ELEC-E8406 Electricity distribution and markets Exam 5.4.2017

You may answer in English (preferred), Finnish or Swedish – this is not a language test! ***Please keep your answers brief****! If John has left any parameters out, make your best guess, and indicate the assumptions you make when answering! There will be no discussion during this exam!*

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Q1. General

a) What is the difference between **voltage sag** (dip) and **voltage drop**? Please give a formula and brief explanation for each. (4p)

b) What are two types of **electricity market?** (very brief explanation of the two out of many you choose) (2p)

Q2. General

a) What are 3 challenges associated with integrating renewable generation in the power system? (3p)

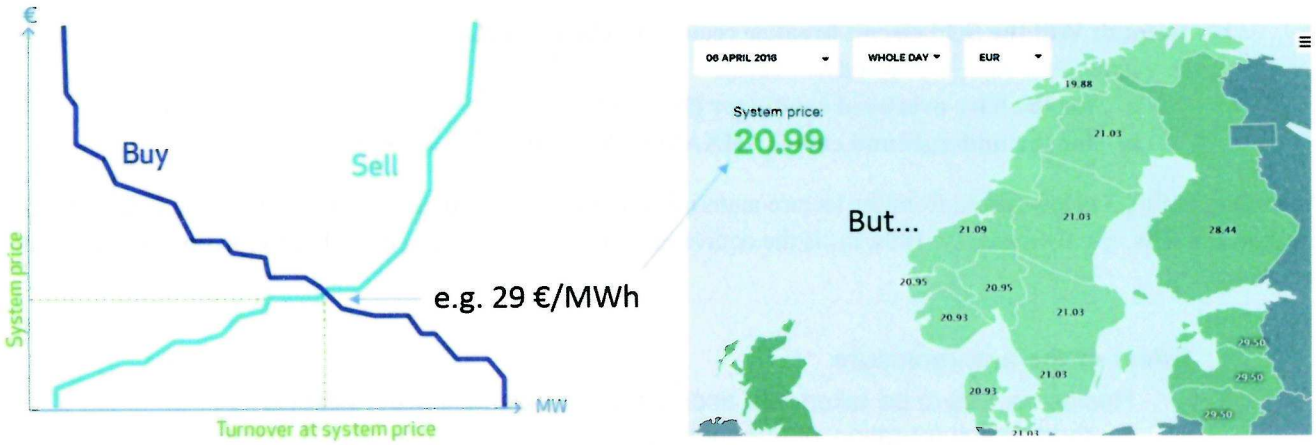

Figure 1

b) What happens when the **system price**, computed by aggregating all the bids and all the offers in the Nordic region, is **technically unsustainable**? Figure 1 may inspire you... (3p)

Q3. 3-phase short circuit limits and time-delayed autoreclosing (td) (6p)

Figure 2 below shows an underground cable connection that feeds a large industrial load, in turn connected to a fault-prone overhead line connected to a small load.

- The main primary substation circuit breaker operates within 600ms.
- The Pigeon cable has a (field) circuit breaker, which operates within 400ms.

The distribution network operator is debating whether or not to introduce time-delayed autoreclosing for the field circuit breaker.

a) First: Are the 3-phase short circuit ratings of the feeder in Fig. 2 OK (without autoreclosing)? Justify your answer.

Table 1 Line data for Q3

	Resistance (Ω/km)	Reactance (Ω/km)	I_{max} (A)	$I_{k,1s}$ (kA)	Cooling time constant, τ (s)
Al/Fe 85/14 (Pigeon)	0.337	0.354	360	8.4	360
AHXAMK-W3x120	0.3	0.123	265	11.4	3600

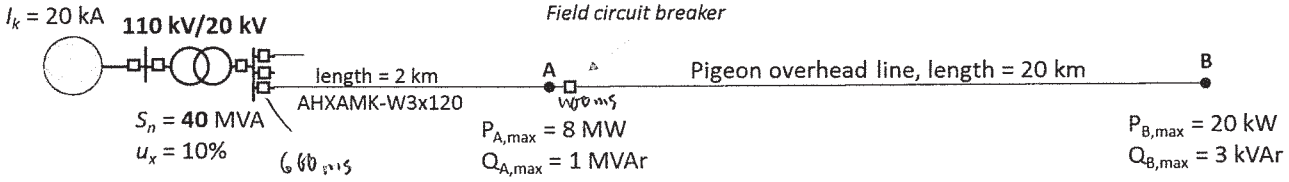

Figure 2

b) Second: Will the field circuit breaker reclosing scheme work (refer to Table 1, the text below and Fig. 3, where t_1 = 0.8s, t_2 = 0.4s and t_0 = 180s)**:**

a. for the bare overhead conductor (Pigeon)? 0,8852 ..

b. for the underground cable (AHXAMK-W3x120)? 1,1605 ..

According to Fig. 3 below (taken from the lecture material, to aid your overworked memories!), for the field circuit breaker, t_1 = 0.8s, t_2 = 0.4s and t_0 = 180s. t_{ekv} is the equivalent time it takes for the circuit breaker to open if there is no reclosing.

