Sistemas Elétricos de Potência

Aula 07-P1 – Cálculo de Curto-circuito Equilibrado em Sistemas em Anel: Forma Matricial

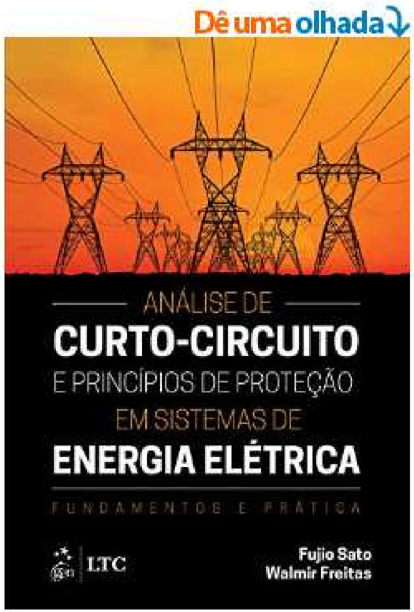
Prof. Heverton Augusto Pereira
heverton.pereira@ufv.br

$$
\begin{bmatrix}
0,00889104 & 0,00132842 & 0,00011167 & 0,00204268 & 0,00056903 & 0,00626215 & 0,00275695 & 0,00102639 \\
0,00132842 & 0,01134623 & 0,00055371 & 0,00833387 & 0,00137805 & 0,00303974 & 0,00532152 & 0,00220239 \\
0,00011167 & 0,00055371 & 0,00475959 & 0,00120070 & 0,00425613 & 0,00085568 & 0,00184769 & 0,00375267 \\
0,00204268 & 0,00833387 & 0,00120070 & 0,06620613 & 0,00792254 & 0,01834370 & 0,04007839 & 0,01464439 \\
0,00056903 & 0,00137805 & 0,00425613 & 0,00792254 & 0,03662437 & 0,00652532 & 0,01446703 & 0,03199261 \\
0,00626215 & 0,00303974 & 0,00085568 & 0,01834370 & 0,00652532 & 0,08999879 & 0,03364765 & 0,01219496 \\
0,00275695 & 0,00532152 & 0,00184769 & 0,04007839 & 0,01446703 & 0,03364765 & 0,07483526 & 0,02708638 \\
0,00102639 & 0,00220239 & 0,00375267 & 0,01464439 & 0,03199261 & 0,01219496 & 0,02708638 & 0,06023255
\end{bmatrix}
$$

Tópicos abordados

- Método Analógico x Digital

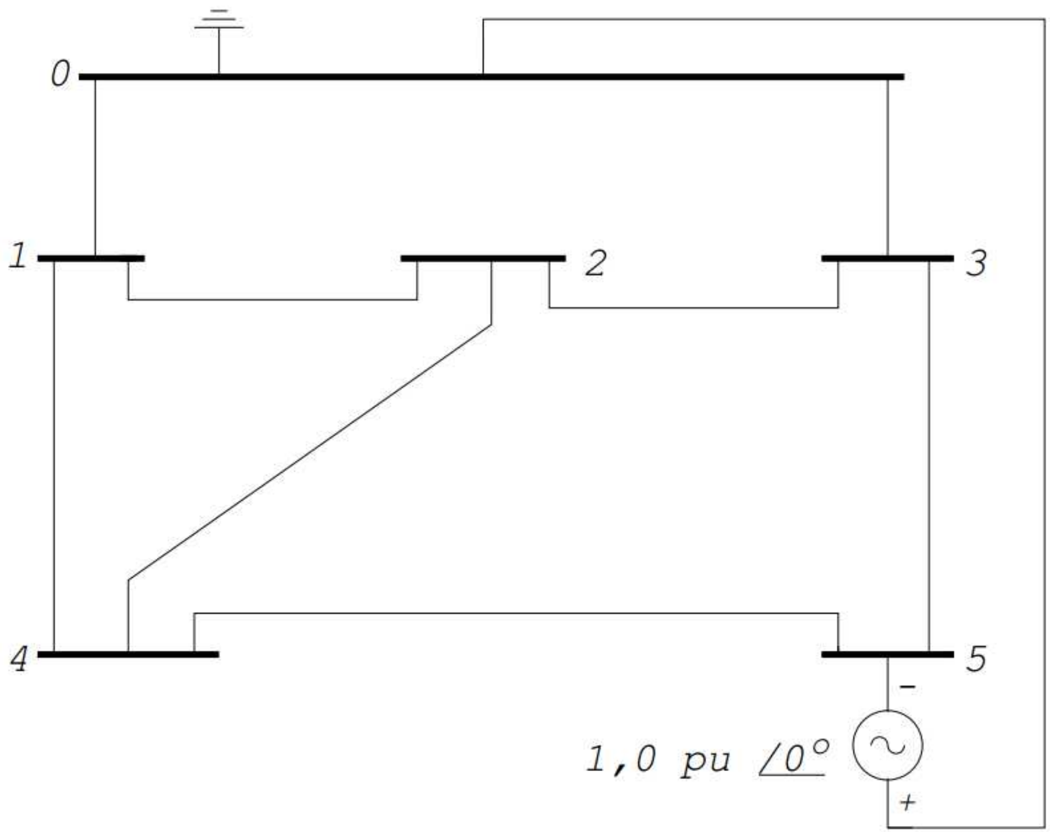
- Capítulo 3



Hipóteses simplificadoras

- As máquinas síncronas operam com tensão $= 1{,}00\angle 0°\ \text{pu}$
- Os parâmetros shunt das linhas são ignorados
- As carga são ignoradas
- Transformadores operando com tape nominal
- A rede de sequência negativa é idêntica a de sequência positiva

Sistema 5 Barras



$$Y_{BARRA}\underline{v} = \underline{i}$$

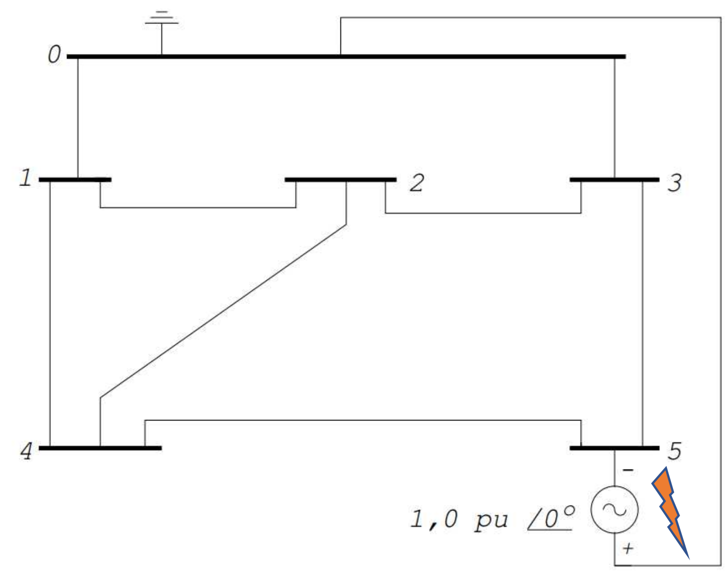
$$Z_{BARRA}\underline{i} = \underline{v}$$

$$v_i^r = 1,0 + v_i$$

$$Z_{BARRA} = \begin{bmatrix} Z_{1,1} & Z_{1,2} & Z_{1,3} & Z_{1,4} & Z_{1,5} \\ Z_{2,1} & Z_{2,2} & Z_{2,3} & Z_{2,4} & Z_{2,5} \\ Z_{3,1} & Z_{3,2} & Z_{3,3} & Z_{3,4} & Z_{3,5} \\ Z_{4,1} & Z_{4,2} & Z_{4,3} & Z_{4,4} & Z_{4,5} \\ Z_{5,1} & Z_{5,2} & Z_{5,3} & Z_{5,4} & Z_{5,5} \end{bmatrix}$$

Cálculos de curto-circuito através da matriz Zbarra

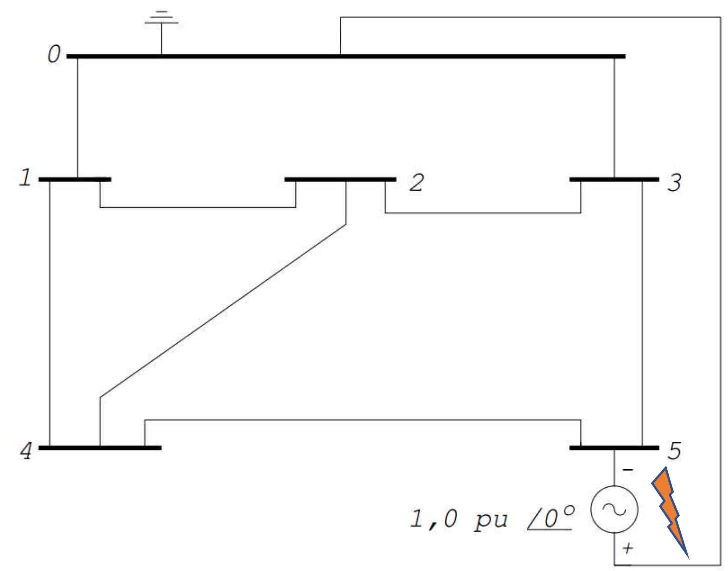
- Correntes de curtos-circuitos nas barras
- Tensões nas barras vizinhas
- Fluxos de correntes nas linhas vizinhas



