



ETAP Technical Report – No. 029

IEC

(Part 1)

ETAP IEC 60909-0, 2001

17 ETAP

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§	(I" k)	Initial Symmetrical Short-Circuit Current
§	(Ip)	Peak Short-Circuit Current
§	(Ib)	Short-Circuit Breaking Current
§	(Ik)	Steady-State Short-Circuit Current
§	(i <sub>dc</sub> )	DC Component
§	(Ith)	Thermal Equivalent Short-Circuit Current

(I" k)

I" k

5 -6

ETAP (IEC)

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§	Voltage Factor (c)	è	7 - 11	
§		è		15
§		è	16 - 17	
	(I" k)	(Ip)	ip	23 -29
X/R	A, B, C	ip	X/R	
	(Ib)	ib		30 -35
Near- to-Generator		μ	q	
Near- to-Generator	Far-Form-Generator			18 -22
	(i <sub>dc</sub> )	i		36
	(I )	Ik		37 -40
	(Ith)	Ith		41 -42
m	n			

IEC TR 60909-1

IEC 60909-4, 2000 Example 4

(I" k, Ip, Ib, Ik)

(I" k, Ip)

[http://www.etap.com/qa\\_casedocs.htm](http://www.etap.com/qa_casedocs.htm)

ETAP (IEC)

# ETAP User Group - No.17

## IEC 60909

IEC

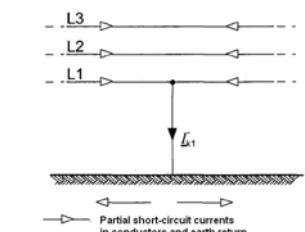
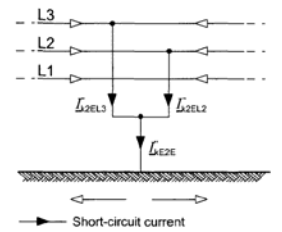
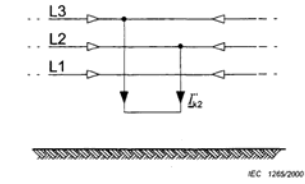
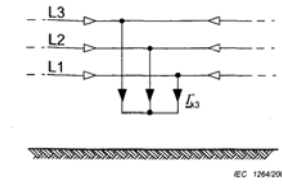
April 19, 2007

Based on IEC 60909-0, 2001

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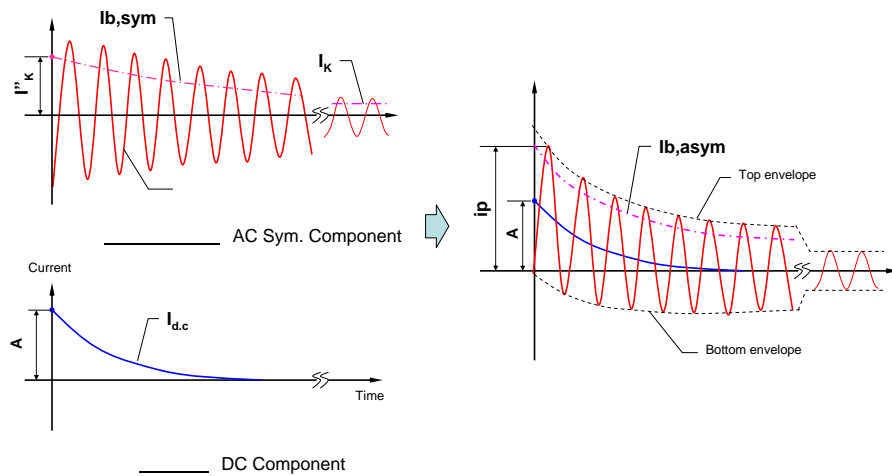
### ETAP



Short-circuit current

Partial short-circuit currents in conductors and earth return

### Component of Short-Circuit Currents



### IEC 909

- §  $(I''_k)$  Initial Symmetrical Short-Circuit Current
- §  $(i_p)$  Peak Short-Circuit Current
- §  $(I_b)$  Short-Circuit Breaking Current
- §  $(I_k)$  Steady-State Short-Circuit Current
- §  $(i_{dc})$  DC Component
- §  $(I_{th})$  Thermal Equivalent Short-Circuit Current

(I''<sub>K</sub>)

(1/2)

