Polski Rejestr Statków

RULES

PUBLICATION NO. 42//P

TESTING OF ELECTRIC ROTATING MACHINES

2017
January

Publications P (Additional Rule Requirements) issued by Polski Rejestr Statków complete or extend the Rules and are mandatory where applicable.

GDAŃSK

Publication No. 42/P – Testing of Electric Rotating Machines – January 2017, which is basing on the Unified Requirements (UR) E13 (Rev.2 August 2016) issued by IACS, is an extension of the requirements contained in *Part VIII – Electrical Installations and Control Systems* of the *Rules for the Classification and Construction of Sea-Going Ships,* as well as in all other PRS *Rules*, in which reference to the *Publication* has been made..

The *Publication* was approved by the PRS Board on 28 December 2016 and enters into force on 1 January 2017.

PRS/OP, 12/2016

CONTENTS

1 GENERAL

All electrical machines of essential services are to have manufacturer's attestations which confirm fulfilment of requirements specified in chapter 3 of this Publication. Such documents are to be presented to PRS surveyor.

Tests and, if necessary, manufacture of motors of 50kW and over or generators of 50 kVA and over, intended for essential services, specified in item 1.3.2.1 of *Part VIII – Electrical Installations and Control Systems* of the *Rules for the Classification and Construction of Sea-going Ships* are to be supervised by the PRS surveyor.

2 MATERIALS FOR CONSTRUCTION OF MACHINE SHAFT

The materials used for the construction of shaft of machines are to comply with requirements of appropriate Standards. The materials for the construction of shaft of main propulsion machines and generators are to comply with requirements of PRS Rules and are to have Certificate issued by classification society recognized by EU.

3 TESTS

Type tests are to be carried out on a prototype machine or on the first of produced batch of machines, while routine tests are to be carried out on subsequent machines of a particular types, in accordance with Table 3.

Test requirements may differ for shaft generators, special purpose machines and machines of novel construction.

Table 3

No.	Item in Publication	Tests	A.C. Generators		Motors	
			Type test [1)]	Routine rest [2)]	Type test [1)]	Routine test [2)]
1	2	3	4	5	6	7
1.	4.1	Examination of the technical documentation and visual inspection	X	X	X	X
2.	4.2	Insulation resistance measurement	X	X	X	X
3.	4.3	Winding resistance measurement	X	X	X	X
4.	4.4	Verification of the voltage regulation system	X	X [3)]	–	–
5.	4.5	Rated load test and temperature rise measurements	X	–	X	–
6.	4.6	Overload/overcurrent test	X	X [4)]	X	X [4)]
7.	4.7	Verification of steady short circuit conditions [5)]	X	–	–	–
8.	4.8	Overspeed test	X	X	X [6)]	X [6)]
9.	4.9	Dielectric strength test	X	X	X	X
10.	4.10	No-load test	X	X	X	X
11.	4.11	Verification of degree of protection	X	–	X	–
12.	4.11	Verification of bearings	X	X	X	X

1 Type tests on prototype machine or on at least the first of a batch of machines.
2 The report of routine test is to contain serial number of the machine which has been type tested and the tests results.
3 Functional test of voltage regulation system only.
4 Applicable only for machines of essential services of power 100kW or above.
5 Applicable only for synchronous generators.
6 Not applicable for squirrel cage motors.

4 TESTS DESCRIPTION

4.1 Examination of the technical documentation and visual inspection

4.1.1 Examination of the technical documentation

Technical documentation of machines rated at 50 kW /kVA/ and over, approved by PRS, is to be presented to PRS surveyor.

4.1.2 Visual inspection

A visual examination of the electrical machine is to be carried out by PRS surveyor to ensure that it complies with the technical documentation.

4.2 Insulation resistance measurement

Immediately after the high voltage tests the insulation resistance is to be measured using a direct current resistance measuring device between:

a) all current carrying parts connected together and earth,
b) all current carrying parts of different polarity or phase, where both ends of each polarity or phase are individually accessible.

The minimum values of test voltage and insulation resistance are specified in Table 4.2. The temperature at which the insulation resistance measurement is carried out is to be close to the operating temperature. Appropriate method of calculation may be also used.

Table 4.2

Rated Voltage U_n (V)	Minimum Test Voltage (V)	Test Minimum Insulation Resistance (MΩ)
$U_n \leq 250$	2 x U_n	1
$250 < U_n \leq 1000$	500	1
$1000 < U_n \leq 7200$	1000	$(U_n/1000) + 1$
$7200 < U_n \leq 15000$	5000	$(U_n/1000) + 1$

4.3 Winding resistance measurement

The resistance of the machine windings is to be measured and recorded using an appropriate bridge method or voltage and current measurement method.

4.4 Verification of the voltage regulation system

The alternating current generator, together with its voltage regulation system shall at all loads from no-load running to full load, be able to keep rated voltage at the rated power factor under steady conditions within ± 2.5%. These limits may be increased to ± 3.5% for emergency sets.

