INDUCED VOLTAGE ON METALLIC SHEATH

Object:

Cable 2XS(FL)2Y-GC-WTC 1x 800RM/225 110kV IEC 60840

Input data:

d_e	*81*	*mm*	Mean diameter of the sheath
D_c	*92,5*	*mm*	External diameter of cable
f	*50*	*Hz*	System frequency
ω	$2 \cdot \pi \cdot f$	*1/s*	Angular frequency of system
I_r	*972*	*A*	*Current in one conductor*
I_{sc}	*31500*	*A*	3-phase short circuit current
I_{ss}	*31500*	*A*	1-phase short circuit current
s	*92,5*	*mm*	Distance between phases axes
R_c	*0,0754*	*Ω/km*	Resistance of earth continuity conductor (*Zemnici kabel*)
γ_c	*7*	*mm*	Geometric mean radius of earth continuity conductor (ecc)
S_{ic}	*325*	*mm*	Geometric mean spacing between ecc and cable phases
E_1, E_2, E_3		*V/km*	Induced Voltage on Metallic Sheath

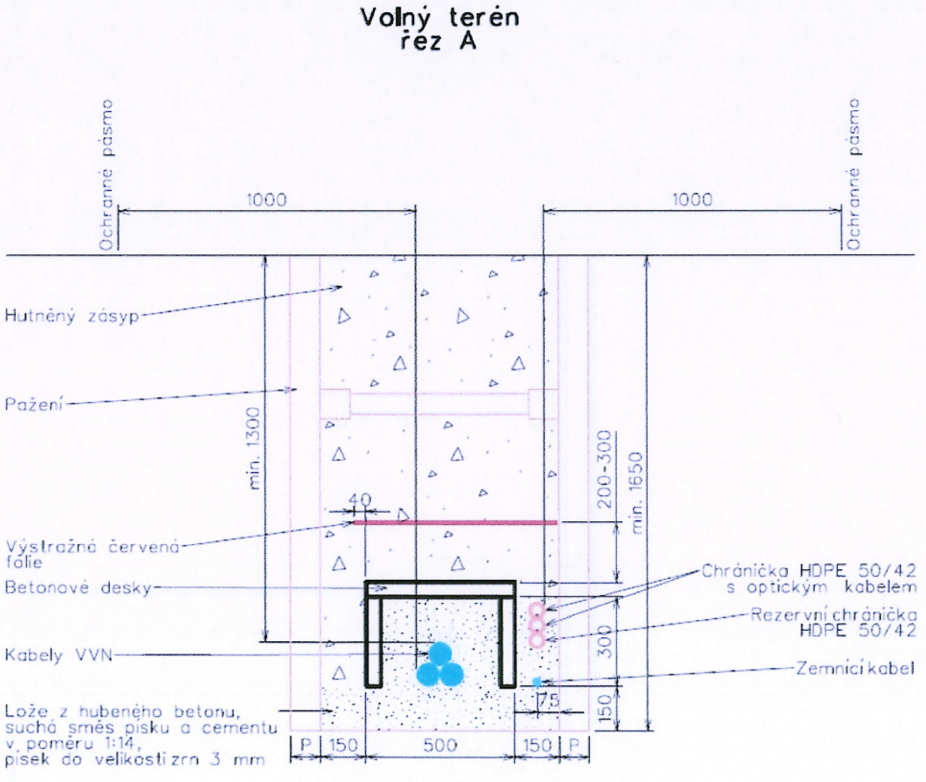

Fig. 1 Cross section of analyzed system.