I''<sub>K</sub>

$$I''_k = \frac{cU_n}{\sqrt{3}Z_k} = \frac{cU_n}{\sqrt{3}\sqrt{R_k^2 + X_k^2}} \quad (29)$$

(Equivalent Voltage Source)

§  
§  
§  
§

(I''<sub>K</sub>)

(2/2)

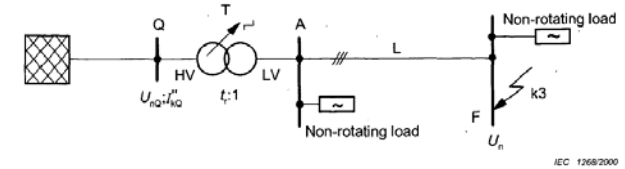
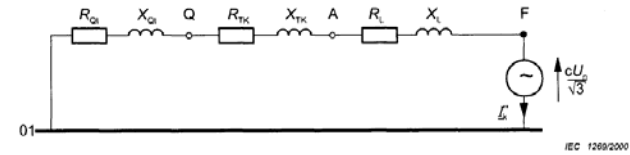


Figure 4a – System diagram



Voltage Factor (c)

(1/5)

Nominal voltage $U_n$	Voltage factor $c$ for the calculation of	
	maximum short-circuit currents $c_{max}^{1)}$	minimum short-circuit currents $c_{min}$
<b>Low voltage</b> 100 V to 1 000 V (IEC 60038, table I)	1,05 <sup>3)</sup> 1,10 <sup>4)</sup>	0,95
<b>Medium voltage</b> >1 kV to 35 kV (IEC 60038, table III)	1,10	1,00
<b>High voltage<sup>2)</sup></b> >35 kV (IEC 60038, table IV)		

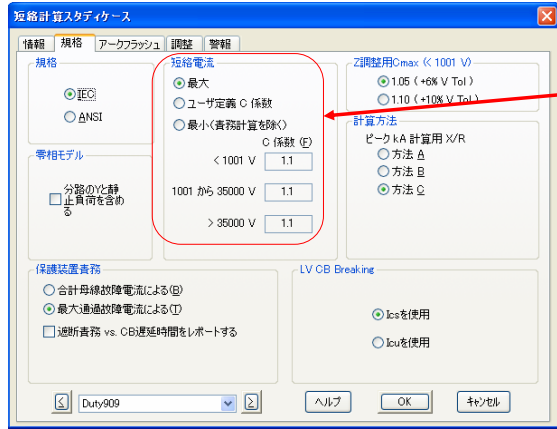
<sup>1)</sup>  $c_{max}U_n$  should not exceed the highest voltage  $U_m$  for equipment of power systems.  
<sup>2)</sup> If no nominal voltage is defined  $c_{max}U_n = U_m$  or  $c_{min}U_n = 0,90 \times U_m$  should be applied.  
<sup>3)</sup> For low-voltage systems with a tolerance of +6 %, for example systems renamed from 380 V to 400 V.  
<sup>4)</sup> For low-voltage systems with a tolerance of +10 %.

Voltage Factor (c)

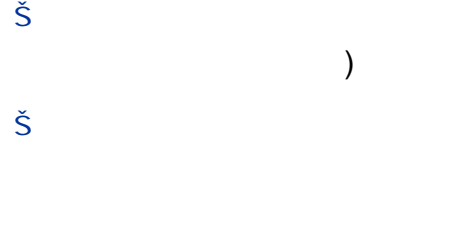
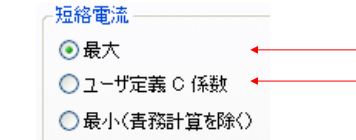
(2/5)

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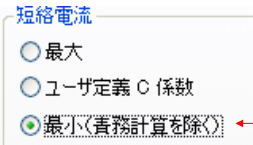
ETAP - Max/Mn SCC (3/5)



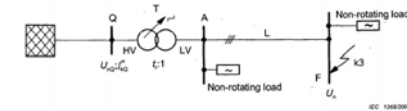
ETAP - Max/Mn SCC (4/5)



ETAP - Max/Mn SCC (5/5)



$Z_k$  (1/4)



Z<sub>k</sub>

(2/4)