When the generator is driven at rated speed, giving its rated voltage, and is subjected to a sudden change of symmetrical load within the limits of specified current and power factor, the voltage is to be in a range from 85% to 120% of the rated voltage.

The voltage of the generator is then to be restored to ±3% of the rated voltage for the main generator set in not more than 1.5 s. For emergency sets, these values may be increased to ±4% and 5 s, respectively.

In the absence of precise information concerning the maximum values of the sudden loads, the following conditions may be assumed: 60% of the rated current with a power factor of between 0.4 lagging and zero to be suddenly switched on with the generator running at no load, and then switched off after steady-state conditions have been reached.

Subject to PRS approval, such voltage regulation during transient conditions may be calculated values based on the previous type test records, and need not to be tested during factory testing of a generator.

4.5 Rated load test and temperature rise measurements

The temperature rises are to be measured at the rated output, voltage, frequency and the duty for which the machine is rated and marked, in accordance with the testing methods specified in IEC Publication 60034-1. One of the following methods is to be applied:

– resistance method (the temperature is determined according to increase of the resistance of machine windings);
– embedded temperature detectors method [ETD] (at least six detectors suitably distributed throughout the machine windings);
– thermometer method (thermometers applied to accessible surfaces and ends of windings of the machine).

Last from a.m. methods is permitted in case in which two previous methods can not be used.

For machines constructed for duty type S1 (continuous duty) the test shall last until thermal equilibrium has been reached, that is when the temperature varies by not more than 2°C over a period of 1 hour. For other duty types thermal equilibrium is reached when difference of temperatures between corresponding points of successive duty cycles of machine, on a temperature plot, is less than 2°C per hour.

Permissible temperature rises of electric machines at ambient temperature +45°C are specified in table 4.5. If the temperature of coolant is lower than a.m. value, temperature rises may be appropriately increased, however, by not more than 10 °C. If the temperature of coolant is higher than a.m. value, temperature rises may be appropriately decreased.

Table 4.5

Item	Parts of electrical machines	Classes of insulating material														
		A	E			B				F				H		
		Method of measurement, [°C]														
		Thermometer	Resistance	Built-in sensors	Thermometer	Resistance	Built-in sensors	Thermometer	Resistance	Built-in sensors	Thermometer	Resistance	Built-in sensors	Thermometer	Resistance	Built-in sensors
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	A.C. windings of synchronous and asynchronous machines rated at 5000 kVA and over, or having a core length of 1 m and over	–	55	55	–	65	65	–	75	75	–	95	95	–	120	120
2	Windings of A.C. machines rated at under 5000 kVA and having a core length of less than 1 m. Field windings of D.C. and A.C. machines, D.C. excited, except such as are listed under 3, 4 and 5. Windings of rotors connected with commutator	45	55	–	60	70	–	65	75	–	80	95	–	100	120	–
3	Field windings of D.C. excited non-salient-pole machines	–	60	–	–	75	–	–	85	–	–	105	–	–	120	–
4	Single-layer field windings with exposed surface	60	60	–	75	75	–	85	85	–	105	105	–	130	130	–

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
5	Low resistance field windings with more than one layer, as well as compensating windings	55	55	–	70	70	–	75	75	–	95	95	–	120	120	–
6	Permanently short-circuited windings, insulated	55	–	–	70	–	–	75	–	–	95	–	–	120	–	–
7	Permanently short-circuited windings, uninsulated	The temperature rises of such parts are not to reach values which can cause damage of insulation or other adjacent materials														
8	Steel cores and other parts out of contact with windings															
9	Steel cores and other parts in contact with windings	55	–	–	70	–	–	75	–	–	95	–	–	120	–	–
10	Commutators and ship rings open and enclosed	55	–	–	65	–	–	75	–	–	85	–	–	95	–	–

4.6 Overload/overcurrent tests

Overload test is to be carried out as type test and depending on type of machine:

– generators: immunity to overload is to be demonstrated. Generators are to have such construction, that after warming up to steady temperature, corresponding to rated load, they are capable of sustain overcurrent of value specified in Table 4.6.

Table 4.6

Item	Type of generator	Overload by current [%]	Overload duration [s]
1	Alternating current	50	120
2	Direct current	50	15

– polyphase induction motors and direct current motors: it is to be demonstrated that during 15 s time machine will withstand without falling out of step and sudden change of speed at least 60% torque excess. Voltage and frequency are to be kept at rated values during test.
– Squirrel-cage induction motors of reduced starting current – below 4.5 times rated current: torque excess value can be lower than above specified but not less than 50%.
– polyphase synchronous motors: it is to be demonstrated that during 15 s time machine will withstand without falling out of step:
  – synchronous induction motor (wound rotor): 35% of torque excess;
  – synchronous motor (cylindrical rotor): 35% of torque excess;
  – synchronous motor (salient pole): 50% of torque excess.

The momentary excess torque for single-phase, commutator and other motor types shall be the subject of agreement with the producer.

Overload test which is performed as routine test can be replaced by overcurrent test. It shall be the proof of current capability of windings, conductors, connections, etc. of machine. Overcurrent test can be carried out at reduced speed (motors) or at short-circuit condition (generators).

