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TECHNICAL REPORT

Short-circuit currents in three-phase a.c. systems –
Part 2: Data of electrical equipment for short-circuit current calculations

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SHORT-CIRCUIT CURRENTS IN THREE-PHASE AC SYSTEMS –

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FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
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The main task of IEC technical committees is to prepare International Standards. However, a technical committee may propose the publication of a technical report when it has collected data of a different kind from that which is normally published as an International Standard, for example "state of the art".

IEC 60909-2, which is a technical report, has been prepared by IEC technical committee 73: Short-circuit currents.

This technical report is to be read in conjunction with IEC 60909-0 and IEC 60909-3.

This second edition cancels and replaces the first edition published in 1992. This edition constitutes a technical revision.

The significant technical changes with respect to the previous edition are as follows:

– Subclause 2.5 gives equations and examples for the calculation of the positive-, the negative and the zero-sequence impedances and reduction factors for high-, medium and low-voltage cables with sheaths and shields earthed at both ends.
– Subclause 2.7 gives equations and figures for the calculation of the positive-sequence impedances of busbar configurations.

The text of this technical report is based on the following documents:

Enquiry draft	Report on voting
73/142/DTR	73/145/RVC

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

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts of the IEC 60909, published under the general title *Short-circuit currents in three-phase a.c. systems*, can be found on the IEC website.

The committee has decided that the contents of this publication will remain unchanged until the maintenance result date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

A bilingual version of this publication may be issued at a later date.

SHORT-CIRCUIT CURRENTS IN THREE-PHASE AC SYSTEMS –

Part 2: Data of electrical equipment for short-circuit current calculations

1 General

1.1 Scope and object

This part of IEC 60909 comprises data of electrical equipment collected from different countries to be used when necessary for the calculation of short-circuit currents in accordance with IEC 60909-0.

Generally, electrical equipment data are given by the manufacturers on the name plate or by the electricity supplier.

In some cases, however, the data may not be available. The data in this report may be applied for calculating short-circuit currents in low-voltage networks if they are in accordance with typical equipment employed in the user's country. The collected data and their evaluation may be used for medium- or high-voltage planning purposes and also for comparison with data given by manufacturers or electricity suppliers. For overhead lines and cables the electrical data may in some cases also be calculated from the physical dimensions and the material following the equations given in this report.

Thus this technical report is an addition to IEC 60909-0. It does not, however, change the basis for the standardized calculation procedure given in IEC 60909-0 and IEC 60909-3.

1.2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60909-0:2001, *Short-circuit currents in three-phase a.c. systems – Part 0: Calculation of currents*

IEC 60909-3:-[1], *Short-circuit currents in three-phase a.c. systems – Part 3: Currents du-ring two separate simultaneous line-to-earth short-circuit currents and partial short-circuit currents flowing through earth*

2 Data for electrical equipment

2.1 General

The data presented are necessary for the calculation of short-circuit currents. They are sometimes presented in the form of curve sheets and sometimes in the form of examples in tables. In the case of easy equations they are given for the calculations of positive-sequence and zero-sequence short-circuit impedances for overhead lines and cables.

1 To be published.

In all, 15 National Committees provided information in response to a questionnaire sent out before the first edition of this report. Table 1 of the first edition of this report is given in Annex A.

In some cases, average values or characteristic trends as function of rated power, rated voltage, etc. are given.

2.2 Data of typical synchronous machines

Characteristic data of synchronous machines are listed in Table 1. The reactances are given as relative values related to $Z_{rG} = U_{rG}^2 / S_{rG}$ (see IEC 60909-0). Sometimes they are given in %.

In Figure 1 the sub-transient reactances of synchronous machines (generators, motors and condensers) in the direct axis of 50 Hz or 60 Hz machines are plotted as a function of the rated power.