**同期発電機のデータ (Synchronous Generator Data)**  
 短絡電流計算に必要な同期発電機に関するデータは、下記のとおりです。

- 定格容量、電圧および力率 (Rated MW, kV, and power factor)
- 初期過渡、過渡リアクタンスおよびX/Rの値 (Xd', Xd'', and X/R)
- 発電機のタイプ (Generator type)
- IECによる励磁機のタイプ (IEC exciter type)

**同期モータのデータ (Synchronous Motor Data)**  
 短絡電流計算に必要な同期モータに関するデータは、下記のとおりです。

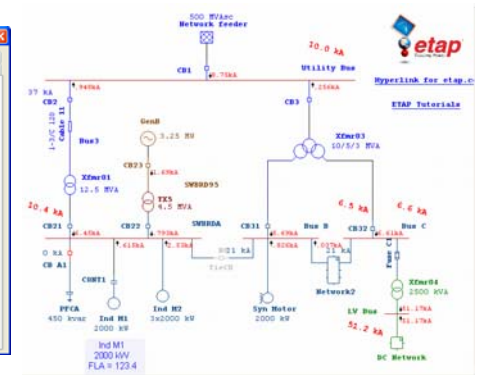
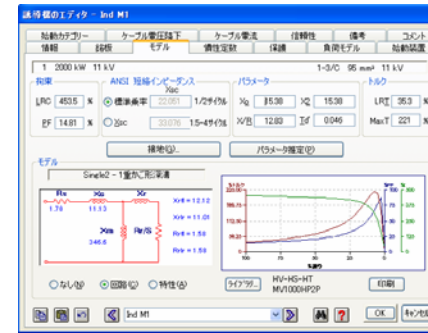
- 定格容量、電圧および極数 (Rated kW/hp, kV, and the number of poles)
- 初期過渡リアクタンスおよびX/Rの値 (Xd' および X/R)
- 始動電流率、直軸リアクタンスおよび初期直軸回路時定数(%LRC, Xd, および Td0'. IECによる短絡電流計算の場合)

**誘導モータのデータ (Induction Machine Data)**  
 短絡電流計算に必要な誘導モータに関するデータは、下記のとおりです。

- 定格出力および電圧 (Rated kW/hp and kV)
- X/Rの値および下記のデータ (どれか1つ)  
 サイクル および1.5から4サイクルにおける Xsc (ANSIにて、Short-Circuit Z オプションを Xsc と設定した場合)  
 %LRC (ANSIにて、Short-Circuit Z オプションを Std MF と設定した場合)  
 %LRC および Td' (IECによる短絡電流計算の場合)

Z<sub>k</sub>

(3/4)



Z<sub>k</sub>

(4/4)

$$Z_M = \frac{1}{I_{LR}/I_{rM}} \cdot \frac{U_{rM}}{\sqrt{3}I_{rM}} = \frac{1}{I_{LR}/I_{rM}} \cdot \frac{U_{rM}^2}{S_{rM}} \quad (26)$$

U<sub>rM</sub>  
I<sub>LR</sub>  
I<sub>rM</sub>  
S<sub>rM</sub>

R<sub>M</sub>/X<sub>M</sub>

P <sub>rM</sub> /	1MW	:	R <sub>M</sub> /X <sub>M</sub> = 0.10, X <sub>M</sub> = 0.995 Z <sub>M</sub>
P <sub>rM</sub> /	< 1MW	:	R <sub>M</sub> /X <sub>M</sub> = 0.15, X <sub>M</sub> = 0.989 Z <sub>M</sub>
		:	R <sub>M</sub> /X <sub>M</sub> = 0.42, X <sub>M</sub> = 0.922 Z <sub>M</sub>

( - 1/2)

S

- (Network XFMR) K<sub>T</sub>
- (Unit XFMR) K<sub>S</sub>, K<sub>SO</sub>
- (Unit XFMR) K<sub>T,S</sub>, K<sub>T,SO</sub>
- (Unit XFMR) K = 1

( - 2/2)

§

- (Unit XFMR  $K_G$ )
- (Unit XFMR  $K_S, K_{SO}$ )
- (aux. system (Unit XFMR  $K_{G,S}, K_{G,SO}$ ))

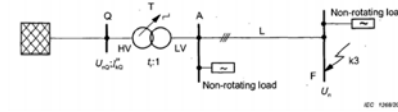
(1/5)

