EE-472 Smart Grids Technologies
Module 4 Quiz (Graded)
27. 05. 2024

With Solutions

Student Name: ____________________________

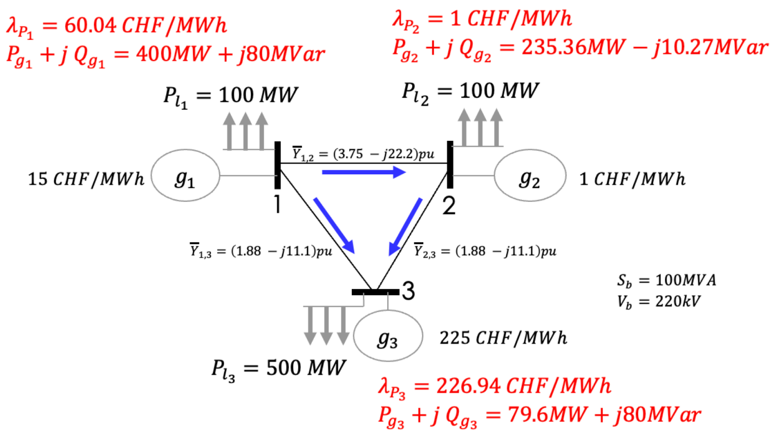
Sciper Number: ☐☐☐☐☐☐

Consider the following system and the corresponding solution.

Question 1

Not yet answered

Not graded



Which of the following statements is true?

- a. The solutions were obtained using the DC flow approximation.
- b. The constraint for generator 2 is binding.
- c. There are no binding constraints.
- d. At least one line flow is limited by a binding constraint.

This question can be answered through elimination of the incorrect answers. If the solutions were obtained through a DC approximation, the sum of the generator power injections should equal the sum of the loads. This is not the case as there are losses. Answer a is thus incorrect. Given the costs for the different generators, it is then easy to exlude answer two as the only way the shadow price at node 2 can be 1CHF is if generator 2 can still provide additional power. Finally, answer three can be eliminated through the same reasoning. If there were no binding constraints, the shadow price at node 1 could not be higher than 15.

Question 2

Not yet answered

Marked out of 10

Consider the following quadratic expression:

$$Q_l \geqslant \frac{P_{ij}^2 + Q_{ij}^2}{V_i} X_l$$

You are asked to reformulate this expression as an equivalent conic expression. Select the correct reformulation.

a.

$$Q_l + \frac{V_i}{X_l} \geqslant \left\| \begin{matrix} 2P_{ij} \\ 2Q_{ij} \\ Q_l - \frac{V_i}{X_l} \end{matrix} \right\|_2$$

b.

$$Q_l - \frac{V_i}{X_l} \geqslant \left\| \begin{matrix} 2P_{ij} \\ 2Q_{ij} \\ Q_l + \frac{V_i}{X_l} \end{matrix} \right\|_2$$

c.

$$Q_l - \frac{V_i}{X_l} \geqslant \left\| \begin{matrix} P_{ij} \\ Q_{ij} \\ Q_l + \frac{V_i}{X_l} \end{matrix} \right\|_2$$

d.

$$Q_l + V_i \geqslant \left\| \begin{matrix} 2P_{ij}X_l \\ 2Q_{ij}X_l \\ Q_l - V_i \end{matrix} \right\|_2$$

The correct answer is answer a. This can be determined by using the trick for the transformation of convex quadratic constraints seen in the lecture. Additionally, by working out the different solutions, the original expression can be found. For answer a, we get:

$$Q_l + \frac{V_i}{X_l} \geqslant \left\| \begin{matrix} 2P_{ij} \\ 2Q_{ij} \\ Q_l - \frac{V_i}{X_l} \end{matrix} \right\|_2$$

$$\iff (Q_l + \frac{V_i}{X_l})^2 \geqslant (\left\| \begin{matrix} 2P_{ij} \\ 2Q_{ij} \\ Q_l - \frac{V_i}{X_l} \end{matrix} \right\|_2)^2$$

