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! Please, no discussion or communication during this exam, online or offline, but you can refer to course material.*

Please type your workings and answers in this document, saved with the name:

ELEC-E8406AprilExam_*YourName_YourStudentNumber*

Remember to keep saving the document as you work, then upload it to MyCourses with any attachments, and if that fails, email the document to john.millar@aalto.fi, with ELEC-E8406AprilExam_YourNameYourStudentNumber in the subject.

Q1. General

- List 3 general differences between **rural** and **urban** electricity distribution systems. (3p)

  Answers:

  i.
  ii.
  iii.

- *In this course we have learnt how to calculate customer interruption costs in terms of* CIC *costs* (€/kW/fault *and* €/kWh). *We also mention in the course about* "Standard Compensations for Long Interruptions" *which are being tightened. For urban customers, distribution companies will have to start compensating customers (up to 2000 €/year) directly for interruptions to supply that last longer than* 6h.

  What does this mean for urban distribution network planning? What kind of topological and technological changes and considerations would you expect are needed in an urban network that still has some overhead network? (3p)

  Answers:

  i.
  ii.
  iii.

Q2. Electricity Markets and Regulation

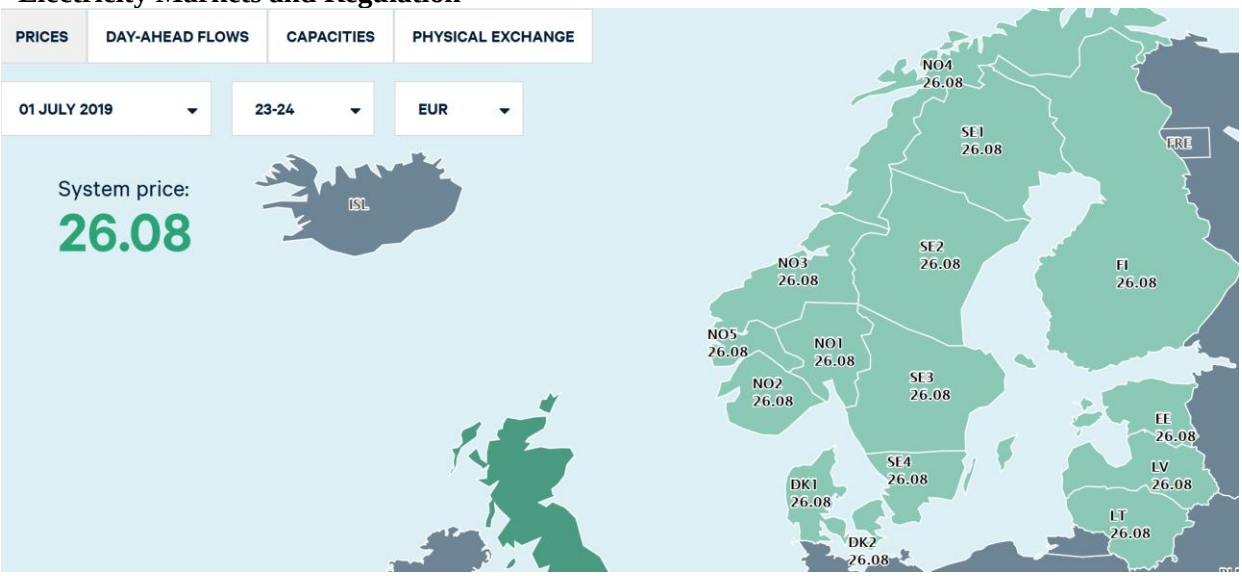

Figure 1 System vs Bidding area prices (when system and bidding area prices are the same)

Source: https://www.nordpoolgroup.com/maps/#/nordic

a) What happens when the system price **cannot** be supported by the transmission system (i) and why does this happen (ii)? (2p)

Answers:

i.

ii.

b) What happens to the price in an area with generation surplus when supply and demand are calculated in each area (e.g. Norway) rather than the entire system (e.g. all the Nordic countries covered by Nordpool) (1p)

Answer:

iii.

c) What happens to the price in an area with generation deficit (consumption surplus) when supply and demand are calculated in each area (e.g. Finland) rather than the entire system (1p)

Answer:

iv.

d) What happens to the price (in the surplus area) when some transmission capacity is allowed for? (1p)

Answer:

v.

e) What happens to the price in the deficit area when some transmission capacity is allowed for? (1p)

Answer:

vi.

Q3.

Figure 2 UN Sustainable Development Goals

Write **6 clear statements** about Sustainable Development Goals (SDG) relevant to this course, Electricity Distribution and Markets, e.g., "Which of the SDGs does this course touch on (and how)?", "Where could we do better?" (6p)

Answers:

i.
ii.
iii.
iv.
v.
vi.

Distribution Network Analysis (Data on this page are for **Q4** and **Q5**)

Table 1 20 kV Line data for Q4 and Q5

	Fault rate (faults/100km/year)	**Resistance** (Ω/km)	**Reactance** (Ω/km)	$\mathbf{I_{max}}$ (A)	$\mathbf{I_{sc,1s}}$ (kA)
AHXAMK-W3x150 underground cable	2	0.25	0.123	240	14.1

Table 2 Nodal (substation) data for Q4 and Q5

Node No	$\boldsymbol{P_{max}}$ (kW)	$\boldsymbol{Q_{max}}$ (kVAr)	CIC (***a***: €/kW/fault)	CIC (***b***: €/kWh)
0 (Primary substation)	0	0	0	0
1 (Primary substation)	0	0	0	0
2 (secondary substation)	1000	0	1.1	11
3 (secondary substation)	800	0	1.1	11
4 (secondary substation)	1800	0	1.1	11