Cálculos de curto-circuito através da matriz Zbarra

- Correntes de curtos-circuitos nas barras

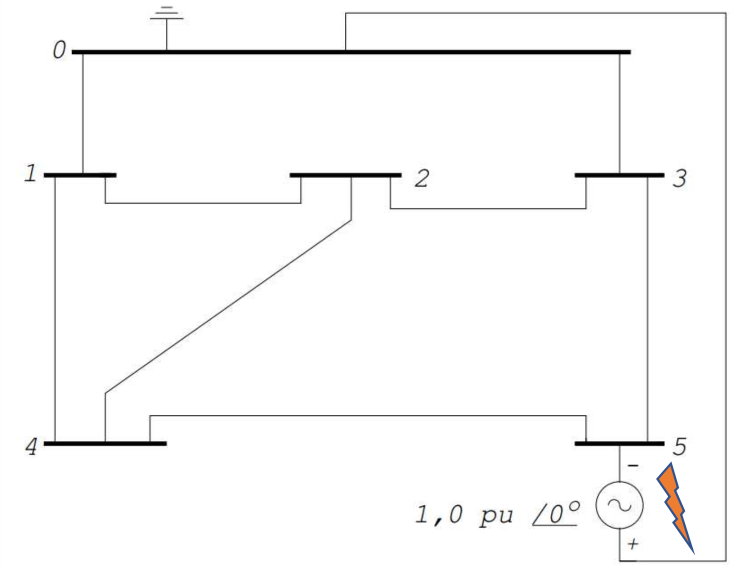
$$i_{cc_5} = \frac{-1,0}{Z_{5,5}}$$



Cálculos de curto-circuito através da matriz Zbarra

- Tensões nas barras vizinhas

$$\begin{bmatrix} Z_{1,1} & Z_{1,2} & Z_{1,3} & Z_{1,4} & Z_{1,5} \\ Z_{2,1} & Z_{2,2} & Z_{2,3} & Z_{2,4} & Z_{2,5} \\ Z_{3,1} & Z_{3,2} & Z_{3,3} & Z_{3,4} & Z_{3,5} \\ Z_{4,1} & Z_{4,2} & Z_{4,3} & Z_{4,4} & Z_{4,5} \\ Z_{5,1} & Z_{5,2} & Z_{5,3} & Z_{5,4} & Z_{5,5} \end{bmatrix} \cdot \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \\ \frac{-1,0}{Z_{5,5}} \end{bmatrix}$$



Cálculos de curto-circuito através da matriz Zbarra

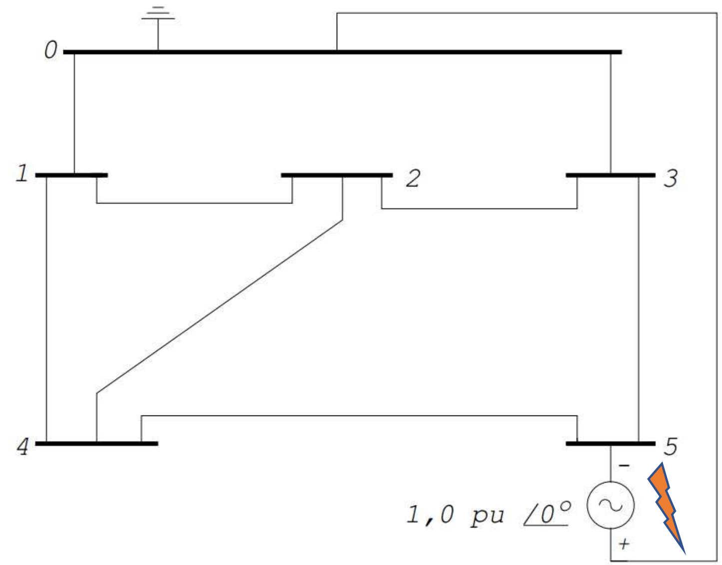
- Tensões nas barras vizinhas

$$\underline{v} = \begin{bmatrix} \frac{-Z_{1,5}}{Z_{5,5}} \\ \frac{-Z_{2,5}}{Z_{5,5}} \\ \frac{-Z_{3,5}}{Z_{5,5}} \\ \frac{-Z_{4,5}}{Z_{5,5}} \\ \frac{-Z_{5,5}}{Z_{5,5}} \end{bmatrix}$$

$$v_i = \frac{-Z_{i,5}}{Z_{5,5}}$$

$$v_i^r = 1,0 + v_i$$

$$v_i^r = 1,0 - \frac{Z_{i,5}}{Z_{5,5}}$$

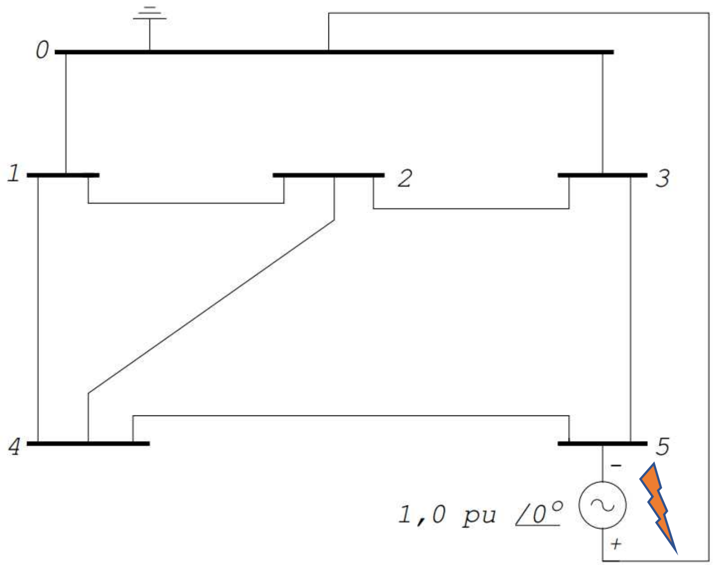


Cálculos de curto-circuito através da matriz Zbarra

- Fluxos de correntes nas linhas vizinhas

$$i_{2-4} = \frac{v_2^r - v_4^r}{z_{2-4}}$$

$$i_{2-4} = \left(\frac{Z_{4,5} - Z_{2,5}}{Z_{5,5}}\right)\left(\frac{1,0}{z_{2-4}}\right)$$



Generalização

- Sistema n barras
- Corrente de curto-circuito na barra k

$$i_{cc_k} = \frac{-1,0}{Z_{k,k}}$$

- Tensões nas barras vizinhas i

$$v_i^r = 1,0 - \frac{Z_{i,k}}{Z_{k,k}}$$

- Fluxos de correntes nas linhas vizinhas p-q

$$i_{p-q} = (\frac{Z_{q,k} - Z_{p,k}}{Z_{k,k}})(\frac{1,0}{z_{p-q}})$$

www.gesep.ufv.br

Gesep

gesep_vicosa

Gesep UFV

EStimate - Sistemas Fotovoltaicos

Google Play

https://play.google.com/store/apps/details?id=br.developer.gesep.estimate

Obrigado!

Heverton Augusto Pereira

Prof. Departamento de Engenheira Eletrica | UFV

Coordenador da Gerência de Especialistas em Sistemas Elétricos de Potência |Gesep

Membro do Programa de Pós-Graduaçao em Engenharia Elétrica | PPGEL/CEFET-MG

E-mail: heverton.pereira@ufv.br

GESEP

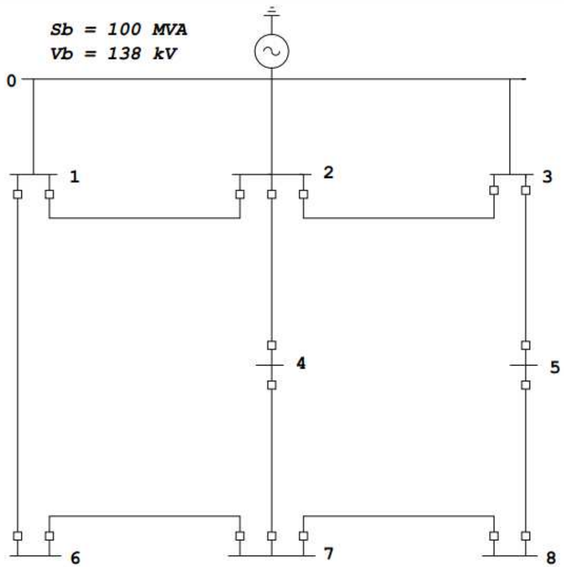
Sistemas Elétricos de Potência

Aula 07-P2 – Cálculo de Curto-circuito Equilibrado em Sistemas em Anel: Exemplo de Aplicação

Prof. Heverton Augusto Pereira
heverton.pereira@ufv.br

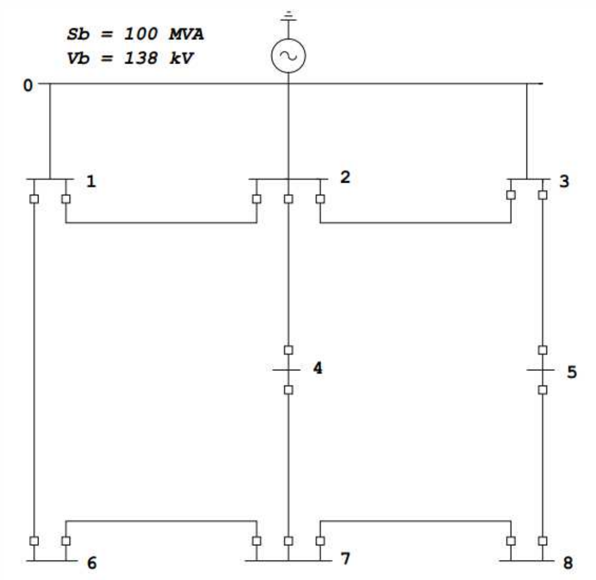
0,00889104	0,00132842	0,00011167	0,00204268	0,00056903	0,00626215	0,00275695	0,00102639
0,00132842	0,01134623	0,00055371	0,00833387	0,00137805	0,00303974	0,00532152	0,00220239
0,00011167	0,00055371	0,00475959	0,00120070	0,00425613	0,00085568	0,00184769	0,00375267
0,00204268	0,00833387	0,00120070	0,06620613	0,00792254	0,01834370	0,04007839	0,01464439
0,00056903	0,00137805	0,00425613	0,00792254	0,03662437	0,00652532	0,01446703	0,03199261
0,00626215	0,00303974	0,00085568	0,01834370	0,00652532	0,08999879	0,03364765	0,01219496
0,00275695	0,00532152	0,00184769	0,04007839	0,01446703	0,03364765	0,07483526	0,02708638
0,00102639	0,00220239	0,00375267	0,01464439	0,03199261	0,01219496	0,02708638	0,06023255