$$\iff Q_l^2 + \frac{V_i^2}{X_l^2} + 2Q_l\frac{V_i}{X_l} \geqslant 4P_{ij}^2 + 4Q_{ij}^2 + Q_l^2 - 2Q_l\frac{V_i}{X_l} + \frac{V_i^2}{X_l^2}$$

$$\iff 2Q_l\frac{V_i}{X_l} \geqslant 4P_{ij}^2 + 4Q_{ij}^2 - 2Q_l\frac{V_i}{X_l}$$

$$\iff 4Q_l\frac{V_i}{X_l} \geqslant 4P_{ij}^2 + 4Q_{ij}^2$$

$$\iff Q_l \geqslant (P_{ij}^2 + Q_{ij}^2)\frac{X_l}{V_i}$$

Question 3

Not yet answered

Marked out of 10

Consider an optimal power flow problem constrained as follows:

$$P_j(t) = \sum_k P_{jk}(t) - P_{ij}(t) + R_{ij} i_{z_{ij}}(t) + G_i v_i(t) + G_j v_j(t), (i,j) \in \mathcal{L}$$
$$Q_j(t) = \sum_k Q_{jk}(t) - Q_{ij}(t) + X_{ij} i_{z_{ij}}(t) + B_i v_i(t) + B_j v_j(t), (i,j) \in \mathcal{L}$$
$$\sum_k P_{ki}(t) + P_i(t) = P_{ij}(t), (i,j) \in \mathcal{L}$$
$$\sum_k Q_{ki}(t) + Q_i(t) = Q_{ij}(t), (i,j) \in \mathcal{L}$$
$$P_j(t) = P_{g_j}(t) + P_{l_j}(t), +P_{s_j}(t), j \in \mathcal{S}$$
$$Q_j(t) = Q_{g_j}(t) + Q_{l_j}(t) + Q_{s_j}(t), j \in \mathcal{S}$$
$$v_j(t) = v_i(t) + \left|\bar{Z}_{ij}\right|^2 i_{z_{ij}}(t) - 2\Re\left[\underline{Z}_{ij}\left(\bar{S}_{ij}(t) - \bar{Y}_i v_i(t)\right)\right], (i,j) \in \mathcal{L}$$
$$P_{g_j}^{min} \le P_{g_j}(t) \le P_{g_j}^{max}, j = 1, \dots, g$$
$$Q_{g_j}^{min} \le Q_{g_j}(t) \le Q_{g_j}^{max}, j = 1, \dots, g$$
$$P_{s_j}^{min} \le P_{s_j}(t) \le P_{s_j}^{max}, j = 1, \dots, m$$
$$Q_{s_j}^{min} \le Q_{s_j}(t) \le Q_{s_j}^{max}, j = 1, \dots, m$$
$$\left|\bar{V}_1\right| = 1pu$$
$$V_{min}^2 \le v_j \le V_{max}^2, j \in \mathcal{S}$$
$$i_{z_{ij}}(t) \ge \frac{\left|\bar{S}_{ij}(t) - \bar{Y}_i v_i(t)\right|^2}{v_i(t)}, (i,j) \in \mathcal{L}$$
$$P_{ij}^2(t) + Q_{ij}^2(t) \le \left(S_{ij}^{max}\right)^2 \text{ or } i_{z_{ij}}(t) \le \left(I_{ij}^{max}\right)^2, (i,j) \in \mathcal{L}$$

Which of the following objectives will lead to a tight relaxation of the original non-approximated optimal power flow problem?

