# EE-472 Smart Grids Technologies
# Module 2 Quiz (Graded)
# 28. 04. 2025 - With Solutions

Full Name: ______________________________

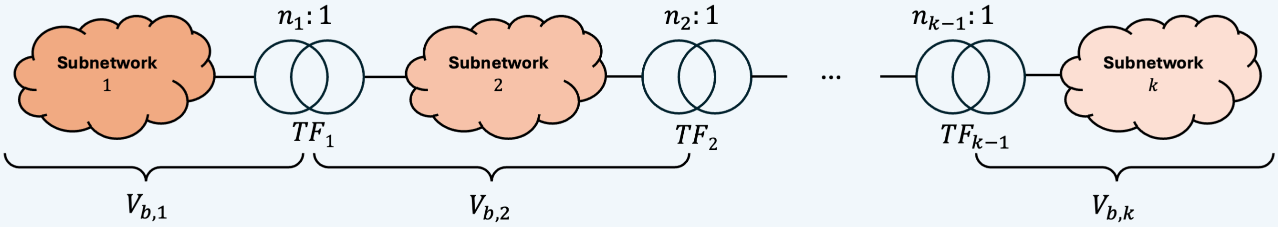
Sciper Number: ☐☐☐☐☐☐

**Question 1**

Marked out of 10

A radial network is divided to $k$ subnetworks connected with $k-1$ transformers, $TF_1$, $TF_2$,..., $TF_{k-1}$, with nominal voltage ratios $n_1 : 1$, $n_2 : 1$,..., $n_{k-1} : 1$, respectively (see Figure below). In absolute units, transformers are modelled by short-circuit impedance and an ideal transformer with the corresponding nominal ratio.

A base voltage $k$-tuple $(V_{b,1}, V_{b,2}, \ldots, V_{b,k})$ is called *model-friendly* if base voltages satisfy the condition such that all transformers per-unit equivalent circuits contain only branch elements, i.e., per-unit short-circuit impedance and no additional shunt elements.




For a model-friendly $k$-tuple $(V_{b,1}, V_{b,2}, \ldots, V_{b,k})$, what can you say about the ratio $\frac{V_{b,1}}{V_{b,k}}$?

☒ a. $\frac{V_{b,1}}{V_{b,k}} = \prod_{i=1}^{k-1} n_i$

○ b. $\frac{V_{b,1}}{V_{b,k}} = \prod_{i=1}^{k-1} \frac{n_i}{n_{i+1}}$

○ c. $\frac{V_{b,1}}{V_{b,k}} = \frac{1}{\prod_{i=1}^{k-1} n_i}$

○ d. It cannot be uniquely determined.

**Question 2**

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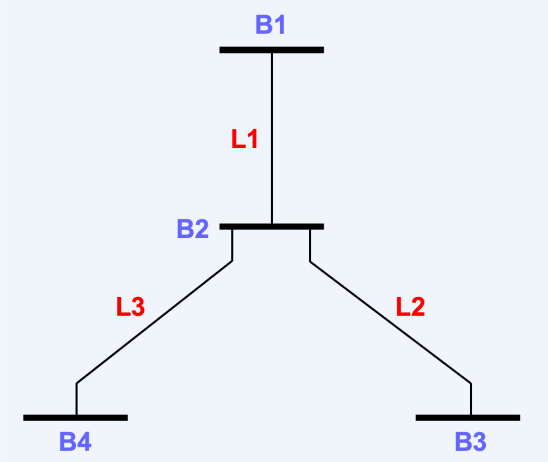
A small radial network (shown in Figure below) where all the shunts are neglected is described by the admittance matrix $\bar{Y}$.




Knowing only elements (in per-unit) $\bar{Y}_{11} = -j5$, $\bar{Y}_{22} = -j11$ and $\bar{Y}_{44} = -j4$ what is the value of $\bar{Y}_{33}$?

