

# TÜRK LOYDU



**TL-R E**

## **Requirements Concerning Electrical and Electronic Installations January 2022**

These requirements are prepared by embedding related IACS Unified Requirements. In order to have consistency, the numbering of the requirements are kept as the same with related IACS Unified Requirements.

Unless otherwise specified, these Rules apply according to the implementation dates as defined in each requirement. See Rule Change Summary on TL website for revision details.

This latest edition incorporates all rule changes.

"General Terms and Conditions" of the respective latest edition will be applicable (see Rules for Classification and Surveys).

If there is a difference between the rules in English and in Turkish, the rule in English is to be considered as valid. This publication is available in print and electronic pdf version. Once downloaded, this document will become UNCONTROLLED. Please check the website below for the valid version.

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# TL- R E10 Test Specification for Type Approval

## E10.1 General

This Test Specification is applicable, but not confined, to electrical, electronic and programmable equipment intended for control, monitoring, alarm and protection systems for use in ships.

## E10.2 Testing

These tests are to demonstrate the ability of the equipment to function as intended under the specified testing conditions.

The extent of the testing (i.e. the selection and sequence of carrying out tests and number of pieces to be tested) is to be determined upon examination and evaluation of the equipment or component subject to testing giving due regard to its intended usage.

Equipment is to be tested in its normal position if otherwise not specified in the test specification.

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### Note:

1. This requirement is implemented for equipment for which the date of application for type approval certification is dated on or after 1 January 2020.
2. Equipment intended to be installed on ships contracted for construction on or after 1 January 2022 is to comply with this requirement.
3. The “contracted for construction” date means the date on which the contract to build the vessel is signed between the prospective owner and the shipbuilder. For further details regarding the date of “contract for construction”, refer to TL- PR 29.
4. The “date of application for type approval” is the date of documents accepted by TL as request for type approval certification of a new equipment type or of an equipment type that has undergone substantive modifications in respect of the one previously type approved, or for renewal of an expired type approval certificate.

Relevant tests are as listed in the Table.

Note:

- a) \* These test requirements are harmonised with IEC 60092-504 “Electrical Installations in Ships - Part 504: Special features - Control and Instrumentation” and IEC 60533 “Electrical and electronic installations in ships – electromagnetic compatibility”. Electrical and electronic equipment on board ships, required neither by classification rules nor by International Conventions, liable to cause electromagnetic disturbance shall be of type which fulfil the test requirements of test specification items 19 and 20.
- b) As used in this document, and in contrast to a complete performance test, a functional test is a simplified test sufficient to verify that the equipment under test (EUT) has not suffered any deterioration caused by the individual environmental tests.

### Type testing condition for equipment covered by E10.1

NO.	TEST	PROCEDURE ACC. TO:*	TEST PARAMETERS	OTHER INFORMATION
<p>* indicates the testing procedure which is normally to be applied. However, equivalent testing procedure may be accepted by the individual Society provided that the Unified Requirements stated in the other columns are fulfilled. The latest edition of the normative reference applies.</p>				
1.	Visual inspection	-	-	- conformance to drawings, design data
2.	Performance test	<p>Manufacturer performance test programme based upon specification and relevant Rule requirements. When the EUT is required to comply with an international performance standard, e.g. protection relays, verification of requirements in the standard are to be part of the performance testing required in this initial test and subsequent performance tests after environmental testing where required in the UR.</p>	<ul style="list-style-type: none"> <li>- standard atmosphere conditions</li> <li>- temperature: 25°C ± 10°C</li> <li>- relative humidity: 60% ± 30%</li> <li>- air pressure: 96 KPa ± 10KPa</li> </ul>	<ul style="list-style-type: none"> <li>- confirmation that operation is in accordance with the requirements specified for particular system or equipment;</li> <li>- checking of self-monitoring features;</li> <li>- checking of specified protection against an access to the memory;</li> <li>- checking against effect of unerroneous use of control elements in the case of computer systems.</li> </ul>



NO.	TEST	PROCEDURE ACC. TO:*	TEST PARAMETERS	OTHER INFORMATION
5.	Dry heat (see note 1)	IEC 60068-2-2 Test Bb for non-heat dissipating equipment	Temperature: 55° ± 2°C Duration: 16 hours or Temperature: 70°C ± 2°C Duration: 16 hours	<ul style="list-style-type: none"> <li>- equipment operating during conditioning and testing;</li> <li>- functional test (b) during the last hour at the test temperature.</li> <li>- for equipment specified for increased temperature the dry heat test is to be conducted at the agreed test temperature and duration.</li> </ul>
		IEC 60068-2-2 Test Be for heat dissipating equipment	Temperature: 55° ± 2°C Duration: 16 hours or Temperature: 70°C ± 2°C Duration: 16 hours	<ul style="list-style-type: none"> <li>- equipment operating during conditioning and testing with cooling system on if provided;</li> <li>- functional test (b) during the last hour at the test temperature.</li> <li>- for equipment specified for increased temperature the dry heat test is to be conducted at the agreed test temperature and duration.</li> </ul>
6.	Damp heat	IEC 60068-2-30 test D <sub>b</sub>	Temperature: 55°C Humidity: 95% Duration: 2 cycles 2 x (12 +12 hours)	<ul style="list-style-type: none"> <li>- measurement of insulation resistance before test;</li> <li>- the test shall start with 25°C ± 3°C and at least 95% humidity;</li> <li>- equipment operating during the complete first cycle and switched off during second cycle except for functional test;</li> <li>- functional test during the first 2 hours of the first cycle at the test temperature and during the last 2 hours of the second cycle at the test temperature; Duration of the second cycle can be extended due to more convenient handling of the functional test.</li> <li>- recovery at standard atmosphere conditions;</li> <li>- insulation resistance measurements and performance test.</li> </ul>
7.	Vibration	IEC 60068-2-6 Test F <sub>c</sub>	<p>2<sup>+3</sup> Hz to 13.2 Hz – amplitude ±1mm<sub>-0</sub></p> <p>13.2 Hz to 100 Hz – acceleration ± 0.7 g. For severe vibration conditions such as, e.g. on diesel engines, air compressors, etc.:</p> <p>2.0 Hz to 25 Hz – amplitude ±1.6 mm 25.0 Hz to 100 Hz – acceleration ± 4.0 g.</p>	<ul style="list-style-type: none"> <li>- duration in case of no resonance condition 90 minutes at 30 Hz;</li> <li>- duration at each resonance frequency at which Q ≥ 2 is recorded - 90 minutes;</li> <li>- during the vibration test, functional tests are to be carried out;</li> <li>- tests to be carried out in three mutually perpendicular planes;</li> <li>- it is recommended as guidance that Q does not exceed 5.</li> </ul>





NO.	TEST	PROCEDURE ACC. TO:*	TEST PARAMETERS	OTHER INFORMATION														
9.	Insulation resistance		<table border="1"> <thead> <tr> <th rowspan="2">Rated supply voltage Un (V)</th> <th rowspan="2">Test voltage (D.C. voltage) (V)</th> <th colspan="2">Min. insulation resistance</th> </tr> <tr> <th>before test M ohms</th> <th>after test M ohms</th> </tr> </thead> <tbody> <tr> <td>Un ≤ 65</td> <td>2 x Un min. 24V</td> <td>10</td> <td>1,0</td> </tr> <tr> <td>Un &gt; 65</td> <td>500</td> <td>100</td> <td>10</td> </tr> </tbody> </table>	Rated supply voltage Un (V)	Test voltage (D.C. voltage) (V)	Min. insulation resistance		before test M ohms	after test M ohms	Un ≤ 65	2 x Un min. 24V	10	1,0	Un > 65	500	100	10	<ul style="list-style-type: none"> <li>- For high voltage equipment, reference is made to UR E11.</li> <li>- insulation resistance test is to be carried out before and after: damp heat test, cold test, salt mist test and high voltage test;</li> <li>- between all phases and earth; and where appropriate, between the phases.</li> </ul> <p>Note: Certain components e.g. for EMC protection may be required to be disconnected for this test.</p>
Rated supply voltage Un (V)	Test voltage (D.C. voltage) (V)	Min. insulation resistance																
		before test M ohms	after test M ohms															
Un ≤ 65	2 x Un min. 24V	10	1,0															
Un > 65	500	100	10															
10.	High voltage		<table border="1"> <thead> <tr> <th>Rated voltage Un (V)</th> <th>Test voltage (A.C. voltage 50 or 60Hz) (V)</th> </tr> </thead> <tbody> <tr> <td>Up to 65</td> <td>2 x Un + 500</td> </tr> <tr> <td>66 to 250</td> <td>1500</td> </tr> <tr> <td>251 to 500</td> <td>2000</td> </tr> <tr> <td>501 to 690</td> <td>2500</td> </tr> </tbody> </table>	Rated voltage Un (V)	Test voltage (A.C. voltage 50 or 60Hz) (V)	Up to 65	2 x Un + 500	66 to 250	1500	251 to 500	2000	501 to 690	2500	<ul style="list-style-type: none"> <li>- For high voltage equipment, reference is made to UR E11.</li> <li>- separate circuits are to be tested against each other and all circuits connected with each other tested against earth;</li> <li>- printed circuits with electronic components may be removed during the test;</li> <li>- period of application of the test voltage: 1 minute</li> </ul>				
Rated voltage Un (V)	Test voltage (A.C. voltage 50 or 60Hz) (V)																	
Up to 65	2 x Un + 500																	
66 to 250	1500																	
251 to 500	2000																	
501 to 690	2500																	
11.	Cold	IEC 60068-2-1	Temperature: +5°C ± 3°C Duration: 2 hours or Temperature: -25°C ± 3°C Duration: 2 hours (see note 2)	<ul style="list-style-type: none"> <li>- initial measurement of insulation resistance;</li> <li>- equipment not operating during conditioning and testing except for functional test;</li> <li>- functional test during the last hour at the test temperature;</li> <li>- insulation resistance measurement and the functional test after recovery</li> </ul>														
12.	Salt mist	IEC 60068-2-52 Test Kb	Four spraying periods with a storage of 7 days after each.	<ul style="list-style-type: none"> <li>- initial measurement of insulation resistance and initial functional test;</li> <li>- equipment not operating during conditioning;</li> <li>- functional test on the 7th day of each storage period;</li> <li>- insulation resistance measurement and performance test 4 to 6h after recovery. (see Note 3)</li> <li>- on completion of exposure, the equipment shall be examined to verify that deterioration or corrosion (if any) is superficial in nature.</li> </ul>														