Effect of the autoreclosure

Reclosure has to be taken into account when calculating the effect of a short circuit (duration of the short circuit)

$$t_{ekv} = t_1 \cdot e^{-t_0/\tau} + t_2$$

t_1 the sc duration before a td

t_o the non-energized time before td

t_2 the s-c duration after td

τ cooling time constant of the feeder

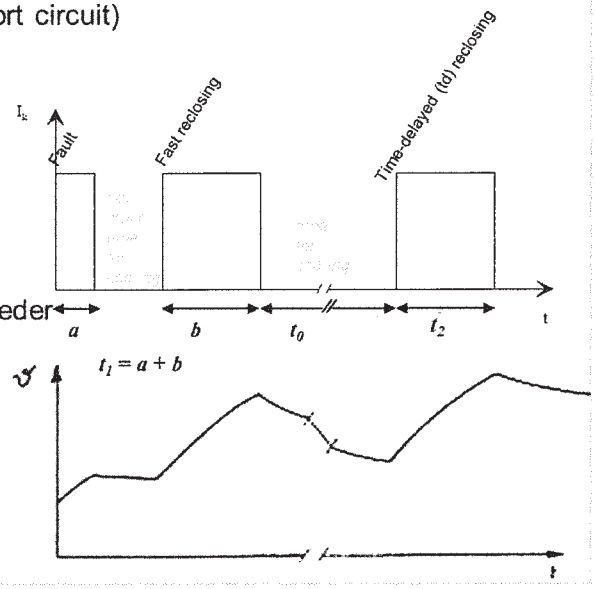

Figure 3

Q4. A single primary substation transformer feeds 100 x 1MW secondary substations (i.e. a total load of 100MW). Each secondary substation has CIC (KAH) costs of a = 1€ / kW / fault and b = 10 € / kWh. The discount factor load (which turns annual costs into the present value of the lifetime costs), κ_{losses} = 20 (years). The primary substation has an average fault frequency of 1 fault / 100 years. It takes 24 hours to replace/repair the single transformer primary substation including switching.

It will cost 110 000 € to provide backup to the 100 secondary substations from another (nearby) primary substation that has enough surplus capacity. The switching would take 30 minutes to make the backup. You can assume that the backup will not significantly affect interruption costs that are caused by line faults.

Is the investment worthwhile? (6pt)

Q5.

a) Explain, generally, what is going on in Fig. 4 (2pt)

b) Briefly explain 4 terms in this figure (4pt)

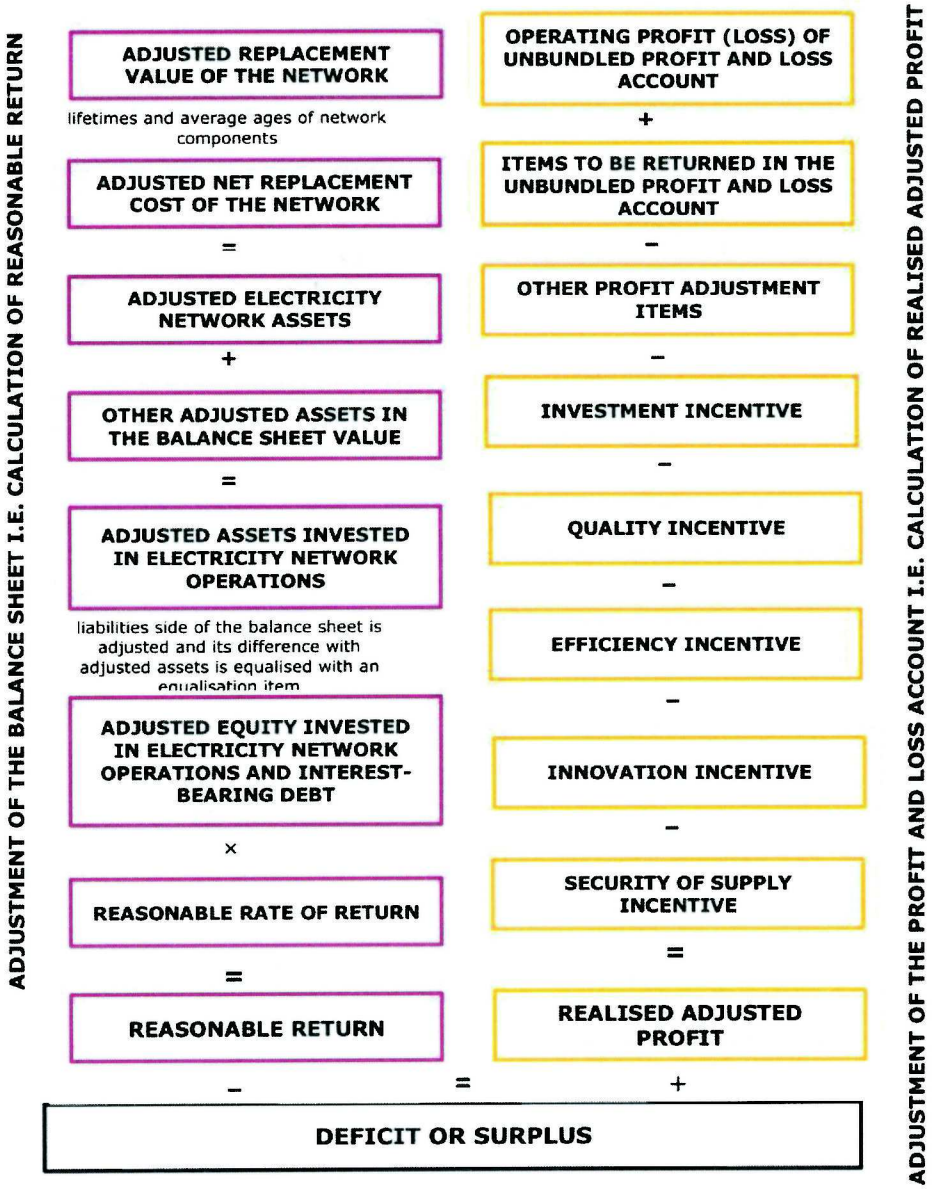

Figure 4 *Regulation methods during regulatory periods 2016-2019 and 2020-2023*