Near-to Generator

1 (I" K) 2

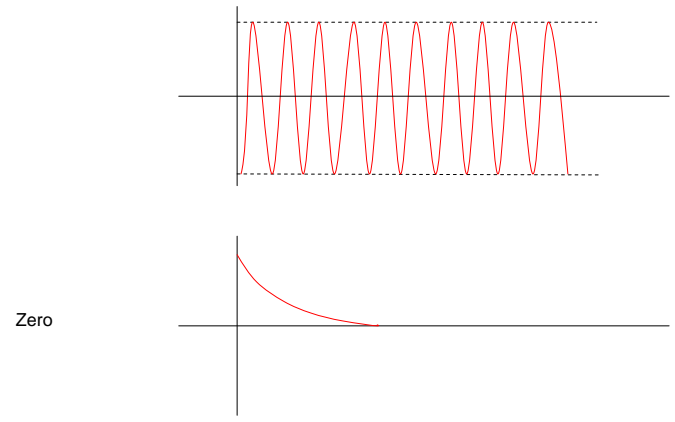
(I" K) 5%

Far-From-Generator



(2/5)

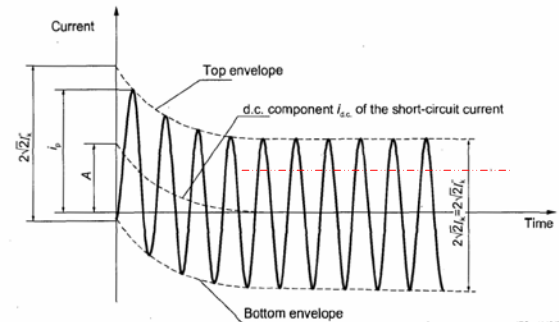
Far-From-Generator



Zero

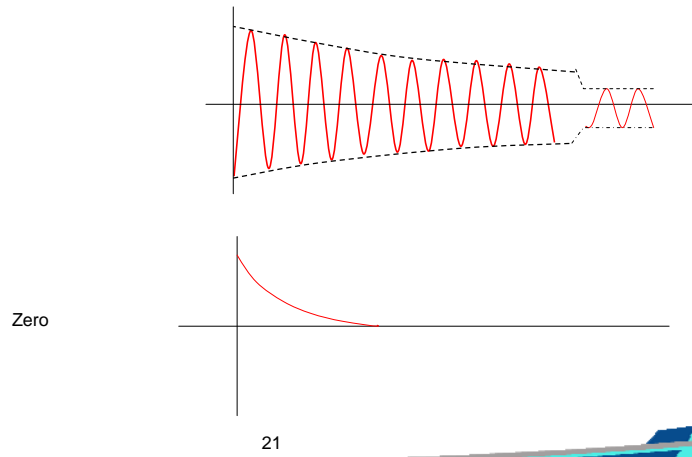
(3/5)

Far-From-Generator

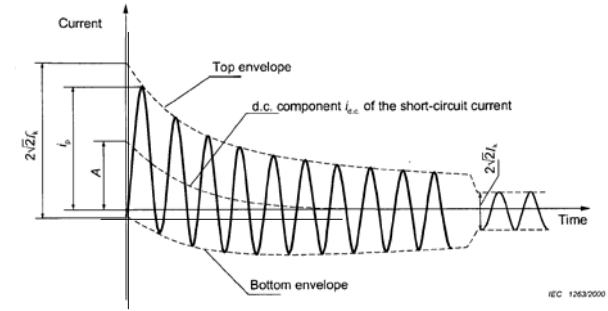


- $I''_k$  = initial symmetrical RMS short-circuit current
- $i_p$  = peak short-circuit current
- $I_k$  = steady state short-circuit current
- $i_{d.c.}$  = d.c component of short-circuit current
- A = initial value of the d.c. component id.c.