NO.	TEST	PROCEDURE ACC. TO:*	TEST PARAMETERS	OTHER INFORMATION
13.	Electrostatic discharge	IEC 61000-4-2	Contact discharge: 6kV Air discharge: 2kV, 4kV, 8kV Interval between single discharges: 1 sec. No. of pulses: 10 per polarity According to test level 3.	<ul style="list-style-type: none"> <li>- to simulate electrostatic discharge as may occur when persons touch the appliance;</li> <li>- the test is to be confined to the points and surfaces that can normally be reached by the operator;</li> <li>- Performance Criterion B (See Note 4).</li> </ul>
14.	Electromagnetic field	IEC 61000-4-3	Frequency range: 80 MHz to 6 GHz Modulation**: 80% AM at 1000Hz Field strength: 10V/m Frequency sweep rate: $\leq 1.5 \times 10^{-3}$ decades/s (or 1%/3 sec) According to test level 3.	<ul style="list-style-type: none"> <li>- to simulate electromagnetic fields radiated by different transmitters;</li> <li>- the test is to be confined to the appliances exposed to direct radiation by transmitters at their place of installation.</li> <li>- Performance criterion A (See Note 5)</li> <li>**If for tests of equipment an input signal with a modulation frequency of 1000 Hz is necessary a modulation frequency of 400 Hz may be chosen.</li> <li>- If an equipment is intended to receive radio signals for the purpose of radio communication (e.g. wifi router, remote radio controller), then the immunity limits at its communication frequency do not apply, subject to the provisions in TL- R E22.5.2.</li> </ul>
15.	Conducted low Frequency		<p>AC: Frequency range: rated frequency to 200th harmonic; Test voltage (rms): 10% of supply to 15th harmonic reducing to 1% at 100th harmonic and maintain this level to the 200th harmonic, min 3 V r.m.s, max 2 W.</p> <p>DC: Frequency range: 50 Hz - 10 kHz; Test voltage (rms): 10% of supply max. 2 W</p>	<ul style="list-style-type: none"> <li>- to stimulate distortions in the power supply system generated for instance, by electronic consumers and coupled in as harmonics;</li> <li>- performance criterion A (see Note 5).</li> <li>- See figure - "Test set-up"</li> <li>- for keeping max. 2W, the voltage of the test signal may be lower.</li> </ul>

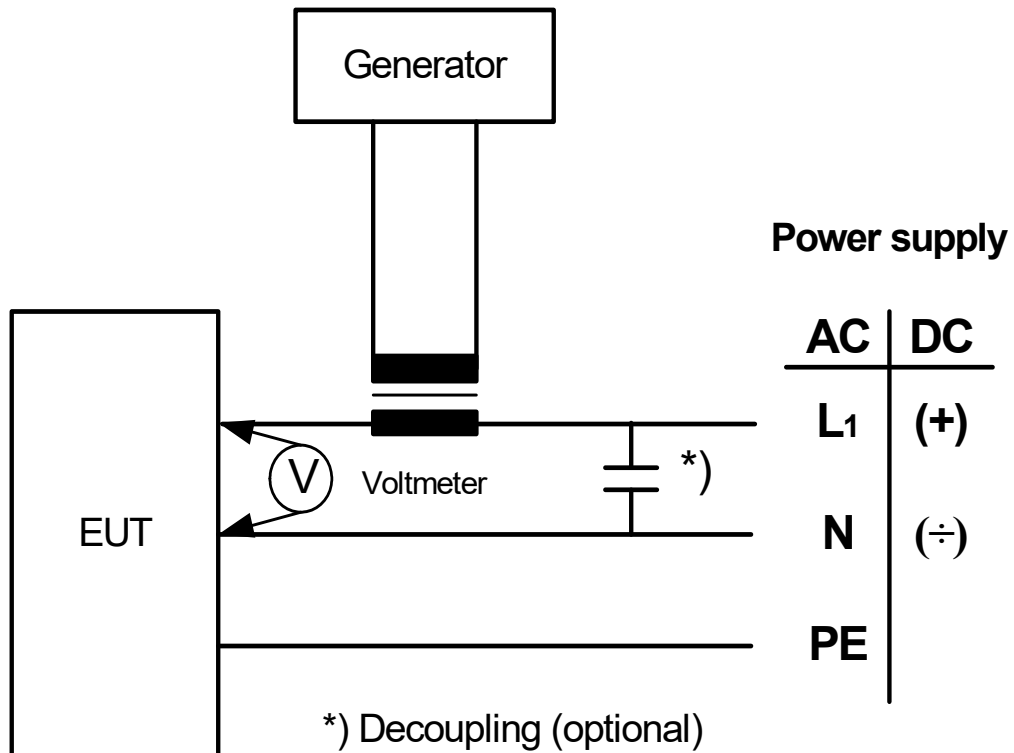
NO.	TEST	PROCEDURE ACC. TO:*	TEST PARAMETERS	OTHER INFORMATION
16.	Conducted Radio Frequency	IEC 61000-4-6	AC, DC, I/O ports and signal/control lines: Frequency range: 150 kHz - 80 MHz Amplitude: 3 V rms (See Note 6) Modulation ***: 80% AM at 1000 Hz Frequency sweep range: $\leq 1.5 \times 10^{-3}$ decades/s (or 1%/3sec.) According to test level 2.	<ul style="list-style-type: none"> <li>- Equipment design and the choice of materials is to stimulate electromagnetic fields coupled as high frequency into the test specimen via the connecting lines.</li> <li>- performance criterion A (see Note 5).</li> <li>*** If for tests of equipment an input signal with a modulation frequency of 1000 Hz is necessary a modulation frequency of 400 Hz may be chosen.</li> </ul>
17.	Electrical Fast Transients / Burst	IEC 61000-4-4	Single pulse rise time: 5 ns (between 10% and 90% value) Single pulse width: 50 ns (50% value) Amplitude (peak): 2kV line on power supply port/earth; 1kV on I/O data control and communication ports (coupling clamp) Pulse period: 300 ms; Burst duration: 15 ms; Duration/polarity: 5 min According to test level 3.	<ul style="list-style-type: none"> <li>- arcs generated when actuating electrical contacts;</li> <li>- interface effect occurring on the power supply, as well as at the external wiring of the test specimen;</li> <li>- performance criterion B (see Note 4).</li> </ul>
18.	Surge	IEC 61000-4-5	Test applicable to AC and DC power ports Open-circuit voltage: Pulse rise time: 1.2 $\mu$ s (front time) Pulse width: 50 $\mu$ s (time to half value) Amplitude (peak): 1kV line/earth; 0.5kV line/line Short-circuit current: Pulse rise time: 8 $\mu$ s (front time) Pulse width: 20 $\mu$ s (time to half value) Repetition rate: $\geq 1$ pulse/min No of pulses: 5 per polarity Application: continuous According to test level 2.	<ul style="list-style-type: none"> <li>- interference generated for instance, by switching "ON" or "OFF" high power inductive consumers;</li> <li>- test procedure in accordance with figure 10 of the standard for equipment where power and signal lines are identical;</li> <li>- performance criterion B (see Note 4).</li> </ul>