a.
$$\min_{\substack{P_{g_1}(t),\dots,P_{g_g}(t),Q_{g_1}(t),\dots,Q_{g_g}(t) \\ P_{s_1}(t),\dots,P_{s_m}(t),Q_{s_1}(t),\dots,Q_{s_m}(t)}} \sum_{t=1}^{T_{max}} \sum_{(j \in \mathcal{S})} \left(V_j(t) - V_{nom}(t)\right)$$

b.
$$\min_{\substack{P_{g_1}(t),\dots,P_{g_g}(t),Q_{g_1}(t),\dots,Q_{g_g}(t) \\ P_{s_1}(t),\dots,P_{s_m}(t),Q_{s_1}(t),\dots,Q_{s_m}(t)}} \sum_{t=1}^{T_{max}} \sum_{(i,j) \in \mathcal{L}} R_{ij} i_{z_{ij}}(t)$$

c. Any convex objective function will ensure the presented constraints lead to a tight relaxation of the non-approximated optimal power flow problem.

d.
$$\min_{\substack{P_{g_1}(t),\dots,P_{g_g}(t),Q_{g_1}(t),\dots,Q_{g_g}(t) \\ P_{s_1}(t),\dots,P_{s_m}(t),Q_{s_1}(t),\dots,Q_{s_m}(t)}} \sum_{t=1}^{T_{max}} \sum_{i=1}^{g} C_i\left(P_{g_i}(t), Q_{g_i(t)}\right) + \sum_{i=1}^{m} C_i\left(P_{s_i}(t)\right)$$

As seen during the lectures, the SOCP relaxation requires the objective to be increasing with the system losses. This is represented by the term in answer b. The other objectives are convex, but do not guarantee the inequality to be tight.

Question 4

Not yet answered

Marked out of 10

Consider an optimal power flow problem formulated as follows using the copper plate approximation.

$$\min_{P_{g_1}(t),\dots P_{g_g}(t)} \sum_{i=1}^{g} C_i\left(P_{g_i}(t)\right)$$
$$s.t.$$
$$\sum_{i=1}^{g} P_{g_i}(t) + \sum_{j=1}^{u} P_{l_j}(t) = 0$$
$$P_{g_i}^{min} \le P_{g_i}(t) \le P_{g_i}^{max}$$

The following statements are made:

i. The marginal cost of power generation is only a consequence of the generator models.

ii. The marginal costs do not reflect the impact of the losses on the operation cost of the system.

Which statement(s) is/are correct?

- a. Both statements are incorrect.
- b. Only statement i. is correct.
- c. Both statements are correct.
- d. Only statement ii. is correct.

It is clear that the problem does not account for losses as the power balance includes only the generator and load power. Statement ii is thus correct. Given that the only constraints are related to the power generation of the generators and the balance with the loads, no other factors influence the marginal cost.

Question 5

Not yet answered

Not graded

Consider the following stochastic optimization problem where C is a convex function:

$$\min_{x,y} \quad C(x,y,d)$$
$$\text{s.t.} \quad x^2 + y^2 \leqslant 1$$
$$y - x - |d| \leqslant 1 \quad \forall d \in \mathcal{D}$$

Two approaches are proposed to solve the problem. Two engineers propose different approaches to solve this problem. Willem proposes to minimise the worst case cost, stating that a robust approach is better suited to solve this problem. Additionally, Willem approximates the uncertainty set as [-1,1].

Vladimir proposes to solve the problem using a stochastic approach, accepting a small probability to violate the constraints. The motivation for this approach is that the system can be optimised for the expected value of the disturbance, which they expect to be closer to the frequently encountered realisations. Vladimir approximates the uncertainty set as a normal distribution N(0,2).

Both Willem and Vladimir claim their solution will always lead to an optimal value for the objective that is lower or equal than the objective value found by their counterpart.

Who is right?

- a. Both are right. The answer is identical.
- b. Only Willem is right.
- c. Both are wrong. It depends on the objective function
- d. Only Vladimir is right.

Working out the robust constraint gives that y-x <= min (1 + |d|) for all the considered values of d. The right hand side of this inequality is minimal for d=0, which is within the uncertainty set of both. Thus they have the same constraints, once the stochastic variable d is eliminated from the constraints. For the objective, Vladimir will take the expected value, while Willem will always consider the worst case. The solution Vladimir proposes will thus always be lower or equal than the one obtained by Willem.