- a. $-j3$
- b. It cannot be uniquely determined. We need additional matrix elements.
- c. $-j4$
- ☒ d. $-j2$

**Question 3**

Not yet answered

Marked out of 10

Consider a transformer with the following nameplate:

| | | |
|---|---|---|
| Nominal voltage primary side | $V_{n,1}$ (V) | 11 000 |
| Nominal voltage secondary side | $V_{n,2}$ (V) | 415 |
| Short-circuit voltage | $V_{sc}$ (%) | 4 |
| Short-circuit active power | $P_{sc}$ (W) | 1740 |
| Nominal power | $A_n$ (kVA) | 100 |

What is the value of the complex short-circuit impedance $\bar{z}_{sc} = r_{sc} + jx_{sc}$ in per-unit, if the base voltages are $V_{b,1} = V_{n,1}$, $V_{b,2} = V_{n,2}$ and base power $A_b = 200$ kVA?

- a. (0.87 + j1.80) %
- b. (1.74 + j3.60) %
- c. (0.00 + j4.00) %
- ☒ d. (3.48 + j7.20) %

**Question 4**

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Consider a small electrical grid of four buses. We assume that the system is balanced and consider a single-phase representation of the grid. The complex nodal injected power of each node is defined as $\bar{S} = P + jQ$ where $P$ and $Q$ are active and reactive power, respectively. The nodal voltages in Cartesian coordinates for each bus are $\bar{V} = V' + jV''$. For each bus, the imposed and unknown parameters are specified in the following table:

| Bus No. | Imposed Parameter 1 | Imposed Parameter 2 | Unknown Parameter 1 | Unknown Parameter 2 |
|---|---|---|---|---|
| 1 | $P_1$ | $Q_1$ | $\arg(\bar{V}_1)$ | $\lvert\bar{V}_1\rvert$ |
| 2 | $P_2$ | $Q_2$ | $\arg(\bar{V}_2)$ | $\lvert\bar{V}_2\rvert$ |
| 3 | $\arg(\bar{V}_3)$ | $\lvert\bar{V}_3\rvert$ | $P_3$ | $Q_3$ |
| 4 | $P_4$ | $\lvert\bar{V}_4\rvert$ | $\arg(\bar{V}_4)$ | $Q_4$ |

To solve the Load-flow equations, one can write the system equations in Cartesian coordinates and use the Newton-Raphson algorithm. In the iterative process:

$$\begin{bmatrix} \Delta\mathbf{P} \\ \Delta\mathbf{Q} \\ \Delta(\mathbf{V}^2) \end{bmatrix} = \begin{bmatrix} \mathbf{J}_{\mathrm{PR}} & \mathbf{J}_{\mathrm{PX}} \\ \mathbf{J}_{\mathrm{QR}} & \mathbf{J}_{\mathrm{QX}} \\ \mathbf{J}_{\mathrm{VR}} & \mathbf{J}_{\mathrm{VX}} \end{bmatrix} \times \begin{bmatrix} \Delta\mathbf{V}' \\ \Delta\mathbf{V}'' \end{bmatrix}$$

we compute the reduced Jacobian matrix that corresponds to load-flow equations excluding the identities. Which of the following matrices correspond to the node types described in the table?