Sistema 8 Barras



De	Para	r+ + j x+
0	1	0,000 + j 0,010
0	2	0,000 + j 0,015
1	2	0,000 + j 0,084
0	3	0,000 + j 0,005
2	3	0,000 + j 0,122
2	4	0,000 + j 0,084
3	5	0,000 + j 0,037
1	6	0,000 + j 0,126
6	7	0,000 + j 0,168
4	7	0,000 + j 0,084
5	8	0,000 + j 0,037
7	8	0,000 + j 0,140

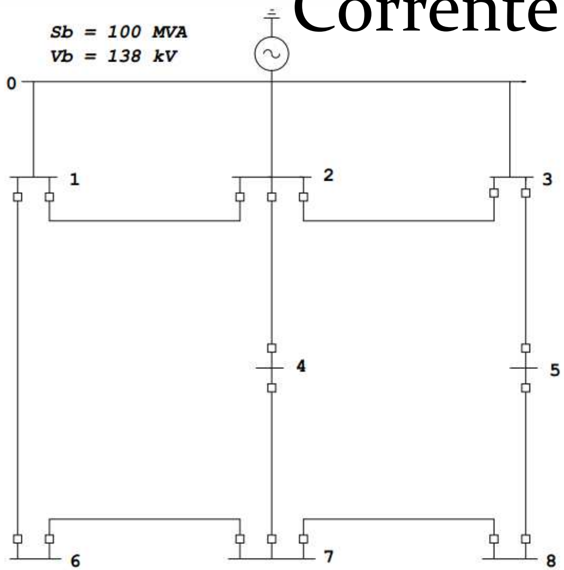
$$\begin{bmatrix}
0,00889104 & 0,00132842 & 0,00011167 & 0,00204268 & 0,00056903 & 0,00626215 & 0,00275695 & 0,00102639 \\
0,00132842 & 0,01134623 & 0,00055371 & 0,00833387 & 0,00137805 & 0,00303974 & 0,00532152 & 0,00220239 \\
0,00011167 & 0,00055371 & 0,00475959 & 0,00120070 & 0,00425613 & 0,00085568 & 0,00184769 & 0,00375267 \\
0,00204268 & 0,00833387 & 0,00120070 & 0,06620613 & 0,00792254 & 0,01834370 & 0,04007839 & 0,01464439 \\
0,00056903 & 0,00137805 & 0,00425613 & 0,00792254 & 0,03662437 & 0,00652532 & 0,01446703 & 0,03199261 \\
0,00626215 & 0,00303974 & 0,00085568 & 0,01834370 & 0,00652532 & 0,08999879 & 0,03364765 & 0,01219496 \\
0,00275695 & 0,00532152 & 0,00184769 & 0,04007839 & 0,01446703 & 0,03364765 & 0,07483526 & 0,02708638 \\
0,00102639 & 0,00220239 & 0,00375267 & 0,01464439 & 0,03199261 & 0,01219496 & 0,02708638 & 0,06023255
\end{bmatrix}$$



Sistema 8 Barras

- Determine:
- Corrente de curto-circuito trifásico na barra 7
- Tensões de fase nas barras 1, 4 e 5
- Fluxos de correntes nas linhas 1-6 e 8-7

Corrente de curto-circuito trifásico na barra 7

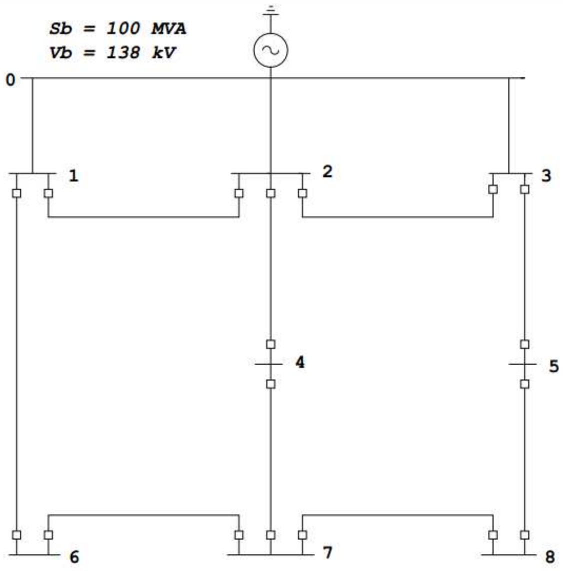


$$i_{cc_7} = \frac{1,0}{Z_{7,7}}$$

$$i_{cc_7} = \frac{1,0}{j0,07483526}$$

0,00889104	0,00132842	0,00011167	0,00204268	0,00056903	0,00626215	0,00275695	0,00102639
0,00132842	0,01134623	0,00055371	0,00833387	0,00137805	0,00303974	0,00532152	0,00220239
0,00011167	0,00055371	0,00475959	0,00120070	0,00425613	0,00085568	0,00184769	0,00375267
0,00204268	0,00833387	0,00120070	0,06620613	0,00792254	0,01834370	0,04007839	0,01464439
0,00056903	0,00137805	0,00425613	0,00792254	0,03662437	0,00652532	0,01446703	0,03199261
0,00626215	0,00303974	0,00085568	0,01834370	0,00652532	0,08999879	0,03364765	0,01219496
0,00275695	0,00532152	0,00184769	0,04007839	0,01446703	0,03364765	0,07483526	0,02708638
0,00102639	0,00220239	0,00375267	0,01464439	0,03199261	0,01219496	0,02708638	0,06023255

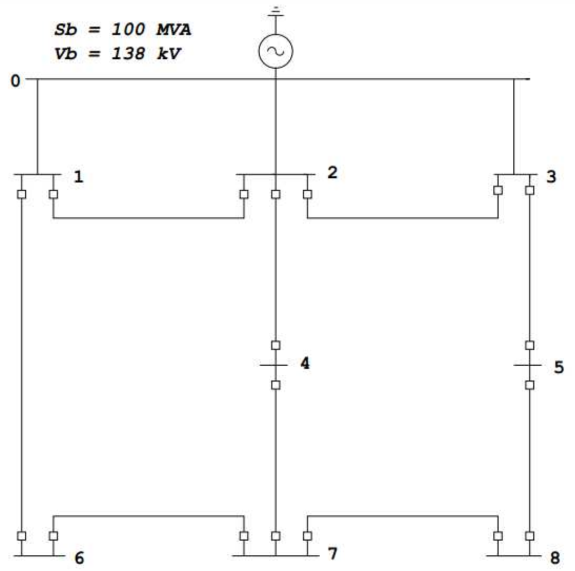
Corrente de curto-circuito trifásico na barra 7



$$I_{base} = \frac{100 \times 10^6}{\sqrt{3} \times 138 \times 10^3} = 418{,}36\ A$$

$$I_{cc7}^{3\emptyset} = -j13{,}3627 \times 418{,}36 = -j5.590{,}5\ A$$

Tensões de fase na barra 1

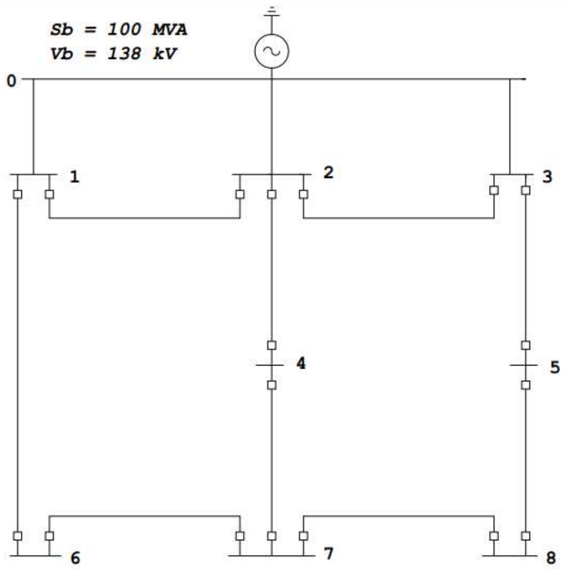


$$v_1^r = 1,0 - \frac{Z_{1,7}}{Z_{7,7}}$$

$$v_1^r = 1,0 - \frac{j0,00275695}{j0,07483526}$$

$$V_1^r = 0,9631 \times (\frac{138}{\sqrt{3}})$$

$$\begin{bmatrix}
0,00889104 & 0,00132842 & 0,00011167 & 0,00204268 & 0,00056903 & 0,00626215 & 0,00275695 & 0,00102639 \\
0,00132842 & 0,01134623 & 0,00055371 & 0,00833387 & 0,00137805 & 0,00303974 & 0,00532152 & 0,00220239 \\
0,00011167 & 0,00055371 & 0,00475959 & 0,00120070 & 0,00425613 & 0,00085568 & 0,00184769 & 0,00375267 \\
0,00204268 & 0,00833387 & 0,00120070 & 0,06620613 & 0,00792254 & 0,01834370 & 0,04007839 & 0,01464439 \\
0,00056903 & 0,00137805 & 0,00425613 & 0,00792254 & 0,03662437 & 0,00652532 & 0,01446703 & 0,03199261 \\
0,00626215 & 0,00303974 & 0,00085568 & 0,01834370 & 0,00652532 & 0,08999879 & 0,03364765 & 0,01219496 \\
0,00275695 & 0,00532152 & 0,00184769 & 0,04007839 & 0,01446703 & 0,03364765 & 0,07483526 & 0,02708638 \\
0,00102639 & 0,00220239 & 0,00375267 & 0,01464439 & 0,03199261 & 0,01219496 & 0,02708638 & 0,06023255
\end{bmatrix}$$