Question 6

Not yet answered

Marked out of 10

Which of the following problems can be solved independently for each time step t?

a.

$$\min_{P_{g_1}(t),\dots,P_{g_g}(t),Q_{g_1}(t),\dots,Q_{g_g}(t)} \sum_{t=1}^{24}\sum_{i=1}^{g} C_i\left(P_{g_i}(t)\right)$$

$s.t.$

$$\overline{S}_i(t) = \overline{V}_i(t)\sum_{j=1}^{n} \underline{V}_j(t)\underline{Y}_{ij}, i = 1,\dots,n$$

$$\overline{S}_i(t) = \left(P_{g_i}(t) + jQ_{g_i}(t)\right) + \left(P_{l_i}(t) + jQ_{l_i}(t)\right), i = 1,\dots,n$$

$$P_{gi}^{min} \le P_{g_i}(t) \le P_{gi}^{max}, i = 1,\dots,g$$

$$Q_{gi}^{min} \le Q_{g_i}(t) \le Q_{gi}^{max}, i = 1,\dots,g$$

$$|\overline{V}_1| = V_n \text{ , } \arg(\overline{V}_1) = 0;$$

$$V_{min} \le |\overline{V}_i(t)| \le V_{max}, i = 2,\dots,n$$

$$|\overline{V}_i(t)|\left|\overline{Y}_{ij}\left(\overline{V}_i(t) - \overline{V}_j(t)\right)\right| \le S_{i,j}^{max}, \text{or } \left|\overline{Y}_{ij}\left(\overline{V}_i(t) - \overline{V}_j(t)\right)\right| \le I_{i,j}^{max}, i \ne j = 1,\dots,n$$

$$\xi_{gi}^{min} \le P_{g_i}(t+1) - P_{g_i}(t) \le \xi_{gi}^{max}$$

b.

$$\min_{\substack{P_{g_1}(t),\dots,P_{g_g}(t),Q_{g_1}(t),\dots,Q_{g_g}(t)\\ P_{s_1}(t),\dots,P_{s_m}(t),Q_{s_1}(t),\dots,Q_{s_m}(t)}} \sum_{t=1}^{24}\left(\sum_{i=1}^{g} C_i\left(P_{g_i}(t)\right) + \sum_{j=1}^{m} C_j\left(P_{s_j}(t)\right)\right)$$

$s.t.$

$$\overline{S}_i(t) = \overline{V}_i(t)\sum_{j=1}^{n} \underline{V}_j(t)\underline{Y}_{ij}, i = 1,\dots,n$$

$$\overline{S}_i(t) = \left(P_{g_i}(t) + jQ_{g_i}(t)\right) + \left(P_{s_i}(t) + jQ_{s_i}(t)\right) + \left(P_{l_i}(t) + jQ_{l_i}(t)\right), i = 1,\dots,n$$

$$P_{gi}^{min} \le P_{g_i}(t) \le P_{gi}^{max}, i = 1,\dots,g$$

$$Q_{gi}^{min} \le Q_{g_i}(t) \le Q_{gi}^{max}, i = 1,\dots,g$$

$$P_{si}^{min} \le P_{s_i}(t) \le P_{si}^{max}, j = 1,\dots,m$$

$$Q_{si}^{min} \le Q_{s_i}(t) \le Q_{si}^{max}, j = 1,\dots,m$$

$$|\overline{V}_1| = V_n \text{ , } \arg(\overline{V}_1) = 0;$$

$$V_{min} \le |\overline{V}_i(t)| \le V_{max}, i = 2,\dots,n$$

$$|\overline{V}_i(t)|\left|\overline{Y}_{ij}\left(\overline{V}_i(t) - \overline{V}_j(t)\right)\right| \le S_{i,j}^{max}, \text{or } \left|\overline{Y}_{ij}\left(\overline{V}_i(t) - \overline{V}_j(t)\right)\right| \le I_{i,j}^{max}, i \ne j = 1,\dots,n$$

