

Exercise Session 6: Basic Components of Power System

EX1 Three Phase Power

How large real power can be transmitted in a three phase system at different voltages, when power factor $\cos \phi = 0.9$ and current is 100 A per phase. The voltage is: a) 400 V, b) 20 kV, c) 110 kV and d) 400 kV.

EX2 Capacity of a Transmission Line

How large real power can be transmitted by 795 kV line over 1000 km?. The conductor cross section is 1095 mm² (radius $r = 21,5$ mm). Spacing between phases is $d = 17$ m . How the power is changed if a bundle conductor is used, radius $r = 30$ cm. The power angle (phase angle between voltages in line ends) is limited to $\delta = 30$ degrees. The power transmitted in a transmission line is obtained from the power-angle equation:

$$P = \frac{U_1 U_2}{X} \sin \delta$$

Line inductance is:

$$L = \frac{\mu_0}{2\pi} \left[\frac{1}{4} + \ln \frac{d}{r} \right]$$

$$\mu_0 = 4\pi \cdot 10^{-7} \text{ H/m}$$

And reactance $X = \omega L = 2\pi f L$ - ω is angular frequency ($2\pi f$), f is frequency (50 Hz)

EX3 Medium Voltage Cable Capacity

Cables are usually short and the capacity is mostly limited by current. Current causes power losses which heat the cable. Heating must be limited due to maximum temperatures accepted to the insulation materials. Let us consider a 20 kV cable $3 * 240$ mm², maximum current $I_{\max} = 385$ A. What is the corresponding maximum power?. And what is the maximum power of $3 * 50$ mm² cable, $I_{\max} = 155$ A ?.

EX4 Capacity of a Medium Voltage Overhead Line

20 kV MV line capacity is mostly limited by voltage drop, due to long distances. Let us take a line with resistance and reactance $r = 0.3$ ohm/km, $x = 0.3$ ohm/km, maximum voltage drop $\Delta U_{\max} = 5\%$, and length 40 km.

What is the maximum power that can be transmitted if power factor is = 1 ($P = S$)

Voltage drop longitudinal component: $\Delta U_p = RI_p + XI_q$

Voltage drop transverse component: $\Delta U_q = RI_q + XI_p$