Near-to-Generator



Near-to-Generator



- $I''_k$  = initial symmetrical RMS short-circuit current
- $i_p$  = peak short-circuit current
- $I_k$  = steady state short-circuit current
- $i_{d.c.}$  = d.c component of short-circuit current
- A = initial value of the d.c. component  $i_{d.c.}$

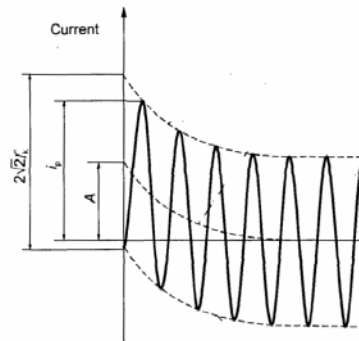
$i_p$

$i_p$

$$i_p = \kappa \sqrt{2} I''_k \quad (54)$$

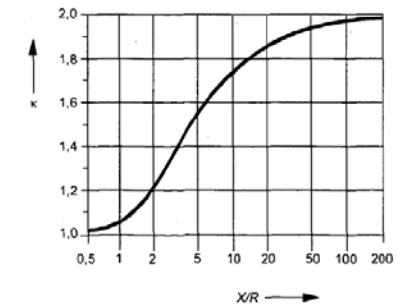
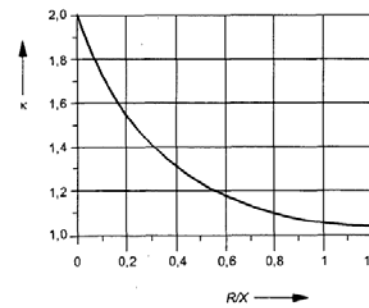
$\kappa$  IEC 15  
(55)

$$\kappa = 1,02 + 0,98e^{-3R/X} \quad (55)$$



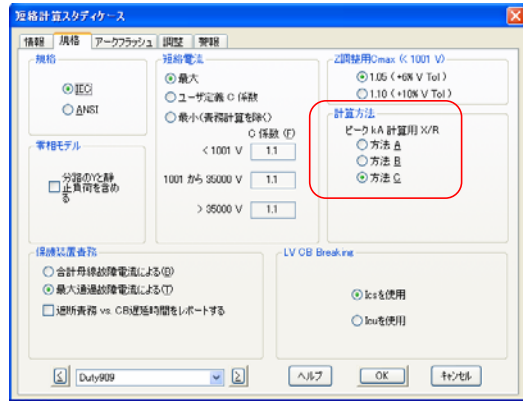
$i_p$  1/2 cycle

$i_p$

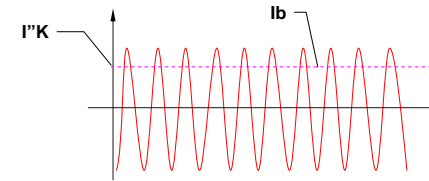






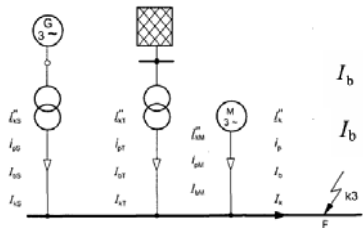


$$I_b = I''_k$$



$$I_b = \mu I''_k$$

$$I_b = \mu q I''_{kM}$$



$$I_b = \sum_i I_{bi}$$

$$I_b = I_{bS} + I_{bT} + I_{bM} = \mu I''_{kS} + I''_{kT} + \mu q I''_{kM}$$

$$I_b = I''_k \tag{74}$$

ETAP  $I_b$

$$\underline{I}_b = \underline{I''}_k - \sum_i \frac{\Delta U''_{Gi}}{c U_n / \sqrt{3}} (1 - \mu_i) \underline{I''}_{kGi} - \sum_j \frac{\Delta U''_{Mj}}{c U_n / \sqrt{3}} (1 - \mu_j q_j) \underline{I''}_{kMj} \tag{75}$$

$$\underline{\Delta U''}_{Gi} = j_j X''_{diK} \underline{I''}_{kGi} \tag{76}$$

$$\underline{\Delta U''}_{Mj} = j_j X''_{Mj} \underline{I''}_{kMj} \tag{77}$$

**$I_b$**  (Near-to-Generator) (4/6)

$\mu$  (

$$\mu = 0,84 + 0,26 e^{-0,26 I_{kG}'' / I_{rG}} \quad \text{for } t_{\min} = 0,02 \text{ s}$$

$$\mu = 0,71 + 0,51 e^{-0,30 I_{kG}'' / I_{rG}} \quad \text{for } t_{\min} = 0,05 \text{ s}$$

$$\mu = 0,62 + 0,72 e^{-0,32 I_{kG}'' / I_{rG}} \quad \text{for } t_{\min} = 0,10 \text{ s}$$

$$\mu = 0,56 + 0,94 e^{-0,38 I_{kG}'' / I_{rG}} \quad \text{for } t_{\min} \geq 0,25 \text{ s}$$