Table 1 – Actual data of typical synchronous generators, motors and condensers

No	Type a)	Rated appar. power	Rated voltage and deviation b)		Power factor	Relative values of reactances and d.c time constant						Note	National Commit-tee
		S_{rG}	U_{rG}	$\pm p_G$	$\cos \varphi_{rG}$	x''_d	$x_{(2)}$ c)	$x_{(0)}$ d)	x_d e)	x_{dsat} f)	T_{DC} g)		
	-	MVA	kV	%	-	-	-	-	-	-	s		
1	TG2	64	13,8	±5	0,85	0,179	0,170	0,104	1,87	1,87	0,220	60 Hz	USA
2	TG2	100	10,5	±5	0,80	0,134	-	-	1,77	1,45	0,246	50 Hz	Germany
3	TG2	125	10,5	±5	0,80	0,160	0,180	0,08	2,13	1,87	0,460	50 Hz	ex-GDR
4	TG2	180	10,5	±5	0,90	0,250	0,230	0,14	1,83	1,77	0,480	50 Hz	Austria
5	TG2	353	18,0	±5	0,85	0,167	0,204	0,089	2,26	2,17	0,194	50 Hz	China
6	TG2	388,9	17,5	±5	0,90	0,203	0,202	0,099	2,42	2,19	0,250	50 Hz	Australia
7	SG14	48	10	±5	0,90	0,16	0,17	0,05	0,78	-	0,16	50 Hz	Italy
8	SG20	290	18,0	±5	0,90	0,22	0,22	0,14	1,03	0,96	0,36	60 Hz	Japan
9	SM2	1,45	10	+5 –10	0,90	0,166	0,166	0,046	1,63	-	0,04	50 Hz	ex-USSR
10	SM3	3,40	4,0	±5	0,80	0,249	0,303	-	2,675	2,675	0,116	60 Hz	USA
11	SC10	40	13,8	±5	0	0,119	0,129	-	1,33	1,33	0,1425	60 Hz	USA
12	SC6	100	10,5	±5	0	0,20	0,25	0,095	1,78	1,60	0,57	50 Hz	ex-Czechos-lovakia

a) TG2: Two-pole turbo generator
SG: Salient pole generator
SM: Synchronous motor
SC: Salient pole synchronous condenser

b) $U_G = U_{rG}\left(1 \pm \frac{p_G}{100\%}\right)$

c) Negative-sequence reactance
d) Zero-sequence reactance
e) Unsaturated synchronous reactance
f) Saturated synchronous reactance
g) DC time constant for a three-phase terminal short circuit