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19.	Radiated Emission	CISPR 16-2-3 IEC 60945 for 156-165 MHz	<p>Limits below 1000 MHz</p> <p>For equipment installed in the bridge and deck zone.</p> <table border="1" data-bbox="1032 328 1480 499"> <thead> <tr> <th>Frequency range:</th> <th>Quasi peak limits:</th> </tr> </thead> <tbody> <tr> <td>0.15 - 0.3 MHz</td> <td>80 - 52 dB<math>\mu</math>V/m</td> </tr> <tr> <td>0.3 - 30 MHz</td> <td>52 - 34 dB<math>\mu</math>V/m</td> </tr> <tr> <td>30 - 1000 MHz</td> <td>54 dB<math>\mu</math>V/m</td> </tr> <tr> <td>except for:</td> <td></td> </tr> <tr> <td>156 - 165 MHz</td> <td>24 dB<math>\mu</math>V/m</td> </tr> </tbody> </table> <p>For equipment installed in the general power distribution zone.</p> <table border="1" data-bbox="1032 611 1480 782"> <thead> <tr> <th>Frequency range:</th> <th>Quasi peak limits:</th> </tr> </thead> <tbody> <tr> <td>0.15 - 30 MHz</td> <td>80 - 50 dB<math>\mu</math>V/m</td> </tr> <tr> <td>30 - 100 MHz</td> <td>60 - 54 dB<math>\mu</math>V/m</td> </tr> <tr> <td>100 - 1000 MHz</td> <td>54 dB<math>\mu</math>V/m</td> </tr> <tr> <td>except for:</td> <td></td> </tr> <tr> <td>156 - 165 MHz</td> <td>24 dB<math>\mu</math>V/m</td> </tr> </tbody> </table> <p>Limits above 1000 MHz</p> <table border="1" data-bbox="1032 863 1480 922"> <thead> <tr> <th>Frequency range:</th> <th>Average limit:</th> </tr> </thead> <tbody> <tr> <td>1000 - 6000 MHz</td> <td>54 dB<math>\mu</math>V/m</td> </tr> </tbody> </table>	Frequency range:	Quasi peak limits:	0.15 - 0.3 MHz	80 - 52 dB $\mu$ V/m	0.3 - 30 MHz	52 - 34 dB $\mu$ V/m	30 - 1000 MHz	54 dB $\mu$ V/m	except for:		156 - 165 MHz	24 dB $\mu$ V/m	Frequency range:	Quasi peak limits:	0.15 - 30 MHz	80 - 50 dB $\mu$ V/m	30 - 100 MHz	60 - 54 dB $\mu$ V/m	100 - 1000 MHz	54 dB $\mu$ V/m	except for:		156 - 165 MHz	24 dB $\mu$ V/m	Frequency range:	Average limit:	1000 - 6000 MHz	54 dB $\mu$ V/m	<p>- procedure in accordance with the standard but distance 3 m between equipment and antenna</p> <p>- for the frequency band 156 MHz to 165 MHz the measurement shall be repeated with a receiver bandwidth of 9 kHz (as per IEC 60945).</p> <p>- alternatively the radiation limit at a distance of 3 m from the enclosure port over the frequency 156 MHz to 165 MHz shall be 30 dB micro-V/m Peak (as per IEC 60945).</p> <p>- procedure in accordance with the standard (distance 3 m between equipment and antenna)</p> <p>- Equipment intended to transmit radio signals for the purpose of radio communication (e.g. wifi router, remote radio controller) may be exempted from limit, within its communication frequency range, subject to the provisions in TL- R E22.5.2.</p>
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20.	Conducted Emission	CISPR 16-2-1	<p>Test applicable to AC and DC power ports</p> <p>For equipment installed in the bridge and deck zone.</p> <table border="1" data-bbox="1032 1161 1480 1278"> <thead> <tr> <th>Frequency range:</th> <th>Limits:</th> </tr> </thead> <tbody> <tr> <td>10 - 150 kHz</td> <td>96 - 50 dB<math>\mu</math>V</td> </tr> <tr> <td>150 - 350 kHz</td> <td>60 - 50 dB<math>\mu</math>V</td> </tr> <tr> <td>350 kHz - 30 MHz</td> <td>50 dB<math>\mu</math>V</td> </tr> </tbody> </table>	Frequency range:	Limits:	10 - 150 kHz	96 - 50 dB $\mu$ V	150 - 350 kHz	60 - 50 dB $\mu$ V	350 kHz - 30 MHz	50 dB $\mu$ V																					
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			<p>For equipment installed in the general power distribution zone.</p> <table border="1" data-bbox="1032 300 1480 416"> <thead> <tr> <th data-bbox="1032 300 1256 331">Frequency range:</th> <th data-bbox="1256 300 1480 331">Limits:</th> </tr> </thead> <tbody> <tr> <td data-bbox="1032 331 1256 355">10 - 150 kHz</td> <td data-bbox="1256 331 1480 355">120 - 69 dB<math>\mu</math>V</td> </tr> <tr> <td data-bbox="1032 355 1256 379">150 - 500 kHz</td> <td data-bbox="1256 355 1480 379">79 dB<math>\mu</math>V</td> </tr> <tr> <td data-bbox="1032 379 1256 416">0.5 - 30 MHz</td> <td data-bbox="1256 379 1480 416">73 dB<math>\mu</math>V</td> </tr> </tbody> </table>	Frequency range:	Limits:	10 - 150 kHz	120 - 69 dB $\mu$ V	150 - 500 kHz	79 dB $\mu$ V	0.5 - 30 MHz	73 dB $\mu$ V	
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21.	Flame retardant	IEC 60092-101 or  IEC 60695-11-5	<p>Flame application: 5 times 15 s each. Interval between each application: 15s or 1 time 30s.</p> <p>Test criteria based upon application.</p> <p>The test is performed with the EUT or housing of the EUT applying needle-flame test method.</p>	<ul style="list-style-type: none"> <li>- the burnt out or damaged part of the specimen by not more than 60 mm long.</li> <li>- no flame, no incandescence or</li> <li>- in the event of a flame or incandescence being present, it shall extinguish itself within 30 s of the removal of the needle flame without full combustion of the test specimen.</li> <li>- any dripping material shall extinguish itself in such a way as not to ignite a wrapping tissue. The drip height is 200 mm <math>\pm</math> 5 mm.</li> </ul>								

Notes:

1. Dry heat at 70 °C is to be carried out to automation, control and instrumentation equipment subject to high degree of heat, for example mounted in consoles, housings, etc. together with other heat dissipating power equipment.
2. For equipment installed in non-weather protected locations or cold locations test is to be carried out at -25°C.
3. Salt mist test is to be carried out for equipment installed in weather exposed areas.
4. Performance Criterion B: (For transient phenomena): The EUT shall continue to operate as intended after the tests. No degradation of performance or loss of function is allowed as defined in the technical specification published by the manufacturer. During the test, degradation or loss of function or performance which is self recoverable is however allowed but no change of actual operating state or stored data is allowed.
5. Performance Criterion A: (For continuous phenomena): The Equipment Under Test shall continue to operate as intended during and after the test. No degradation of performance or loss of function is allowed as defined in relevant equipment standard and the technical specification published by the manufacturer.
6. For equipment installed on the bridge and deck zone, the test levels shall be increased to 10V rms for spot frequencies in accordance with IEC 60945 at 2, 3, 4, 6.2, 8.2, 12.6, 16.5, 18.8, 22, 25 MHz.



**Figure - Test Set-up – Conducted Low Frequency Test**

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# TL- R E11 Unified requirements for systems with voltages above 1 kV up to 15 kV

## 1. General

### 1.1 Field of application

The following requirements apply to a.c. three-phase systems with nominal voltage exceeding 1kV, the nominal voltage is the voltage between phases.

If not otherwise stated herein, construction and installation applicable to low voltage equipment generally apply to high voltage equipment.

### 1.2 Nominal system voltage

The nominal system voltage is not to exceed 15 kV.

Note: Where necessary for special application, higher voltages may be accepted by TL

### 1.3 High-voltage, low-voltage segregation

Equipment with voltage above about 1 kV is not to be installed in the same enclosure as low voltage equipment, unless segregation or other suitable measures are taken to ensure that access to low voltage equipment is obtained without danger.

## 2. System Design

### 2.1 Distribution

#### 2.1.1 Network configuration for continuity of ship services

It is to be possible to split the main switchboard into at least two independent sections, by means of at least one circuit breaker or other suitable disconnecting devices, each supplied by at least one generator. If two separate switchboards are provided and interconnected with cables, a circuit breaker is to be provided at each end of the cable.

Services which are duplicated are to be divided between the sections.

#### 2.1.2 Earthed neutral systems

In case of earth fault, the current is not to be greater than full load current of the largest generator on the switchboard or relevant switchboard section and not less than three times the minimum current required to operate any device against earth fault.

It is to be assured that at least one source neutral to ground connection is available whenever the system is in the energised mode. Electrical equipment in directly earthed neutral or other neutral earthed systems is to withstand the current due to a single phase fault against earth for the time necessary to trip the protection device.

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Note:

1. This requirement is implemented from 1 July 2016.

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### 2.1.3 Neutral disconnection

Means of disconnection are to be fitted in the neutral earthing connection of each generator so that the generator may be disconnected for maintenance and for insulation resistance measurement.

### 2.1.4 Hull connection of earthing impedance

All earthing impedances are to be connected to the hull. The connection to the hull is to be so arranged that any circulating currents in the earth connections do not interfere with radio, radar, communication and control equipment circuits.

### 2.1.5 Divided systems

In the systems with neutral earthed, connection of the neutral to the hull is to be provided for each section.

## 2.2 Degrees of protection

### 2.2.1 General

Each part of the electrical installation is to be provided with a degree of protection appropriate to the location, as a minimum the requirements of IEC 60092-201.

### 2.2.2 Rotating machines

The degree of protection of enclosures of rotating electrical machines is to be at least IP 23. The degree of protection of terminals is to be at least IP44.

For motors installed in spaces accessible to unqualified personnel, a degree of protection against approaching or contact with live or moving parts of at least IP4X is required.

### 2.2.3 Transformers

The degree of protection of enclosures of transformers is to be at least IP23.

For transformers installed in spaces accessible to unqualified personnel a degree of protection of at least IP4X is required.

For transformers not contained in enclosures, see para 7.1.

### 2.2.4 Switchgear, controlgear assemblies and converters

The degree of protection of metal enclosed switchgear, controlgear assemblies and static converters is to be at least IP32. For switchgear, control gear assemblies and static converters installed in spaces accessible to unqualified personnel, a degree of protection of at least IP4X is required.

## 2.3 Insulation

### 2.3.1 Air clearance

In general, for Non Type Tested equipment phase-to-phase air clearances and phase-to-earth air clearances between non-insulated parts are to be not less than those specified in Table 2.3.1.