Calculation of induced voltage for balanced load condition:

$$E_1 = j \cdot 2 \cdot \omega \cdot I_r \cdot 10^{-4} \cdot \left(-\frac{1}{2} + j\frac{\sqrt{3}}{2}\right) ln\left(\frac{2 \cdot s}{d_e}\right) = -43{,}7 - j25{,}2\ \frac{V}{km}$$

$$E_1 = |E_1| = 50{,}4\ \frac{V}{km}$$

$$E_2 = j \cdot 2 \cdot \omega \cdot I_r \cdot 10^{-4} \cdot ln\left(\frac{2 \cdot s}{d_e}\right) = 50{,}4\ \frac{V}{km}$$

$$E_2 = |E_2| = 50{,}4\ \frac{V}{km}$$

$$E_3 = j \cdot 2 \cdot \omega \cdot I_r \cdot 10^{-4} \cdot \left(-\frac{1}{2} - j\frac{\sqrt{3}}{2}\right) ln\left(\frac{2 \cdot s}{d_e}\right) = 43{,}7 - j25{,}2\ \frac{V}{km}$$

$$E_3 = |E_3| = 50{,}4\ \frac{V}{km}$$

For 1,44 km $E_1 = E_2 = E_3 = 72{,}6\ V$

Calculation of induced voltage for 3-phase short circuit:

$$E_1 = j \cdot 2 \cdot \omega \cdot I_{sc} \cdot 10^{-4} \cdot \left(-\frac{1}{2} + j\frac{\sqrt{3}}{2}\right) ln\left(\frac{2 \cdot s}{d_e}\right) = -1415 - j817\ \frac{V}{km}$$

$$E_1 = |E_1| = 1635\ \frac{V}{km}$$

$$E_2 = j \cdot 2 \cdot \omega \cdot I_{sc} \cdot 10^{-4} \cdot ln\left(\frac{2 \cdot s}{d_e}\right) = 1635\ \frac{V}{km}$$

$$E_2 = |E_2| = 1635\ \frac{V}{km}$$

$$E_3 = j \cdot 2 \cdot \omega \cdot I_{sc} \cdot 10^{-4} \cdot \left(-\frac{1}{2} - j\frac{\sqrt{3}}{2}\right) ln\left(\frac{2 \cdot s}{d_e}\right) = 1415 - j817\ \frac{V}{km}$$

$$E_3 = |E_3| = 1635\ \frac{V}{km}$$

For 1,44 km $E_1 = E_2 = E_3 = 2{,}35\ kV$

Calculation of induced voltage for 1-phase short circuit:

$$E = \left[R_c + j \cdot 2 \cdot \omega \cdot 10^{-4} \cdot ln\left(\frac{2 \cdot S_{ic}}{d_e \cdot \gamma_c}\right)\right] \cdot I_{sc} = -2{,}4 - j11{,}8\ \frac{kV}{km}$$

$$E = |E| = 12\ \frac{kV}{km}$$

For 1,44 km $E = 17{,}3\ kV$

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ω	$2\cdot\pi\cdot f$	1/s	Angular frequency of system
I_r	972	A	*Current in one conductor*
I_{sc}	25000	A	3-phase short circuit current
I_{ss}	25000	A	1-phase short circuit current
s	92,5	mm	Distance between phases axes
R_c	0,0754	Ω/km	Resistance of earth continuity conductor (*Zemnici kabel*)
γ_c	7	mm	Geometric mean radius of earth continuity conductor (ecc)
S_{ic}	50	mm	Geometric mean spacing between ecc and cable phases
E_1, E_2, E_3		V/km	Induced Voltage on Metallic Sheath

