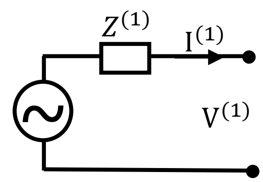
Sequence Network

1. Introduction

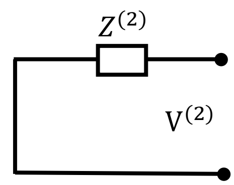
Sequence network is the representation of reactance diagram using positive negative and zero sequences. For the balance faults studied previously, we have one reactance diagram (positive sequence reactance diagram)

However, for unbalanced faults, three reactance diagrams are needed (network models):

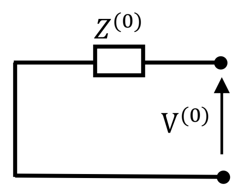
1- one reactance diagram for positive sequence



2- one reactance diagram for negative sequence



3- one reactance diagram for zero sequence



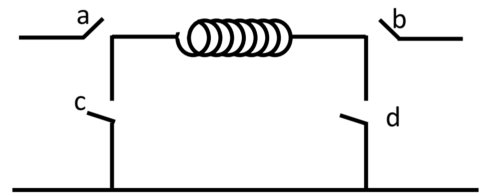
- In positive sequence reactance diagram: system is drowned as usual.
- In negative sequence reactance diagram, same as positive sequence but synchronous machines are shorted.
- For zero sequence reactance diagram, we can define two basic concepts:
  1- Sequence network for transformer.
  2- Sequence network for generator.

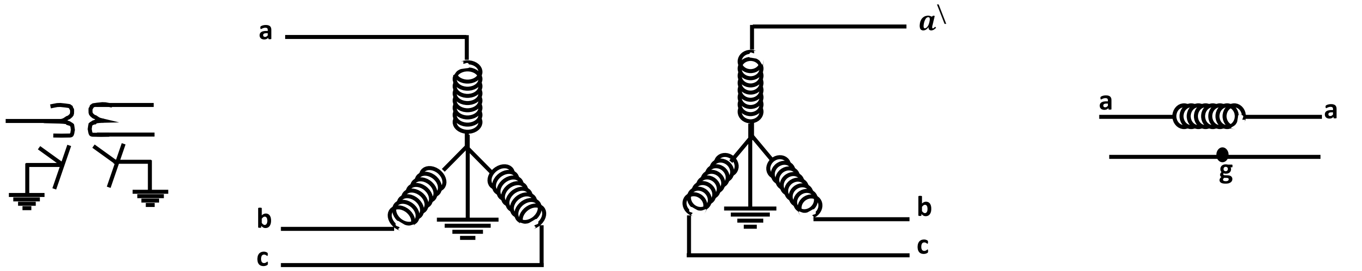
There are different configurations for the transformer and generators reactance's based on the connection type.

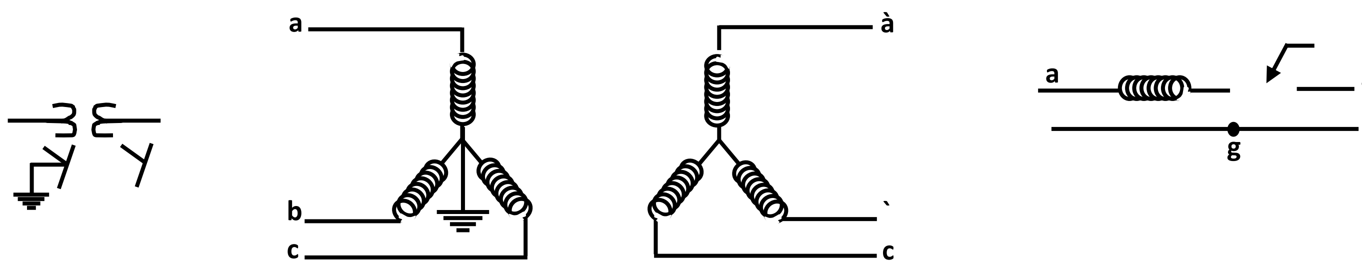
2. Sequence impedance of transformer:

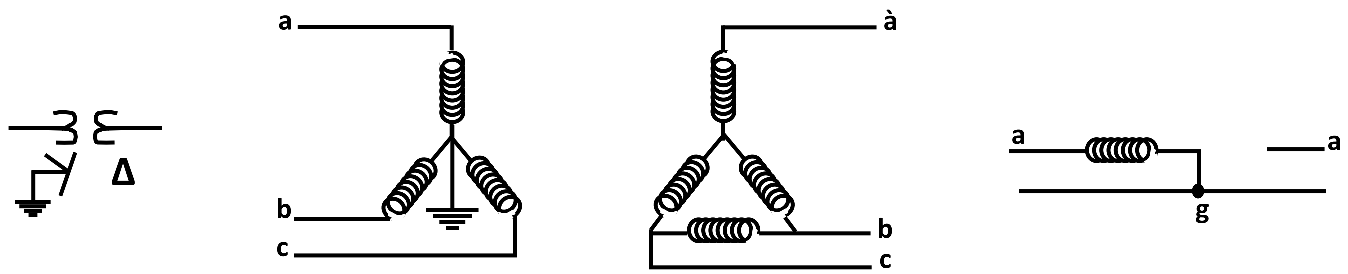
The transformer is modeled with:

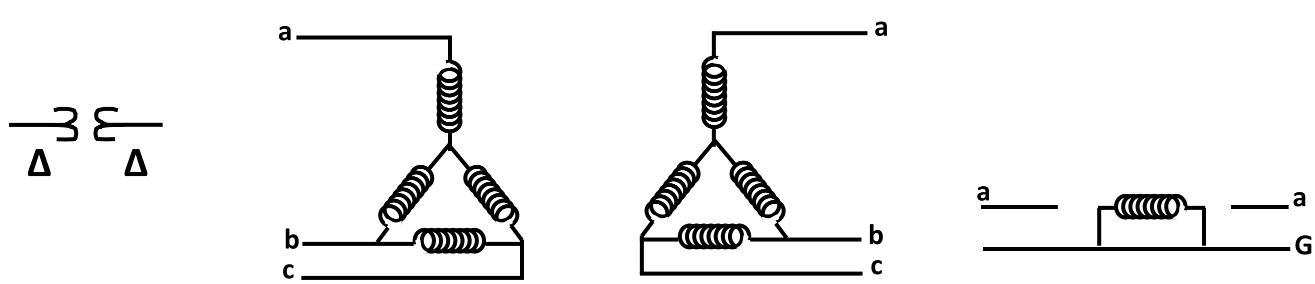
- ✓ rule 01 close a (stare grounding)
- ✓ rule 02 close b (stare grounding)
- ✓ rule 03 close c (Delta connection)
- ✓ rule 04 close d (Delta connection)