Table 3. Switching times

Remote switch	0.1667 h
Circuit breaker	0.4 sec

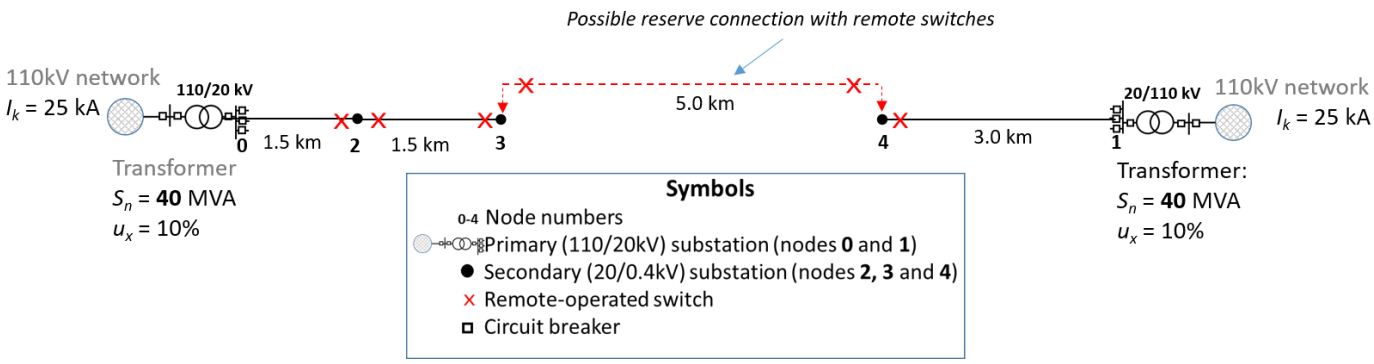

Figure 3 Network diagram for Q4 and Q5

You may need some of the following formulae:

$$\gamma = \frac{(1+r)}{(1+p)}, \quad \gamma_1 = \frac{(1+r)^2}{(1+p)} \quad \text{and} \quad \gamma_2 = \frac{1}{1+p}$$

$$\kappa_{losses} = \gamma_1 \frac{\gamma_1^{t'} - 1}{\gamma_1 - 1} + \frac{(1+r)^{2t'}}{(1+p)^{t'}} \gamma_2 \frac{\gamma_2^{T-t'} - 1}{\gamma_2 - 1}$$

$$\kappa_{load} = \gamma \frac{\gamma^{t'} - 1}{\gamma - 1} + \frac{(1+r)^{t'}}{(1+p)^{t'}} \gamma_2 \frac{\gamma_2^{T-t'} - 1}{\gamma_2 - 1}$$

Fig. 1 shows an underground cable connection that is planned to be built between two primary substations feeding 3 important secondary substations. Apart from the primary substation circuit breakers, all switches are remote operated, and can isolate faulted sections and restore supply to the affected customers in 0.1667 h.

The load growth is 3 % / year for **20 years**, then remains constant for the remainder of the **40 year review period**. The interest rate is 4 % / year (for the entire network life of 40 years). The main circuit breakers operate within 0.4 seconds.

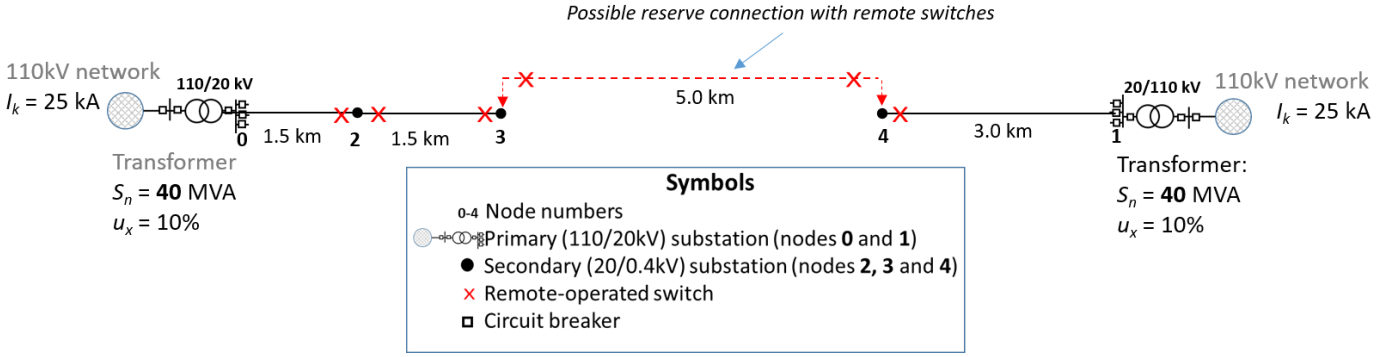

Figure 3 is repeated here for your convenience

Q4. Reliability and Optimal Open Point (6p)

How cheap would the *possible reserve connection with remote switches* (-x----------x-) in Fig. 3 have to be to be economically beneficial in terms of reliability? How reasonable would this investment cost be in your opinion? Is there any other consideration that may favour the investment?

Customer interruption costs are given in Table 2 *along with maximum demand for each secondary substation.*

Answers and calculations (if you prefer to make hand calculations, photograph and paste them here, but preferably type directly into this document!:

Q5. Technical Constraints (6p)

If the reserve connection in Fig. 3 is installed, is the network technically feasible? Justify your answer.

Answers and calculations (if you prefer to make hand calculations, photograph and paste them here, but preferably type directly into this document!):