Additional information: Publication IEC 60034-1, item 9.4.

4.7 Verification of steady short-circuit conditions

It is to be verified that under steady-state short-circuit conditions, the generator with its voltage regulation system is capable of maintaining, without sustaining any damage, a current of at least three times the rated current for a duration of 2 s or, where precise data is available, for a duration of any time delay which will be fitted in the tripping device for discrimination purposes.

In order to provide sufficient information to the party responsible for determining the discrimination settings in the distribution system where the generator is going to be used, the generator manufacturer shall provide documentation showing the transient behaviour of the short circuit current upon a sudden short-circuit occurring when excited, and running at nominal speed. The influence of the automatic voltage regulator shall be taken into account, and the setting parameters for the voltage regulator shall be noted together with the decrement curve. Such a decrement curve shall be available when the setting of the distribution system's short-circuit protection is calculated. The decrement curve need not be based on physical testing. The manufacturer's simulation model for the generator and the voltage regulator may be used where this has been validated through the previous type test on the same model..

4.8 Overspeed test

Electric machines are to withstand without damages and permanent deformations during 2 minutes increased rotational speed test carried out according to the following requirements:

a) generators, converters, motor-generator sets: 120% of the rated speed, but at least by 3% more than the maximum number of revolutions in transient conditions.
b) series-wound motors: 120% of the maximum permissible rotational speed specified on the rating plate, but not less than 150% of the rated speed.
c) all other motors (other than a.m.): 120% of the maximum rotational speed at no-load running.

Test is not applicable for squirrel cage motors.

4.9 Dielectric strength test

The insulation of electric machines windings is to withstand during 1 minute, without breakdown and spark-over, an alternating test voltage, practically sinusoidal, of frequency 50 Hz and of the root-mean-square value specified in table 4.9. Such voltage shall be applied between the windings under test and the frame of the machine. Core and the windings which are not under test are to be connected to the frame.

Table 4.9

Item	Electric machine part(s)		Test voltage r.m.s. value, U_p, [V]
1	2		3
1	Insulated parts of machines rated at	less than 1 kW (kVA)	$2\,U_n + 500$
		from 1 kW (kVA) to 10 000 kW (kVA)	$2\,U_n + 1000$ but not less than 1500
2	Field windings of direct-current machines supplied from external source		$2\,U_w + 1000$ but not less than 1500
3	Field windings of synchronous generators		$10\,U_w$ but not less than 1500 and not more than 3500
4	Field windings of synchronous motors, when:	starting with the field winding short-circuited or connected directly to the rotor or starting with the a.c. winding idle	$2\,U_w + 1000$ but not less than 1500
		starting either with the field winding closed through, connected in series, resistance, or with the field winding open, regardless of whether it is sectionalized or not	$2\,U_m + 1000$ but not less than 1500

1	2		3
5	Rotor windings of slip-ring induction motors or of synchronous induction motors if not permanently short-circuited (e.g. if intended for resistor starting):	for non-reversing motors or motors reversible from standstill only	2 U_r + 1000 but not less than 1500
		for reversible motors, as well as those braked by counter-current	4 U_r + 1000 but not less than 1500
6	Rotor windings of direct-current reversible crane motors		3 U_n + 1000 but not less than 1500
7	Exciters, except those mentioned in items 2 and 8		As for the field windings they are intended to supply
8	Exciters of synchronous motors or synchronous induction motors if they are disconnected from the motor during starting, or if one of the poles is connected to earth		2 U_n + 1000 but not less than 1500

U_n – rated voltage [V];
U_w – maximum value of rated excitation voltage [V];
U_m – maximum value of voltage which may occur under starting conditions between the terminals of the field winding, or, in the case of a sectionalized field winding, between branch terminals [V];
U_r – voltage between the slip rings or terminals of the rotor at standstill, with rated voltage applied to the stator terminals [V];

Additional information: Publication IEC 60034-1, item 9.2.

High voltage machines are to be taken under additional tests, which are to be carried out according to requirements of the *Rules for the Classification and Construction of Sea-Going Ships*, *Part VIII – Electrical Installations and Control Systems*:
– item 18.7.5: High voltage test at high frequency on single coils;
– item 18.10: High voltage tests and insulation resistance measurement.

4.10 No load test

Machines are to be operated at no load and rated speed whilst being supplied at rated voltage and frequency as a motor or if a generator it is to be driven by a suitable means and excited to give rated terminal voltage.

During the running test, the vibration of the machine and operation of the bearing lubrication system, if appropriate, are to be checked.

4.11 Verification of degree of protection

According to IEC Publication 60034-5.

4.12 Verification of bearings

After completion of the above tests, upon request by the PRS surveyor, machines which are provided with sleeve bearings are to be opened to establish that the shaft is correctly seated in the bearing shells.

List of amendments effective as of 1 January 2017

Item	*Title/Subject*	*Source*
Table 4.2	Insulation resistance test	IACS UR E13 (Rev.2)
4.4	Voltage regulation	
4.7	Steady short-circuit conditions	