$$\boldsymbol{J}^a = \left[\begin{array}{ccc|ccc}
\frac{\partial P_1}{\partial V_1'} & \frac{\partial P_1}{\partial V_2'} & \frac{\partial P_1}{\partial V_4'} & \frac{\partial P_1}{\partial V_1''} & \frac{\partial P_1}{\partial V_2''} & \frac{\partial P_1}{\partial V_3''} \\
\frac{\partial P_2}{\partial V_1'} & \frac{\partial P_2}{\partial V_2'} & \frac{\partial P_2}{\partial V_4'} & \frac{\partial P_2}{\partial V_1''} & \frac{\partial P_2}{\partial V_2''} & \frac{\partial P_2}{\partial V_3''} \\
\frac{\partial P_4}{\partial V_1'} & \frac{\partial P_4}{\partial V_2'} & \frac{\partial P_4}{\partial V_4'} & \frac{\partial P_4}{\partial V_1''} & \frac{\partial P_4}{\partial V_2''} & \frac{\partial P_4}{\partial V_3''} \\
\hline
\frac{\partial Q_1}{\partial V_1'} & \frac{\partial Q_1}{\partial V_2'} & \frac{\partial Q_1}{\partial V_4'} & \frac{\partial Q_1}{\partial V_1''} & \frac{\partial Q_1}{\partial V_2''} & \frac{\partial Q_1}{\partial V_3''} \\
\frac{\partial Q_2}{\partial V_1'} & \frac{\partial Q_2}{\partial V_2'} & \frac{\partial Q_2}{\partial V_4'} & \frac{\partial Q_2}{\partial V_1''} & \frac{\partial Q_2}{\partial V_2''} & \frac{\partial Q_2}{\partial V_3''} \\
\hline
\frac{\partial V_4^2}{\partial V_1'} & \frac{\partial V_4^2}{\partial V_2'} & \frac{\partial V_4^2}{\partial V_4'} & \frac{\partial V_4^2}{\partial V_1''} & \frac{\partial V_4^2}{\partial V_2''} & \frac{\partial V_4^2}{\partial V_3''}
\end{array}\right]
\qquad
\boldsymbol{J}^b = \left[\begin{array}{ccc|ccc}
\frac{\partial P_1}{\partial V_1'} & \frac{\partial P_2}{\partial V_1'} & \frac{\partial P_4}{\partial V_1'} & \frac{\partial P_1}{\partial V_1''} & \frac{\partial P_2}{\partial V_1''} & \frac{\partial P_4}{\partial V_1''} \\
\frac{\partial P_1}{\partial V_2'} & \frac{\partial P_2}{\partial V_2'} & \frac{\partial P_4}{\partial V_2'} & \frac{\partial P_1}{\partial V_2''} & \frac{\partial P_2}{\partial V_2''} & \frac{\partial P_4}{\partial V_2''} \\
\frac{\partial P_1}{\partial V_4'} & \frac{\partial P_2}{\partial V_4'} & \frac{\partial P_4}{\partial V_4'} & \frac{\partial P_1}{\partial V_4''} & \frac{\partial P_2}{\partial V_4''} & \frac{\partial P_4}{\partial V_4''} \\
\hline
\frac{\partial Q_1}{\partial V_1'} & \frac{\partial Q_2}{\partial V_1'} & \frac{\partial Q_4}{\partial V_1'} & \frac{\partial Q_1}{\partial V_1''} & \frac{\partial Q_2}{\partial V_1''} & \frac{\partial Q_4}{\partial V_1''} \\
\frac{\partial Q_1}{\partial V_2'} & \frac{\partial Q_2}{\partial V_2'} & \frac{\partial Q_4}{\partial V_2'} & \frac{\partial Q_1}{\partial V_2''} & \frac{\partial Q_2}{\partial V_2''} & \frac{\partial Q_4}{\partial V_2''} \\
\hline
\frac{\partial V_1^2}{\partial V_4'} & \frac{\partial V_2^2}{\partial V_4'} & \frac{\partial V_4^2}{\partial V_4'} & \frac{\partial V_1^2}{\partial V_4''} & \frac{\partial V_2^2}{\partial V_4''} & \frac{\partial V_4^2}{\partial V_4''}
\end{array}\right]$$