$I_{kG}'' / I_{rG} \geq 2$  (Far-From-Generator) ( $t_{\min}$ )  
 $\mu = 1$

**$I_b$**  (Near-to-Generator) (5/6)

$q$  (

$$q = 1,03 + 0,12 \ln(P_{rM}/p) \quad \text{for } t_{\min} = 0,02 \text{ s}$$

$$q = 0,79 + 0,12 \ln(P_{rM}/p) \quad \text{for } t_{\min} = 0,05 \text{ s}$$

$$q = 0,57 + 0,12 \ln(P_{rM}/p) \quad \text{for } t_{\min} = 0,10 \text{ s}$$

$$q = 0,26 + 0,10 \ln(P_{rM}/p) \quad \text{for } t_{\min} \geq 0,25 \text{ s}$$

$P_{rM}$  - (MW)  
 $P$  - (number of pairs of poles of the motor)  
 $q > 1$        $q = 1$

**$I_b$**  (6/6)

where

- $\mu_i, \mu_j$  are the values given in equation (70) for both synchronous (i) and asynchronous (j) machines;
- $q_j$  is the value given in equation (73) for asynchronous motors (j);
- $cU_n/\sqrt{3}$  is the equivalent voltage source at the short-circuit location;
- $I_{kG}''$ ,  $I_b$  are respectively the initial symmetrical short-circuit current and the symmetrical short-circuit breaking current with influence of all network feeders, synchronous machines and asynchronous motors;
- $\Delta U_{G_i}''$ ,  $\Delta U_{M_j}''$  are the initial voltage drops at the terminals of the synchronous machines (i) and the asynchronous motors (j);
- $X_{dk}''$  is the corrected subtransient reactance of the synchronous machine (i):  
 $X_{dk}'' = K_v X_{d0}''$  with  $K_v = K_G, K_S$  or  $K_{SO}$ ;
- $X_{M_j}$  is the reactance for the asynchronous motor (j);
- $I_{kG}''$ ,  $I_{kM_j}''$  are the contributions to the initial symmetrical short-circuit current from the synchronous machines (i) and the asynchronous motors (j) as measured at the terminals of the machines.

Note that the values  $I_{kG}''$  and  $\Delta U_{G_i}''$  of equations (76) and (77) are measured at terminals of the machine and that they are related to the same voltage.

**$i$**  ( /1)

$$i_{d.c.} = \sqrt{2} I_k'' e^{-2\pi f t R/X}$$

$I_k''$   
 $f$   
 $t$   
 $R/X$        $R/X$       ( $t_{\min}$ )

Meshed networks      R/X      X/R      C  
 $t$        $f_c/f$

$f \cdot t$	<1	<2,5	<5	<12,5
$f_c/f$	0,27	0,15	0,092	0,055

§

(Generator maximum excitation)

$$I_{kmax} = \lambda_{max} I_{rG} \quad (78)$$

(Generator No excitation)

$$I_{kmin} = \lambda_{min} I_{rG} \quad (79)$$

$I_{rG}$  :

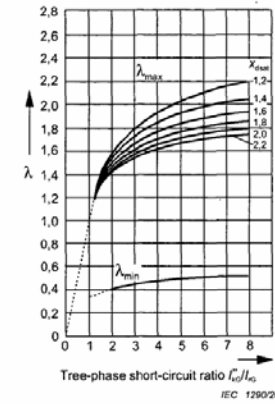


Figure 18a –  $\lambda_{min}$  and  $\lambda_{max}$  factors of series 1 (see 4.6.1.1)

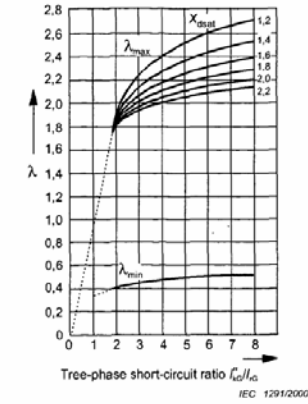


Figure 18b –  $\lambda_{min}$  and  $\lambda_{max}$  factors of series 2 (see 4.6.1.1)

