11. Calculation of short-circuit ratios in the power plant's own consumption

Short circuits in the schematic only make sense in parts operated with the center of the power supply effectively grounded, i.e., outside the alternator, power take-off, and adjacent windings of the block transformer and self-consumption transformer.

The calculation is usually done in proportional quantities:

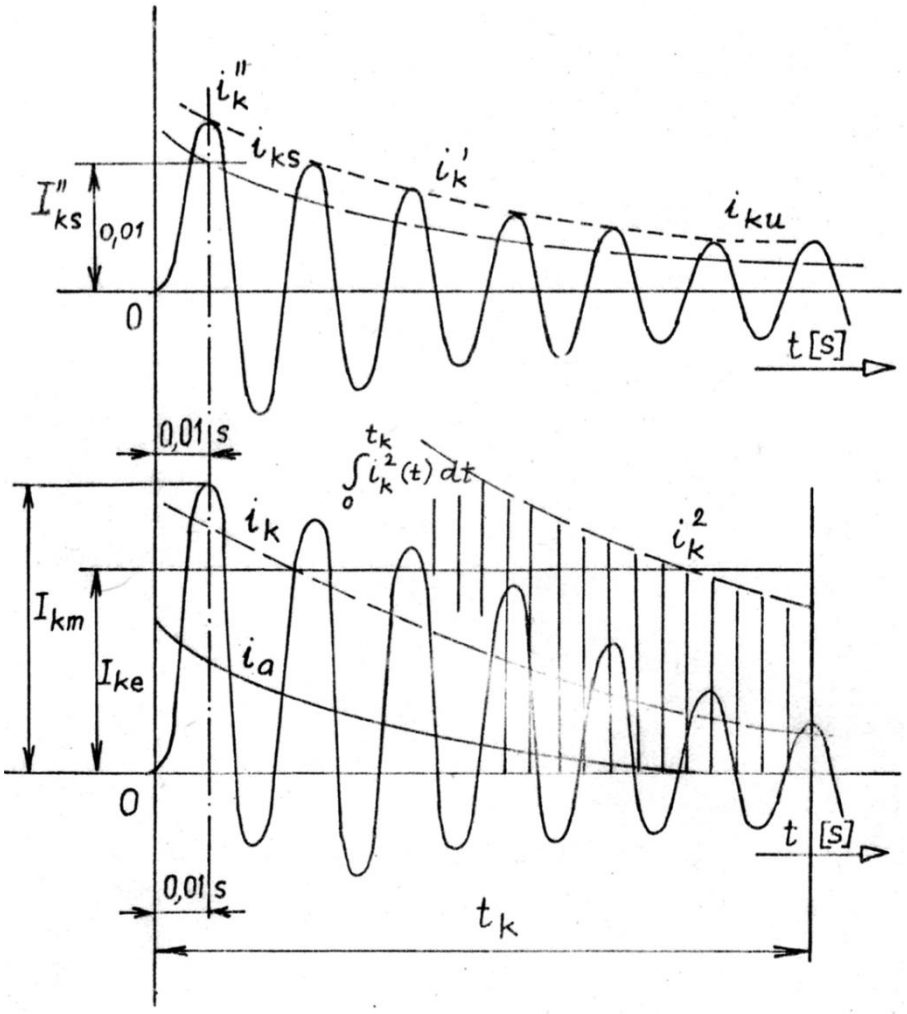
$$x_{\%} = \Delta u_{\%} = \frac{\Delta U}{U_N} 100 = \frac{\sqrt{3} \cdot X \cdot I_N}{U_N} 100 = X \frac{S_N}{U_N{}^2} 100$$

The actual values of the short-circuit parameters in the named quantities are then:

$$I_{KS} = c \frac{U_N}{\sqrt{3} X} = c \frac{\sqrt{3} U_N \cdot I_N}{\sqrt{3} U_N \cdot x_{\%}} 100 = c \frac{I_N}{x_{\%}} 100$$

$$S_{KS} = \sqrt{3} U_N \cdot I_{KS} = c \frac{\sqrt{3} U_N I_N}{x_{\%}} = c \frac{S_N}{x_{\%}} 100$$ where *c* is most often considered

1.1 Short circuit current flow:



$$i_K(t)=\sqrt{2}\left[\left(I_K''-I_K'\right)e^{-\frac{t}{T_D''}}\cos(\omega t+\pi)+\left(I_K'-I_{KU}\right)e^{-\frac{t}{T_D'}}\cos(\omega t+\pi)\right.$$

$$\left.I_{KU}\cos(\omega t+\pi)+I_K''e^{-\frac{t}{T_A}}\right]$$

Equivalent currents for determining force and thermal effects:

$$I_{KM}=K\cdot\sqrt{2}\cdot I_{KS\,0.01}''$$

I_{KM} - equivalent dynamic short-circuit current, i.e. the maximum instantaneous value of the short-circuit current during the duration of the short-circuit