Tensões de fase na barra 4

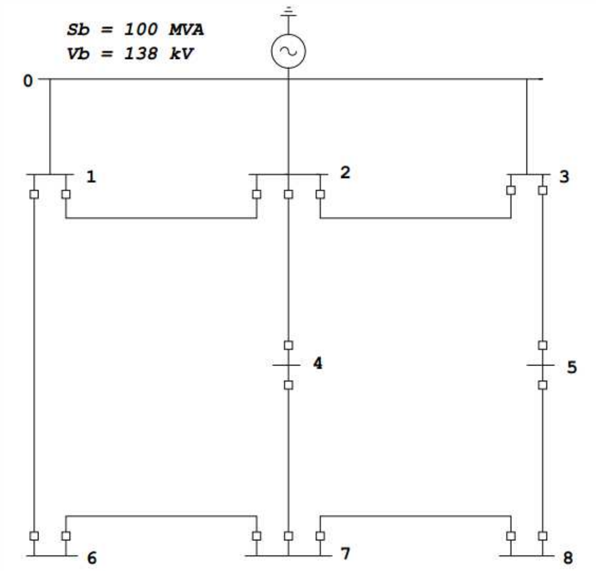
$$v_4^r = 1,0 - \frac{Z_{4,7}}{Z_{7,7}}$$

$$v_4^r = 1,0 - \frac{j0,04007839}{j0,07483526}$$

$$V_4^r = 0,4644 \times \left(\frac{138}{\sqrt{3}}\right)$$

$$\begin{bmatrix}
0,00889104 & 0,00132842 & 0,00011167 & 0,00204268 & 0,00056903 & 0,00626215 & 0,00275695 & 0,00102639 \\
0,00132842 & 0,01134623 & 0,00055371 & 0,00833387 & 0,00137805 & 0,00303974 & 0,00532152 & 0,00220239 \\
0,00011167 & 0,00055371 & 0,00475959 & 0,00120070 & 0,00425613 & 0,00085568 & 0,00184769 & 0,00375267 \\
0,00204268 & 0,00833387 & 0,00120070 & 0,06620613 & 0,00792254 & 0,01834370 & 0,04007839 & 0,01464439 \\
0,00056903 & 0,00137805 & 0,00425613 & 0,00792254 & 0,03662437 & 0,00652532 & 0,01446703 & 0,03199261 \\
0,00626215 & 0,00303974 & 0,00085568 & 0,01834370 & 0,00652532 & 0,08999879 & 0,03364765 & 0,01219496 \\
0,00275695 & 0,00532152 & 0,00184769 & 0,04007839 & 0,01446703 & 0,03364765 & 0,07483526 & 0,02708638 \\
0,00102639 & 0,00220239 & 0,00375267 & 0,01464439 & 0,03199261 & 0,01219496 & 0,02708638 & 0,06023255
\end{bmatrix}$$

Tensões de fase na barra 5



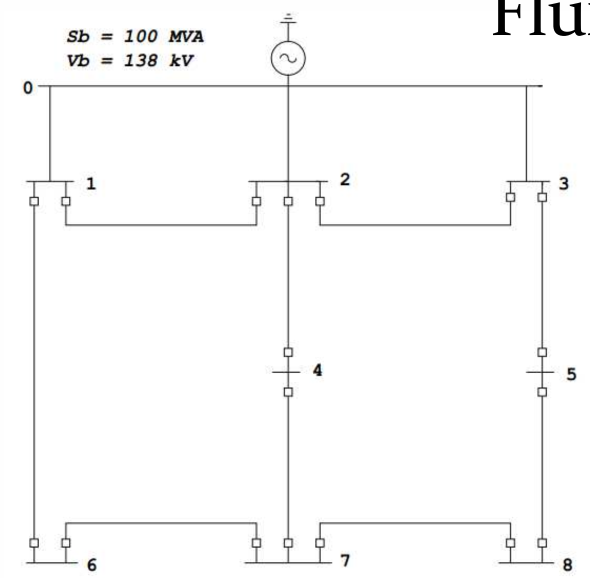
$$v_5^r = 1,0 - \frac{Z_{5,7}}{Z_{7,7}}$$

$$v_5^r = 1,0 - \frac{j0,01446703}{j0,07483526}$$

$$V_5^r = 0,8067 \times \left(\frac{138}{\sqrt{3}}\right)$$

$$\begin{bmatrix}
0,00889104 & 0,00132842 & 0,00011167 & 0,00204268 & 0,00056903 & 0,00626215 & 0,00275695 & 0,00102639 \\
0,00132842 & 0,01134623 & 0,00055371 & 0,00833387 & 0,00137805 & 0,00303974 & 0,00532152 & 0,00220239 \\
0,00011167 & 0,00055371 & 0,00475959 & 0,00120070 & 0,00425613 & 0,00085568 & 0,00184769 & 0,00375267 \\
0,00204268 & 0,00833387 & 0,00120070 & 0,06620613 & 0,00792254 & 0,01834370 & 0,04007839 & 0,01464439 \\
0,00056903 & 0,00137805 & 0,00425613 & 0,00792254 & 0,03662437 & 0,00652532 & \boxed{0,01446703} & 0,03199261 \\
0,00626215 & 0,00303974 & 0,00085568 & 0,01834370 & 0,00652532 & 0,08999879 & 0,03364765 & 0,01219496 \\
0,00275695 & 0,00532152 & 0,00184769 & 0,04007839 & 0,01446703 & 0,03364765 & \boxed{0,07483526} & 0,02708638 \\
0,00102639 & 0,00220239 & 0,00375267 & 0,01464439 & 0,03199261 & 0,01219496 & 0,02708638 & 0,06023255
\end{bmatrix}$$

Fluxos de correntes nas linhas 1-6

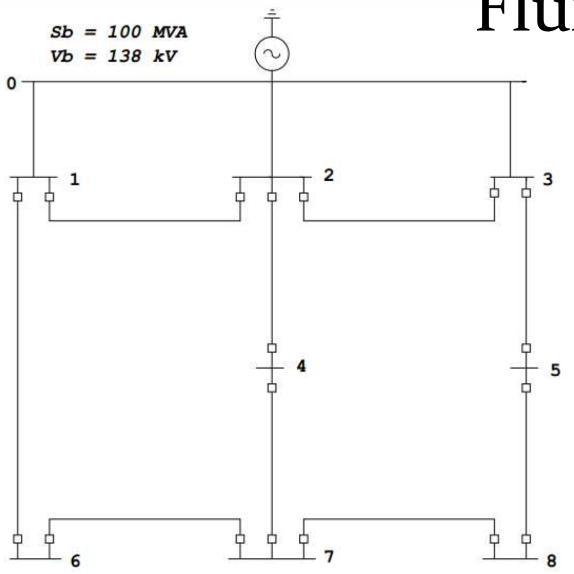


$$i_{1-6} = \left(\frac{Z_{6,7} - Z_{1,7}}{Z_{7,7}}\right)\left(\frac{1,0}{z_{1,6}}\right)$$

De	Para	r+ + j x+
0	1	0,000 + j 0,010
0	2	0,000 + j 0,015
1	2	0,000 + j 0,084
0	3	0,000 + j 0,005
2	3	0,000 + j 0,122
2	4	0,000 + j 0,084
3	5	0,000 + j 0,037
1	6	0,000 + j 0,126
6	7	0,000 + j 0,168
4	7	0,000 + j 0,084
5	8	0,000 + j 0,037
7	8	0,000 + j 0,140

$$\begin{bmatrix}
0,00889104 & 0,00132842 & 0,00011167 & 0,00204268 & 0,00056903 & 0,00626215 & 0,00275695 & 0,00102639 \\
0,00132842 & 0,01134623 & 0,00055371 & 0,00833387 & 0,00137805 & 0,00303974 & 0,00532152 & 0,00220239 \\
0,00011167 & 0,00055371 & 0,00475959 & 0,00120070 & 0,00425613 & 0,00085568 & 0,00184769 & 0,00375267 \\
0,00204268 & 0,00833387 & 0,00120070 & 0,06620613 & 0,00792254 & 0,01834370 & 0,04007839 & 0,01464439 \\
0,00056903 & 0,00137805 & 0,00425613 & 0,00792254 & 0,03662437 & 0,00652532 & 0,01446703 & 0,03199261 \\
0,00626215 & 0,00303974 & 0,00085568 & 0,01834370 & 0,00652532 & 0,08999879 & 0,03364765 & 0,01219496 \\
0,00275695 & 0,00532152 & 0,00184769 & 0,04007839 & 0,01446703 & 0,03364765 & 0,07483526 & 0,02708638 \\
0,00102639 & 0,00220239 & 0,00375267 & 0,01464439 & 0,03199261 & 0,01219496 & 0,02708638 & 0,06023255
\end{bmatrix}$$