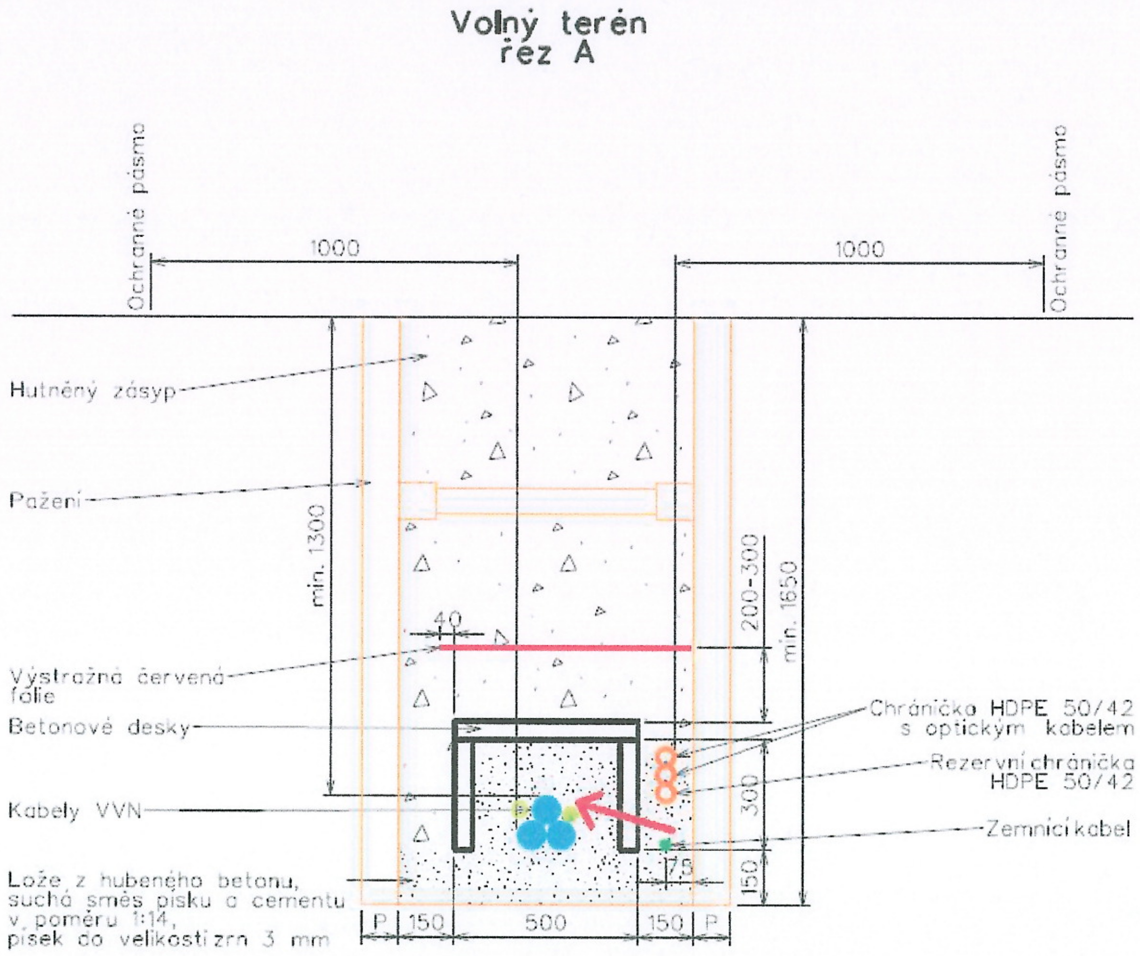

Fig. 1 Cross section of analyzed system.

Calculation of induced voltage for balanced load condition:

$$E_1 = j \cdot 2 \cdot \omega \cdot I_r \cdot 10^{-4} \cdot \left(-\frac{1}{2} + j\frac{\sqrt{3}}{2}\right) ln\left(\frac{2 \cdot s}{d_e}\right) = -43{,}7 - j25{,}2\ \frac{V}{km}$$

$$E_1 = |E_1| = 50{,}4\ \frac{V}{km}$$

$$E_2 = j \cdot 2 \cdot \omega \cdot I_r \cdot 10^{-4} \cdot ln\left(\frac{2 \cdot s}{d_e}\right) = 50{,}4\ \frac{V}{km}$$

$$E_2 = |E_2| = 50{,}4\ \frac{V}{km}$$

$$E_3 = j \cdot 2 \cdot \omega \cdot I_r \cdot 10^{-4} \cdot \left(-\frac{1}{2} - j\frac{\sqrt{3}}{2}\right) ln\left(\frac{2 \cdot s}{d_e}\right) = 43{,}7 - j25{,}2\ \frac{V}{km}$$

$$E_3 = |E_3| = 50{,}4\ \frac{V}{km}$$

For 1,44 km $E_1 = E_2 = E_3 = 72{,}6\ V$

Calculation of induced voltage for 3-phase short circuit:

$$E_1 = j \cdot 2 \cdot \omega \cdot I_{sc} \cdot 10^{-4} \cdot \left(-\frac{1}{2} + j\frac{\sqrt{3}}{2}\right) ln\left(\frac{2 \cdot s}{d_e}\right) = -1123 - j649\ \frac{V}{km}$$