**Table 2.3.1**

<b>Nominal Voltage (kV)</b>	<b>Minimum air clearance (mm)</b>
3(3.3)	55
6 (6.6)	90
10 (11)	120
15	160

Intermediate values may be accepted for nominal voltages provided that the next higher air clearance is observed.

In the case of smaller distances, appropriate voltage impulse test must be applied.

### 2.3.2 Creepage distances

Creepage distances between live parts and between live parts and earthed metal parts are to be in accordance with IEC 60092-503 for the nominal voltage of the system, the nature of the insulation material and the transient overvoltage developed by switch and fault conditions.

## 2.4 Protection

### 2.4.1 Faults on the generator side of circuit breaker

Protective devices are to be provided against phase-to-phase faults in the cables connecting the generators to the main switchboard and against interwinding faults within the generators. The protective devices are to trip the generator circuit breaker and to automatically de-excite the generator.

In distribution systems with a neutral earthed, phase to earth faults are also to be treated as above.

### 2.4.2 Faults to earth

Any earth fault in the system is to be indicated by means of a visual and audible alarm. In low impedance or direct earthed systems provision is to be made to automatic disconnect the faulty circuits. In high impedance earthed systems, where outgoing feeders will not be isolated in case of an earth fault, the insulation of the equipment is to be designed for the phase to phase voltage.

Note: Earthing factor is defined as the ratio between the phase to earth voltage of the health phase and the phase to phase voltage. This factor may vary between  $(1/\sqrt{3})$  and 1.

A system is defined effectively earthed (low impedance) when this factor is lower than 0.8. A system is defined non-effectively earthed (high impedance) when this factor is higher than 0.8.

### 2.4.3 Power transformers

Power transformers are to be provided with overload and short circuit protection. When transformers are connected in parallel, tripping of the protective devices at the primary side has to automatically trip the switch connected at the secondary side.

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#### 2.4.4 Voltage transformers for control and instrumentation

Voltage transformers are to be provided with overload and short circuit protection on the secondary side.

#### 2.4.5 Fuses

Fuses are not to be used for overload protection.

#### 2.4.6 Low voltage systems

Lower voltage systems supplied through transformers from high voltage systems are to be protected against overvoltages. This may be achieved by:

- i) direct earthing of the lower voltage system.
- ii) appropriate neutral voltage limiters.
- iii) earthed screen between the primary and secondary windings of transformers.

### 3. Rotating machinery

#### 3.1 Stator windings of generators

Generator stator windings are to have all phase ends brought out for the installation of the differential protection.

#### 3.2 Temperature detectors

Rotating machinery is to be provided with temperature detectors in their stator windings to actuate a visual and audible alarm in a normally attended position whenever the temperature exceeds the permissible limit.

If embedded temperature detectors are used, means are to be provided to protect the circuit against overvoltage.

#### 3.3 Tests

In addition to the tests normally required for rotating machinery, a high frequency high voltage test in accordance with IEC 60034-15 is to be carried out on the individual coils in order to demonstrate a satisfactory withstand level of the inter-turn insulation to steep fronted switching surges.

### 4. Power Transformers

#### 4.1 General

Dry type transformers have to comply with IEC 60076-11. Liquid cooled transformers have to comply with IEC 60076. Oil immersed transformers are to be provided with the following alarms and protections:

- liquid level (Low) - alarm
- liquid temperature (High) - alarm
- liquid level (Low) - trip or load reduction
- liquid temperature (High) - trip or load reduction
- gas pressure relay (High) - trip

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## **5. Cables**

### 5.1 General

Cables are to be constructed in accordance with the IEC 60092-353 and 60092-354 or other equivalent Standard.

## **6. Switchgear and controlgear assemblies**

### 6.1 General

Switchgear and controlgear assemblies are to be constructed according to the IEC 62271-200 and the following additional requirements.

### 6.2 Construction

#### 6.2.1 Mechanical construction

Switchgear is to be of metal – enclosed type in accordance with IEC 62271-200 or of the insulation – enclosed type in accordance with the IEC 62271-201.

#### 6.2.2 Locking facilities

Withdrawable circuit breakers and switches are to be provided with mechanical locking facilities in both service and disconnected positions. For maintenance purposes, key locking of withdrawable circuit breakers and switches and fixed disconnectors is to be possible.

Withdrawable circuit breakers are to be located in the service position so that there is no relative motion between fixed and moving portions.

#### 6.2.3 Shutters

The fixed contacts of withdrawable circuit breakers and switches are to be so arranged that in the withdrawable position the live contacts are automatically covered.

Shutters are to be clearly marked for incoming and outgoing circuits. This may be achieved with the use of colours or labels.

#### 6.2.4 Earthing and short-circuiting

For maintenance purposes an adequate number of earthing and short-circuiting devices is to be provided to enable circuits to be worked upon with safety.

#### 6.2.5 Internal arc Classification (IAC)

Switchgear and controlgear assemblies shall be internal arc classified (IAC).

Where switchgear and controlgear are accessible by authorized personnel only Accessibility Type A is sufficient (IEC 62271-200; Annex AA; AA 2.2). Accessibility Type B is required if accessible by non-authorized personnel.

Installation and location of the switchgear and controlgear shall correspond with its internal arc classification and classified sides (F, L and R).

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## 6.3 Auxiliary systems

### 6.3.1 Source and capacity of supply

If electrical energy and/or physical energy is required for the operation of circuit breakers and switches, a stored supply of such energy is to be provided for at least two operations of all the components.

However, the tripping due to overload or short-circuit, and under-voltage is to be independent of any stored electrical energy sources. This does not preclude shunt tripping provided that alarms are activated upon lack of continuity in the release circuits and power supply failures.

### 6.3.2 Number of external supply sources

When external source of supply is necessary for auxiliary circuits, at least two external sources of supply are to be provided and so arranged that a failure or loss of one source will not cause the loss of more than one generator set and/or set of essential services. Where necessary one source of supply is to be from the emergency source of electrical power for the start up from dead ship condition.

## 6.4 High voltage test

A power-frequency voltage test is to be carried out on any switchgear and controlgear assemblies. The test procedure and voltages are to be according to the IEC 62271-200 section 7/ routine test.

## 7. Installation

### 7.1 Electrical equipment

Where equipment is not contained in an enclosure but a room forms the enclosure of the equipment, the access doors are to be so interlocked that they cannot be opened until the supply is isolated and the equipment earthed down.

At the entrance of the spaces where high-voltage electrical equipment is installed, a suitable marking is to be placed which indicates danger of high-voltage. As regard the high-voltage electrical equipment installed out-side a.m. spaces, the similar marking is to be provided. An adequate, unobstructed working space is to be left in the vicinity of high voltage equipment for preventing potential severe injuries to personnel performing maintenance activities. In addition, the clearance between the switchboard and the ceiling/deckhead above is to meet the requirements of the Internal Arc Classification according to IEC 62271-200 (see 6.2.5).

### 7.2 Cables

#### 7.2.1 Runs of cables

In accommodation spaces, high voltage cables are to be run in enclosed cable transit systems.

#### 7.2.2 Segregation

High voltage cables are to be segregated from cables operating at different voltage ratings each other; in particular, they are not to be run in the same cable bunch, nor in the same ducts or pipes, or, in the same box.

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Where high voltage cables of different voltage ratings are installed on the same cable tray, the air clearance between cables is not to be less than the minimum air clearance for the higher voltage side in 2.3.1. However, high voltage cables are not to be installed on the same cable tray for the cables operating at the nominal system voltage of 1 kV and less.

### 7.2.3 Installation arrangements

High voltage cables, in general, are to be installed on cable trays when they are provided with a continuous metallic sheath or armour which is effectively bonded to earth; otherwise they are to be installed for their entire length in metallic castings effectively bonded to earth.

### 7.2.4 Terminations

Terminations in all conductors of high voltage cables are to be, as far as practicable, effectively covered with suitable insulating material. In terminal boxes, if conductors are not insulated, phases are to be separated from earth and from each other by substantial barriers of suitable insulating materials.

High voltage cables of the radial field type, i.e. having a conductive layer to control the electric field within the insulation, are to have terminations which provide electric stress control.

Terminations are to be of a type compatible with the insulation and jacket material of the cable and are to be provided with means to ground all metallic shielding components (i.e. tapes, wires etc).

### 7.2.5 Marking

High voltage cables are to be readily identifiable by suitable marking.

### 7.2.6 Test after installation

Before a new high voltage cable installation, or an addition to an existing installation, is put into service a voltage withstand test is to be satisfactorily carried out on each completed cable and its accessories.

The test is to be carried out after an insulation resistance test.

For cables with rated voltage ( $U_0/U$ ) above 1.8/3 kV ( $U_m=3.6$  kV) an a.c. voltage withstand test may be carried out upon advice from high voltage cable manufacturer. One of the following test methods to be used:

- a) test for 5 min with the phase-to-phase voltage of the system applied between the conductor and the metallic screen/sheath.
- b) test for 24 h with the normal operating voltage of the system.

Alternatively, a d.c. test voltage equal to  $4 U_0$  may be applied for 15 minutes.

For cables with rated voltage ( $U_0/U$ ) up to 1.8/3 kV ( $U_m=3.6$  kV) a d.c. voltage equal to  $4 U_0$  shall be applied for 15 minutes.

After completion of the test, the conductors are to be connected to earth for a sufficient period in order to remove any trapped electric charge.