Fluxos de correntes nas linhas 1-6



$$i_{1-6} = \left(\frac{Z_{6,7} - Z_{1,7}}{Z_{7,7}}\right)\left(\frac{1,0}{z_{1,6}}\right)$$

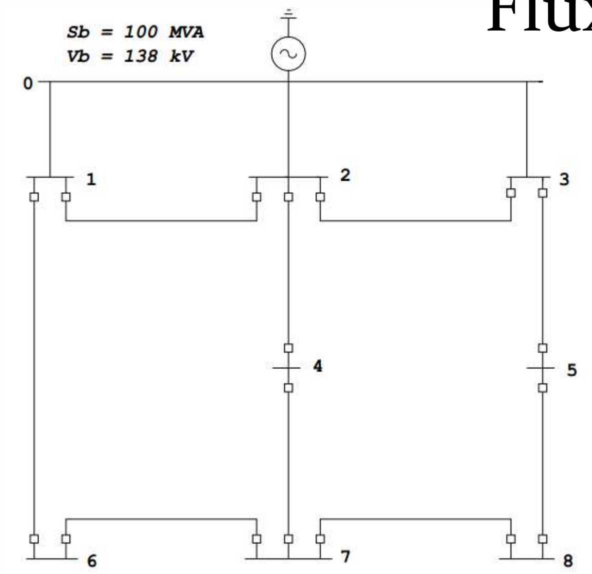
$$i_{1-6} = \left(\frac{j0,03364765 - j0,00275695}{j0,07483526}\right)\left(\frac{1,0}{j0,126}\right)$$

$$i_{1-6} = -j3,276pu$$

$$I_{base} = \frac{100 \times 10^6}{\sqrt{3} \times 138 \times 10^3} = 418{,}36\ A$$

$$I_{1-6}^{3\emptyset} = -j3{,}276 \times 418{,}36 = -j1.371\ A$$

Fluxos de correntes nas linhas 8-7

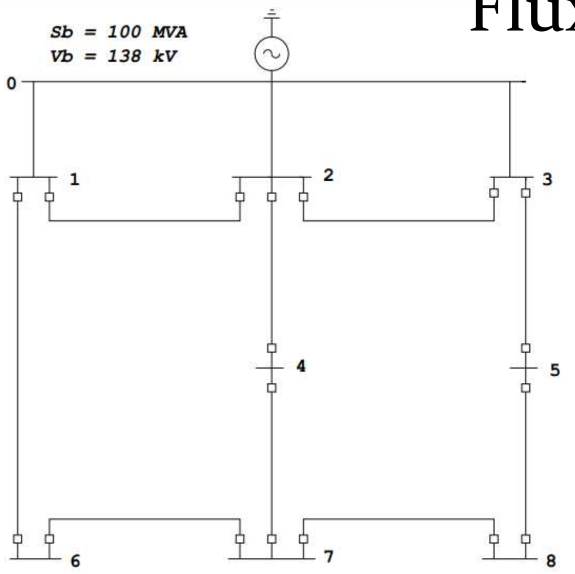


$$i_{8-7} = \left(\frac{Z_{7,7} - Z_{8,7}}{Z_{7,7}}\right)\left(\frac{1,0}{z_{8,7}}\right)$$

De – Para — r+ + j x+
0 — 1 — 0,000 + j 0,010
0 — 2 — 0,000 + j 0,015
1 — 2 — 0,000 + j 0,084
0 — 3 — 0,000 + j 0,005
2 — 3 — 0,000 + j 0,122
2 — 4 — 0,000 + j 0,084
3 — 5 — 0,000 + j 0,037
1 — 6 — 0,000 + j 0,126
6 — 7 — 0,000 + j 0,168
4 — 7 — 0,000 + j 0,084
5 — 8 — 0,000 + j 0,037
7 — 8 — 0,000 + j 0,140

$$\begin{bmatrix}
0,00889104 & 0,00132842 & 0,00011167 & 0,00204268 & 0,00056903 & 0,00626215 & 0,00275695 & 0,00102639 \\
0,00132842 & 0,01134623 & 0,00055371 & 0,00833387 & 0,00137805 & 0,00303974 & 0,00532152 & 0,00220239 \\
0,00011167 & 0,00055371 & 0,00475959 & 0,00120070 & 0,00425613 & 0,00085568 & 0,00184769 & 0,00375267 \\
0,00204268 & 0,00833387 & 0,00120070 & 0,06620613 & 0,00792254 & 0,01834370 & 0,04007839 & 0,01464439 \\
0,00056903 & 0,00137805 & 0,00425613 & 0,00792254 & 0,03662437 & 0,00652532 & 0,01446703 & 0,03199261 \\
0,00626215 & 0,00303974 & 0,00085568 & 0,01834370 & 0,00652532 & 0,08999879 & 0,03364765 & 0,01219496 \\
0,00275695 & 0,00532152 & 0,00184769 & 0,04007839 & 0,01446703 & 0,03364765 & 0,07483526 & 0,02708638 \\
0,00102639 & 0,00220239 & 0,00375267 & 0,01464439 & 0,03199261 & 0,01219496 & 0,02708638 & 0,06023255
\end{bmatrix}$$

Fluxos de correntes nas linhas 8-7



$$i_{8-7} = \left(\frac{Z_{7,7} - Z_{8,7}}{Z_{7,7}}\right)\left(\frac{1,0}{z_{8,7}}\right)$$

$$i_{8-7} = \left(\frac{j0,07483526 - j0,02708638}{j0,07483526}\right)\left(\frac{1,0}{j0,14}\right)$$

$$i_{8-7} = -j4,558 \text{ pu}$$

$$I_{base} = \frac{100 \times 10^6}{\sqrt{3} \times 138 \times 10^3} = 418,36\ A$$

$$I_{8-7}^{3\emptyset} = -j4,558 \times 418,36 = -j1.907\ A$$

www.gesep.ufv.br

Gesep

gesep_vicosa

Gesep UFV

EStimate - Sistemas Fotovoltaicos

Google Play

https://play.google.com/store/apps/details?id=br.developer.gesep.estimate

Obrigado!

Heverton Augusto Pereira

Prof. Departamento de Engenheira Eletrica | UFV

Coordenador da Gerência de Especialistas em Sistemas Elétricos de Potência |Gesep

Membro do Programa de Pós-Graduaçao em Engenharia Elétrica | PPGEL/CEFET-MG

E-mail: heverton.pereira@ufv.br

Sistemas Elétricos de Potência

Aula 07-P3 – Cálculo de Curto-circuito Bifásico em Sistemas em Anel: Forma Matricial

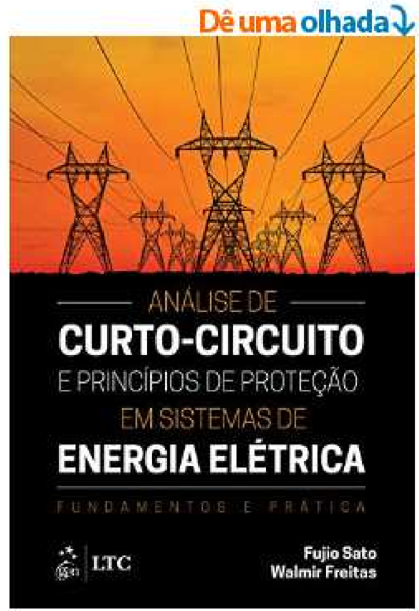
Prof. Heverton Augusto Pereira
heverton.pereira@ufv.br

$$
\begin{bmatrix}
0,00889104 & 0,00132842 & 0,00011167 & 0,00204268 & 0,00056903 & 0,00626215 & 0,00275695 & 0,00102639 \\
0,00132842 & 0,01134623 & 0,00055371 & 0,00833387 & 0,00137805 & 0,00303974 & 0,00532152 & 0,00220239 \\
0,00011167 & 0,00055371 & 0,00475959 & 0,00120070 & 0,00425613 & 0,00085568 & 0,00184769 & 0,00375267 \\
0,00204268 & 0,00833387 & 0,00120070 & 0,06620613 & 0,00792254 & 0,01834370 & 0,04007839 & 0,01464439 \\
0,00056903 & 0,00137805 & 0,00425613 & 0,00792254 & 0,03662437 & 0,00652532 & 0,01446703 & 0,03199261 \\
0,00626215 & 0,00303974 & 0,00085568 & 0,01834370 & 0,00652532 & 0,08999879 & 0,03364765 & 0,01219496 \\
0,00275695 & 0,00532152 & 0,00184769 & 0,04007839 & 0,01446703 & 0,03364765 & 0,07483526 & 0,02708638 \\
0,00102639 & 0,00220239 & 0,00375267 & 0,01464439 & 0,03199261 & 0,01219496 & 0,02708638 & 0,06023255
\end{bmatrix}
$$

Tópicos abordados

- Capítulo 4

- Capítulo 6 – Exemplo de aplicação



Hipóteses simplificadoras

- As máquinas síncronas operam com tensão $= 1{,}00\angle 0°$ pu
- Os parâmetros shunt das linhas são ignorados
- As carga são ignoradas
- Transformadores operando com tape nominal
- A rede de sequência negativa é idêntica a de sequência positiva