$SoC_j(t+1) = SoC_j(t) + P_{g_j}(t+1)\Delta t,\ j = 1,\dots,m$ (lossless model of the storage device j)

$$SoC_j^{min} \le SoC_j(t+1) \le SoC_j^{max}, j = 1,\dots,m$$

c.

$$\min_{\substack{P_{g_1}(t),\dots,P_{g_g}(t),Q_{g_1}(t),\dots,Q_{g_g}(t)\\ P_{s_1}(t),\dots,P_{s_m}(t),Q_{s_1}(t),\dots,Q_{s_m}(t)}} \sum_{t=1}^{24}\left(\sum_{i=1}^{g} C_i\left(P_{g_i}(t)\right) + \sum_{j=1}^{m} C_j\left(P_{s_j}(t)\right)\right)$$

$s.t.$

$$\overline{S}_i(t) = \overline{V}_i(t)\sum_{j=1}^{n} \underline{V}_j(t)\underline{Y}_{ij}, i = 1,\dots,n$$

$$\overline{S}_i(t) = \left(P_{g_i}(t) + jQ_{g_i}(t)\right) + \left(P_{s_i}(t) + jQ_{s_i}(t)\right) + \left(P_{l_i}(t) + jQ_{l_i}(t)\right), i = 1,\dots,n$$

$$P_{gi}^{min} \le P_{g_i}(t) \le P_{gi}^{max}, i = 1,\dots,g$$

$$Q_{gi}^{min} \le Q_{g_i}(t) \le Q_{gi}^{max}, i = 1,\dots,g$$

$$P_{si}^{min} \le P_{s_i}(t) \le P_{si}^{max}, j = 1,\dots,m$$

$$Q_{si}^{min} \le Q_{s_i}(t) \le Q_{si}^{max}, j = 1,\dots,m$$

$$|\overline{V}_1| = V_n \text{ , } \arg(\overline{V}_1) = 0;$$

$$V_{min} \le |\overline{V}_i(t)| \le V_{max}, i = 2,\dots,n$$

$$|\overline{V}_i(t)|\left|\overline{Y}_{ij}\left(\overline{V}_i(t) - \overline{V}_j(t)\right)\right| \le S_{i,j}^{max}, \text{or } \left|\overline{Y}_{ij}\left(\overline{V}_i(t) - \overline{V}_j(t)\right)\right| \le I_{i,j}^{max}, i \ne j = 1,\dots,n$$

$$\xi_{gi}^{min} \le P_{g_i}(t+1) - P_{g_i}(t) \le \xi_{gi}^{max}$$

$SoC_j(t+1) = SoC_j(t) + P_{g_j}(t+1)\Delta t,\ j = 1,\dots,m$ (lossless model of the storage device j)

$$SoC_j^{min} \le SoC_j(t+1) \le SoC_j^{max}, j = 1,\dots,m$$

d.

$$\min_{P_{g_1}(t),\dots,P_{g_g}(t),Q_{g_1}(t),\dots,Q_{g_g}(t)} \sum_{t=1}^{24}\sum_{i=1}^{g} C_i(t)\left(P_{g_i}(t)\right)$$

$s.t.$

$$\overline{S}_i(t) = \overline{V}_i(t) \sum_{j=1}^{n} \underline{V}_j(t)\underline{Y}_{ij}\,, i = 1, \dots, n$$

$$\overline{S}_i(t) = \left(P_{g_i}(t) + jQ_{g_i}(t)\right) + \left(P_{l_i}(t) + jQ_{l_i}(t)\right), i = 1, \dots, n$$

$$P_{g_i}^{min} \le P_{g_i}(t) \le P_{g_i}^{max}, i = 1, \dots, g$$

$$Q_{g_i}^{min} \le Q_{g_i}(t) \le Q_{g_i}^{max}, i = 1, \dots, g$$

$$|\overline{V}_1| = V_n \;,\; \arg(\overline{V}_1) = 0;$$

$$V_{min} \le |\overline{V}_i(t)| \le V_{max}, i = 2, \dots, n$$

$$|\overline{V}_i(t)| \left|\overline{Y}_{ij}\left(\overline{V}_i(t) - \overline{V}_j(t)\right)\right| \le S_{i,j}^{max}, \text{or } \left|\overline{Y}_{ij}\left(\overline{V}_i(t) - \overline{V}_j(t)\right)\right| \le I_{i,j}^{max}, i \ne j = 1, \dots, n$$