K - normalized coefficient dependent on the ratio of *L* and *R* in the loop in which the short-circuit current is closed, it is tabulated according to the voltage level

vvn=> *R* << *L* => time const. T_A is long=> *K*->*2*

...

nn=> *R* >= *L* => time const. T_A is short=> *K*->*1*.3

$$I_{KE}=\sqrt{\frac{1}{t_K}\int_0^{t_K}i_K^{\,2}(t)dt}=K_E\cdot I_{KS\,0.01}''$$

I_{KE} - the equivalent short-circuit warming current is the magnitude of the DC (rms) current that has the same thermal effects as the actual short-circuit current during the duration of the short-circuit.

t_K - short circuit duration

K_E - normalized coefficient dependent on the ratio of *L* and *R* in the loop and the duration of the short circuit, it is tabulated according to the voltage level and the duration of the short circuit

Necessary tests for short-circuit conditions:

$$S\geq\frac{I_{KE}\sqrt{t_K}}{K_\vartheta}\qquad K_\vartheta=\sqrt{\frac{(\vartheta_F+20)c_{V0}}{\rho_{20}}\ln\frac{\vartheta_F+\vartheta_K}{\vartheta_F+\vartheta_1}}$$

Greatness	Meaning of	Size to be planted
ϑ_F	Fictitious conductor temperature - the temperature difference required with a change in conductor resistance of one Ω	Cu - 234.5 °C /Ω Al - 228.0 °C /Ω Fe - 222.0 °C / Ω
ϑ_1	Temperature of the conductor immediately before the short circuit occurs	Maximum permanent permissible insulation temperature
ϑ_K	Conductor temperature at the time of short circuit tripping	Maximum short-term allowable insulation temperature

Material	$c_{V0}\,[J/cm^3\cdot K]$ $[J/mm^2\cdot m\cdot K]$	$\rho_{20}\,[\mu\cdot\Omega\cdot m]$ $[\Omega\cdot mm^2/m]$
Cu	3.500	0.0179
Al	2.417	0.0294
Fe	3.770	0.1430

$$2\cdot\sigma_{0.2}\geq\sigma_0=\frac{M_0}{W_0}\qquad M_0=\frac{F\cdot l}{k_3}\qquad F=2\cdot k_1\cdot k_2\frac{I_{KM}^2}{d}l\cdot 10^{-7}$$

$$W_0=\frac{J}{b/2}=\frac{b^2h}{6}\qquad J=\int_S x^2\cdot dS=2\int_0^{b/2}h\cdot x^2dx=2h\left[\frac{x^3}{3}\right]_0^{b/2}=h\frac{b^3}{12}$$

$\sigma_{0.2}$ - yield strength of the conductor material

W_0 - the bending modulus given by the ability to resist bending

M_0 - bending moment acting on the conductor

$\sigma_{0.2\ Al}$=44.1

$\sigma_{0.2\ Cu}$=88.0

[MPa]

k_1 - respects the correction of the cross-sectional shape of the conductors

$k_2=\frac{\sqrt{3}}{2}$

k_2 - respects 3f system and planar arrangement of conductors

k_3 - respects the different stiffness and strength of the wire attachment (2 to 10)

l- length of free conductor between supports

d- axial distance of conductors

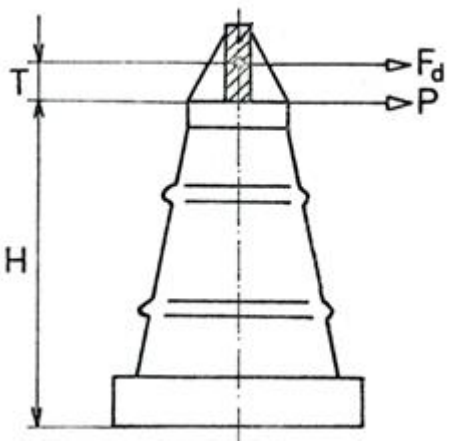
$$F_K=v_F\cdot F\leq F_D=0.8P\frac{H}{H+T}$$