Curto-circuito Bifásico

$$\hat{i}_{A+} = \frac{100,0}{2 \times Z_{k,k}} \qquad \hat{i}_{A-} = -\hat{i}_{A+}$$

$$\hat{i}_{A} = \hat{i}_{A_+} - \hat{i}_{A_+} = 0,0$$

$$\hat{i}_{B} = a^2\hat{i}_{A_+} - a\hat{i}_{A_+} = (a^2 - a)\hat{i}_{A_+}$$

$$\hat{i}_{C} = a\hat{i}_{A_+} - a^2\hat{i}_{A_+} = (a - a^2)\hat{i}_{A_+}$$

Matrix Zbarra – Sequência positiva

$$[Z_{BARRA}][\underline{i_+}] = [\underline{v_+}]$$

$$\begin{bmatrix} Z_{1,1} & \cdots & Z_{1,k} & \cdots & Z_{1,p} & Z_{1,q} & \cdots & Z_{1,n} \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ Z_{k,1} & \cdots & Z_{k,k} & \cdots & Z_{k,p} & Z_{k,q} & \cdots & Z_{k,n} \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ Z_{p,1} & \cdots & Z_{p,k} & \cdots & Z_{p,p} & Z_{p,q} & \cdots & Z_{p,n} \\ Z_{q,1} & \cdots & Z_{q,k} & \cdots & Z_{q,p} & Z_{q,q} & \cdots & Z_{q,n} \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ Z_{n,1} & \cdots & Z_{n,k} & \cdots & Z_{n,p} & Z_{n,q} & \cdots & Z_{n,n} \end{bmatrix} \cdot \begin{bmatrix} 0 \\ . \\ \frac{-100{,}0}{2 \times Z_{k,k}} \\ . \\ 0 \\ 0 \\ . \\ 0 \end{bmatrix}$$

$$\hat{v}_{i+}^{r} = 100,0 + \hat{v}_{i+}$$

$$\hat{v}_{i+}^{r} = 100,0 - \frac{100,0 \times Z_{i,k}}{2 \times Z_{k,k}}$$

GESEP

Matrix Zbarra – Sequência negativa

$$[Z_{BARRA}][\underline{i_-}] = [\underline{v_-}]$$

$$\begin{bmatrix} Z_{1,1} & \dots & Z_{1,k} & \dots & Z_{1,p} & Z_{1,q} & \dots & Z_{1,n} \\ \dots & \dots & \dots & \dots & \dots & \dots & \dots & \dots \\ Z_{k,1} & \dots & Z_{k,k} & \dots & Z_{k,p} & Z_{k,q} & \dots & Z_{k,n} \\ \dots & \dots & \dots & \dots & \dots & \dots & \dots & \dots \\ Z_{p,1} & \dots & Z_{p,k} & \dots & Z_{p,p} & Z_{p,q} & \dots & Z_{p,n} \\ Z_{q,1} & \dots & Z_{q,k} & \dots & Z_{q,p} & Z_{q,q} & \dots & Z_{q,n} \\ \dots & \dots & \dots & \dots & \dots & \dots & \dots & \dots \\ Z_{n,1} & \dots & Z_{n,k} & \dots & Z_{n,p} & Z_{n,q} & \dots & Z_{n,n} \end{bmatrix} \cdot \begin{bmatrix} 0 \\ . \\ \frac{100{,}0}{2 \times Z_{k,k}} \\ . \\ 0 \\ 0 \\ . \\ 0 \end{bmatrix}$$

$$\hat{v}^r_{i\_} = 0 + \hat{v}_{i-} \Rightarrow \boxed{\hat{v}^r_{i-} = \frac{100,0 \times Z_{i,k}}{2 \times Z_{k,k}}}$$

Tensões nas fases

$$\hat{v}_{A_i} = \hat{v}_{i+}^r + \hat{v}_{i-}^r = 100,0 - \frac{100,0 \times Z_{i,k}}{2 \times Z_{k,k}} + \frac{100,0 \times Z_{i,k}}{2 \times Z_{k,k}}$$

$$\hat{v}_{B_i} = a^2 \hat{v}_{i+}^r + a \hat{v}_{i-}^r = a^2 (100,0 - \frac{100,0 \times Z_{i,k}}{2 \times Z_{k,k}}) + a (\frac{100,0 \times Z_{i,k}}{2 \times Z_{k,k}})$$

$$\hat{v}_{C_i} = a \hat{v}_{i+}^r + a^2 \hat{v}_{i-}^r = a (100,0 - \frac{100,0 \times Z_{i,k}}{2 \times Z_{k,k}}) + a^2 (\frac{100,0 \times Z_{i,k}}{2 \times Z_{k,k}})$$

$$\hat{v}_{A_i} = 100,0$$

$$\hat{v}_{B_i} = 100,0[a^2 + j\sqrt{3}(\frac{Z_{i,k}}{2 \times Z_{k,k}})]$$

$$\hat{v}_{C_i} = 100,0[a - j\sqrt{3}(\frac{Z_{i,k}}{2 \times Z_{k,k}})]$$

Correntes nas linhas p-q

$$\hat{i}_{p,q_+} = \frac{\hat{v}^r_{p+} - \hat{v}^r_{q+}}{z_{p,q_+}}$$

$$\hat{i}_{p,q_+} = \frac{100,0 - \frac{100,0 \times Z_{p,k}}{2 \times Z_{k,k}} - 100,0 + \frac{100,0 \times Z_{q,k}}{2 \times Z_{k,k}}}{z_{p,q_+}}$$

$$\hat{i}_{p,q_+} = (\frac{Z_{q,k} - Z_{p,k}}{2 \times Z_{k,k}}) \times \frac{100,0}{z_{p,q_+}}$$

$$\hat{i}_{p,q_-} = \frac{\hat{v}^r_{p-} - \hat{v}^r_{q-}}{z_{p,q_+}}$$

$$\hat{i}_{p,q_-} = \frac{\frac{100,0 \times Z_{p,k}}{2 \times Z_{k,k}} - \frac{100,0 \times Z_{q,k}}{2 \times Z_{k,k}}}{z_{p,q_+}}$$

$$\hat{i}_{p,q_-} = (\frac{Z_{p,k} - Z_{q,k}}{2 \times Z_{k,k}}) \times \frac{100,0}{z_{p,q_+}}$$

Correntes nas linhas p-q

$$\hat{i}_{p,q_A} = \hat{i}_{p,q_+} + \hat{i}_{p,q_-}$$

$$\hat{i}_{p,q_A} = (\frac{Z_{q,k} - Z_{p,k}}{2 \times Z_{k,k}}) \times \frac{100,0}{z_{p,q_+}} + (\frac{Z_{p,k} - Z_{q,k}}{2 \times Z_{k,k}}) \times \frac{100,0}{z_{p,q_+}}$$

$$\hat{i}_{p,q_B} = a^2\hat{i}_{p,q_+} + a\hat{i}_{p,q_-}$$

$$\hat{i}_{p,q_B} = a^2(\frac{Z_{q,k} - Z_{p,k}}{2 \times Z_{k,k}}) \times \frac{100,0}{z_{p,q_+}} + a(\frac{Z_{p,k} - Z_{q,k}}{2 \times Z_{k,k}}) \times \frac{100,0}{z_{p,q_+}}$$

$$\hat{i}_{p,q_C} = a\hat{i}_{p,q_+} + a^2\hat{i}_{p,q_-}$$

$$\hat{i}_{p,q_C} = a(\frac{Z_{q,k} - Z_{p,k}}{2 \times Z_{k,k}}) \times \frac{100,0}{z_{p,q_+}} + a^2(\frac{Z_{p,k} - Z_{q,k}}{2 \times Z_{k,k}}) \times \frac{100,0}{z_{p,q_+}}$$