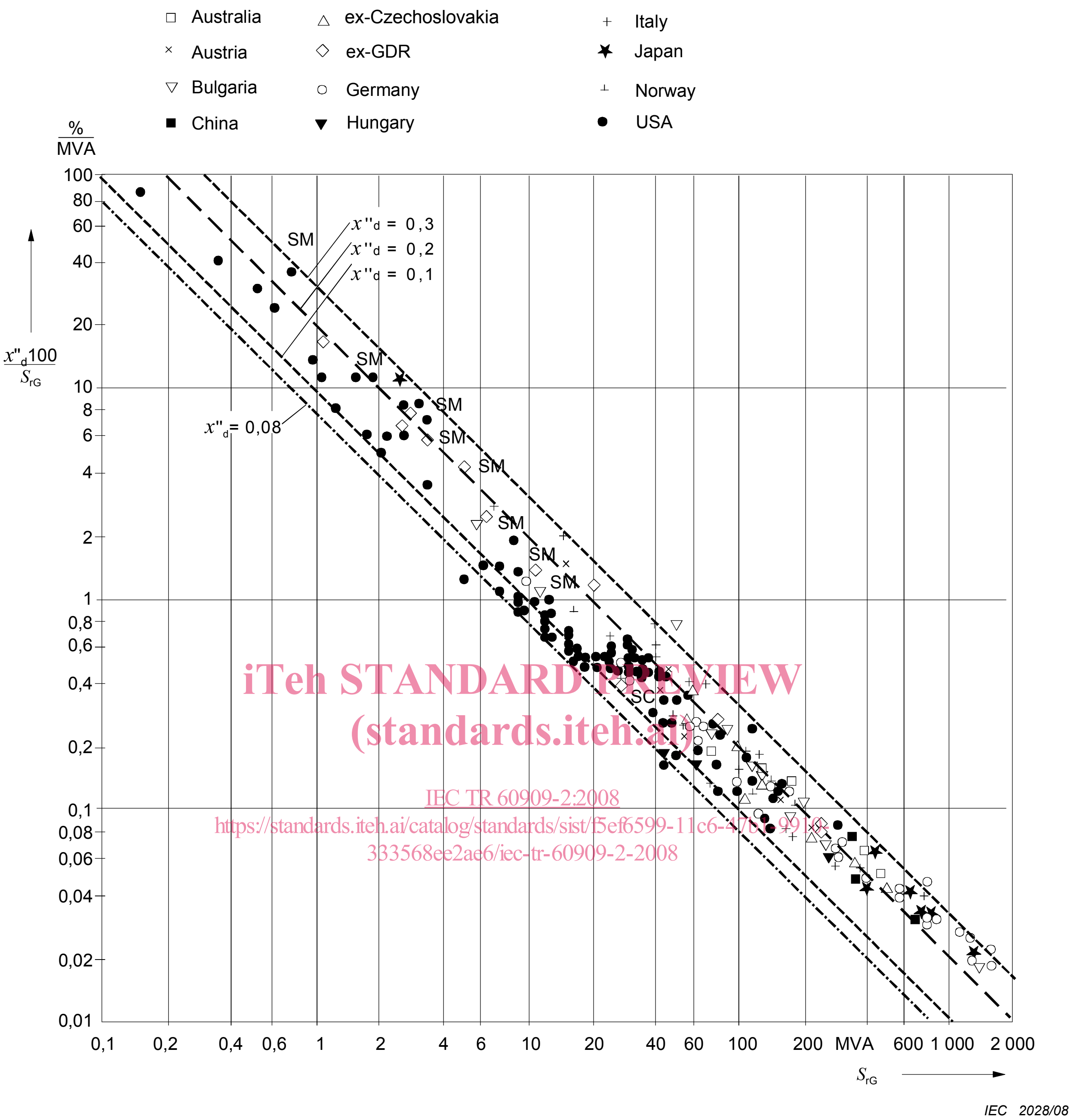

Figure 1 – Subtransient reactance of synchronous machines 50 Hz and 60 Hz (Turbogenerators, salient pole generators, motors SM and condensers SC)

In Figure 2 the rated voltages and power factors of 50 Hz or 60 Hz synchronous machines (generators, motors) are plotted as a function of the rated power.

In Figure 3 unsaturated and saturated (x_{dsat}/x_d) synchronous reactances for 50 Hz and 60 Hz turbogenerators, used for the calculation of the steady state short-circuit current, are plotted as a function of the rated power.

Data are also given for the zero-sequence reactance. It is recommended that the relationship $X_{(0)} / X''_d$ = 0,5 is used.

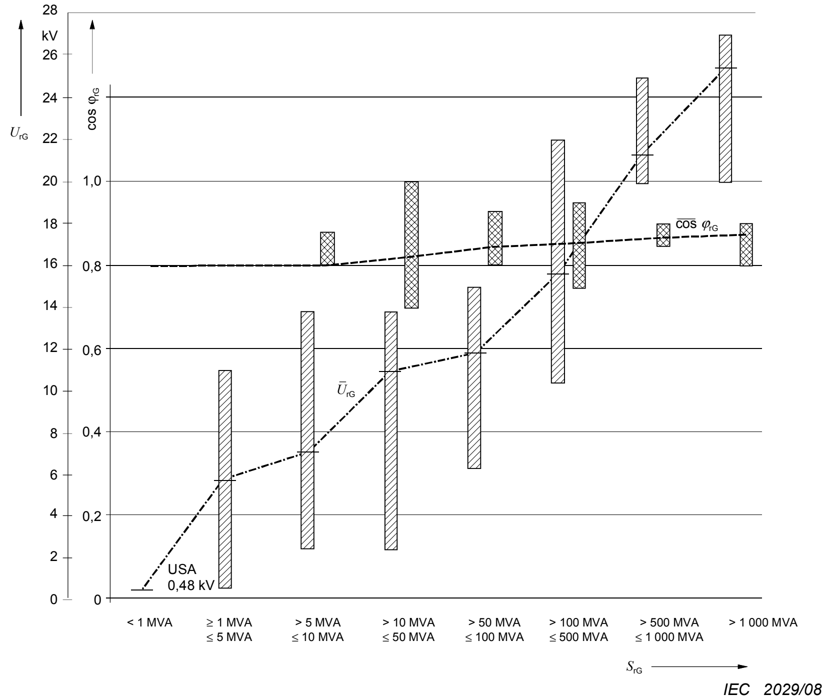

Figure 2 – Rated Voltage U_{rG} and rated power factor $\cos\varphi_{rG}$ of synchronous machines (Turbo generators, salient pole generators, motors and condensers 50 Hz and 60 Hz)