$v_F=\frac{0.8\sigma_{0.2}}{\sigma_0}$ But

minimum 1 and maximum 5

v_F -resonance respecting coefficient

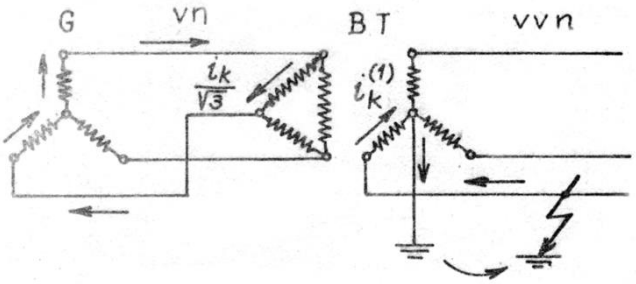
P -mechanical strength of the support

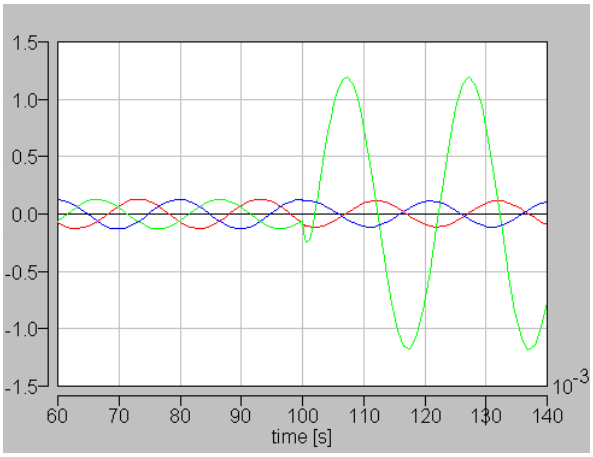


Asymmetrical short circuits in V.S.

Single-phase short circuit: $i_{K1F}=\frac{3\cdot e_V}{x_c^{(1)}+x_c^{(2)}+x_c^{(0)}}=\frac{3\cdot 1.1}{x_c^{(1)}+x_c^{(2)}+x_c^{(0)}}$