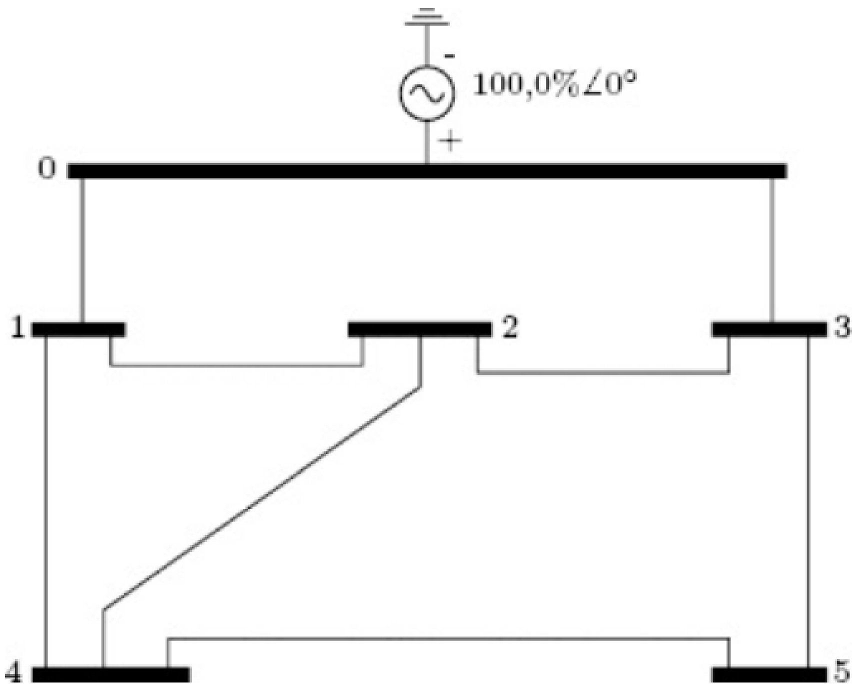
Correntes nas linhas p-q

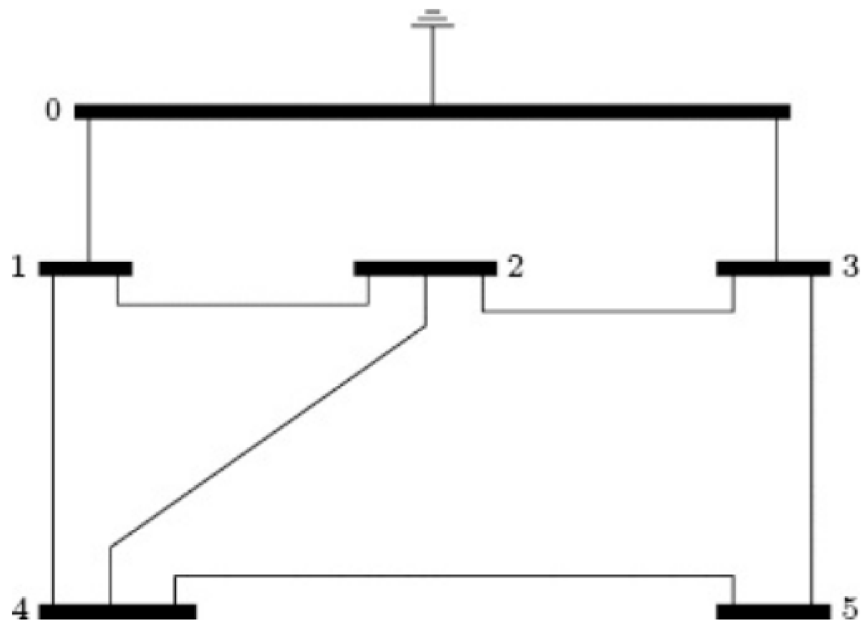
$$\hat{i}_{p,q_A} = 0,0$$

$$\hat{i}_{p,q_B} = j\left(\frac{Z_{p,k} - Z_{q,k}}{2 \times Z_{k,k}}\right) \times \sqrt{3}\left(\frac{100,0}{z_{p,q_+}}\right)$$

$$\hat{i}_{p,q_C} = j\left(\frac{Z_{q,k} - Z_{p,k}}{2 \times Z_{k,k}}\right) \times \sqrt{3}\left(\frac{100,0}{z_{p,q_+}}\right)$$

Exemplo – 5 Barras - Sequência Positiva e Zero





Exemplo – 5 Barras –Matriz Impedância

$$[Z^{+}_{BARRA}] = \begin{bmatrix} j1{,}7295 & j1{,}4072 & j0{,}9905 & j1{,}4690 & j1{,}2161 \\ j1{,}4072 & j2{,}4659 & j1{,}5811 & j1{,}8702 & j1{,}7174 \\ j0{,}9905 & j1{,}5811 & j2{,}3447 & j1{,}4679 & j1{,}9313 \\ j1{,}4690 & j1{,}8702 & j1{,}4679 & j2{,}6420 & j2{,}0215 \\ j1{,}2161 & j1{,}7174 & j1{,}9313 & j2{,}0215 & j3{,}4166 \end{bmatrix} \%$$

DE	PARA	x_+ %	x_0 %
0	1	$j2{,}27$	$j0{,}77$
0	3	$j4{,}16$	$j1{,}05$
1	2	$j2{,}47$	$j10{,}63$
2	4	$j2{,}47$	$j10{,}63$
2	3	$j2{,}68$	$j11{,}48$
1	4	$j2{,}42$	$j10{,}40$
4	5	$j3{,}06$	$j13{,}04$
3	5	$j2{,}73$	$j11{,}70$

$$[Z^{0}_{BARRA}] = \begin{bmatrix} j0{,}7308 & j0{,}4346 & j0{,}0534 & j0{,}4913 & j0{,}2605 \\ j0{,}4346 & j4{,}6660 & j0{,}4574 & j2{,}1644 & j1{,}2647 \\ j0{,}0534 & j0{,}4574 & j0{,}9771 & j0{,}3801 & j0{,}6948 \\ j0{,}4913 & j2{,}1644 & j0{,}3801 & j5{,}4898 & j2{,}7966 \\ j0{,}2605 & j1{,}2647 & j0{,}6948 & j2{,}7966 & j7{,}8556 \end{bmatrix} \%$$

Corrente de curto Bifásico na barra 5

$$i_{ccAk}^{2\emptyset} = 0{,}0$$

$$i_{ccBk}^{2\emptyset} = -j\sqrt{3}\left(\frac{100}{2Z_{k,k}^{+}}\right)$$

$$i_{ccCk}^{2\emptyset} = j\sqrt{3}\left(\frac{100}{2Z_{k,k}^{+}}\right)$$

$$i_{ccA5}^{2\emptyset} = 0{,}0$$

$$i_{ccB5}^{2\emptyset} = -j\sqrt{3}\left(\frac{100}{2 \times j3{,}4166}\right) = -25{,}34\ pu$$

$$i_{ccC5}^{2\emptyset} = j\sqrt{3}\left(\frac{100}{2 \times j3{,}4166}\right) = 25{,}34\angle 0°\ pu$$

$$I_{base} = \frac{100 \times 10^6}{\sqrt{3} \times 500 \times 10^3} = 115{,}47\ A$$

$$I_{ccA5}^{2\emptyset} = 0{,}0$$

$$I_{ccB5}^{2\emptyset} = -25{,}34 \times 115{,}47 = 2.926\angle 180°\ A$$

$$I_{ccC5}^{2\emptyset} = 25{,}34 \times 115{,}47 = 2.926\angle 0°\ A$$

Tensão na barra 4

$\hat{v}_{Ai} = 1{,}0\ \angle 0°$

$\hat{v}_{A4} = 1{,}0\ \angle 0°$

$$\hat{v}_{Bi} = a^2 + j\sqrt{3}\left(\frac{Z_{i,k}^{+}}{2Z_{k,k}^{+}}\right)$$

$$\hat{v}_{B4} = a^2 + j\sqrt{3}\left(\frac{j2{,}0215}{2 \times j3{,}4166}\right) = 0{,}612\angle 215{,}3°\ pu$$

$$\hat{v}_{Ci} = a - j\sqrt{3}\left(\frac{Z_{i,k}^{+}}{2Z_{k,k}^{+}}\right)$$

$$\hat{v}_{C4} = a - j\sqrt{3}\left(\frac{j2{,}0215}{2 \times j3{,}4166}\right) = 0{,}612\angle 144{,}7°\ pu$$

$$\hat{V}_{A4} = 1{,}0\left(\frac{500}{\sqrt{3}}\right) = 288{,}7\angle 0°\ kV$$

$$\hat{V}_{B4} = 0{,}612\left(\frac{500}{\sqrt{3}}\right) = 176{,}7\angle 215{,}3°\ kV$$

$$\hat{V}_{C4} = 0{,}612\left(\frac{500}{\sqrt{3}}\right) = 176{,}7\angle 144{,}7°\ kV$$

Corrente na linha 2-4

$$\hat{\imath}_{A\ p,q} = 0{,}0 \qquad \hat{\imath}_{B\ p,q} = j\left(\frac{Z^{+}_{p,k} - Z^{+}_{q,k}}{2Z^{+}_{k,k}}\right)\sqrt{3}\left(\frac{100}{z^{+}_{p,q}}\right) \qquad \hat{\imath}_{C\ p,q} = j\left(\frac{Z^{+}_{q,k} - Z^{+}_{p,k}}{2Z^{+}_{k,k}}\right)\sqrt{3}\left(\frac{100}{z^{+}_{p,q}}\right)$$

$$\hat{\imath}_{A\ 2,4} = 0{,}0$$

$$\hat{\imath}_{B\ 2,4} = j\left(\frac{j1{,}7174 - j2{,}0215}{2 \times j3{,}4166}\right)\sqrt{3}\left(\frac{100}{j2{,}47}\right) = 3{,}121\angle 180° pu$$

$$\hat{\imath}_{C\ 2,4} = j\left(\frac{j2{,}0215 - j1{,}7174}{2 \times j3{,}4166}\right)\sqrt{3}\left(\frac{100}{j2{,}47}\right) = 3{,}121\angle 0° pu$$

$$I_{base} = \frac{100 \times 10^{6}}{\sqrt{3} \times 500 \times 10^{3}} = 115{,}47\ A$$

$$\hat{I}_{A\ 2,4} = 0{,}0$$

$$\hat{I}_{B\ 2,4} = 3{,}121 \times 115{,}47 = 360{,}4\angle 180° A$$

$$\hat{I}_{C\ 2,4} = 3{,}121 \times 115{,}47 = 360{,}4\angle 0° A$$

www.gesep.ufv.br

Gesep

gesep_vicosa

Gesep UFV

EStimate - Sistemas Fotovoltaicos

Google Play

https://play.google.com/store/apps/details?id=br.developer.gesep.estimate

Obrigado!