$$E_1 = |E_1| = 1297\ \frac{V}{km}$$

$$E_2 = j \cdot 2 \cdot \omega \cdot I_{sc} \cdot 10^{-4} \cdot ln\left(\frac{2 \cdot s}{d_e}\right) = 1297\ \frac{V}{km}$$

$$E_2 = |E_2| = 1297\ \frac{V}{km}$$

$$E_3 = j \cdot 2 \cdot \omega \cdot I_{sc} \cdot 10^{-4} \cdot \left(-\frac{1}{2} - j\frac{\sqrt{3}}{2}\right) ln\left(\frac{2 \cdot s}{d_e}\right) = 1123 - j649\ \frac{V}{km}$$

$$E_3 = |E_3| = 1297\ \frac{V}{km}$$

For 1,44 km $E_1 = E_2 = E_3 = 1{,}87\ kV$

Calculation of induced voltage for 1-phase short circuit:

$$E = \left[R_c + j \cdot 2 \cdot \omega \cdot 10^{-4} \cdot ln\left(\frac{2 \cdot S_{ic}}{d_e \cdot \gamma_c}\right)\right] \cdot I_{sc} = -1{,}9 - j3{,}4\ \frac{kV}{km}$$

$$E = |E| = 3{,}9\ \frac{kV}{km}$$

For 1,44 km $E = 5{,}7\ kV$

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I_r	*1005*	*A*	*Current in one conductor*
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I_{ss}	*31500*	*A*	1-phase short circuit current
s	*250*	*mm*	Distance between phases axes
R_c	*0,0754*	*Ω/km*	Resistance of earth continuity conductor (*Zemnici kabel*)
γ_c	*7*	*mm*	Geometric mean radius of earth continuity conductor (ecc)
S_{ic}	*955*	*mm*	Geometric mean spacing between ecc and cable phases
E_1, E_2, E_3		*V/km*	Induced Voltage on Metallic Sheath