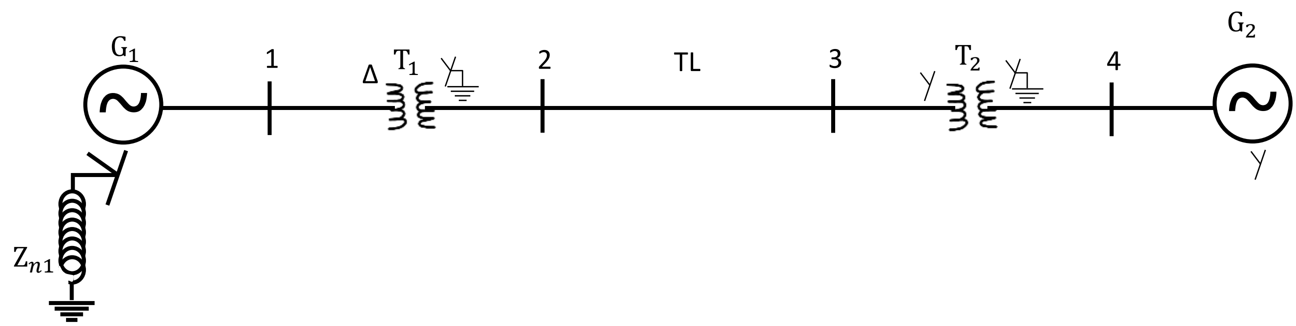




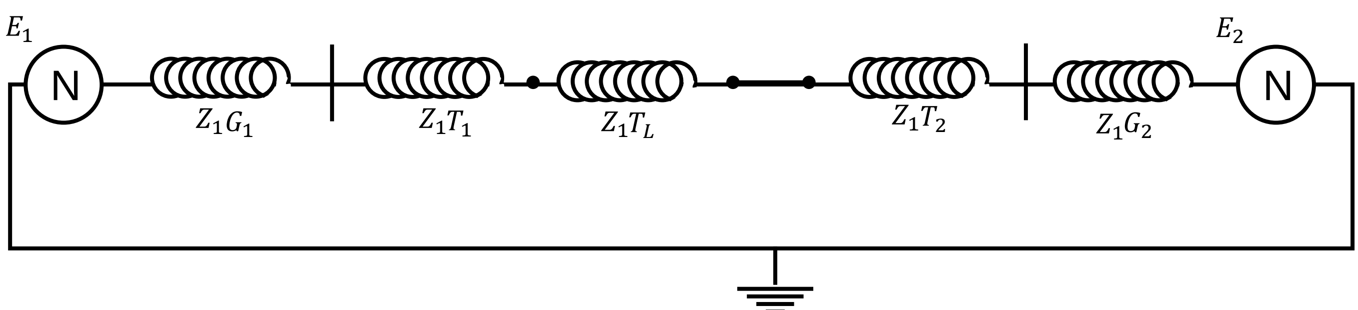




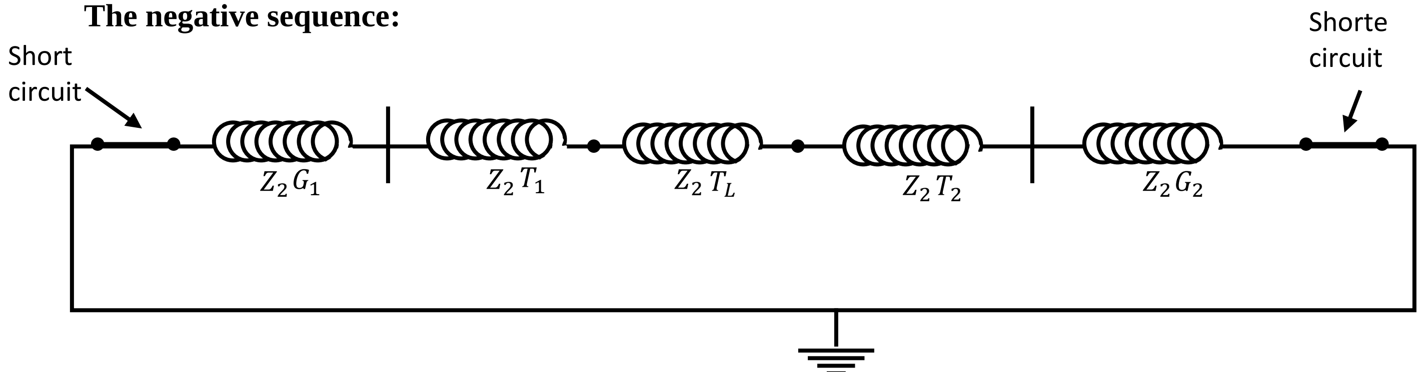
Example: Draw the Zero sequence, Positive sequence and Negative sequence of the system (SLD) of the power system shown below:



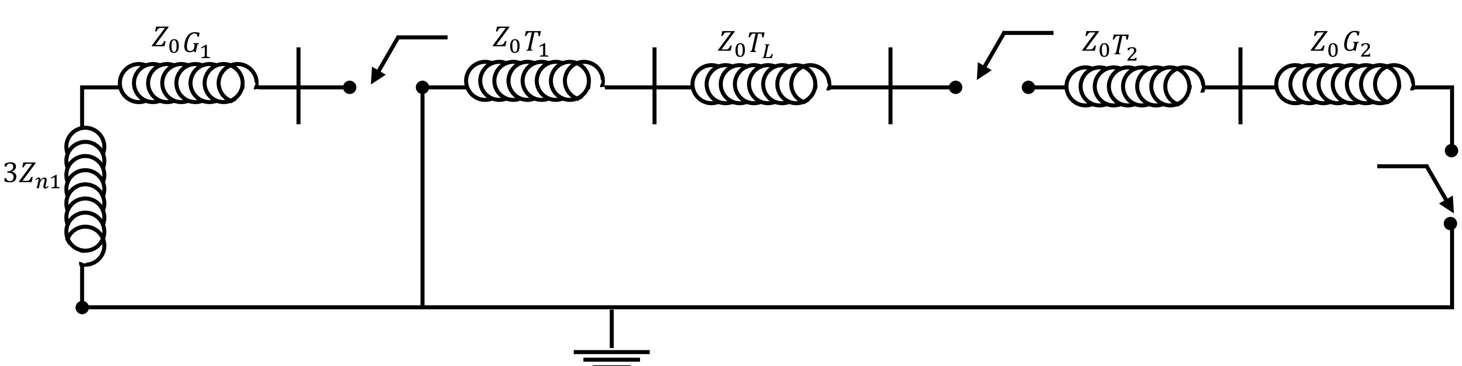
The positive sequence:



The negative sequence:



Zero sequence:



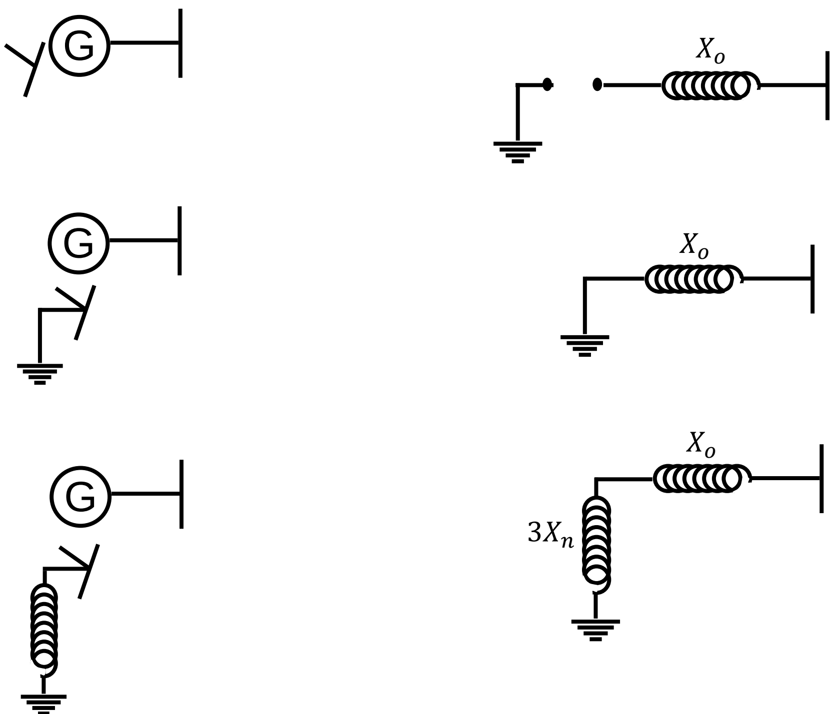
The positive, negative and zero sequence impedance of transformer are equal which correspond to the transformer leakage impedance.

3. Sequence impedance of transmission lines:

- Positive and Negative impedances are equal.
- The zero-sequence impedance is more than (two to the six times) the positive or negative sequence impedance.

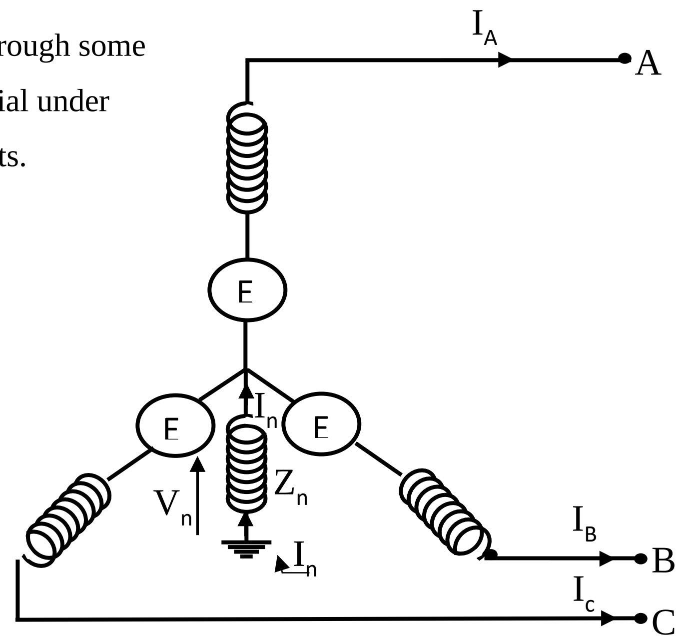
4. Sequence impedance of synchronous machines:

The negative sequence impedance is close to the positive sequence sub transient impedance, the zero sequence is represented as the figure in bellow:



5. The voltage of the neutral:

The potential of the neutral when it is grounded through some impedance or isolated will not be at ground potential under unbalanced conditions such as unsymmetrical faults.



$$V_n = -I_n Z_n$$

Where:

Z_n is the neutral grounding impedance and I_n the neutral current

The negative sign is used as the current flows from the ground to the neutral of the system and the potential of the neutral is lower than the ground.

For a three-phase system:

$$I_n = I_A + I_B + I_C$$

$$I_A = I_A^{(1)} + I_A^{(2)} + I_A^{(0)}$$

$$I_B = I_A^{(0)} + a^2 I_A^{(1)} + a\, I_A^{(2)}$$

$$I_C = I_A^{(0)} + a I_A^{(1)} + a^2\, I_A^{(2)}$$

$$I_n = \left(I_A^{(1)} + I_A^{(2)} + I_A^{(0)}\right) + \left(I_A^{(0)} + a^2 I_A^{(1)} + a\, I_A^{(2)}\right) + \left(I_A^{(0)} + a I_A^{(1)} + a^2\, I_A^{(2)}\right)$$

$$I_n = I_A^{(1)}(1 + a + a^2) + I_A^{(2)}(1 + a + a^2) + 3I_A^{(0)}$$

$$I_n = 3I_A^{(0)}$$

$$\boxed{V_n = -3I_A^{(0)} Z_n}$$

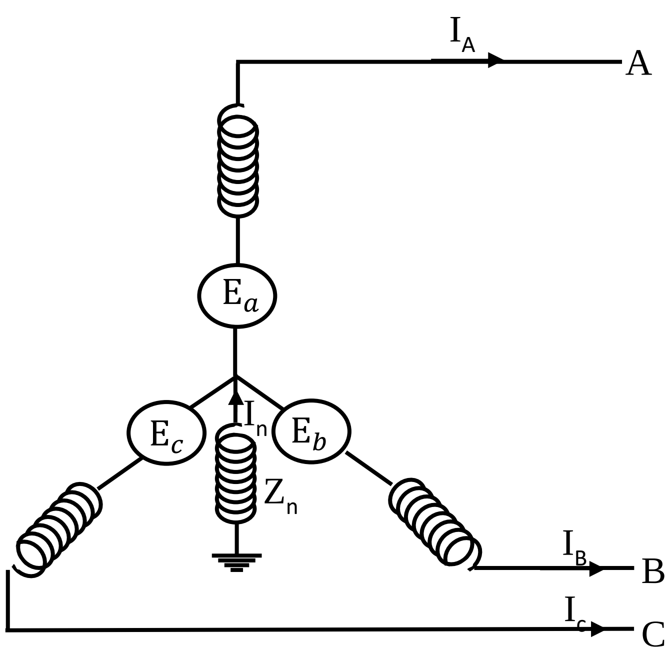
- Since the positive sequence and negative sequence components of currents through the neutral are absent, the drops due to this current are also zero.
- also, for a balanced set of current or voltage, the neutral is at the ground potential; therefore, for positive and negative sequence networks, neutral of the system will be taken as the reference.

6. Sequence network equations:

the main objective when analyzing and balanced faults are:

1- Evaluating symmetrical components for currents (positive, negative and zero sequence currents) $I_A^{(0)}, I_A^{(1)}, I_A^{(2)}$

2- the evaluating the faults currents I_f



- Then, the phase currents (the original unbalance system parameters) I_A, I_B, I_C can be calculated from The Matrix.
- Also, bus voltage online currents for each sequence can be calculated.

The positive sequence components of voltage and the fourth point is

$$V_A^{(1)} = E_A - I_A^{(1)} Z^{(1)}$$

Similarly, the negative sequence components of voltage of the sport points is:

$$V_A^{(2)} = E_A^{(2)} - I_A^{(2)} Z^{(2)}$$

since the negative sequence voltage generated is zero.

