

Electrical installations of ships and mobile and fixed offshore units —

Part 1: Procedures for calculating short-circuit currents in three-phase a.c.

ICS 47.020.60

National foreword

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The UK participation in its preparation was entrusted to Technical Committee JPEL/18, Electrical installations of ships and of mobile and fixed offshore units, which has the responsibility to:

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- present to the responsible international/European committee any enquiries on the interpretation, or proposals for change, and keep the UK interests informed;
- monitor related international and European developments and promulgate them in the UK.

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**Installations électriques à bord des navires
et des plates-formes mobiles et fixes en mer –**

**Partie 1:
Evaluation des courants de court-circuit
en c.a. triphasé**

**Electrical installations of ships and mobile
and fixed offshore units –**

**Part 1:
Procedures for calculating short-circuit currents
in three-phase a.c.**



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INTERNATIONAL ELECTROTECHNICAL COMMISSION

**ELECTRICAL INSTALLATIONS OF SHIPS AND
MOBILE AND FIXED OFFSHORE UNITS –**

**Part 1: Procedures for calculating short-circuit
currents in three-phase a.c.**

FOREWORD

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This part of International Standard IEC 61363 has been prepared by IEC technical committee 18: Electrical installations of ships and of mobile and fixed offshore units.

This standard cancels and replaces IEC 60363, published in 1972.

The text of this standard is based on the following documents:

FDIS	Report on voting
18/831/FDIS	18/837/RVD

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

ELECTRICAL INSTALLATIONS OF SHIPS AND MOBILE AND FIXED OFFSHORE UNITS –

Part 1: Procedures for calculating short-circuit currents in three-phase a.c.

1 Scope and object

This International Standard outlines procedures for calculating short-circuit currents that may occur on a marine or offshore a.c. electrical installation.

The calculation methods are for use on unmeshed three-phase alternating current systems,

- a) operating at 50 Hz or 60 Hz;
- b) having any system voltage specified in IEC 60092-201 table 2;
- c) having one or more different voltage levels;
- d) comprising generators, motors (both synchronous and asynchronous), transformers, reactor coils, cables, and converter units;
- e) having their neutral point connected to the ship's hull through an impedance (designed to limit the short-circuit current flowing to the ship's hull);
- f) having their neutral point isolated from the ship's hull.

The calculation procedures are for a three-phase symmetrical short-circuit condition i.e. three-phase conductors shorted together, or shorted to the ship's hull and for which the short-circuit occurs on all three poles simultaneously. The calculation of short-circuit currents resulting from asymmetric short-circuit conditions can lead to higher aperiodic (d.c.) components of the short-circuit current and is not considered in this standard.

The calculating formulae and methods described produce sufficiently accurate results to calculate the short-circuit current during the first 100 ms of a fault condition. They can be used to calculate the short-circuit current for periods longer than 100 ms when calculating on a bus system to which the generators are directly connected. For time periods beyond 100 ms the controlling effects of the system voltage regulators may be predominant. Calculations including the voltage regulator effects are not considered in this standard.

The object of this standard is to present formulae for calculating short-circuit currents of the active components of an electrical system and to indicate how such formulae may be simplified when calculating the short-circuit current at various locations on the electrical system. The calculations give estimates of the prospective short-circuit current when the system's active components produce their maximum contribution.

The calculating formulae are developed from basic electrical engineering theories relevant to the system components. To simplify the calculation methods yet retain an acceptable level of accuracy in the results, suitable assumptions are outlined and their effects on the calculation results indicated.

This standard provides a calculation procedure. It gives guidance on the interpretation and application of simplifying formulae and the corresponding results when applied to the selection of switchgear. The standard is not intended to provide any other information other than the calculation of the short-circuit current which may flow in the network.

In order to understand the methods, and consequences of the results, it is assumed that the person responsible for initiating the short-circuit current calculations, is thoroughly familiar with valid electrical engineering fundamentals.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this International Standard. At the time of publication, the editions indicated were valid. All normative documents are subject to revision, and parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

IEC 60034-4:1985, *Rotating electrical machines – Part 4: Methods for determining synchronous machine quantities from tests*

IEC 60038:1983, *IEC standard voltages*

IEC 60050(151):1978, *International Electrotechnical Vocabulary (IEV) – Chapter 151: Electrical and magnetic devices*

IEC 60050(411):1996, *International Electrotechnical Vocabulary (IEV) – Chapter 411: Rotating machinery*

IEC 60050(441):1984, *International Electrotechnical Vocabulary (IEV) – Chapter 441: Switchgear, controlgear and fuses*

IEC 60092-201:1994, *Electrical installations in ships – Part 201: System design – General*

IEC 60092-202:1994, *Electrical installations in ships – Part 202: System design – Protection*

IEC 60909:1988, *Short-circuit current calculation in three-phase a.c. systems*

3 Definitions, symbols, subscripts and superscripts

3.1 Definitions

For the purpose of this International Standard the following definitions and symbols apply.