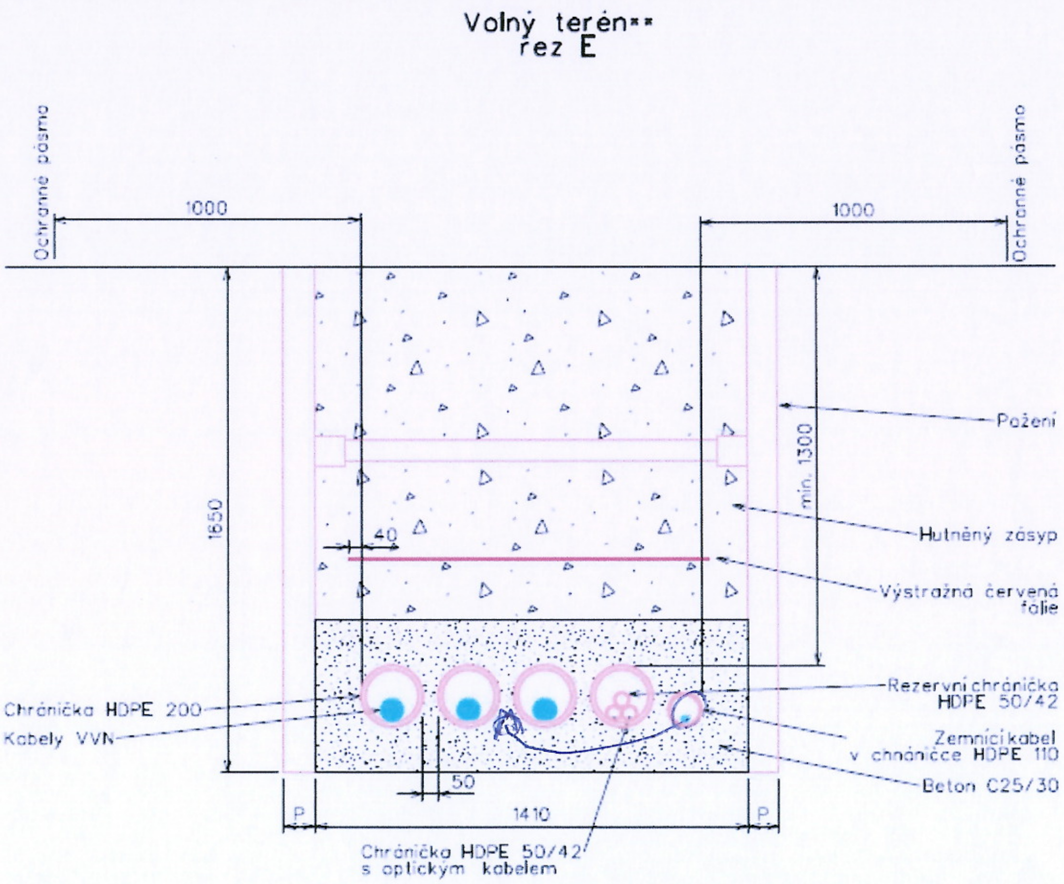

Fig. 1 Cross section of analyzed system.

Calculation of induced voltage for balanced load condition:

$$E_1 = j \cdot 2 \cdot \omega \cdot I_r \cdot 10^{-4} \cdot \left(-\frac{1}{2} + j\frac{\sqrt{3}}{2}\right) ln\left(\frac{2 \cdot s}{d_e}\right) = -137{,}4 - j35{,}6\ \frac{V}{km}$$

$$E_1 = |E_1| = 142\ \frac{V}{km}$$

$$E_2 = j \cdot 2 \cdot \omega \cdot I_r \cdot 10^{-4} \cdot ln\left(\frac{2 \cdot s}{d_e}\right) = 115\ \frac{V}{km}$$

$$E_2 = |E_2| = 115\ \frac{V}{km}$$

$$E_3 = j \cdot 2 \cdot \omega \cdot I_r \cdot 10^{-4} \cdot \left(-\frac{1}{2} - j\frac{\sqrt{3}}{2}\right) ln\left(\frac{2 \cdot s}{d_e}\right) = 137{,}4 - j35{,}6\ \frac{V}{km}$$

$$E_3 = |E_3| = 142\ \frac{V}{km}$$

For 1,44 km $E_1 = E_3 = 204\ V\ and\ E_2 = 165\ V$

Calculation of induced voltage for 3-phase short circuit:

$$E_1 = j \cdot 2 \cdot \omega \cdot I_{sc} \cdot 10^{-4} \cdot \left(-\frac{1}{2} + j\frac{\sqrt{3}}{2}\right) ln\left(\frac{2 \cdot s}{d_e}\right) = -4308 - j1115\ \frac{V}{km}$$

$$E_1 = |E_1| = 4445\ \frac{V}{km}$$

$$E_2 = j \cdot 2 \cdot \omega \cdot I_{sc} \cdot 10^{-4} \cdot ln\left(\frac{2 \cdot s}{d_e}\right) = 3602\ \frac{V}{km}$$

$$E_2 = |E_2| = 3602\ \frac{V}{km}$$

$$E_3 = j \cdot 2 \cdot \omega \cdot I_{sc} \cdot 10^{-4} \cdot \left(-\frac{1}{2} - j\frac{\sqrt{3}}{2}\right) ln\left(\frac{2 \cdot s}{d_e}\right) = 4308 - j1115\ \frac{V}{km}$$

$$E_3 = |E_3| = 4445\ \frac{V}{km}$$

For 1,44 km $E_1 = E_3 = 6{,}41\ kV\ and\ E_2 = 5{,}19\ kV$

Calculation of induced voltage for 1-phase short circuit:

$$E = \left[R_c + j \cdot 2 \cdot \omega \cdot 10^{-4} \cdot ln\left(\frac{2 \cdot S_{ic}}{d_e \cdot \gamma_c}\right)\right] \cdot I_{sc} = -2{,}4 - j16\ \frac{kV}{km}$$

$$E = |E| = 16{,}2\ \frac{kV}{km}$$

For 1,44 km $E = 23{,}4\ kV$

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