$$\boldsymbol{J}^c = \left[\begin{array}{ccc|ccc}
\frac{\partial P_1}{\partial V_1'} & \frac{\partial P_1}{\partial V_2'} & \frac{\partial P_1}{\partial V_4'} & \frac{\partial P_1}{\partial V_1''} & \frac{\partial P_1}{\partial V_2''} & \frac{\partial P_1}{\partial V_4''} \\
\frac{\partial P_2}{\partial V_1'} & \frac{\partial P_2}{\partial V_2'} & \frac{\partial P_2}{\partial V_4'} & \frac{\partial P_2}{\partial V_1''} & \frac{\partial P_2}{\partial V_2''} & \frac{\partial P_2}{\partial V_4''} \\
\frac{\partial P_4}{\partial V_1'} & \frac{\partial P_4}{\partial V_2'} & \frac{\partial P_4}{\partial V_4'} & \frac{\partial P_4}{\partial V_1''} & \frac{\partial P_4}{\partial V_2''} & \frac{\partial P_4}{\partial V_4''} \\
\hline
\frac{\partial Q_1}{\partial V_1'} & \frac{\partial Q_1}{\partial V_2'} & \frac{\partial Q_1}{\partial V_4'} & \frac{\partial Q_1}{\partial V_1''} & \frac{\partial Q_1}{\partial V_2''} & \frac{\partial Q_1}{\partial V_4''} \\
\frac{\partial Q_2}{\partial V_1'} & \frac{\partial Q_2}{\partial V_2'} & \frac{\partial Q_2}{\partial V_4'} & \frac{\partial Q_2}{\partial V_1''} & \frac{\partial Q_2}{\partial V_2''} & \frac{\partial Q_2}{\partial V_4''} \\
\hline
\frac{\partial V_4^2}{\partial V_1'} & \frac{\partial V_4^2}{\partial V_2'} & \frac{\partial V_4^2}{\partial V_4'} & \frac{\partial V_4^2}{\partial V_1''} & \frac{\partial V_4^2}{\partial V_2''} & \frac{\partial V_4^2}{\partial V_4''}
\end{array}\right]
\qquad
\boldsymbol{J}^d = \left[\begin{array}{ccc|ccc}
\frac{\partial P_1}{\partial V_1'} & \frac{\partial P_1}{\partial V_2'} & \frac{\partial P_1}{\partial V_4'} & \frac{\partial P_1}{\partial V_1''} & \frac{\partial P_1}{\partial V_2''} & \frac{\partial P_1}{\partial V_4''} \\
\frac{\partial P_2}{\partial V_1'} & \frac{\partial P_2}{\partial V_2'} & \frac{\partial P_2}{\partial V_4'} & \frac{\partial P_2}{\partial V_1''} & \frac{\partial P_2}{\partial V_2''} & \frac{\partial P_2}{\partial V_4''} \\
\frac{\partial P_4}{\partial V_1'} & \frac{\partial P_4}{\partial V_2'} & \frac{\partial P_4}{\partial V_4'} & \frac{\partial P_4}{\partial V_1''} & \frac{\partial P_4}{\partial V_2''} & \frac{\partial P_4}{\partial V_4''} \\
\hline
\frac{\partial Q_1}{\partial V_1'} & \frac{\partial Q_1}{\partial V_2'} & \frac{\partial Q_1}{\partial V_4'} & \frac{\partial Q_1}{\partial V_1''} & \frac{\partial Q_1}{\partial V_2''} & \frac{\partial Q_1}{\partial V_4''} \\
\frac{\partial Q_2}{\partial V_1'} & \frac{\partial Q_2}{\partial V_2'} & \frac{\partial Q_2}{\partial V_4'} & \frac{\partial Q_2}{\partial V_1''} & \frac{\partial Q_2}{\partial V_2''} & \frac{\partial Q_2}{\partial V_4''} \\
\frac{\partial Q_4}{\partial V_1'} & \frac{\partial Q_4}{\partial V_2'} & \frac{\partial Q_4}{\partial V_4'} & \frac{\partial Q_4}{\partial V_1''} & \frac{\partial Q_4}{\partial V_2''} & \frac{\partial Q_4}{\partial V_4''}
\end{array}\right]$$

- ○ 1. $\boldsymbol{J}^a$.
- ○ 2. $\boldsymbol{J}^d$.
- ☒ 3. $\boldsymbol{J}^c$.
- ○ 4. $\boldsymbol{J}^b$.

**Question 5**

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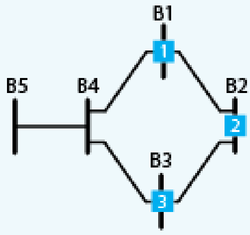
Let's consider the following 5-node grid that is equipped with 3 PMUs. Every PMU measures the current injection and the nodal voltage phasors.




Assume the measurement matrix is composed as: $\mathbf{H} = \begin{bmatrix} \mathbf{H}_V \\ \mathbf{H}_I \end{bmatrix}$.