Only problems without time-linking constraints can be solved independently per time step. This is not the case for problem a due to the ramping constraint. For problem b this is also not the case due to the constraint on the battery state of charge. Problem c has both these time-linking constraints and it thus also not separable. Problem 4 has no time-linking constraints and can thus be solved separately for every time step.

Question 7

Not yet answered

Not graded

Consider the following important problems in the scheduling and planning of power systems.

i. A generating company with N assets needs to bid the quantity of electricity it wants to sell on the electricity for the next day. The company has vast experience in this scheduling problem and they rely on statistical distributions that approximate the uncertainty of their generators quite well.

ii. The transmission system operator needs to decide if it needs to reinforce a critical transmission line on the network. It only knows the maximum generation and consumption at the different nodes of the system. A failure of this transmission line may lead to a partial black-out in the system.

Which of the following approaches is best suited for each of these two problems?

Approach A: A stochastic optimization approach

Approach B: A robust optimization approach

Approach C: A deterministic optimization approach

- a. Problem i: Approach C

  Problem ii: Approach B

- b. Problem i: Approach C

  Problem ii: Approach A

- c. Problem i: Approach A

  Problem ii: Approach B

- d. Problem i: Approach B

  Problem ii: Approach B

In both cases, their is an uncertain aspect to the problem. A deterministic approach is thus not suitable. For the reinforcement problem, the costs are associated with extreme events and it is important to consider worst-case scenarios. The bidding problem naturally presents itself as a stochastic optimization problem, where the goal is to optimize the expected outcome. The correct answer is thus answer c.

Question 8

Not yet answered

Marked out of 10

Which of the following problems can be rewritten as an equivalent convex linear program?

a.
$$\begin{aligned} \min_{x,y} \quad & xy \\ \text{s.t.} \quad & x + y \leqslant c \\ & x \leqslant |y| \end{aligned}$$

b.
$$\begin{aligned} \min_{x,y} \quad & x - y \\ \text{s.t.} \quad & x + y \leqslant c \\ & x \leqslant |y| \end{aligned}$$

c.
$$\begin{aligned} \min_{x,y} \quad & x - y \\ \text{s.t.} \quad & x + y \leqslant c \\ & x \geqslant |y| \end{aligned}$$

d.
$$\begin{aligned} \min_{x,y} \quad & x + y \\ \text{s.t.} \quad & x^2 + y^2 \leqslant c^2 \end{aligned}$$

Problem a has a bilinear objective function and is thus non-convex. It can be relaxed, but not equivalently reformulated as a linear problem. Problem d also has a quadratic constraint. This cannot be reformulated in a linear way. Problem c is clearly a problem that can be reformulated using the max removal technique and is thus correct. For problem b, the inequality with the absolute value cannot be reformulated without the inclusion of integer variables.

Question 9

Not yet answered

Not graded

Consider the following optimization problem:

$$\begin{aligned} \min_{x,y} \quad & x - y + d \\ \text{s.t.} \quad & x - y \geqslant 0 \\ & x - y + d \geqslant 0 \quad \forall d \in [-1, 1] \\ & 2.5 + y - x - d \geqslant 1 \quad \forall d \in [-1, 1] \end{aligned}$$

Determine the worst-case optimal objective value.

- a. 1
- b. The problem is infeasible.
- c. -1
- d. 1.5

Rewriting the uncertain constraints yields x-y >= 1 and 2.5 + y- x >= 2. Rewriting these inequalities gives y <= x-1 and y>= 2+x, which is a clear contradiction. The problem is thus infeasible.

