KTH Electrical Engineering

Partial exam 2 in EG2050 System Planning, 26 February 2014, 13:00-14:00, Q31, Q33, Q34, Q36

Instructions

Students must arrive to the partial exam within 45 minutes of the start time of the test. No students may leave the room until the end of the test.

Write all answers on the answer sheet provided. Motivations and calculations do not have to be presented. (Those who want may also submit complete solutions, but the answer sheet should be filled out nevertheless!)

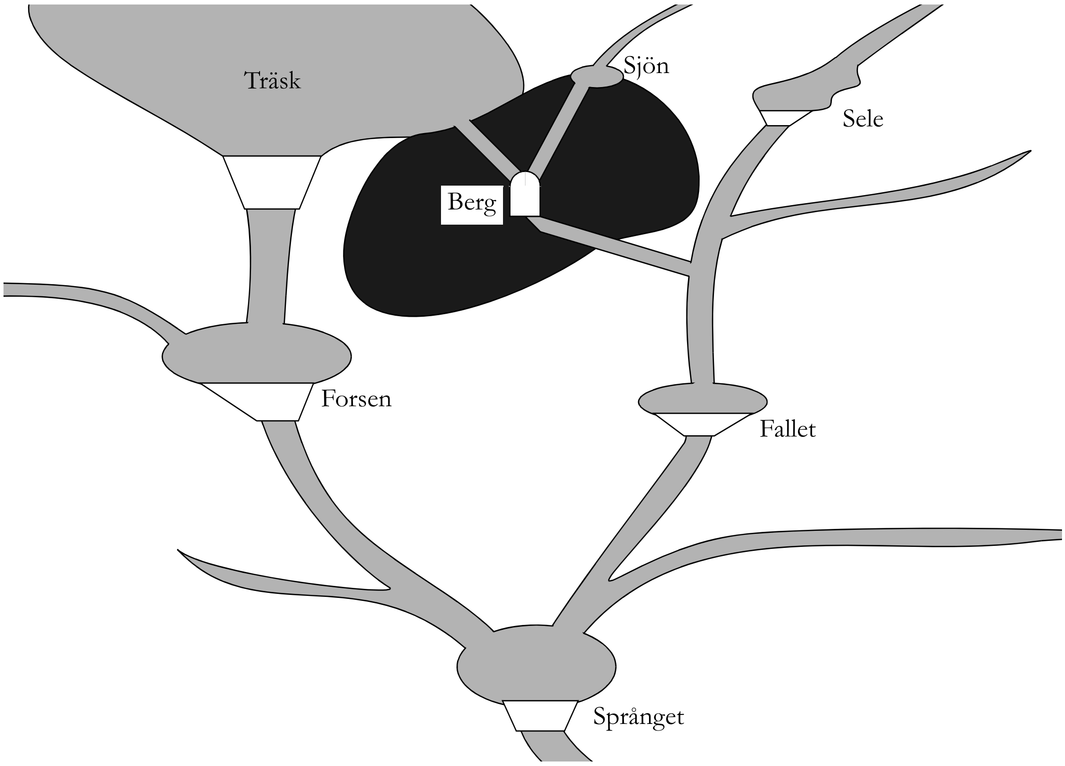
Together, the three partial exams offered during the course correspond to part I in the final exam. A total score in the partial exams of at least 33 points is required to pass.

Allowed aids

In this partial exam you are allowed to use the following aids:

- Calculator without information relevant to the course.
- One **handwritten**, **single-sided** A4-page with **your own** notes (original, not a copy), which should be handed in together with the answer sheet.

Problem 4 (12 p)



AB Vattenkraft owns five hydro power plants located as in the figure above. Berg is an underground pumped storage hydro power plants, which can be operated in three different ways:

- Water from Träsk can be discharged through the turbines in Berg.
- Water from Sjön can be discharged through the turbines in Berg.
- Water from Träsk can be pumped via Berg to Sjön.

It should be noted that water that is discharged through the turbines in Berg will be released in the reservoir of Fallet, whereas water that is spilled from Träsk passes through the natural riverbed to Forsen. The hydro reservoir Sjön does not have any spillways, i.e., the only way to lower the water level in Sjön is to dicharge water through Berg!

The following symbols have been introduced in a short-term planning problem for these hydro power plants:

Indices for the power plants: Träsk 1, Sjön 2, Sele 3, Forsen 4, Fallet 5, Språnget 6.

