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
\( \varepsilon \) = 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
\( \varepsilon_0 \) = electrical field constant 8.85 pF/m
\( \varepsilon_r \) = relative dielectric constant
\( a \) = Radius of the insulation
\( r \) = Radius of the conductor

2.2 Three-core belted cables

\[
C_b = C_e + 3 \cdot C_L
\]

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

\( C_L \) = Phase-phase capacitance
\( a \) = Radius of the insulation
\( r \) = Radius of the conductor
\( c \) = Cable centre – conductor centre distance
3 Overhead cable

![Overhead cable diagram]

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

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

\[ h_m = \text{average height above the ground (sag)} \]
\[ d_m = \text{average phase distance} \]
\[ D_m = \text{average reflection distance} \]

Characteristics of a conductor

<table>
<thead>
<tr>
<th>Cable Type</th>
<th>( C_b ) nF/km</th>
<th>( C_e ) nF/km</th>
<th>( C_L ) nF/km</th>
<th>( I_e ) A/km</th>
<th>( I_L ) A/km</th>
</tr>
</thead>
<tbody>
<tr>
<td>20 kV overhead cable</td>
<td>9</td>
<td>4.5</td>
<td>1.5</td>
<td>0.05</td>
<td>0.03</td>
</tr>
<tr>
<td>110 kV overhead cable</td>
<td>11</td>
<td>5</td>
<td>1.6</td>
<td>0.3</td>
<td>0.22</td>
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<tr>
<td>10 kV cable N(A)KBA 3x120 mm²</td>
<td>560</td>
<td>410</td>
<td>50</td>
<td>2.2</td>
<td>1.0</td>
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<tr>
<td>20 kV cable N2XY 1x150 mm²</td>
<td>250</td>
<td>250</td>
<td>0</td>
<td>3.0</td>
<td>1.0</td>
</tr>
</tbody>
</table>

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:

Author: Dieter Spiertz
www.info@a-eberle.de

The series will be continued.
We will gladly supply missing Info Letters at any time!