Question 10

Not yet answered

Marked out of 10

Consider the following formulations of the optimal power flow problem.

i. The non-approximated optimal power flow problem:

$$\min_{P_{g1},P_{g2},P_{gs},Q_{g1},Q_{g2},Q_{gs}} \sum_{i=1}^{G} C_i\left(P_{g_i}\right)$$

$$s.t.$$

$$\bar{S}_i = \bar{V}_i \sum_{j=1}^{S} \underline{V_j} \underline{Y_{ij}}, i = 1..S$$

$$\bar{S}_i = \left(P_{g_i} + jQ_{g_i}\right) + \left(P_{l_i} + jQ_{l_i}\right)$$

$$P_{gi}^{min} \leq P_{g_i} \leq P_{gi}^{max}, i = 1..G$$

$$Q_{gi}^{min} \leq Q_{g_i} \leq Q_{gi}^{max}, i = 1..G$$

$$|\bar{V}_1| = 1\text{pu}, \ \arg(\bar{V}_1) = 0;$$

$$V_{min} \leq |\bar{V}_i| \leq V_{max}$$

$$|\bar{V}_i||\bar{Y}_{ij}(\bar{V}_i - \bar{V}_j)| \leq S_{i,j}^{max}, i \neq j$$

ii. The linearised formulation of the optimal power flow problem using sensitivity coefficients:

$$\min_{P_{g1},\ldots,P_{gs},Q_{g1},\ldots,Q_{gs}} \sum_{i=1}^{G} C_i\left(P_{gi}, Q_{gi}\right)$$

$$s.t.$$

$$\begin{bmatrix} V_2 - V_2^* \\ \vdots \\ V_s - V_s^* \end{bmatrix} = [\mathbf{K}_{P,V}] \begin{bmatrix} P_2 - P_2^* \\ \vdots \\ P_s - P_s^* \end{bmatrix} + [\mathbf{K}_{Q,V}] \begin{bmatrix} Q_2 - Q_2^* \\ \vdots \\ Q_s - Q_s^* \end{bmatrix}$$

$$[\mathbf{I}_{ij}] - [\mathbf{I}_{ij}^*] = [\mathbf{K}_{P,I}] \begin{bmatrix} P_2 - P_2^* \\ \vdots \\ P_s - P_s^* \end{bmatrix} + [\mathbf{K}_{Q,I}] \begin{bmatrix} Q_2 - Q_2^* \\ \vdots \\ Q_s - Q_s^* \end{bmatrix}$$

$$P_i = P_{g_i} + P_{l_i}, i = 1, \ldots, s$$

$$Q_i = Q_{g_i} + Q_{l_i}, i = 1, \ldots, s$$

$$P_{gi}^{min} \leq P_{g_i} \leq P_{gi}^{max}, \ i = 1, \ldots, g$$

$$Q_{gi}^{min} \leq Q_{g_i} \leq Q_{gi}^{max}, \ i = 1, \ldots, g$$

$$|\bar{V}_1| = 1pu, \ \arg(\bar{V}_1) = \theta_1 = 0;$$

$$V_{min} \leq V_i \leq V_{max}, i = 2, \ldots, s$$

$$I_{ij} \leq I_{i,j}^{max}, i \neq j = 1, \ldots, s$$

Which of the following statements regarding the linearised formulation of the optimal power flow problem is true?

- a. This problem is always convex, thus one can easily find the global optimum.
- b. The optimal solution of this problem is always the optimal solution of the non-approximated OPF problem.
- c. The optimal solution of this problem provides a lower bound for the solution of the non-approximated OPF problem.
- d. The optimal solution of this problem is always a feasible solution of the non-approximated OPF problem.

The linearised OPF is a convex problem as it is fully linear. This means that it is indeed easy to find the optimal solution of the linearised problem. Answer a is thus correct. Answer b is incorrect as the linearisation is an approximation. Solving the linearised problem is thus not the same as solving the non-approximated problem and the solutions may thus differ. Answer c is wrong as this is a property of relaxations, while the linearised problem is an approximation of the original problem. Finally, as the linearised problem is an approximate problem, not all constraints of the original problem are guaranteed to be satisfied.