An insulation resistance test is then repeated.

# Test requirements for Rotating Machines

## 1. General

All machines are to be tested by the manufacturer.

Manufacturer's test records are to be provided for machines for essential services, for other machines they are to be available upon request.

All tests are to be carried out according to IEC 60092-301:1980/AMD2:1995.

All machines of 100kW and over, intended for essential services, are to be surveyed by the Society during test and, if appropriate, during manufacturing.

Note: An alternative survey scheme may be agreed by the Society with the manufacturer whereby attendance of the Surveyor will not be required as required above.

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### Note:

1. Rev.2 of this requirement is to be implemented for rotating machines:

- i) when an application for certification of a rotating machine is dated on or after 1 January 2017; or
- ii) which are installed in new ships for which the date of contract for construction is on or after 1 January 2017.

2. Rev.3 of this requirement is to be implemented for rotating machines:

- i) when an application for certification of a rotating machine is dated on or after 1 January 2022; or
- ii) which are installed in new ships for which the date of contract for construction is on or after 1 January 2022.

3. The "contracted for construction" date means the date on which the contract to build the vessel is signed between the prospective owner and the shipbuilder. For further details regarding the date of "contract for construction", refer to TL Procedural Requirement (TL-PR) No. 29.

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## **2. Shaft Material**

Shaft material for electric propulsion motors and for main engine driven generators where the shaft is part of the propulsion shafting is to be certified by the Society.

Shaft material for other machines is to be in accordance with recognised international or national standard.

## **3. Tests**

Type tests are to be carried out on a prototype machine or on the first of a batch of machines, and routine tests carried out on subsequent machines in accordance with Table 1.

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

**Table 1**

No.	Tests	A.C. Generators		Motors	
		Type test <sup>1)</sup>	Routine test <sup>2)</sup>	Type test <sup>1)</sup>	Routine test <sup>2)</sup>
1.	Examination of the technical documentation, as appropriate and visual inspection	x	x	x	x
2.	Insulation resistance measurement	x	x	x	x
3.	Winding resistance measurement	x	x	x	x
4.	Verification of the voltage regulation system	x	x <sup>3)</sup>		
5.	Rated load test and temperature rise measurements	x		x	
6.	Overload/overcurrent test	x	x <sup>4)</sup>	x	x <sup>4)</sup>
7.	Verification of steady short circuit conditions <sup>5)</sup>	x			
8.	Overspeed test	x	x	x <sup>6)</sup>	x <sup>6)</sup>
9.	Dielectric strength test	x	x	x	x
10.	No-load test	x	x	x	x
11.	Verification of degree of protection	x		x	
12.	Verification of bearings	x	x	x	x

1) Type tests on prototype machine or tests on at least the first batch of machines.

2) The report of machines routine tested is to contain the manufacturer's serial number of the machine which has been type tested and the test result.

3) Only functional test of voltage regulator system.

4) Only applicable for machine of essential services rated above 100kW.

5) Verification of steady short circuit condition applies to synchronous generators only.

6) Not applicable for squirrel cage motors.



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## 4. Description of the test

### 4.1 Examination of the technical documentation, as appropriate and visual inspection

#### 4.1.1 Examination of the technical documentation

Technical documentation of machines rated at 100kW and over is to be available for examination by the Surveyor.

#### 4.1.2 Visual inspection

A visual examination is to be made of the machine to ensure, as far as is practicable, that it complies with technical documentation.

### 4.2 Insulation resistance measurement

Immediately after the high voltage tests the insulation resistances are to be measured using a direct current insulation tester 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 voltages and corresponding insulation resistances are given in Table 2. The insulation resistance is to be measured close to the operating temperature, or an appropriate method of calculation is to be used.

**Table 2**

Related Voltage Un (V)	Minimum Test Voltage (V)	Test Minimum Insulation Resistance (MΩ)
Un ≤ 250	2 x Un	1
250 < Un ≤ 1000	500	1
1000 < Un ≤ 7200	1000	(Un / 1000) + 1
7200 < Un ≤ 15000	5000	(Un / 1000) + 1

### 4.3 Winding resistance measurement

The resistances of the machine windings are to be measured and recorded using an appropriate bridge method or voltage and current 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 not to fall below 85% nor exceed 120% of the rated voltage.

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The voltage of the generator is then to be restored to within plus or minus 3% of the rated voltage for the main generator sets in not more than 1.5 s. For emergency sets, these values may be increased to plus or minus 4% in not more than 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 Classification Society's 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 60034-1:2017, or by means of a combination of other tests.

The limits of temperature rise are those specified in Table 1 of IEC 60034-1:2017 adjusted as necessary for the ambient reference temperatures specified in TL-R M40.

#### **4.6 Overload/overcurrent tests**

Overload test is to be carried out as a type test for generators as a proof of overload capability of generators and excitation system, for motors as a proof of momentary excess torque as required in IEC 60034-1:2017. The overload test can be replaced at routine test by the overcurrent test. The over current test shall be the proof of current capability of windings, wires, connections etc. of each machine. The overcurrent test can be done at reduced speed (motors) or at short circuit (generators).

#### **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 regulating system is capable of maintaining, without sustaining any damage, a current of at least three times the rated current for a duration of at least 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.

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#### **4.8 Overspeed test**

Machines are to withstand the overspeed test as specified in IEC 60034-1:2017. This test is not applicable for squirrel cage motors.

#### **4.9 Dielectric strength test**

Machines are to withstand a dielectric test as specified in IEC 60034-1:2017.

For high voltage machine an impulse test is to be carried out on the coils according to TL-R E11.

#### **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**

As specified in IEC 60034-5:2000+AMD1:2006.

#### **4.12 Verification of bearings**

Upon completion of the above tests, machines which have sleeve bearings are to be opened upon request for examination by the Classification Society Surveyor, to establish that the shaft is correctly seated in the bearing shells.

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# TL-R E15 Electrical Services Required to be Operable Under Fire Conditions and Fire Resistant Cables

- 1 Electrical services required to be operable under fire conditions are as follows:
  - Control and power systems to power-operated fire doors and status indication for all fire doors
  - Control and power systems to power-operated watertight doors and their status indication
  - Emergency fire pump
  - Emergency lighting
  - Fire and general alarms
  - Fire detection systems
  - Fire-extinguishing systems and fire-extinguishing media release alarms
  - Low location lighting
  - Public address systems
  - Remote emergency stop/shutdown arrangements for systems which may support the propagation of fire and/or explosion

2 Where cables for services specified in 1 including their power supplies pass through high fire risk areas, and in addition for passenger ships, main vertical fire zones, other than those which they serve, they are to be so arranged that a fire in any of these areas or zones does not affect the operation of the service in any other area or zone. This may be achieved by either of the following measures:

- a) Cables being of a fire resistant type complying with IEC 60331-1:2018 for cables of greater than 20 mm overall diameter, otherwise IEC 60331-21:1999+AMD1:2009 or IEC 60331-2:2018 for cables with an overall diameter not exceeding 20 mm, are installed and run continuous to keep the fire integrity within the high fire risk area, see Figure 1.

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## Notes:

1. Rev.3 of this TL Requirement is to be implemented from 1 January 2016.
2. Rev.4 of this TL Requirement is to be implemented on ships contracted for construction on and after 1 January 2022.
3. The “contracted for construction” date means the date on which the contract to build the vessel is signed between the prospective owner and the shipbuilder. For further details regarding the date of “contract for construction”, refer to TL Procedural Requirement (TL-PR) No. 29.

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## TL-R E15

- b) At least two-loops/radial distributions run as widely apart as is practicable and so arranged that in the event of damage by fire at least one of the loops/radial distributions remains operational.
- c) Systems that are self monitoring, fail safe or duplicated with cable runs as widely separated as is practicable may be exempted.

3 The electrical cables to the emergency fire pump are not to pass through the machinery spaces containing the main fire pumps and their source(s) of power and prime mover(s). They are to be of a fire resistant type, in accordance with 2 (a), where they pass through other high fire risk areas.

Notes:

a) For the purpose of E15 application, the definition for “high fire risk areas” is the following:

- (i) Machinery spaces as defined by Regulation 3.30 of SOLAS Chapter II-2, as amended by IMO resolutions up to MSC.421(98) (hereinafter the same), except spaces having little or no fire risk as defined by paragraphs (10) of Regulation 9.2.2.3.2.2 of SOLAS Chapter II-2. (Including the interpretations for tables 9.3, 9.4, 9.5, 9.6, 9.7 and 9.8 given in MSC/Circ.1120 as amended by MSC.1/Circ.1436 and MSC.1/Circ.1510)
- (ii) Spaces containing fuel treatment equipment and other highly flammable substances
- (iii) Galley and Pantries containing cooking appliances
- (iv) Laundry containing drying equipment
- (v) Spaces as defined by paragraphs (8), (12), and (14) of Regulation 9.2.2.3.2.2 of SOLAS Chapter II-2 for ships carrying more than 36 passengers