3.1.1

short circuit

accidental or intentional connection, by a relatively low resistance or impedance, of two or more points in a circuit which are normally at different voltages. [IEV 151-03-41]

3.1.2

short-circuit current

over-current resulting from a short circuit due to a fault or an incorrect connection in an electric circuit. [IEV 441-11-07]

3.1.3**prospective current** (with respect to a switching device)

short-circuit current that would flow in the circuit if each pole of the device were replaced by a conductor of negligible impedance. [IEV 441-17-01, modified]

3.1.4**symmetrical short-circuit current**

r.m.s. value of the a.c. symmetrical component of a prospective (available) short-circuit current, the aperiodic component of current, if any, being neglected. (IEC 60909, subclause 3.4)

3.1.5**initial symmetrical short-circuit current I''_k**

r.m.s. value of the a.c. symmetrical component of a prospective (available) short-circuit current applicable at the instant of short circuit if the impedance remains at zero-time value. (3.5 of IEC 60909, see also figure 2).

3.1.6**subtransient short-circuit current I''_{kd} in the direct axis**

r.m.s. value of the short-circuit current flowing through a circuit with rotating machine(s) having an impedance (reactance) equal to the subtransient impedance (reactance) of the circuit.

3.1.7**transient short-circuit current I'_k in the direct axis**

r.m.s. value of the short-circuit current flowing through a circuit with rotating machine(s) having an impedance (reactance) equal to the transient impedance (reactance) of the circuit.

3.1.8**steady-state short-circuit current I_{kd} in the direct axis**

r.m.s. value of the short-circuit symmetrical current flowing through a circuit with generator(s) which remains after the decay of the transient phenomena.

3.1.9**aperiodic (d.c.) component of the short-circuit current i_{dc}**

component of current in a circuit immediately after it has been suddenly short-circuited, all components of fundamental and higher frequencies being excluded.

NOTE – It is the mean value between the top and bottom envelope of a short-circuit current decaying from an initial value A to zero according to figure 2.

3.1.10**peak short-circuit current i_p**

maximum possible instantaneous value of the prospective (available) short-circuit current (see figure 2 and 3.8 of IEC 60909).

NOTE – For three-phase short circuits it is assumed that the short circuit occurs simultaneously in all phase conductors.

3.1.11**direct-axis subtransient short-circuit time constant T''_d**

time required for the rapidly changing component, present during the first few cycles in the direct-axis short-circuit current following a sudden change in operating conditions, to decrease to $1/e$, i.e. 0,368 of its initial value, the machine (or equivalent machine) running at rated speed. [IEV 411-48-30, modified]

3.1.12**direct-axis subtransient open-circuit time constant T''_{do}**

time required for the rapidly changing component present during the first few cycles of the open-circuit primary winding voltage which is due to direct-axis flux following a sudden change in operation, to decrease to $1/e$ i.e. 0,368 of its initial value, the machine running at rated speed. [IEV 411-48-29, modified]

3.1.13

direct-axis transient short-circuit time constant T'_d

time required for the slowly changing component of the direct-axis short-circuit primary current following a sudden change in operating conditions, to decrease to $1/e$ i.e. 0,368 of its initial value, the machine running at rated speed. [IEC 411-48-28, modified]

3.1.14

direct-axis transient open-circuit time constant T'_{do}

time required for a slowly changing component of the open-circuit primary voltage, which is due to the direct-axis flux, following a sudden change in operating conditions, to decrease to $1/e$ i.e. 0,368 of its initial value, the machine running at rated speed. [IEV 411-48-27, modified]

3.1.15

DC time constant T_{dc}

time required for the d.c. component present in the short-circuit current, following a sudden change in operating conditions, to decrease to $1/e$ i.e. 0,368 of its initial value, the machine running at rated speed (see clause 20 of IEC 60034-4).