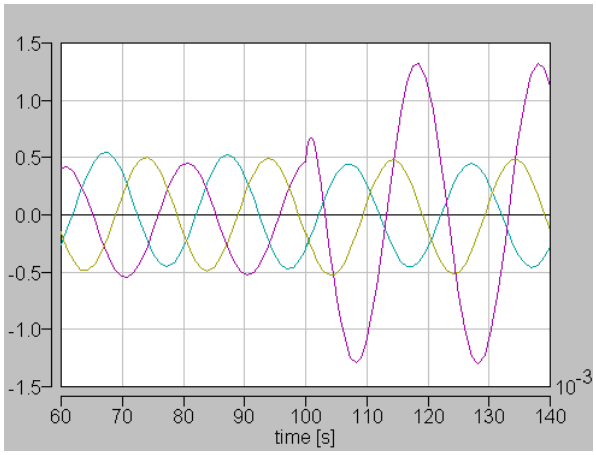
Transformer currents on the fault side

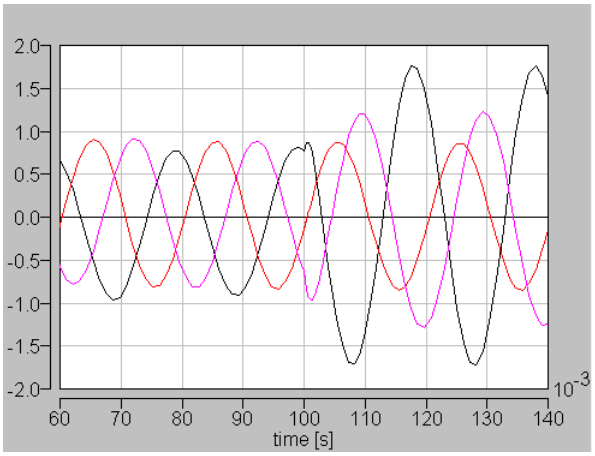




Transformer currents on the alternator side

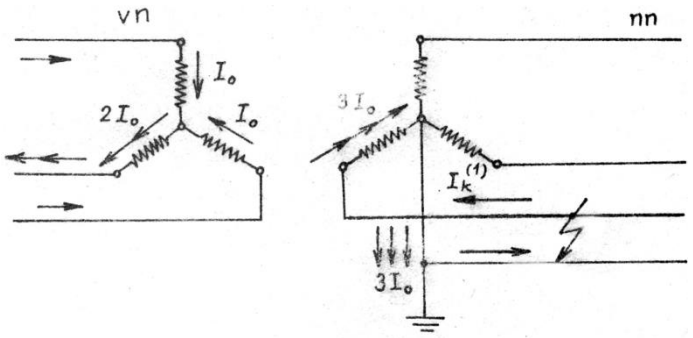
Alternator stator currents



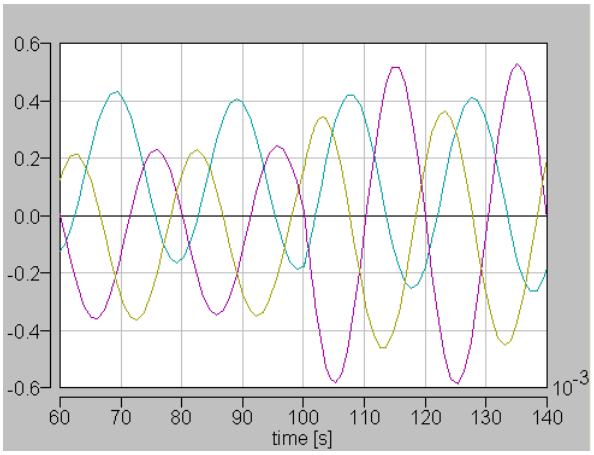


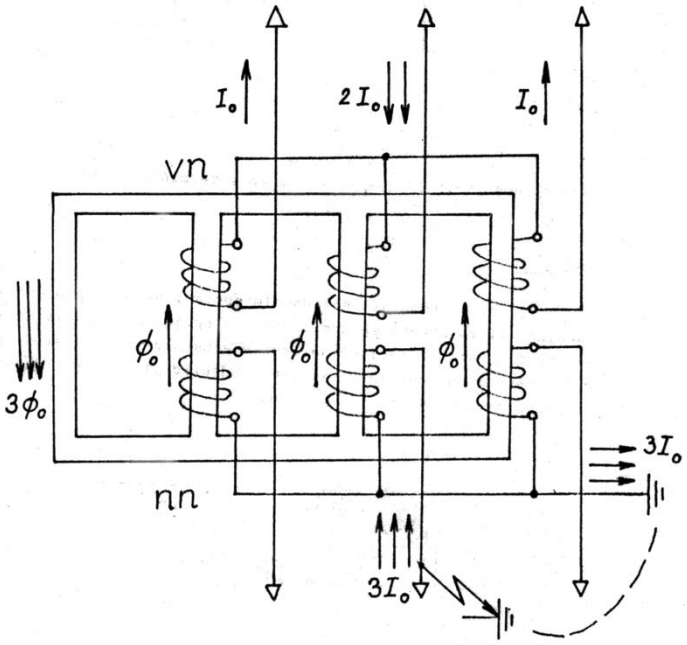
The positive effect of the transformer connection in the triangle is evident.

When short circuits in LV system when the wiring is Yyn:

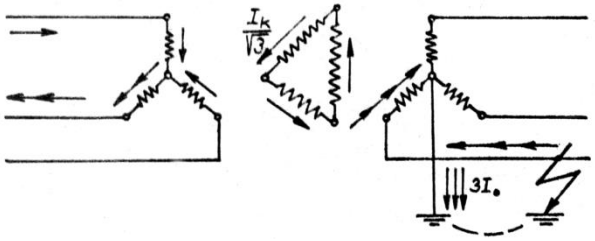


The currents of the Vn side





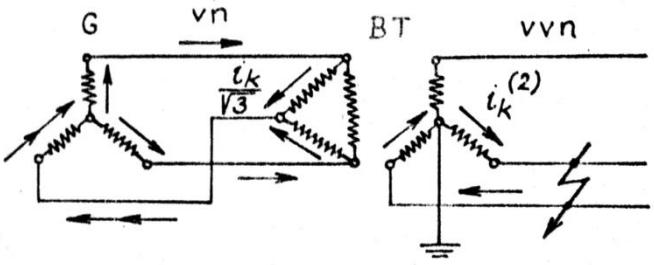
Distribution of currents in the case of of the tertiary winding into a triangle



The resulting flow$_0$ is unidirectional and is closed across the transformer shell and vessel, thus increasing the reactance for the non-rotating component current system and thus limiting the single-phase short-circuit current.

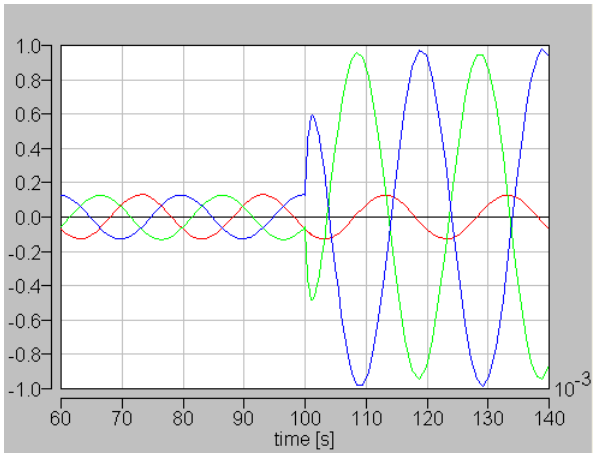
Two-phase short circuit: $i_{K2F} = \frac{\sqrt{3} \cdot e_V}{x_c^{(1)} + x_c^{(2)}} = \frac{\sqrt{3} \cdot 1.1}{x_c^{(1)} + x_c^{(2)}}$

Three-phase short circuit: $i_{K3F} = \frac{e_V}{x_c^{(1)}} = \frac{1.1}{x_c^{(1)}}$



Transformer currents on the alternator side

Transformer currents on the fault side



Alternator stator currents

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