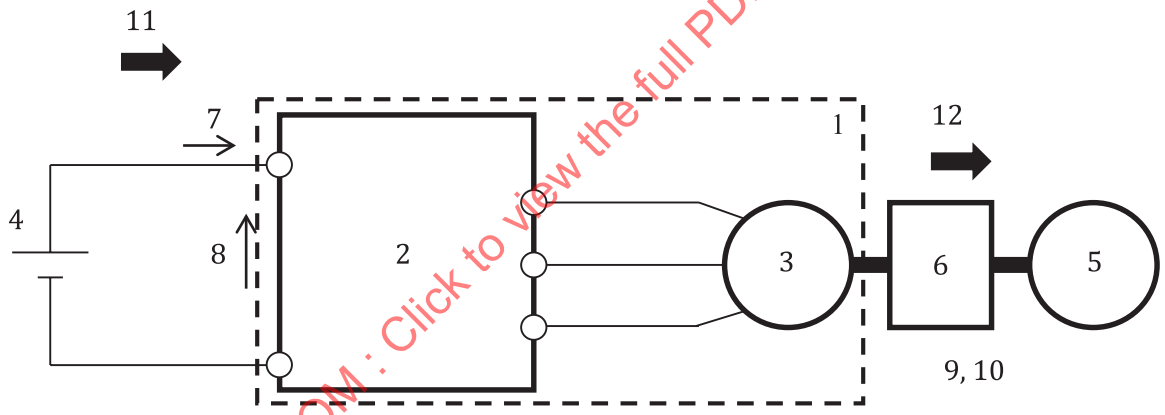
Table 6 *(continued)*

Operating point	**Motor speed** (in min^{-1}) **/frequency** (in Hz)	**Torque** (in Nm) **/current** (in A)	**Output power** (in W)
p_7'	0,5 × (maximum speed/frequency – rated speed/frequency) + rated speed/frequency	—	$0,8 \times -P_{t=2,\,10}$
p_8'	0,5 × (maximum speed/frequency – rated speed/frequency) + rated speed/frequency	—	$0,4 \times -P_{t=2,\,10}$
p_9'	0,75 × (maximum speed/frequency – rated speed/frequency) + rated speed/frequency	—	$0,8 \times -P_{t=2,\,10}$
p_{10}'	0,9 × (maximum speed/frequency – rated speed/frequency) + rated speed/frequency	—	$0,8 \times -P_{t=2,\,10}$

5.2 Provision for current, voltage and power measurement

Current, voltage and power as used in the test are defined in Figure 2, 3, 4 and 5.

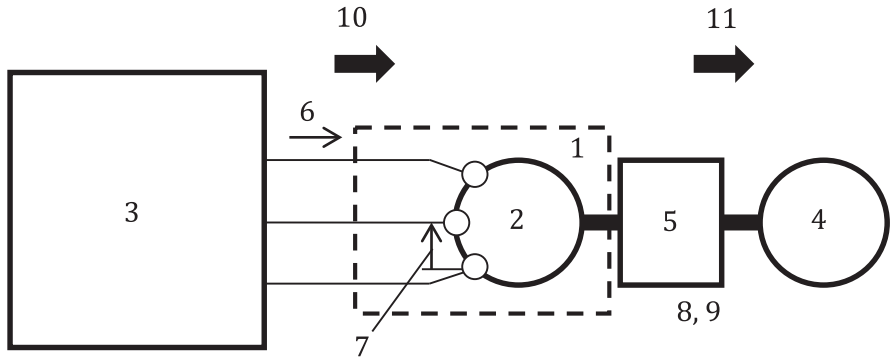
See Annex A for formulae of power.



Key

1	DUT	7	inverter input current (in A)
2	inverter	8	inverter input voltage (in V)
3	motor	9	motor torque (in Nm)
4	DC power supply	10	motor speed (in min^{-1})
5	load	11	inverter input power (in W)
6	torque/speed meter	12	motor output power (in W)

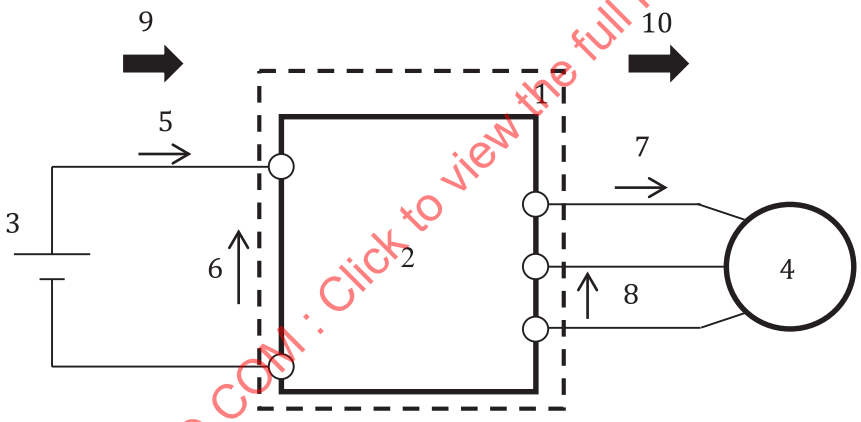
Figure 2 — Provision for current, voltage and power measurement: motor system



Key

1	DUT	7	motor input voltage (in V)
2	motor	8	motor torque (in Nm)
3	inverter	9	motor speed (in min^{-1})
4	load	10	motor input power (in W)
5	torque/speed meter	11	motor output power (in W)
6	motor input current (in A)		