The state vector is constructed as: $\mathbf{x} = \begin{bmatrix} \Re\{\bar{\mathbf{V}}\} \\ \Im\{\bar{\mathbf{V}}\} \end{bmatrix}$ and the measurement vector as: $\mathbf{z} = \begin{bmatrix} \mathbf{z}_V \\ \mathbf{z}_I \end{bmatrix}$, with $\mathbf{z}_V = \begin{bmatrix} \Re\{\widetilde{\mathbf{V}}\} \\ \Im\{\widetilde{\mathbf{V}}\} \end{bmatrix}$ and $\mathbf{z}_I = \begin{bmatrix} \Re\{\widetilde{\mathbf{I}}\} \\ \Im\{\widetilde{\mathbf{I}}\} \end{bmatrix}$.

Furthermore, the compound admittance matrix of the system is given as $\bar{\mathbf{Y}} = \mathbf{G} + j\mathbf{B}$, where the non-zero $(i, j)$-th element is expressed as $g_{ij} + jb_{ij}$.

Which of the following matrices correctly represents the measurement model of the above-given system?

$$\mathbf{H}^a = \begin{bmatrix}
1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\
0 & g_{12} & 0 & g_{14} & 0 & 0 & -b_{12} & 0 & -b_{14} & 0 \\
g_{21} & 0 & g_{23} & 0 & 0 & -b_{21} & 0 & -b_{23} & 0 & 0 \\
0 & g_{32} & 0 & g_{34} & 0 & 0 & -b_{32} & 0 & -b_{34} & 0 \\
0 & b_{12} & 0 & b_{14} & 0 & 0 & g_{12} & 0 & g_{14} & 0 \\
b_{21} & 0 & b_{23} & 0 & 0 & g_{21} & 0 & g_{23} & 0 & 0 \\
0 & b_{32} & 0 & b_{34} & 0 & 0 & g_{32} & 0 & g_{34} & 0
\end{bmatrix}
\quad
\mathbf{H}^b = \begin{bmatrix}
1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\
g_{11} & g_{12} & 0 & g_{14} & 0 & -b_{11} & -b_{12} & 0 & -b_{14} & 0 \\
g_{21} & g_{22} & g_{23} & 0 & 0 & -b_{21} & -b_{22} & -b_{23} & 0 & 0 \\
0 & g_{32} & g_{33} & g_{34} & 0 & 0 & -b_{32} & -b_{33} & -b_{34} & 0 \\
b_{11} & b_{12} & 0 & b_{14} & 0 & g_{11} & g_{12} & 0 & g_{14} & 0 \\
b_{21} & b_{22} & b_{23} & 0 & 0 & g_{21} & g_{22} & g_{23} & 0 & 0 \\
0 & b_{32} & b_{33} & b_{34} & 0 & 0 & g_{32} & g_{33} & g_{34} & 0
\end{bmatrix}$$

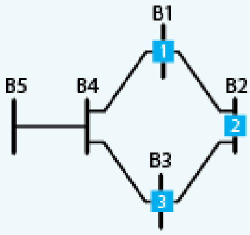
$$\mathbf{H}^c = \begin{bmatrix}
1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\
0 & g_{32} & g_{33} & g_{34} & 0 & 0 & -b_{32} & -b_{33} & -b_{34} & 0 \\
g_{21} & g_{22} & g_{23} & 0 & 0 & -b_{21} & -b_{22} & b_{23} & 0 & 0 \\
g_{11} & g_{12} & 0 & g_{14} & 0 & -b_{11} & -b_{12} & 0 & -b_{14} & 0 \\
0 & b_{32} & g_{33} & b_{34} & 0 & 0 & g_{32} & g_{33} & g_{34} & 0 \\
b_{21} & b_{22} & b_{23} & 0 & 0 & g_{21} & g_{22} & g_{23} & 0 & 0 \\
b_{11} & b_{12} & 0 & b_{14} & 0 & g_{11} & g_{12} & 0 & g_{14} & 0
\end{bmatrix}$$

- ○ 1. $\mathbf{H}^c$
- ○ 2. $\mathbf{H}^a$
- ○ 3. None of the above.
- ☒ 4. $\mathbf{H}^b$

**Question 6**

Marked out of 10

Let's consider the following 5-node grid that is equipped with 3 PMUs. Every PMU measures the current injection and the nodal voltage phasors.