3.1.16

direct-axis subtransient reactance X''_d (saturated value)

quotient of the initial value of a sudden change in that fundamental a.c. component of primary voltage, which is produced by the total direct-axis primary flux, and the value of the simultaneous change in fundamental a.c. component of direct-axis primary current, the machine running at rated speed. [IEV 411-50-11, modified].

3.1.17

direct-axis transient reactance X'_d (saturated value)

quotient of the initial value of a sudden change in that fundamental a.c. component of primary voltage which is produced by the total direct-axis primary flux, and the value of the simultaneous change in fundamental a.c. component of direct-axis primary current, the machine running at rated speed and the high decrement components during the first cycles being excluded. [IEV 411-50-09, modified]

3.1.18

direct-axis synchronous reactance X_d

quotient of the steady-state value of that fundamental a.c. component of primary voltage which is produced by the total direct-axis primary flux, and direct-axis primary current after the decay of the transient phenomena.

3.1.19

stator resistance of a generator R_a

resistance of the stator of a synchronous machine, measured at d.c. current.

3.1.20

short-circuit impedance Z

quotient of the sinusoidal voltage per phase on a balanced a.c. system and the same frequency component of the short-circuit current in that system.

3.1.21

voltage source

active element which can be represented by an ideal voltage source independent of all currents and voltages in the circuit, in series with a passive circuit element. [IEV 131-01-37]

3.1.22**nominal system voltage U_n**

voltage (line-to-line) by which a system is designated and to which certain operating characteristics are referred (see IEC 60038).

3.1.23**subtransient voltage of a rotating machine E''**

r.m.s. value of the symmetrical internal voltage of a machine which is active behind the subtransient impedance Z'' at the moment of short circuit.

3.1.24**transient voltage of a rotating machine E'**

r.m.s. value of the symmetrical internal voltage of a machine which is active behind the transient impedance Z' at the moment of short circuit.

3.1.25**nominal value (n)**

suitable approximate quantity value used to designate or identify a component, device or equipment. [IEV 151-04-01]

3.1.26**rated value (r)**

quantity value assigned, generally by a manufacturer, for a specified operating condition of a component, device or equipment. [IEV 151-04-03]

3.1.27**equivalent generator (motor)**

fictitious generator (motor) having characteristics which will produce the same short-circuit current at any point on an electrical installation, as would be produced by a combination of generators (motors) having different ratings and different characteristics, which are connected to the system (see clause 7).

3.2 Symbols

All equations are written without units specified. The symbols represent quantities possessing both numerical values and dimensions that are independent of units provided a coherent unit system is chosen, i.e. "système international d'unités (SI)".

In case of impedance, reactance, resistance and voltage drops, capital letters denote absolute values and lower-case letters denote relative values (per unit or per cent).

For time-dependent values (current, voltage), capital letters denote r.m.s. values and lower, case letters denote momentary (instantaneous) values.

ϕ	phase angle
E''_q E'_q	subtransient and transient q-axis voltage of a generator (r.m.s.)
E''_M	subtransient voltage of a motor (r.m.s.)
f	frequency
f_e	lowest frequency of a shaft generator
f_r	rated frequency of a network
I'' I'	subtransient and transient short-circuit current of the equivalent generator (r.m.s.)
I_*	current of an equivalent generator (r.m.s.)

$I''_M I''_{M*}$	subtransient short-circuit current of an asynchronous motor and an equivalent motor (r.m.s.)
$I''_{kd} I'_{kd}$	subtransient and transient initial short-circuit current of a synchronous machine (r.m.s.)
I	current (r.m.s.)
I_{ac}	a.c. component of the short-circuit current of a synchronous machine (r.m.s.)
I_{acM}	symmetrical short-circuit current of an asynchronous motor (r.m.s.)
I_{LR}	asynchronous motor locked rotor current
i_{dc}	d.c. component of the short-circuit current of a synchronous machine (instantaneous)
i_{dcM}	d.c. component of the short-circuit current of an asynchronous motor and an equivalent motor (instantaneous)
i_k	upper envelope of the short-circuit current
I_*	steady-state short-circuit current of an equivalent generator (r.m.s.)
I_{kd}	steady-state short-circuit current of a synchronous machine (r.m.s.)
i_M	upper envelope of the short-circuit current of an asynchronous motor
$i_p i_{pM}$	peak value of the short-circuit current of a synchronous machine and an asynchronous motor
I_r	rated current (r.m.s.)
L''_{SC}	subtransient inductance of a synchronous condenser of a shaft generator system (synchronous machine)
L''_{SG}	subtransient inductance of a synchronous shaft generator system with converter
L_C	cable inductance
L_{com}	inductance of the commutation coils of a synchronous shaft generator system with converter
L_{dc}	inductance of the d.c. circuit of a synchronous shaft generator system with converter
P_{Cu}	copper losses of a transformer at rated frequency
R	resistance
R_*	resistance of an equivalent generator
R_a	stator resistance of a synchronous machine
R_C	cable resistance
R_{dc}	d.c. resistance
R_M	resistance of an asynchronous motor
R_R	rotor resistance of an asynchronous motor
R_{R*}	rotor resistance of an equivalent asynchronous motor
R_S	stator resistance of an asynchronous motor
R_{S*}	stator resistance of an equivalent asynchronous motor
R_T	resistance of a transformer
S_{rT}	rated power of a transformer
t	time duration from the beginning of a short circuit
t_r	the quotient of the rated high voltage and the rated low voltage of a transformer
t_x	defined time duration from the beginning of a short circuit

