PHYS-E0483 Advances in New Energy Technologies (5 cr)

Exam 12 April 2022, 5-8pm

You may write your answers in English, Finnish, German, or Swedish.
Handwrite on paper, scan or photo your answers and upload in MyCourses, at latest 8:15 pm
Include your name and study number on each page.
Peter Lund: tel. 0405150144, peter.lund@aalto.fi. Answer all 5 questions.

1. Energy system flexibility strategies (6p, each 3p)

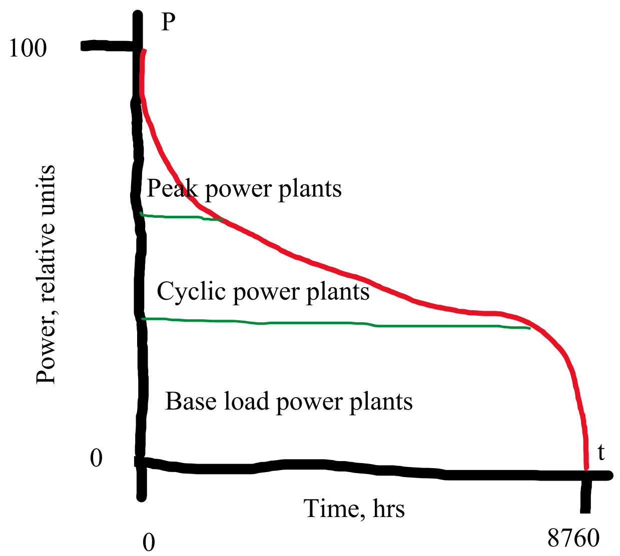
a) In which ways can measures on the final energy end-use side affect energy system flexibility?
b) Explain how a sorption material could work as a long-term heat storage?

2. Energy system analysis (6p, each 2p)

Typically, the mix of power plants required to meet the power demand (P) consists of base, cyclic, and peak power plants. Adding wind or solar power (RE) to the energy system will affect the power demand profile, which the traditional power plants also need to meet, i.e. the residual power demand P-RE. For analyzing how RE affects the residual demand and plant portfolio, one may use the power duration curve.

Your task is to draw the resulting power duration curve for the residual power P-RE, when RE is added and explain how the mix of base, cyclic, and peak power shown in the figure would be influenced. The cases are the following, assuming that RE is wind power:

(a) RE is sized so that the yearly wind power production equals the yearly power demand
(b) Same case as (a) but adding short-term diurnal electric storage to wind power
(c) Same as (a) but adding a long-term seasonal electric storage that can store all PV



On the left, we have the power duration curve of the power demand P (the hourly power demand over a year sorted in descending order). At point t=0, we have the maximum power demand, which is equal to 100 units,

Also, the shares of different types of power plants to meet the demand are shown.

Draw the residual power P-RE-curves. Does not need to exactly be in scale.

3. Disruption in energy system (6p, each 3p)

a) Let's assume a power system with an inertia constant of T=10 seconds. Describe quantitatively how will the frequency of the power system behave during 30 seconds after a sudden +30% jump in the nominal power. The nominal frequency is 50 Hz.

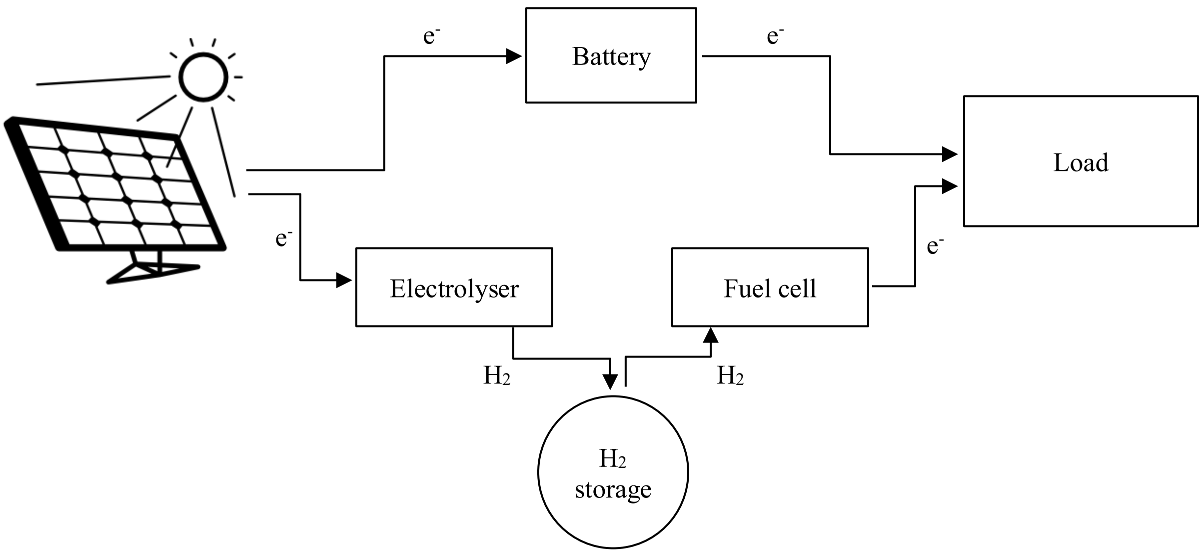
b) The inertia of a power system can be increased e.g. by using a flywheel. To add 1 MWh of electrical storage, estimate how large mass is required if the flywheel is designed for a spinning rate of 100000 rpm.

4. Storage system analysis (6p)

Consider a system with solar PV and storage. PV produces electricity mostly in the summer, but electricity can also be stored for the winter. The nominal power of the PV panels is 10 kW_p, and the panels have 850 full load hours in a year resulting in 8500 kWh of electricity. The maximum power of the load is 20 kW. Over a year, 1/3 of the total PV output can be used directly to cover the instantaneous power demand (=self-use).

<u>Your task is to design a storage system, which is able to store the excess solar electricity output over one year so that the PV system could be self-sufficient</u>. There are two options for the storage system: (1) Li-ion battery; (2) Hydrogen-based storage system which includes an electrolyser, a hydrogen storage and a fuel cell. The specifications of the system components can be found in the table.

a) Calculate the total volume of both storage options (in litres or m^3) and the available electricity after storage assuming that the storage is full loaded. Discuss your results. (4p)
b) What is the difference between the two systems in terms of energy and power capacity? (2p)



	Energy density (kWh/l)	Power density (kW/l)	Efficiency (%)
Li-ion battery	0.40	2.5	90 %
Electrolyser	-	2.0	75 %
Fuel cell	-	2.5	60 %
Hydrogen storage	1.4	-	95 %

5. Power market analysis (6p)

Day-ahead Elspot price curves for 25.5.2016 5pm in Finland are presented below. The second figure is a zoom-in of the first figure near the cross-section point. Answer the following questions:

a) What does the buy and sell curves represent? Explain the shape of the curves. (2p)

b) Determine the demand and the current price of electricity from the price curves. (1p)

What would happen to the demand and the price of electricity if

c) A power plant (maximum power output 1000 MW) that will be turned on when the price of electricity exceeds 35 €/MWh is not able to operate? (1p)

d) The amount of wind power available is 3 GW smaller? (1p)

e) A major chemical factory (electricity demand 1 GW) is closed due to a maintenance? (1p)

Justify your answers based on the Elspot-price curves in the next.