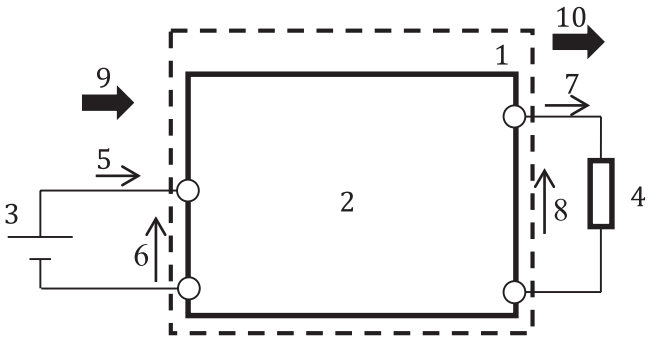
Figure 3 — Provision for current, voltage and power measurement: motor



Key

1	DUT	6	inverter input voltage (in V)
2	inverter	7	inverter output current (in A)
3	DC power supply	8	inverter output voltage (in V)
4	AC load	9	inverter input power (in W)
5	inverter input current (in A)	10	inverter output power (in W)

Figure 4 — Provision for current, voltage and power measurement: inverter



Key

1	DUT	6	chopper input voltage (in V)
2	chopper	7	chopper output current (in A)
3	DC power supply	8	chopper output voltage (in V)
4	load	9	chopper input power (in W)
5	chopper input current (in A)	10	chopper output power (in W)

Figure 5 — Provision for current, voltage and power measurement: chopper

5.3 DC input voltage

The DC input voltage shall be in a range of ±2 % of the rated component or system DC input voltage, unless other values are specified in the different parts of the ISO 21782 series or are agreed upon between the supplier and customer.

5.4 Temperature and humidity

Unless otherwise specified, all tests shall be performed at RT of (23 ± 5) °C and with a relative humidity between 25 % to 75 %.

5.5 Measurement accuracy

The measurement shall be conducted with an accuracy as shown below.

Current: ±1,0 %

Voltage: ±0,5 %

Torque: ±0,2 %

Motor speed: ±0,5 %

Temperature: ±2 K

Relative humidity: ±5 %

All measurement values, except temperature and relative humidity values, shall be measured with and recorded at a frequency of not less than 10 Hz. For temperature and relative humidity values, a measurement frequency of 1 Hz is sufficient.

Annex A
(informative)

Formula of power

A.1 Inverter input power

The inverter input power is calculated according to Formula (A.1):

$$P_{ii} = V_{ii} \times I_{ii} \tag{A.1}$$

where

P_{ii} is the inverter input power (in W);

V_{ii} is the inverter input voltage (in V);

I_{ii} is the inverter input current (in A).

A.2 Average inverter input power

The average inverter input power is calculated according to Formula (A.2):

$$P_{ii\_mean} = V_{ii\_mean} \times I_{ii\_mean} \tag{A.2}$$

where

P_{ii_mean} is the average inverter input power (in W);

V_{ii_mean} is the average inverter input voltage (in V);

I_{ii_mean} is the average inverter input current (in A).

A.3 Inverter output power

The inverter output power is calculated according to Formula (A.3), in case of three-wattmeter method:

$$P_{io} = \frac{1}{T}\int_0^T v_{io\_u}(t) \times i_{io\_u}(t)dt + \frac{1}{T}\int_0^T v_{io\_v}(t) \times i_{io\_v}(t)dt + \frac{1}{T}\int_0^T v_{io\_w}(t) \times i_{io\_w}(t)dt \tag{A.3}$$

where

P_{io} is the inverter output power (in W);

$v_{io\_u}(t)$ is the inverter u-phase output voltage at time "t" second (in V);

$v_{io\_v}(t)$ is the inverter v-phase output voltage at time "t" second (in V);

$v_{io\_w}(t)$ is the inverter w-phase output voltage at time "t" second (in V);

$i_{io\_u}(t)$ is the inverter u-phase output current at time "t" second (in A);

$i_{io\_v}(t)$ is the inverter v-phase output current at time "t" second (in A);

$i_{io\_w}(t)$ is the inverter w-phase output current at time "t" second (in A).

In case of two-wattmeter method, it is calculated according to Formula (A.4):

$$P_{io} = \frac{1}{T}\int_0^T v_{io\_uv}(t) \times i_{io\_u}(t)dt + \frac{1}{T}\int_0^T v_{io\_wv}(t) \times i_{io\_w}(t)dt \quad \text{(A.4)}$$

where

P_{io} is the inverter output power (in W);

$v_{io\_uv}(t)$ is the inverter output line voltage between u-phase and v –phase at time "t" second (in V);

$v_{io\_wv}(t)$ is the inverter output line voltage between w-phase and v –phase at time "t" second (in V);

$i_{io\_u}(t)$ is the inverter u-phase output current at time "t" second (in A);

$i_{io\_w}(t)$ is the inverter w-phase output current at time "t" second (in A).

A.4 Fundamental inverter output power

The fundamental inverter output power is calculated according to Formula (A.5):

$$P_{io\_fund} = \sqrt{3} \times V_{io\_fund} \times I_{io\_fund} \times \cos\theta \quad \text{(A.5)}$$

where

P_{io_fund} is the fundamental inverter output power (in W);

V_{io_fund} is the fundamental inverter output voltage (in V);

I_{io_fund} is the fundamental inverter output current (in A);

$\cos\theta$ is the power factor.

A.5 Chopper input power

The chopper input power is calculated according to Formula (A.6):

$$P_{ci} = \frac{1}{T}\int_0^T v_{ci}(t) \times i_{ci}(t)dt \quad \text{(A.6)}$$

where

P_{ci} is the chopper input power (in W);

$v_{ci}(t)$ is the chopper input voltage at time "t" second (in V);

$i_{ci}(t)$ is the chopper input current at time "t" second (in A).