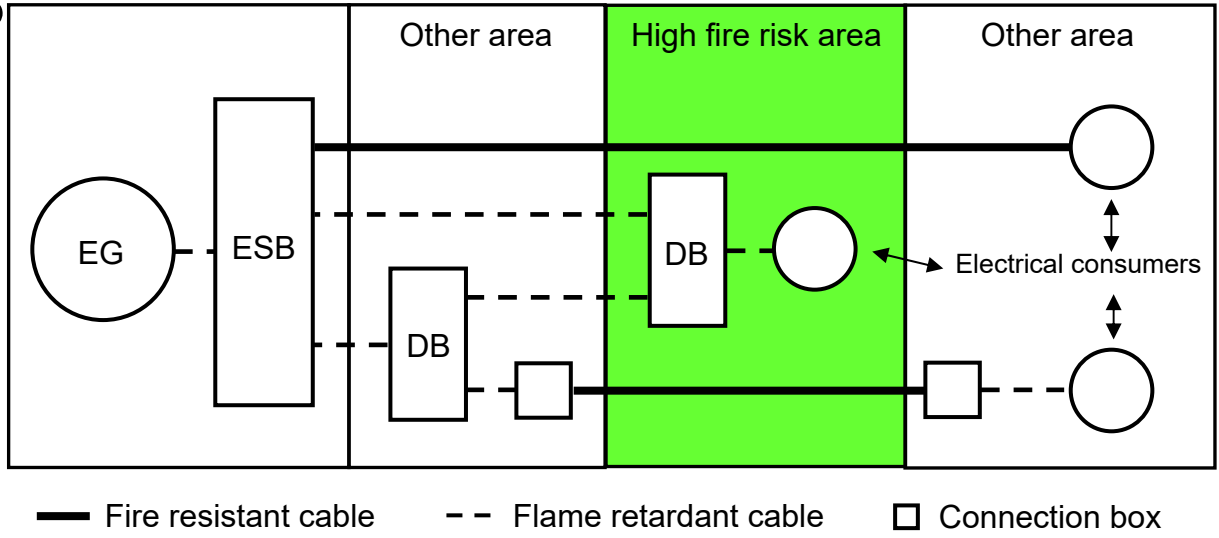
b) Fire resistant type cables should be easily distinguishable.

c) For special cables, requirements in the following standards may be used:

IEC 60331-23:1999: Procedures and requirements – Electric data cables

IEC 60331-25:1999: Procedures and requirements – Optical fibre cables

**TL-R E15**



**Figure 1**

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# TL- R E16 Cable trays/protective casings made of plastics materials

## 1. General requirement

Cable trays/protective casings made of plastics materials are to be type tested <sup>1)</sup>.

Note: "Plastics" means both thermoplastic and thermosetting plastic materials with or without reinforcement, such as PVC and fibre reinforced plastics - FRP.  
"Protective casing" means a closed cover in the form of a pipe or other closed ducts of non-circular shape.

## 2. Installation Requirements

**2.1.** Cable trays/protective casings made of plastics materials are to be supplemented by metallic fixing and straps such that in the event of a fire they, and the cables affixed, are prevented from falling and causing an injury to personnel and/or an obstruction to any escape route.

Note: When plastics cable trays/protective casings are used on open deck, they are additionally to be protected against UV light.

**2.2.** The load on the cable trays/protective casings is to be within the Safe Working Load (SWL). The support spacing is not to be greater than the Manufacturer's recommendation nor in excess of spacing at the SWL test. In general the spacing is not to exceed 2 meters.

Note: The selection and spacing of cable tray/protective casing supports are to take into account:

- cable trays/protective casings' dimensions;
- mechanical and physical properties of their material;
- mass of cable trays/protective casings;
- loads due weight of cables, external forces, thrust forces and vibrations;
- maximum accelerations to which the system may be subjected;
- combination of loads .

**2.3.** The sum of the cables' total cross-sectional area, based on the cables' external diameter, is not to exceed 40% of the protective casing's internal cross-sectional area. This does not apply to a single cable in a protective casing.

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Note:

1) Cable trays/protective casings made of plastic materials are to be type tested in accordance with the Type Approval Procedure applied by TL. For guidance on testing, refer to TL- G 73.



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# TL- R E22      **On Board Use and Application of Computer based systems**

## 1. Introduction

### 1.1 Scope

These requirements apply to design, construction, commissioning and maintenance of computer based systems where they depend on software for the proper achievement of their functions. The requirements focus on the functionality of the software and on the hardware supporting the software. These requirements apply to the use of computer based systems which provide control, alarm, monitoring, safety or internal communication functions which are subject to classification requirements.

### 1.2 Exclusion

Navigation systems required by SOLAS Chapter V, Radio-communication systems required by SOLAS Chapter IV, and vessel loading instrument/stability computer are not in the scope of this requirement.

Note: For loading instrument/stability computer, TL- G 48 may be considered.

### 1.3 References

For the purpose of application of this requirement, the following identified standards can be used for the development of hardware/software of computer based systems. Other industry standards may be considered:

- IEC 61508: Functional safety of electrical/electronic/programmable electronic safety-related systems
- ISO/IEC 12207: Systems and software engineering - Software life cycle processes
- ISO 9001:2008 Quality Management Systems - Requirements

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#### Note:

1. This requirement is to be applied only to such systems on new ships contracted for construction on and after 1 July 2017.
2. The “contracted for construction” date means the date on which the contract to build the vessel is signed between the prospective owner and the shipbuilder. For further details regarding the date of “contract for construction”, refer to TL- PR 29.



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- ISO/IEC 90003: Software engineering - Guidelines for the application of ISO 9001:2008 to computer software
  - IEC 60092-504: Electrical installations in ships - Part 504: Special features - Control and instrumentation
  - ISO/IEC 25000: Systems and software engineering - Systems and software Quality Requirements and Evaluation (SQuaRE) - Guide to SQuaRE
  - ISO/IEC 25041: Systems and software engineering - Systems and software Quality Requirements and Evaluation (SQuaRE) - Evaluation guide for developers, acquirers and independent evaluators
  - IEC 61511: Functional safety - Safety instrumented systems for the process industry sector
  - ISO/IEC 15288: Systems and software engineering - system life cycle process

## **2. Definitions**

### 2.1 Stakeholders

#### 2.1.1 Owner

The Owner is responsible for contracting the system integrator and/or suppliers to provide a hardware system including software according to the owner's specification. The Owner could be the Ship Builder Integrator (Builder or Shipyard) during initial construction. After vessel delivery, the owner may delegate some responsibilities to the vessel operating company.

#### 2.1.2 System integrator

The role of system integrator shall be taken by the yard unless an alternative organisation is specifically contracted/assigned this responsibility. The system integrator is responsible for the integration of systems and products provided by suppliers into the system invoked by the requirements specified herein and for providing the integrated system. The system integrator may also be responsible for integration of systems in the vessel.

If there are multiple parties performing system integration at any one time a single party is to be responsible for overall system integration and coordinating the integration activities. If there are multiple stages of integration different System Integrators may be responsible for specific stages of integration but a single party is to be responsible for defining and coordinating all of the stages of integration.

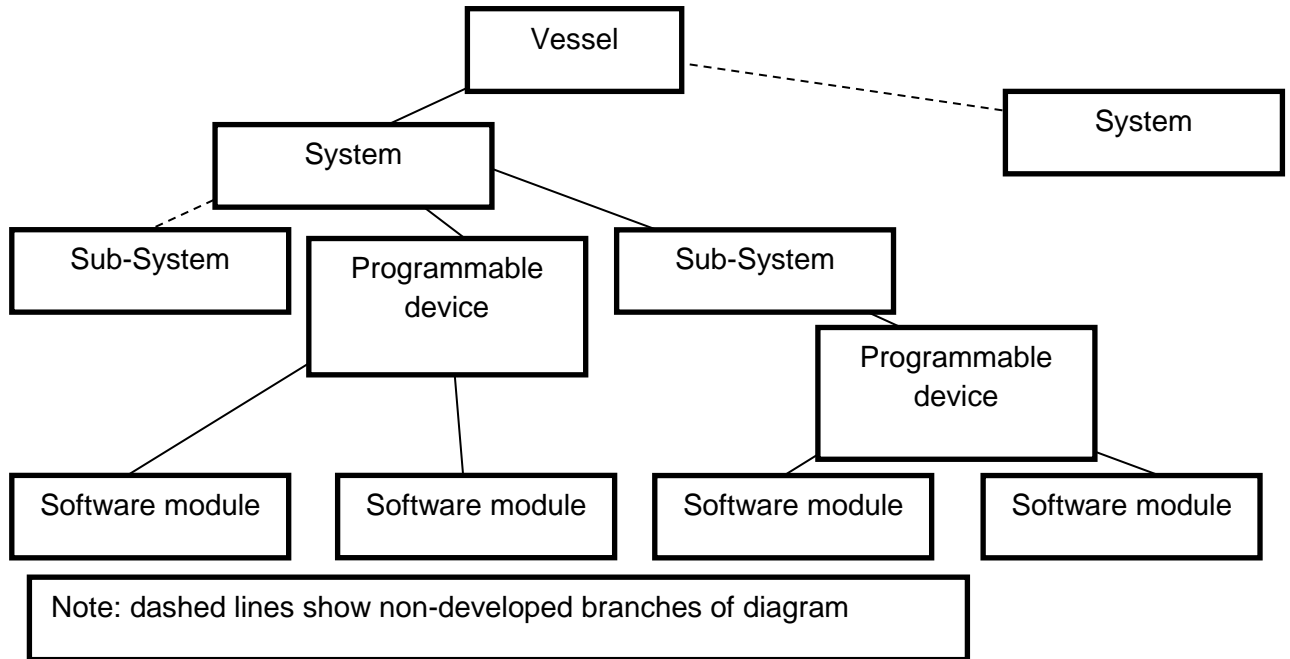
#### 2.1.3 Supplier

The Supplier is any contracted or subcontracted provider of system components or software under the coordination of the System Integrator or Shipyard. The supplier is responsible for providing programmable devices, sub-systems or systems to the system integrator. The supplier provides a description of the software functionality that meets the Owner's specification, applicable international and national standards, and the requirements specified herein.