T''_d T'_d	subtransient and transient time constant of a synchronous machine
T''_{d*} T'_{d*}	subtransient and transient time constant of an equivalent generator
T''_{do} T'_{do}	subtransient and transient open-circuit time constant of a synchronous machine
T''_e T'_e	subtransient and transient time constant of a synchronous machine including the non-active components
T''_M T'_M	subtransient time constant of an asynchronous motor and an equivalent asynchronous motor
T''_{Me}	subtransient time constant of an equivalent asynchronous motor including the connecting cables
T_{dc} T_{dc*}	d.c. time constant of a synchronous machine and an equivalent generator
T_{dce}	d.c. time constant of a synchronous machine including the non-active components
T_{dcM} T_{dcM*}	d.c. time constant of an asynchronous motor and an equivalent asynchronous motor
T_{dcMe}	d.c. time constant of an asynchronous motor including the connecting cables
U_0	prefault voltage (line-to-line)
U_n	nominal voltage (line-to-line)
U_r	rated voltage (line-to-line)
u_{rk}	rated short-circuit voltage of a transformer
u_{rL}	rated short-circuit voltage of a reactor coil
U_{rM}	rated voltage of a motor
u_{rR}	rated ohmic voltage of a transformer
ω_r	$2\pi f_r$
X''_*	subtransient reactance of an equivalent generator
X	reactance
X''_d X'_d	subtransient and transient reactance of a synchronous machine in the d-axis
X''_M	subtransient reactance of an asynchronous motor
X''_{M*}	subtransient reactance of an equivalent asynchronous motor
X''_{Me}	subtransient reactance of an asynchronous motor including the connecting cables
X_d	reactance of a synchronous machine in the d-axis
X_R X_S	rotor and stator reactance of an asynchronous motor
X_L	reactance of a coil
X_T	reactance of a transformer
Z Z_*	impedance and equivalent impedance
Z''_*	subtransient impedance of an equivalent generator
Z''_d Z'_d	subtransient and transient impedance of a synchronous machine
Z''_e Z'_e	subtransient and transient impedance of a synchronous machine including the non-active components
Z''_M	subtransient impedance of an asynchronous motor
Z''_{M*}	subtransient impedance of an equivalent asynchronous motor
Z_T	impedance of a transformer

3.3 Subscripts

*	equivalent generator or asynchronous motor
0	prefault conditions
ac	alternating current
C	cable
com	commutation coil of a shaft generator
d	direct axis
dc	direct current
e	value including non-active components (external)
<u>E</u> , <u>I</u> , <u>U</u>	phasors of E, I, U
G	synchronous generator
HV	high-voltage side of a transformer
i	number of generators
j	number of motors
k	short circuit
L	inductance
LV	low-voltage side of a transformer
M	asynchronous motor or group of motors
n	nominal value
q	quadrature-axis
R	rotor of an asynchronous motor
r	rated value
S	stator of an asynchronous motor
SC	shaft generator synchronous condenser machine
SG	shaft generator
To	total
T	transformer
<u>Z</u>	complex impedance

3.4 Superscripts

"	subtransient value
'	transient value

4 Introductory information

4.1 General

The planning, design and operation of a marine or offshore electrical installation may require several studies to assist in the evaluation of system performance, reliability, safety and operation under both normal and short-circuit conditions. Such studies may be for load flow, stability, motor starting, transient conditions, earthing or harmonics. The system design engineer decides which studies are required for any particular installation. Short-circuit current studies are considered to be the most likely required for marine and offshore systems, regardless of their size and complication.