Therefore:

$$E_A^{(2)} = 0$$

$$V_A^{(2)} = -I_A^{(2)} Z^{(2)}$$

Similarly for zero sequence voltages

$$E_A^{(0)} = 0$$

$$V_A^{(0)} = V_n - I_A^{(0)} Z_g^{(0)}$$

$$V_A^{(0)} = -3\, I_A^{(0)} Z_n - I_A^{(0)} Z_g^{(0)}$$

$$\boxed{V_A^{(0)} = -I_A^{(0)} (\, Z_g^{(0)} + 3\, Z_n)}$$

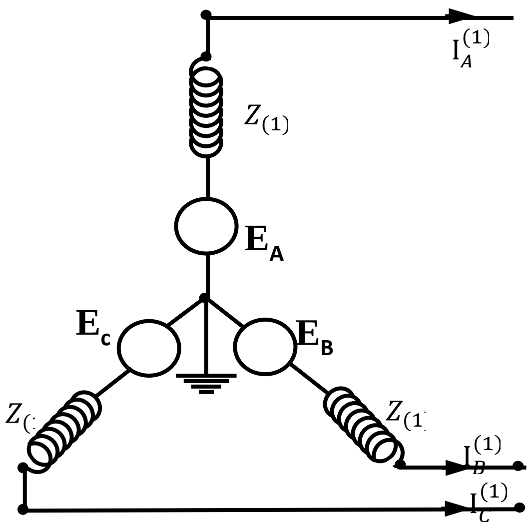
where is the zero-sequence impedance of the generator and Z_n is the natural impedance.

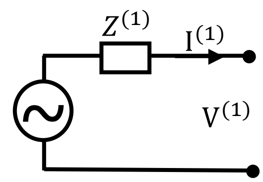
- the three sequence Network equations are:

$$\begin{aligned} V_A^{(1)} &= E_A - I_A^{(1)} Z^{(1)} \\ V_A^{(2)} &= -I_A^{(1)} Z^{(1)} \\ V_A^{(0)} &= -I_A^{(0)} Z^{(0)} \end{aligned}$$

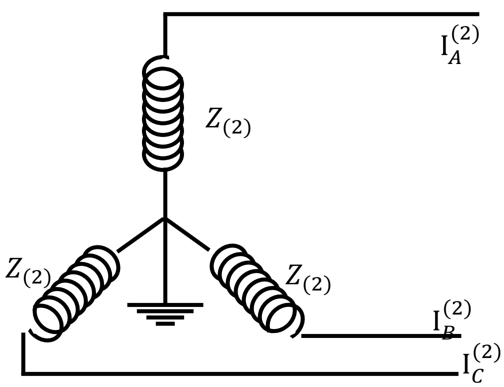
- Where $Z^{(0)} = Z_g^{(0)} + 3Z_n$ and the corresponding sequence Network for the unloaded alternator are shown by:

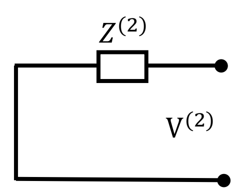
Positive sequence



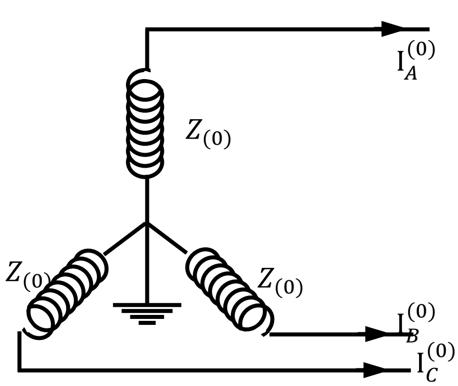


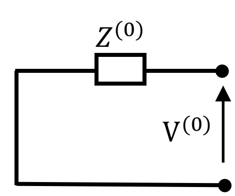
Negative sequence





Zero sequence





The sequence Network equation with matrix notation will be:

$$\begin{bmatrix} V_A^{(0)} \\ V_A^{(1)} \\ V_A^{(2)} \end{bmatrix} = \begin{bmatrix} 0 \\ E_A \\ 0 \end{bmatrix} \begin{bmatrix} Z^{(0)} & 0 & 0 \\ 0 & Z^{(1)} & 0 \\ 0 & 0 & Z^{(2)} \end{bmatrix} \begin{bmatrix} I_A^{(0)} \\ I_A^{(1)} \\ I_A^{(2)} \end{bmatrix}$$