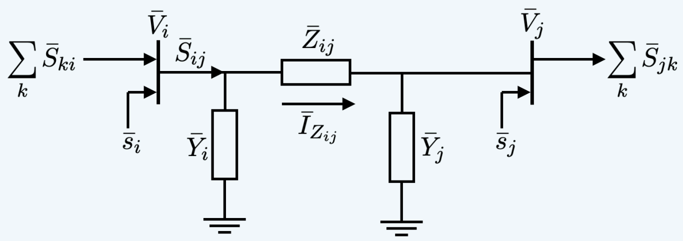

What can you say about the observability of the system?

- [ ] a. The system is observable. However, the measurements from PMU 2 and PMU 3 are both critical measurements. Therefore, if any of these measurements is removed, the state cannot be inferred anymore.
- [ ] b. The rule-of-thumb is satisfied, and therefore this system is observable.
- [x] c. The only sufficient condition to guarantee observability is for the measurement model to have full rank.
- [ ] d. The system comprises 10 state variables and 12 measurements, resulting in an overdetermined measurement model since the number of measurements exceeds the number of states. This is a sufficient condition to guarantee observability.

**Question 7**

Marked out of 10

For the branch connecting nodes $i$ and $j$ in a generic network, the branch-flow model equations are given by (★).



Branch connecting nodes $i$ and $j$.

$$\left.\begin{aligned}
&\bar{S}_{ij} - \bar{Z}_{ij} i_{Z_{ij}} - \bar{Y}_i v_i - \bar{Y}_j v_j + \bar{s}_j = \sum_k \bar{S}_{jk} \\
&v_j = v_i + |\bar{Z}_{ij}|^2 i_{Z_{ij}} - 2\Re\left[\underline{Z}_{ij}(\bar{S}_{ij} - \bar{Y}_i v_i)\right] \\
&\sum_k \bar{S}_{ki} + \bar{s}_i = \bar{S}_{ij} \\
&i_{Z_{ij}} = \frac{|\bar{S}_{ij} - \bar{Y}_i v_i|^2}{v_i} \\
&v_i = |\bar{V}_i|^2, v_j = |\bar{V}_j|^2 \text{ and } i_{Z_{ij}} = |\bar{I}_{Z_{ij}}|^2 \\
&\arg(\bar{V}_i) + \arg(\underline{V}_j) = \arg\left(v_i - \underline{Z}_{ij}(\bar{S}_{ij} - \bar{Y}_i v_i)^2\right)
\end{aligned}\right\} (\bigstar)$$

Which of the following statements is correct?

- [x] a. For a radial network with $N$ nodes, once the squared voltage magnitudes are obtained from the branch-flow model, we can retrieve the voltage angles by solving the system of $N-1$ linear equations, written by using the last equation of (★) expressing $\arg(\bar{V}_i) + \arg(\underline{V}_j)$ for each branch, with one angle chosen as the reference.
- ( ) b. The power balance over a branch can be expressed as a linear combination of the voltage and current magnitudes, $|\bar{V}_i|$, $|\bar{V}_j|$ and $|\bar{I}_{Z_{ij}}|$.
- ( ) c. The system of equations (★) can be written for equivalent circuits of transformers, modelled in per-unit, only if we include the transformer shunt admittance.
- ( ) d. For radial networks (without loops), load flow equations are formulated as a branch flow model, whereas for meshed networks, we use the nodal load-flow model.

**Question 8**

Marked out of 10

Consider the following statements about the nodal admittance matrix $\bar{\mathbf{Y}}$ of a linear, passive and reciprocal AC network.

1. $\bar{\mathbf{Y}}$ is diagonally dominant if inductances and capacitances are not null.
2. $\bar{\mathbf{Y}}$ is symmetric.

