PHYS-E0483 Advances in New Energy Technologies 5cr, Spring 2016

Outline of exams:

- Scope of exam is the same as covered by the lectures and exams
- Reading for exams:

1) General introduction to the themes: Jacob Klimstra, Power supply challenges – Solutions for Integrating Renewables. Wärstilä, 2014, 190 pages. The book can be downloaded from http://pages.wartsila.net/PowerSupplyChallenges_GA
2) Special treatment of topics : Review Articles under the lectures and tools
3) Lecture notes and exercises #1-#10

- Key areas to be examed:

1. Structure and characteristics of the energy system (heat, power)
2. Principles of the electricity system
3. Grid voltage, frequency, reactive power etc.
4. Energy supply and demand patterns
5. Impacts of new energy technologies on energy systems and markets
6. System integration principles of new energy technologies
7. Energy systems and their planning with high shares of renewable electricity
8. Smart power systems
9. Energy transitions
10. Energy system and grid topologies
11. Multi-carrier energy networks
12. Urban energy systems/flexibility
13. Energy chains
14. Energy supply characteristics and response times
15. Polygeneration
16. Energy system flexibility strategies
17. Demand side management (DSM)
18. Energy storage
19. Batteries
20. Thermal energy storage

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

Exam 25.8.2015

You may write your answers in English, Finnish, German, Swedish. You are allowed to use a calculator in the exam (Peter Lund 0405150144). Observe that there are questions on the both side of the paper.

1. Choose either 1a) or 1b)

   a) Explain the key <u>power supply side</u> principles to provide necessary energy system flexibility when integrating large amounts of variable renewable power into to power system.

   OR

   b) Explain in details the rationale and realization of <u>Demand-Side-Management</u> (DSM) flexibility strategy.

2. The energy effectiveness (r_{CHP}) of a combined heat and power (CHP) plants compared to a separated system can be described with the formula

$$r_{CHP} = \frac{total\ fuel\ used,\ separated\ system}{total\ fuel\ used, CHP} = \frac{\eta_{CHP,elec}}{\eta_{elec}} + \frac{\eta_{CHP,heat}}{\eta_{heat}}$$

   in which $\eta_{CHP,elec}$ and $\eta_{CHP,heat}$ denote energy conversion efficiencies for electricity and heat in a CHP plant, and η_{elec} and η_{heat} the conversion efficiencies in separate electricity and heat plants.

a) Helsinki Salmisaari CHP-plant produces electricity and heat with efficiencies $\eta_{CHP,elec} = \eta_{CHP,heat} = 40\ \%$. An alternative system produces electricity and heat separately. The heat is produced by a boiler ($\eta_{heat} = 95\ \%$) and the electricity by a separate plant. How high electricity production efficiency (η_{elec}) is needed so that the separate production chain is more energy-efficient than CHP-production? (2p)

b) Salmisaari CHP-plant is fired by coal (specific CO_2 emission per fuel used c_c = 94.6 $kgCO_2/GJ$) and the separate production plants by natural gas (c_{ng} = 59.1 $kgCO_2/GJ$). How high electricity production efficiency (η_{elec}) is needed so that the separate production chain produces less CO_2 emissions than CHP-production? (4p)

3. A region has a constant electricity demand (D_{el}) of 1000 MW. The region produces energy by solar power and has an ideal balancing power system. The market price of electricity in the domestic market has been observed to follow the formula $C_{el} = 50 \cdot (1 - P_{sol} / D_{el})$ €/MWh, where P_{sol} is the amount of solar power supplied to the grid. On a sunny day the solar energy production exceeds the electricity demand.

a) Calculate the maximum revenue of solar power (€/hour). What is the optimal amount of solar power supplied to the grid? You can assume that the solar energy production, which is not supplied to the grid, is wasted.

b) The region makes a contract which allows them to export solar electricity with a constant price (C_{export}= 35 €/MWh) Determine the limit solar production (P_{limit}) after which it is more profitable to export the extra solar electricity than to sell it to domestic market.

4. Explain shortly the 5 questions below:

a) Natural inertia of the power system
b) Active and reactive power
c) Primary and secondary reserves in the power system
d) Response time of different type (min. 3) of power plants
e) Give 5 examples of distributed power technologies