D_t = contracted load hour t, t = 1, …, 24,
$M_{i,0}$ = contents of reservoir i at the beginning of the planning period, i = 1, …, 6,
$M_{i,t}$ = contents of reservoir i at the end of hour t, i = 1, …, 6, t = 1, …, 24,
$\overline{M}_i$ = maximal contents of reservoir i, i = 1, …, 6,
$\mu_{i,j}$ = marginal production equivalent for discharge from reservoir i, segment j, i = 1, …, 6, j = 1, 2,
γ_P = production equivalent for pumping from Träsk to Sjön (notice that $\gamma_P < 0$, as electricity is consumed when pumping),
$Q_{i,j,t}$ = discharge from reservoir i, segment j, during hour t, i = 1, …, 6, j = 1, 2, t = 1, …, 24,
Q_{Pt} = pumping from Träsk to Sjön during hour t, t = 1, …, 24,
$\overline{Q}_{i,j}$ = maximal discharge from reservoir i, segment j, i = 1, …, 6, j = 1, 2,
$\overline{Q}_P$ = maximal pumping from Träsk to Sjön,
$S_{i,t}$ = spillage from reservoir i during hour t, i = 1, 3, …, 6, t = 1, …, 24,
$\overline{S}_i$ = maximal spillage from reservoir i, i = 1, 3, …, 6,
$V_{i,t}$ = local inflow to reservoir i during hour t, i = 1, …, 6, t = 1, …, 24.

a) (5 p) AB Vattenkraft sells power to the local power exchange, ElKräng. The result of the trading at ElKräng is published at 1 pm and then AB Vattenkraft knows hom much they will have to generate every hour the following day. Their short-term planning problem is now to maximise the value of stored water while generating the contracted load. Formulate the load balance constraint of the company. Use the symbols defined above.

Hint: You may assume that the other parts of the short-term planning problem are formulated such that Berg in a given hour only can be used in one of the above described ways. Hence, there are constraints that prevent for example that $Q_{1,1,t} > 0$ at the same time as $Q_{2,1,t} > 0$.

b) (5 p) Formulate the hydrological constraint of Fallet, hour t. The water delay time between the power plants can be neglected. Use the symbols above.

c) (2 p) The following variables and parameters have been introduced in a short-term planning problem for a a thermal power plant:

C^* = start-up cost of the power plant after one hour down-time,
C^{**} = start-up cost of the power plant after at least two hours down-time,
G_t = generation in the power plant during hour t,
s_t^* = start-up of the power plant at the beginning of hour t after one hour down-time (1 if the power plant is started after one hour down-time, otherwise 0),
s_t^{**} = start-up of the power plant at the beginning of hour t after at least two hours down-time (1 if the power plant is started after at least two hours down-time, otherwise 0),
u_t = unit commitment of the power plant in hour t (1 if the power plant is committed, otherwise 0),
β = variable operation cost.

The following objective function is used in the planning problem:

$$\text{minimise} \quad \sum_{t \in \mathcal{T}} (\beta G_t + C^* s_t^* + C^{**} s_t^{**}).$$

Two linear constraints are needed in order to get correct values of s_t^* and s_t^{**} The first constraint forces s_t^{**} to be equal to one if the power plant is committed in hour t, while it has not been committed during hours $t-1$ and $t-2$ respectively:

$$s_t^{**} \geq u_t - u_{t-1} - u_{t-2}.$$

The second constraint should force s_t^* to be equal to one if the power plant has been committed in hours t and $t-2$ respectively, but has not been committed during hour $t-1$. Which of the following relations can be used for the second constraint?

I) $s_t^* \geq u_t - u_{t-1} - s_t^{**}$.

II) $s_t^* \geq u_t - u_{t-1} - u_{t-2}$.

III) $s_t^* - u_{t-2} \geq u_t - u_{t-1}$.

1. None of the alternatives is correct.
2. Only alternative I is correct.
3. Only alternative II is correct.
4. Only alternative III is correct.
5. One can choose between using alternative I and alternative II.

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Answer sheet

Name: ....

Personal number: ....

Problem 4

a) ....

....

b) ....

....

c) Alternative .... is correct.

Problem 4

a) $\sum_{i=1}^{6} \sum_{j=1}^{2} \mu_{i,j} Q_{i,j,t} + \gamma_P Q_{Pt} = D_t$.

b) $M_{5,t} = M_{5,t-1} + V_{5,t} + Q_{1,1,t} + Q_{1,2,t} + Q_{2,1,t} + Q_{2,2,t} + Q_{3,1,t} + Q_{3,2,t} + S_{3,t} - Q_{5,1,t} - Q_{5,2,t} - S_{5,t}$.

c) 2.