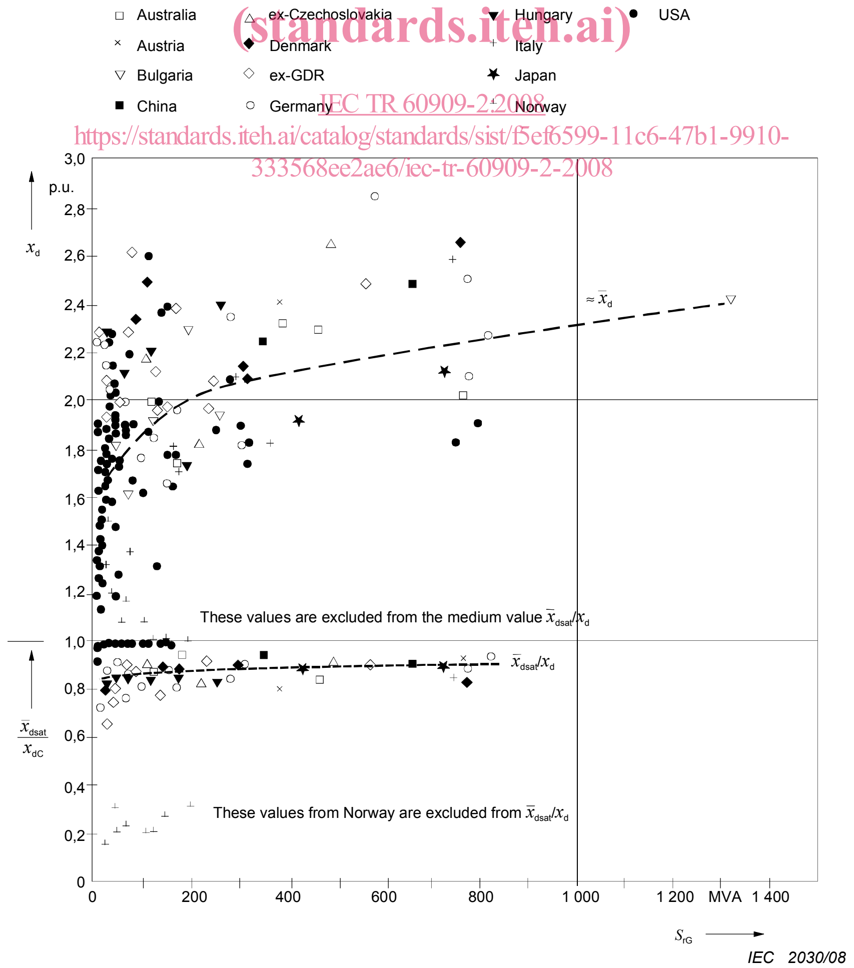

Figure 3 – Unsaturated and saturated synchronous reactance of two-pole turbo generators 50 Hz and 60 Hz (relative values)

2.3 Data of typical two-winding, three-winding and auto-transformers

In Tables 2, 3 and 4 characteristic data of two-winding, three-winding and auto-trans-formers are listed.

Table 2 – Actual data of typical two-winding transformers (NT: network; ST: power station)

