Info Letter No. 20

Capacitance of conductors

1 Conductors as capacitors

In the conductors of electrical power supplies, a distinction is made between the operating capacitance C_b, the three phase-phase capacitances C_L and the three phase-earth capacitances C_e. The operating capacitance is determined by the capacitive reactive power demand of a conductor and the phase-earth capacitance of the single-phase fault current in the insulated or compensated networks. Single conductor cables are designed to have no phase-phase capacitance.

The capacitance of a parallel plate capacitor depends on the size of the plates, the electrical properties of the dielectric and the distance between the plates.

$$C = \frac{A \cdot \varepsilon}{a}$$

A = Plate size

ε = Dielectric constant

a = Distance between plates

An electrical conductor is a cylindrical capacitance where the surface is a circle. And thus the equation changes.

$$C = \frac{2 \cdot \pi \cdot l \cdot \varepsilon}{ln \frac{a}{r}}$$

l = Length of the cylinder

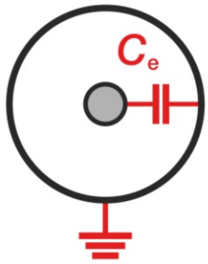
ln = Natural logarithm

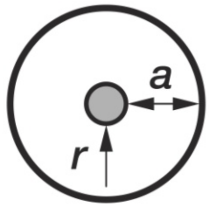
a = Radius of the insulation

r = Conductor radius

2 Cable

2.1 Single core radial field cable





$$C_b = C_e$$

$$C_e = \frac{2 \cdot \pi \cdot \varepsilon_0 \cdot \varepsilon_r}{ln \frac{a}{r}}$$

C_b = Operating capacitance

C_e = Phase-earth capacitance

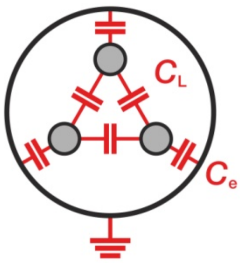
ε_0 = electrical field constant 8.85 pF/m

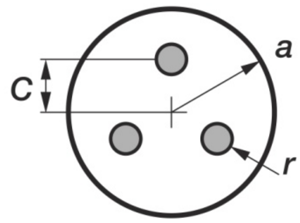
ε_r = relative dielectric constant

a = Radius of the insulation

r = Radius of the conductor

2.2 Three-core belted cables





$$C_b = C_e + 3 \cdot C_L$$

$$C_e = \frac{2 \cdot \pi \cdot \varepsilon_0 \cdot \varepsilon_r}{ln \frac{a^6 - c^6}{3 \cdot c^2 \cdot r \cdot a^3}}$$

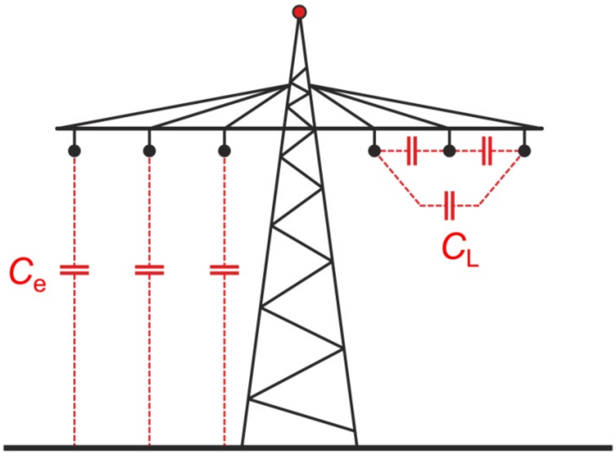
C_L = Phase-phase capacitance

a = Radius of the insulation

r = Radius of the conductor

c = Cable centre – conductor centre distance

3 Overhead cable



$$C_b = C_e + 3 \cdot C_L \qquad C_e = \frac{2 \cdot \pi \cdot \varepsilon_0 \cdot \varepsilon_r}{ln \frac{2 \cdot h_m \cdot d_m}{r \cdot D_m}}$$

h_m = average height above the ground (sag)

d_m = average phase distance

D_m = average reflection distance

To calculate the operating capacitance, the delta-connected phase-phase capacitance has to be converted into an equivalent star connection and added to the phase-earth capacitances.

$$C_b = C_e + 3 \cdot C_L$$

The load current per phase is then

$$I_L = \frac{U_N}{\sqrt{3}} \cdot \omega \cdot C_b$$

and the earth fault current per phase is

$$I_{Ce} = U_N \cdot \omega \cdot C_e$$

and for one conductor

$$I_{Ce} = \sqrt{3} \cdot U_N \cdot \omega \cdot C_e$$

Characteristics of a conductor

	C_b	C_e	C_L	I_e	I_L
20 kV overhead cable	~ 9 nF/km	~ 4.5 nF/km	~ 1.5 nF/km	0.05 A/km	0.03 A/km
110 kV overhead cable	~ 11 nF/km	~ 5 nF/km	~ 1.6 nF/km	0.3 A/km	0.22 A/km
10 kV cable N(A)KBA 3x120 mm^2	~ 560 nF/km	~ 410 nF/km	~ 50 nF/km	2.2 A/km	1.0 A/km
20 kV cable N2XSY 1x150 mm^2	~ 250 nF/km	~ 250 nF/km	0	3.0 A/km	1.0 A/km

If, for example, a 20 kV cable is used in a 10 kV network, the capacitive currents are then reduced by half (half operating voltage)!

References:

[1] Flosdorff, R.; Hilgarth, G.: **Elektrische Energieverteilung.** B.G. Teubner Verlag Stuttgart

[2] Heinbold, L.: **Kabel und Leitungen für Starkstrom.** Teil 1, 4. Auflage 1987 Verlag Siemens AG.

[3] Gremmel, H.: **Schaltanlagen**. 12 Auflage, ABB Calor Emag Mannheim Cornelsen Verlag

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