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## 2.2 Objects

The following diagram (Figure 1) shows the hierarchy and relationships of a typical computer based system.



**Figure 1 - Illustrative System Hierarchy**

### 2.2.1 Object definitions

#### 2.2.1.1 Vessel

Ship or offshore unit where the system is to be installed.

#### 2.2.1.2 System

Combination of interacting programmable devices and/or sub-systems organized to achieve one or more specified purposes.

#### 2.2.1.3 Sub-system

Identifiable part of a system, which may perform a specific function or set of functions.

#### 2.2.1.4 Programmable device

Physical component where software is installed.

#### 2.2.1.5 Software module

A module is a standalone piece of code that provides specific and closely coupled functionality.

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## 2.3 System categories

The following table (Table 1) shows how to assign system categories based on their effects on system functionality.

**Table 1 System categories**

Category	Effects	Typical System functionality
I	Those systems, failure of which will not lead to dangerous situations for human safety, safety of the vessel and/or threat to the environment.	- Monitoring function for informational/ administrative tasks
II	Those systems, failure of which could eventually lead to dangerous situations for human safety, safety of the vessel and/or threat to the environment.	- Alarm and monitoring functions - Control functions which are necessary to maintain the ship in its normal operational and habitable conditions
III	Those systems, failure of which could immediately lead to dangerous situations for human safety, safety of the vessel and/or threat to the environment.	- Control functions for maintaining the vessel's propulsion and steering - Vessel safety functions

The following systems typically belong to Category III, the exact category being dependent on the risk assessment for all operational scenarios:

- Propulsion system of a ship, meaning the means to generate and control mechanical thrust in order to move the ship (devices used only during manoeuvring are not in the scope of this requirement such as bow tunnel thrusters)
- Steering system control system
- Electric power system (including power management system)
- Ship safety systems covering fire detection and fighting, flooding detection and fighting, internal communication systems involved in evacuation phases, ship systems involved in operation of life saving appliances equipment
- Dynamic positioning system of equipment classes 2 and 3 according to IMO MSC/Circ.645
- Drilling systems

The following systems typically belong to Category II, the exact category being dependent on the risk assessment for all operational scenarios:

- Liquid cargo transfer control system
- Bilge level detection and associated control of pumps

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- Fuel oil treatment system
  - Ballast transfer valve remote control system
  - Stabilization and ride control systems
  - Alarm and monitoring systems for propulsion systems

The example systems are not exhaustive.

## 2.4 Other terminology

### 2.4.1 Simulation tests

Control system testing where the equipment under control is partly or fully replaced with simulation tools, or where parts of the communication network and lines are replaced with simulation tools.

## 3. Requirements for software and supporting hardware

### 3.1 Life cycle approach

A global top to bottom approach shall be undertaken regarding software and the integration in a system, spanning the software lifecycle. This approach shall be accomplished according to software development standards as listed herein or other standards recognized by the Class Society.

#### 3.1.1 Quality system

System integrators and suppliers shall operate a quality system regarding software development and testing and associated hardware such as ISO 9001 taking into account ISO 90003.

Satisfaction of this requirement shall be demonstrated by either:

- The quality system being certified as compliant to the recognized standard by an organisation with accreditation under a national accreditation scheme, or
- The Class Society confirming compliance to the standard through a specific assessment.

This quality system shall include:

3.1.1.1 Relevant procedures regarding responsibilities, system documentation, configuration management and competent staff.

3.1.1.2 Relevant procedures regarding software lifecycle and associated hardware:

- Organization set in place for acquisition of related hardware and software from suppliers
- Organization set in place for software code writing and verification
- Organization set in place for system validation before integration in the vessel

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### 3.1.1.3 Minimum requirements for approval of Quality system:

- Having a specific procedure for verification of software code of Category II and III at the level of systems, sub-systems and programmable devices and modules
- Having check points for TL for Category II and III systems (see Annex for the minimum check points<sup>1</sup>)
- Having a specific procedure for software modification and installation on board the vessel defining interactions with owners

### 3.1.1.4 Quality Plan

A document, referred to herein as a Quality Plan, shall be produced that records how the quality management system will be applied for the specific computer based system and that includes, as a minimum, all of material required by paragraphs 3.1.1.1 to 3.1.1.3 inclusively.

## 3.1.2 Design phase

### 3.1.2.1 Risk assessment of system

This step shall be undertaken to determine the risk to the system throughout the lifecycle by identifying and evaluating the hazards associated with each function of the system. A risk assessment report shall upon request be submitted to TL:

This document shall normally be submitted by the System Integrator or the Supplier, including data coming from other suppliers.

IEC/ISO31010 "Risk management - Risk assessment techniques" may be applied in order to determine method of risk assessment. The method of risk assessment shall be agreed by the society.

Based on the risk assessment, a revised system category might need to be agreed between Class and the system supplier.

Where the risks associated with a computer based system are well understood, it is permissible for the risk assessment to be omitted, however in such cases the supplier or the system integrator shall provide a justification for the omission. The justification should give consideration to:

- How the risks are known
- The equivalence of the context of use of the current computer based system and the computer based system initially used to determine the risks
- The adequacy of existing control measures in the current context of use

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<sup>1</sup> Examples of check points can be a required submittal of documentation, a test event, a technical design review meeting, or peer review meeting.

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### 3.1.2.2 Code production and testing

The following documentation shall be provided to TL for Category II and III systems:

- Software modules functional description and associated hardware description for programmable devices. This shall be provided by Supplier and System Integrator.
- Evidence of verification (detection and correction of software errors) for software modules, in accordance with the selected software development standard. Evidence requirements of the selected software standard might differ depending on how critical the correct operation of the software is to the function it performs (i.e. IEC 61508 has different requirements depending on SILs, similar approaches are taken by other recognized standard). This shall be supplied by the Supplier and System Integrator.
- Evidence of functional tests for programmable devices at the software module, sub-system, and system level. This shall be supplied by the Supplier via the System Integrator. The functional testing shall be designed to test the provisions of features used by the software but provided by the operating system, function libraries, customized layer of software and any set of parameters.

### 3.1.3 Integration testing before installation on board

Intra-system integration testing shall be done between system and sub-system software modules before being integrated on board. The objective is to check that software functions are properly executed, that the software and the hardware it controls interact and function properly together and that software systems react properly in case of failures. Faults are to be simulated as realistically as possible to demonstrate appropriate system fault detection and system response. The results of any required failure analysis are to be observed. Functional and failure testing can be demonstrated by simulation tests.

For Category II and III systems:

- Test programs and procedures for functional tests and failure tests shall be submitted to TL. A FMEA may be requested by TL in order to support containment of failure tests programs.
- Factory acceptance test including functional and failure tests shall be witnessed TL.

Following documentation shall be provided:

- (i) Functional description of software
- (ii) List and versions of software installed in system
- (iii) User manual including instructions for use during software maintenance
- (iv) List of interfaces between system and other ship systems
- (v) List of standards used for data links
- (vi) Additional documentation as requested by TL which might include an FMEA or equivalent to demonstrate the adequacy of failure test case applied

### 3.1.4 Approval of programmable devices for Category II and III systems

Approval of programmable devices integrated inside a system shall be delivered to the system integrator or supplier. Approval can be granted on case by case basis, or as part of a product type approval, so long as above mentioned documents have been

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reviewed/approved (as per annex) and the required tests have been witnessed by TL (also see paragraph 4 regarding hardware environmental type tests). Documentation should address the compatibility of the programmable device in the ship's application, the necessity to have on board tests during ship integration and should identify the components of system using the approved programmable devices.

### 3.1.5 Final integration and on board testing

Simulation tests are to be undertaken before installation, when it is found necessary to check safe interaction with other computerized systems and functions that could not be tested previously.

On board tests shall check that a computer based system in its final environment, integrated with all other systems with which it interacts is:

- Performing functions it was designed for
- Reacting safely in case of failures originated internally or by devices external to the system
- Interacting safely with other systems implemented on board vessel

For final integration and on board testing of Category II and III systems:

- Test specifications shall be submitted to TL for approval The tests shall
- be witnessed by TL.

### 3.2 Limited approval

Sub-systems and programmable devices may be approved for limited applications with service restrictions by TL when the ship system where they will be integrated is not known. In this case, requirements about Quality systems under paragraph 3.1.1 might need to be fulfilled as required by TL. Additional drawings, details, tests reports and surveys related to the Standard declared by the Supplier may be required by TL upon request.

Sub-systems and programmable devices may in this case be granted with a limited approval mentioning the required checks and tests performed.

### 3.3 Modifications during operation

#### 3.3.1 Responsibilities

Organizations in charge of software modifications shall be clearly declared by Owner to TL. A System integrator shall be designated by the Owner and shall fulfil requirements mentioned in paragraph 3.1. Limited life cycle steps may be considered for modifications already considered and accepted in the scope of initial approval. The level of documentation needed to be provided for the modification shall be determined by TL.

At the vessel level, it is the responsibility of Owner to manage traceability of these modifications; the achievement of this responsibility shall be supported by system integrators updating the Software Registry. This Software Registry shall contain:

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- List and versions of software installed in systems required in paragraph 3.1.3
  - Results of security scans as described in paragraph 3.4

### 3.3.2 Change management

The owner shall ensure that necessary procedures for software and hardware change management exist on board, and that any software modification/upgrade are performed according to the procedure. All changes to computer based systems in the operational phase shall be recorded and be traceable.