No	Rated appar. power	Rated voltage		Rated short-circuit voltage		Winding connec-tion symbol HV LV	Side of Earth-ing	$\frac{X_{(0)}}{X_{(1)}}$	Tap-changer			Notes	National Commit-tee
	S_{rT}	U_{rTHV}	U_{rTLV}	u_{kr}	u_{Rr}				$\pm p_T$	u_{k+}	u_{k-}		
	MVA	kV	kV	%	%	–		–	%	%	%		
1	0,63	20	0,4	6,0	1,2	Dyn5	LV	≈ 1	±5	off-load		NT, 50 Hz, 3 limb	ex-GDR
2	24	33	11	24,2	1,12	YNyn0	HV, LV	0,7	±10	24,1	25,3	NT, 50 Hz, 3 limb	UK
3	31,5	112	22,2	12,8	0,37	YNd5	HV	≈ 1	±18	13,9	10,5	NT, 50 Hz	Germany
4	80	121	6,3	10,5	–	YNd5	HV	0,71	2×2,5	–	–-	NT, 50 Hz, 3 limb	Bulgaria
5[a)]	500	400	132	26,1	0,30	YNynd5	HV, LV	≈ 1,6	±13			NT, 50 Hz	Denmark
6	20	138	13,2	10,58	0,49	Dyn1	LV	0,93	+2,5 – 7,5			ST, 60 Hz, 3 limb	USA
7	25	132	6,3	10,5		YNd11	HV	1,0				ST, 59 Hz, 3 limb	Hungary
8	180	110	10,5	12,0	0,221	Yd11		0,78	±12			ST, 50 Hz	Austria
9	390	350	23,0	15,92	0,554	YNd1	HV	1,0	+10 – 15	16,7	15,5	ST, 50 Hz, 3 limb	Australia
10	780	230	21,0	15,3	0,2	YNd5	HV	≈ 0,8	±15	16,7	14,3	ST, 50 Hz	Germany

a) Two-winding transformer with an auxiliary winding in delta-connection (see Table 3).

Table 3 – Actual data of typical three-winding transformers

No	Rated apparent powers			Rated voltages			Rated short-circuit voltages			Winding connection symbol	Zero-sequence reactances related to side A			Note	National Commit-tee
	S_{rTAB}	S_{rTAC}	S_{rTBC}	U_{rTA}	U_{rTB}	U_{rTC}	u_{krAB}	u_{krAC}	u_{krBC}		$X_{(0)A}$	$X_{(0)B}$	$X_{(0)C}$		
	MVA	MVA	MVA	kV	kV	kV	%	%	%	HV MV LV	Ω	Ω	Ω		
1	7,5	7,5	7,5	34,5	13,8	13,8	3,65	3,58	7,96	YN d1 d1	–	–	–	60 Hz 3 limb	USA
2	25	16	16	120	22	11	11,0	14,5	3,5	YN yn0 d11	99,0	–	3,15	50 Hz 3 limb	Hungary
3	31,5	31,5	31,5	110	38,5	6,3	10,5	17,5	6,5	YN yn0 d11	6,13	17,23	18,24	“	China
4	94	94	94	239	130	13,8	11,79	11,31	12,44	YN yn0 d11	32,39	39,23	36,31	“	Italy
5	125	42	42	230	63	20	11,7	10,6	5,9	YN yn0 d11	124,6	-	5,74	50 Hz 5 limb	ex-GDR
6	600	150	150	400	230	30	17,5	16,5	11,3	YN yn0 d5	50,5	-3,8	125,3	“	Austria

For the transformer No. 6 in Table 3 the following Figure 4 gives additional information. The low-voltage winding C (30 kV) is laying near the iron core, the medium-voltage winding B (230 kV) between the windings A and C. The high-voltage winding A has a main part and an additional tap winding connected to the on-load tap changer (see b in Figure 4) near the star point at the high-voltage side of the transformer.

The reactances X_A, X_B, X_C in the positive-sequence system can be calculated from the short-circuit voltages given in Table 3. Related to the high-voltage side A (U_{rTA} = 400 kV) the results are: X_A = 51,1 Ω, X_B = – 4,4 Ω and X_C = 124,93 Ω without impedance correction factors (see IEC 60909-0). The value X_C has a small negative value similar to $X_{(0)B}$ given in Table 3.

If only the star point at the high-voltage side is earthed then $X_{(0)T} = X_{(0)A} + X_{(0)C}$ shall be used. If, on the other side, only the star point at the medium-voltage side is earthed, then $X_{(0)T} = X_{(0)B} + X_{(0)C}$ is valid related to the high-voltage side or related to the medium-voltage side: $X_{(0)Tt} = (X_{(0)B} + X_{(0)C}) \times (230\ \text{kV})^2 / (400\ \text{kV})^2$.