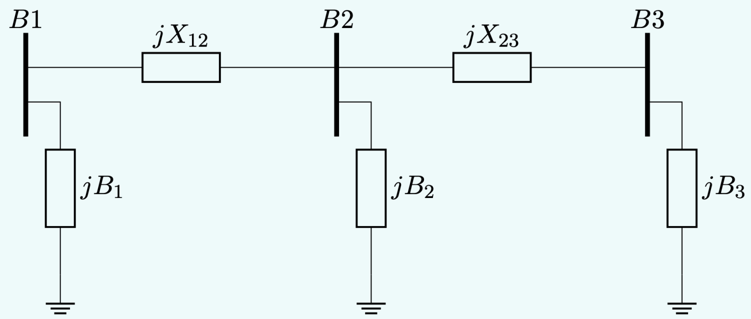
Which statement is correct?

- a. Both 1 and 2.
- b. Only 1.
- ☒ c. Only 2.
- d. None.

**Question 9**

Marked out of 10

Consider a simple three-bus power system shown in the Figure below. In absolute units, longitudinal reactances $X_{12}$ and $X_{23}$ are in ohms ($\Omega$), and shunt susceptances are in siemens (S).




Consider the following matrices:

$$\bar{\mathbf{Y}}_a = \begin{bmatrix} -j\frac{1}{X_{12}} + jB_1 & j\frac{1}{X_{12}} & 0 \\ j\frac{1}{X_{12}} & -j\left(\frac{1}{X_{12}} + \frac{1}{X_{23}}\right) + jB_2 & j\frac{1}{X_{23}} \\ 0 & j\frac{1}{X_{23}} & -j\frac{1}{X_{23}} + jB_3 \end{bmatrix} \quad \bar{\mathbf{Y}}_c = \begin{bmatrix} j\frac{1}{X_{12}} + jB_1 & -j\frac{1}{X_{12}} & 0 \\ -j\frac{1}{X_{12}} & j\left(\frac{1}{X_{12}} + \frac{1}{X_{23}}\right) + jB_2 & -j\frac{1}{X_{23}} \\ 0 & -j\frac{1}{X_{23}} & j\frac{1}{X_{23}} + jB_3 \end{bmatrix}$$

$$\bar{\mathbf{Y}}_b = \begin{bmatrix} -j\frac{1}{X_{12}} - jB_1 & j\frac{1}{X_{12}} & 0 \\ j\frac{1}{X_{12}} & -j\left(\frac{1}{X_{12}} + \frac{1}{X_{23}}\right) - jB_2 & j\frac{1}{X_{23}} \\ 0 & j\frac{1}{X_{23}} & -j\frac{1}{X_{23}} - jB_3 \end{bmatrix} \quad \bar{\mathbf{Y}}_d = \begin{bmatrix} j\frac{1}{X_{12}} - jB_1 & -j\frac{1}{X_{12}} & 0 \\ -j\frac{1}{X_{12}} & j\left(\frac{1}{X_{12}} + \frac{1}{X_{23}}\right) - jB_2 & -j\frac{1}{X_{23}} \\ 0 & -j\frac{1}{X_{23}} & j\frac{1}{X_{23}} - jB_3 \end{bmatrix}$$

The admittance matrix of the system is:

- $\bar{\mathbf{Y}}_d$.
- ☒ $\bar{\mathbf{Y}}_a$.
- $\bar{\mathbf{Y}}_c$.
- $\bar{\mathbf{Y}}_b$.

Question **10**

Marked out of 10

The dependency on the voltage of the absorbed active/reactive powers absorbed by the loads can be represented using exponential models:

$$P = P_0\left(\frac{V}{V_0}\right)^{\alpha_p} \text{ and } Q = Q_0\left(\frac{V}{V_0}\right)^{\alpha_q}.$$

Which statement about coefficients $\alpha_p$ and $\alpha_q$ is **incorrect**?

- a. $0 \leqslant \alpha_p \leqslant 2$ and $0 \leqslant \alpha_q \leqslant 2$.
- ☒ b. $\alpha_p$ and $\alpha_q$ cannot change throughout the day.
- c. $\alpha_p = \alpha_q = 0$ if all the loads behave as constant power.
- d. If all the loads behave as constant current, then $\alpha_p = \alpha_q = 1$.