### 3.4 System security

Owner, system integrator and suppliers shall adopt security policies and include these in their quality systems and procedures.

For Category I, II, and III systems, physical and logical security measures shall be in place to prevent unauthorized or unintentional modification of software, whether undertaken at the physical system or remotely.

Prior to installation, all artefacts, software code, executables and the physical medium used for installation on the vessel are to be scanned for viruses and malicious software. Results of the scan are to be documented and kept with the Software Registry.

## 4. Requirements for hardware regarding environment

Evidence of environmental type testing according to TL- R E10 regarding hardware elements included in the system and sub-systems shall be submitted to TL for Category I, II and III computer based systems. This requirement is not mandatory for Category I computer based systems not considered by Class.

## 5. Requirements for data links for Category II and III systems

### 5.1 General requirements

5.1.1 Loss of a data link shall be specifically addressed in risk assessment analysis.

5.1.2 A single failure in data link hardware shall be automatically treated in order to restore proper working of system. For Category III systems a single failure in data link hardware shall not influence the proper working of the system.

5.1.3 Characteristics of data link shall prevent overloading in any operational condition of system.

5.1.4 Data link shall be self-checking, detecting failures on the link itself and data communication failures on nodes connected to the link. Detected failures shall initiate an alarm.

### 5.2 Specific requirements for wireless data links

5.2.1 Category III systems shall not use wireless data links unless specifically considered by TL on the basis of an engineering analysis carried out in accordance with an International or National Standard acceptable to TL.



5.2.2 Other categories of systems may use wireless data links with following requirements:

5.2.2.1 Recognised international wireless communication system protocols shall be employed, incorporating:

- Message integrity. Fault prevention, detection, diagnosis, and correction so that the received message is not corrupted or altered when compared to the transmitted message.
- Configuration and device authentication. Shall only permit connection of devices that are included in the system design.
- Message encryption. Protection of the confidentiality and or criticality of the data content.
- Security management. Protection of network assets, prevention of unauthorized access to network assets.

5.2.2.2 The internal wireless system within the vessel shall comply with the radio frequency and power level requirements of International Telecommunication Union and flag state requirements.

Consideration should be given to system operation in the event of port state and local regulations that pertain to the use of radio-frequency transmission prohibiting the operation of a wireless data communication link due to frequency and power level restrictions.

5.2.2.3 For wireless data communication equipment, tests during harbour and sea trials are to be conducted to demonstrate that radio-frequency transmission does not cause failure of any equipment and does not its self-fail as a result of electromagnetic interference during expected operating conditions.

### Annex: Documents for Class Society and test attendance

Ⓐ Submitted (For Approval)    ① Provided (For Information)    Ⓜ Witness

<sup>1</sup> Additional documentation may be required upon request

<sup>2</sup> Upon request

<sup>3</sup> If in the scope of Class requirement

Requirement	SUPPLIER INVOLVED	SYSTEM INTEGRATOR INVOLVED	OWNER INVOLVED	CATEGORY I <sup>1</sup>	CATEGORY II	CATEGORY III
Quality Plan	X	X		Ⓐ <sup>2</sup>	Ⓐ	Ⓐ
Risk assessment report		X		① <sup>2</sup>	① <sup>2</sup>	① <sup>2</sup>
Software modules functional description and associated hardware description	X (if necessary)	X			①	①
Evidence of verification of software code	X (if necessary)	X			①	①
Evidence of functional tests for elements included in systems of Category II and III at the level of software module, sub-system and system	X	X			①	①
Test programs and procedures for functional tests and failure tests including a supporting FMEA or equivalent, at the request of TL		X			Ⓐ	Ⓐ
Factory acceptance test event including functional and failure tests	X	X			Ⓜ	Ⓜ
Test program for simulation tests for final integration		X			Ⓐ	Ⓐ
Simulation tests for final integration		X			Ⓜ	Ⓜ
Test program for on board tests (includes wireless network testing)		X			Ⓐ	Ⓐ
On board integration tests (includes wireless network testing)		X			Ⓜ	Ⓜ

Requirement	SUPPLIER INVOLVED	SYSTEM INTEGRATOR INVOLVED	OWNER INVOLVED	CATEGORY I <sup>1</sup>	CATEGORY II	CATEGORY III
- List and versions of software installed in system - Functional description of software - User manual including instructions during software maintenance - List of interfaces between system and other ship systems		X			①	①
Updated Software Registry		X	X		①	①
Procedures and documentation related to Security Policy					①	①
Test reports according to TL- R E10 requirements	X	X		Ⓐ <sup>3</sup>	Ⓐ	Ⓐ

# **Harmonic Distortion for Ship Electrical Distribution System including Harmonic Filters**

## **1. Scope**

This requirement apply to ships where harmonic filters are installed on main busbars of electrical distribution system, other than those installed for single application frequency drives such as pump motors.

## **2. General**

The total harmonic distortion (THD) of electrical distribution systems is not to exceed 8%.

This limit may be exceeded where all installed equipment and systems have been designed for a higher specified limit and this relaxation on limits is documented (harmonic distortion calculation report) and made available on board as a reference for the surveyor at each periodical survey.

## **3. Monitoring of harmonic distortion levels for a ship including harmonic filters**

3.1 The ships are to be fitted with facilities to continuously monitor the levels of harmonic distortion experienced on the main busbar as well as alerting the crew should the level of harmonic distortion exceed the acceptable limits. Where the engine room is provided with automation systems, this reading should be logged electronically, otherwise it is to be recorded in the engine log book for future inspection by the surveyor.

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### **Note:**

1. This requirement, except for Section 3.2, is implemented:
  - i. for ships contracted for construction on or after 1 July 2020 or
  - ii. the retrofit of harmonic filters is dated on or after 1 July 2020.
2. Section 3.2 is implemented for ships contracted for construction before 1 July 2017, at any scheduled Machinery periodical survey having a due date on or after 1 July 2017.
3. The “contracted for construction” date means the date on which the contract to build the vessel is signed between the prospective owner and the shipbuilder. For further details regarding the date of “contract for construction”, refer to TL- PR 29.

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3.2 As a minimum, harmonic distortion levels of main busbar on board such existing ships are to be measured annually under seagoing conditions as close to the periodical machinery survey as possible so as to give a clear representation of the condition of the entire plant to the surveyor. Harmonic distortion readings are to be carried out when the greatest amount of distortion is indicated by the measuring equipment. An entry showing which equipment was running and/or filters in service is to be recorded in the log so this can be replicated for the next periodical survey. Harmonic distortion levels are also to be measured following any modification to the ship's electrical distribution system or associated consumers by suitably trained ship's personnel or from a qualified outside source.

Records of all the above measurements are to be made available to the surveyor at each periodical survey.

#### **4. Mitigation of the effects of harmonic filter failure on a ship's operation**

Where the electrical distribution system on board a ship includes harmonic filters the system integrator of the distribution system is to show, by calculation, the effect of a failure of a harmonic filter on the level of harmonic distortion experienced.

The system integrator of the distribution system is to provide the ship owner with guidance documenting permitted modes of operation of the electrical distribution system while maintaining harmonic distortion levels within acceptable limits during normal operation as well as following the failure of any combination of harmonic filters.

The calculation results and validity of the guidance provided are to be verified by the surveyor during sea trials.

#### **5. Protection arrangements for harmonic filters**

Arrangements are to be provided to alert the crew in the event of activation of the protection of a harmonic filter circuit.

A harmonic filter should be arranged as a three phase unit with individual protection of each phase. The activation of the protection arrangement in a single phase shall result in automatic disconnection of the complete filter. Additionally, there shall be installed a current unbalance detection system independent of the overcurrent protection alerting the crew in case of current unbalance.

Consideration is to be given to additional protection for the individual capacitor element as e.g. relief valve or overpressure disconnecter in order to protect against damage from rupturing. This consideration should take into account the type of capacitors used.

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# TL- R E25      **Failure detection and response of all types of steering control systems**

## **1. Failure detection**

1.1 The most probable failures that may cause reduced or erroneous system performance shall be automatically detected and at least the following failure scenarios shall be considered:

- (a) Power supply failure
- (b) Earth fault on AC and DC circuits
- (c) Loop failures in closed loop systems, both command and feedback loops (normally short circuit, broken connections and earth faults)
- (d) Data communication errors
- (e) Programmable system failures (Hardware and software failures)
- (f) Hydraulic locking
- (g) Deviation between rudder order and feedback\*

\* Deviation alarm shall be initiated if the rudder's actual position does not reach the set point within acceptable time limits for the closed loop control systems (e.g. follow-up control and autopilot). Deviation alarm may be caused by mechanical, hydraulic or electrical failures.

1.2 All failures detected shall initiate audible and individual visual alarm on the navigation bridge.

## **2. System response upon failure**

2.1 The failures (as defined but not limited to those in 1.1) likely to cause uncontrolled movements of rudder are to be clearly identified. In the event of detection of such failure, the rudder should stop in the current position. Alternatively the rudder can be set to return to the midship/neutral position in the event of a failure. This is subject to the discretion of TL.

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Note:

- 1. This requirement is implemented on ships contracted for construction (as defined in TL- PR 29) on or after 1 July 2017.
- 2. The "contracted for construction" date means the date on which the contract to build the vessel is signed between the prospective owner and the shipbuilder. For further details regarding the date of "contract for construction", refer to TL- PR 29.