ELEC-E8422 An Introduction to Electric Energy

Exercise Session 9: Black Outs and Future Power Systems

EX1 Spinning Reserve

The generation capacity of an area is 1500 MW and the load 1000 MW. Import to the area is 500 MW and export 800 MW. How large a spinning reserve there must be in addition to the fixed generation if a 30% margin is required.

EX2 Electrical Load

The load in a power system varies during 24 hours as follows:

$$P = 2 + 2e^{\frac{-(t-9)^2}{8}} \quad \text{GW}$$

Calculate maximum power, its time and average power.

EX3 Electrical Vehicles

Compare the annual energy costs and $C0_2$ emissions of EVs and gasoline (ICE) cars. Data: Consumption 15 kWh/100km or 7 liters/100km. Power price 15 c/kWh, gasoline price 1,4 €/litra. CO_2 –emissions 140g/kWh and for ICE car 150g/km. Driving amount 20000 km per annum. What is the reason for differences?

EX4 Power Transmission

The reactance between two three phase busbars is 0.5 Ω. The voltage in both is 10 kV and the angle between the busbars is 10 degrees. How big power is transmitted between the busbars? How increasing he voltage affects the power? How increasing the angle affects the power? What is the maximum power that theoretically can be transmitted between the busbars using 10 kV voltage?

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$Ps = \lambda(P_L + P_{export}) - (P_G + P_{import}) = 1{,}3*(1000+800) - (1500+500) = 340$ MW

EX2 Electrical Load

The load in a power system varies during 24 hours as follows:

$$P = 2 + 2e^{\frac{-(t-9)^2}{8}} \text{ GW}$$

Calculate maximum power, its time and average power.

Maximum power is at 9, and since $e^0 = 1$, is maximum power 4 GW

Average power is obtained by integrating over full day and dividing by 24h ⇔ 2.418 GW

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Energy costs:

EV: 20000 km/a * 0,15 kWh/km * 0,15 €/kWh = 450 €/a
ICE: 20000 km/a * 0,07 l/km * 1,4 €/l = 1960 €/a

CO_2 –emissions:

EV: 20000 km/a * 0,15 kWh/km * 0,14 kg/kWh = 420 kg/a
ICE: 20000 km/a * 0,15 kg/km = 3000 kg/a

The differences are mostly due to the better efficiency of EV.

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

$U_1 = U_2 = 10$ kV & $\delta = 10$ degrees ⇔ P = 34.7 MW

Increasing voltage increases the power transmission in relation to second power of voltage (U^2).

Increasing the angle increases power until 90 degrees, which gives the maximum power (200 MW)