Figure 18 –  $\lambda_{min}$  and  $\lambda_{max}$  factors for cylindrical rotor generators

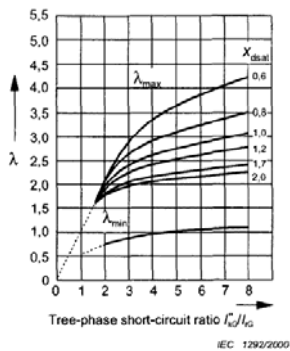


Figure 19a –  $\lambda_{min}$  and  $\lambda_{max}$  factors of series 1 (see 4.6.1.1)

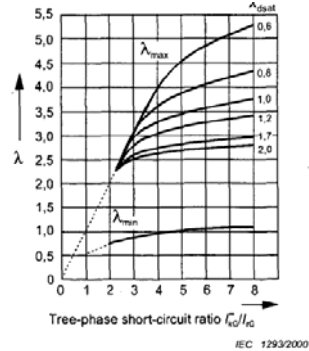
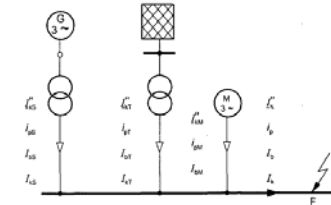


Figure 19b –  $\lambda_{min}$  and  $\lambda_{max}$  factors of series 2 (see 4.6.1.1)

Figure 19 – Factors  $\lambda_{min}$  and  $\lambda_{max}$  for salient-pole generators

§ 3

(Non-meshed networks)



$$I_k = \sum_i I_{ki} \quad (82)$$

$$I_k = I_{kS} + I_{kT} + I_{kM} = \lambda I_{rG} + I_{kT}'' \quad (83)$$

§ 3

(Meshed networks)

$$I_{kmax} = I_{kmaxM}'' \quad (84)$$

$$I_{kmin} = I_{kmin}'' \quad (85)$$

$I_{th}$

1/2)

The joule integral  $\int i^2 dt$  is a measure of the energy generated in the resistive element of the system by the short-circuit current. In this standard it is calculated using a factor  $m$  for the time-dependent heat effect of the d.c. component of the short-circuit current and a factor  $n$  for the time-dependent heat effect of the a.c. component of the short-circuit current (see figures 21 and 22)

$$\int i^2 dt = \sum_{i=1}^{i=r} I_{ki}^2 (m_i + n_i) T_{ki} = I_{th}^2 T_k \tag{104}$$

$$I_{th} = \sqrt{\frac{\int i^2 dt}{T_k}} \tag{105}$$

$$T_k = \sum_{i=1}^{i=r} T_{ki} \tag{106}$$

- $I_{ki}^2$  is the initial symmetrical three-phase short-circuit current for each short circuit
- $I_{th}$  is the thermal equivalent short-circuit current
- $m_i$  is the factor for the heat effect of the d.c. component for each short-circuit current
- $n_i$  is the factor for the heat effect of the a.c. component for each short-circuit current
- $T_{ki}$  is the duration of the short-circuit current for each short circuit
- $T_k$  is the sum of the durations for each short-circuit current (see equation (106))

$I_{th}$

2/2)

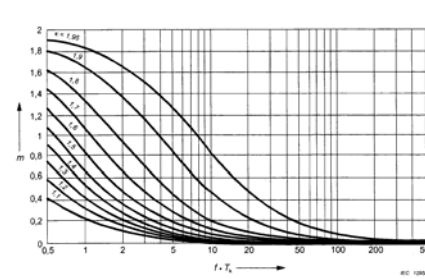


Figure 21 - Factor  $m$  for the heat effect of the d.c. component of the short-circuit current (for programming, the equation for  $m$  is given in annex A)

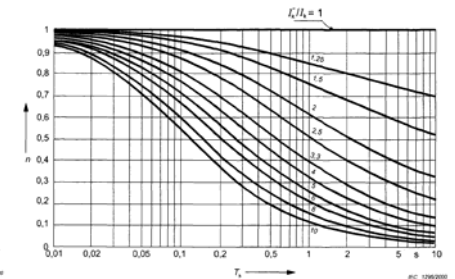


Figure 22 - Factor  $n$  for the heat effect of the a.c. component of the short-circuit current (for programming, the equation for  $n$  is given in annex A)