Heverton Augusto Pereira
Prof. Departamento de Engenheira Eletrica | UFV
Coordenador da Gerência de Especialistas em Sistemas Elétricos de Potência |Gesep
Membro do Programa de Pós-Graduaçao em Engenharia Elétrica | PPGEL/CEFET-MG
E-mail: heverton.pereira@ufv.br

Sistemas Elétricos de Potência

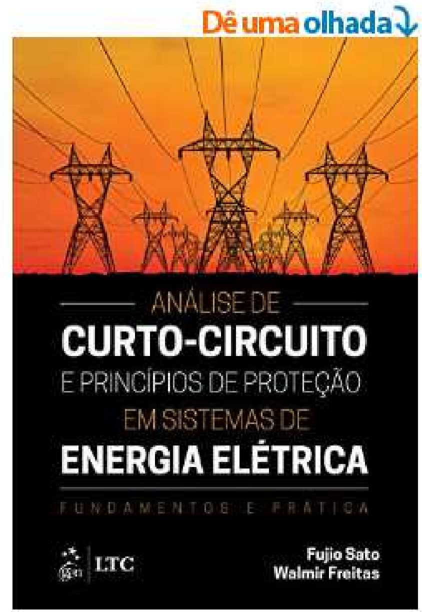
Aula 07-P4 – Cálculo de Curto-circuito Monofásico em Sistemas em Anel: Forma Matricial

Prof. Heverton Augusto Pereira
heverton.pereira@ufv.br

$$\begin{bmatrix}
0,00889104 & 0,00132842 & 0,00011167 & 0,00204268 & 0,00056903 & 0,00626215 & 0,00275695 & 0,00102639 \\
0,00132842 & 0,01134623 & 0,00055371 & 0,00833387 & 0,00137805 & 0,00303974 & 0,00532152 & 0,00220239 \\
0,00011167 & 0,00055371 & 0,00475959 & 0,00120070 & 0,00425613 & 0,00085568 & 0,00184769 & 0,00375267 \\
0,00204268 & 0,00833387 & 0,00120070 & 0,06620613 & 0,00792254 & 0,01834370 & 0,04007839 & 0,01464439 \\
0,00056903 & 0,00137805 & 0,00425613 & 0,00792254 & 0,03662437 & 0,00652532 & 0,01446703 & 0,03199261 \\
0,00626215 & 0,00303974 & 0,00085568 & 0,01834370 & 0,00652532 & 0,08999879 & 0,03364765 & 0,01219496 \\
0,00275695 & 0,00532152 & 0,00184769 & 0,04007839 & 0,01446703 & 0,03364765 & 0,07483526 & 0,02708638 \\
0,00102639 & 0,00220239 & 0,00375267 & 0,01464439 & 0,03199261 & 0,01219496 & 0,02708638 & 0,06023255
\end{bmatrix}$$

Tópicos abordados

- Capítulo 4
- Capítulo 6 – Exemplo de aplicação



Curto-circuito Monofásico

$$\hat{i}_{A+} = \frac{100,0}{2 \times Z_{k,k} + Z^0_{k,k}}$$

$$\hat{i}_{A-} = \hat{i}_{A+}$$

$$\hat{i}_{Ao} = \hat{i}_{A+}$$

$$\hat{i}_A = \hat{i}_{A_+} + \hat{i}_{A_-} + \hat{i}_{A_o} = \frac{3 \times 100,0}{2 \times Z_{k,k} + Z^0_{k,k}}$$

$$\hat{i}_B = a^2 \hat{i}_{A_+} + a \hat{i}_{A_-} + \hat{i}_{A_o} = 0,0$$

$$\hat{i}_C = a \hat{i}_{A_+} + a^2 \hat{i}_{A_-} + \hat{i}_{A_o} = 0,0$$

Matrix Zbarra – Sequência positiva

$$[Z_{BARRA}][\underline{i_+}] = [\underline{v_+}]$$

$$\begin{bmatrix} Z_{1,1} & \cdots & Z_{1,k} & \cdots & Z_{1,p} & Z_{1,q} & \cdots & Z_{1,n} \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ Z_{k,1} & \cdots & Z_{k,k} & \cdots & Z_{k,p} & Z_{k,q} & \cdots & Z_{k,n} \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ Z_{p,1} & \cdots & Z_{p,k} & \cdots & Z_{p,p} & Z_{p,q} & \cdots & Z_{p,n} \\ Z_{q,1} & \cdots & Z_{q,k} & \cdots & Z_{q,p} & Z_{q,q} & \cdots & Z_{q,n} \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ Z_{n,1} & \cdots & Z_{n,k} & \cdots & Z_{n,p} & Z_{n,q} & \cdots & Z_{n,n} \end{bmatrix} \cdot \begin{bmatrix} 0 \\ . \\ \hat{i}_{A+} \\ . \\ 0 \\ 0 \\ . \\ 0 \end{bmatrix} = \begin{bmatrix} \frac{-100,0 \times Z_{1,k}}{2 \times Z_{k,k} + Z^0_{k,k}} \\ . \\ \frac{-100,0 \times Z_{k,k}}{2 \times Z_{k,k} + Z^0_{k,k}} \\ . \\ \frac{-100,0 \times Z_{p,k}}{2 \times Z_{k,k} + Z^0_{k,k}} \\ \frac{-100,0 \times Z_{q,k}}{2 \times Z_{k,k} + Z^0_{k,k}} \\ . \\ \frac{-100,0 \times Z_{n,k}}{2 \times Z_{k,k} + Z^0_{k,k}} \end{bmatrix}$$

$$\hat{v}^r_{i+} = 100,0 + \hat{v}_{i+} \qquad \hat{v}^r_{i+} = 100,0 - \frac{100,0 \times Z_{i,k}}{2 \times Z_{k,k} + Z^0_{k,k}}$$

Matrix Zbarra – Sequência negativa

$$[Z_{BARRA}][i_-] = [v_-]$$

$$\begin{bmatrix} Z_{1,1} & \cdots & Z_{1,k} & \cdots & Z_{1,p} & Z_{1,q} & \cdots & Z_{1,n} \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ Z_{k,1} & \cdots & Z_{k,k} & \cdots & Z_{k,p} & Z_{k,q} & \cdots & Z_{k,n} \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ Z_{p,1} & \cdots & Z_{p,k} & \cdots & Z_{p,p} & Z_{p,q} & \cdots & Z_{p,n} \\ Z_{q,1} & \cdots & Z_{q,k} & \cdots & Z_{q,p} & Z_{q,q} & \cdots & Z_{q,n} \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ Z_{n,1} & \cdots & Z_{n,k} & \cdots & Z_{n,p} & Z_{n,q} & \cdots & Z_{n,n} \end{bmatrix} \cdot \begin{bmatrix} 0 \\ . \\ \hat{i}_{A_-} \\ . \\ 0 \\ 0 \\ . \\ 0 \end{bmatrix} = \begin{bmatrix} \frac{-100,0 \times Z_{1,k}}{2 \times Z_{k,k} + Z^0_{k,k}} \\ . \\ \frac{-100,0 \times Z_{k,k}}{2 \times Z_{k,k} + Z^0_{k,k}} \\ . \\ \frac{-100,0 \times Z_{p,k}}{2 \times Z_{k,k} + Z^0_{k,k}} \\ \frac{-100,0 \times Z_{q,k}}{2 \times Z_{k,k} + Z^0_{k,k}} \\ . \\ \frac{-100,0 \times Z_{n,k}}{2 \times Z_{k,k} + Z^0_{k,k}} \end{bmatrix}$$

$$\hat{v}^r_{i-} = 0,0 + \hat{v}_{i-}$$

$$\hat{v}^r_{i-} = -\frac{100,0 \times Z_{i,k}}{2 \times Z_{k,k} + Z^0_{k,k}}$$

Matrix Zbarra – Sequência zero

$$[Z^0_{BARRA}][\underline{i_o}] = [\underline{v_o}]$$

$$\begin{bmatrix} Z^0_{1,1} & \cdots & Z^0_{1,k} & \cdots & Z^0_{1,p} & Z^0_{1,q} & \cdots & Z^0_{1,n} \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ Z^0_{k,1} & \cdots & Z^0_{k,k} & \cdots & Z^0_{k,p} & Z^0_{k,q} & \cdots & Z^0_{k,n} \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ Z^0_{p,1} & \cdots & Z^0_{p,k} & \cdots & Z^0_{p,p} & Z^0_{p,q} & \cdots & Z^0_{p,n} \\ Z^0_{q,1} & \cdots & Z^0_{q,k} & \cdots & Z^0_{q,p} & Z^0_{q,q} & \cdots & Z^0_{q,n} \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ Z^0_{n,1} & \cdots & Z^0_{n,k} & \cdots & Z^0_{n,p} & Z^0_{n,q} & \cdots & Z^0_{n,n} \end{bmatrix} \cdot \begin{bmatrix} 0 \\ . \\ \hat{i}_{A_o} \\ . \\ 0 \\ 0 \\ . \\ 0 \end{bmatrix} = \begin{bmatrix} \frac{-100,0 \times Z^0_{1,k}}{2 \times Z_{k,k} + Z^0_{k,k}} \\ . \\ \frac{-100,0 \times Z^0_{k,k}}{2 \times Z_{k,k} + Z^0_{k,k}} \\ . \\ \frac{-100,0 \times Z^0_{p,k}}{2 \times Z_{k,k} + Z^0_{k,k}} \\ \frac{-100,0 \times Z^0_{q,k}}{2 \times Z_{k,k} + Z^0_{k,k}} \\ . \\ \frac{-100,0 \times Z^0_{n,k}}{2 \times Z_{k,k} + Z^0_{k,k}} \end{bmatrix}$$

$$\hat{v}^r_{io} = -\frac{100,0 \times Z^0_{i,k}}{2 \times Z_{k,k} + Z^0_{k,k}}$$

$$\hat{v}^r_{io} = 0 + \hat{v}_{io}$$

Tensões nas fases

$$\hat{v}_{A_i} = \hat{v}^r_{i+} + \hat{v}^r_{i-} + \hat{v}^r_{io}$$

$$\hat{v}_{B_i} = a^2\hat{v}^r_{i+} + a\hat{v}^r_{i-} + \hat{v}^r_{io}$$

$$\hat{v}_{C_i} = a\hat{v}^r_{i+} + a^2\hat{v}^r_{i-} + \hat{v}^r_{io}$$

$$\hat{v}_{A_i} = 100,0 - \frac{100,0 \times Z_{i,k}}{2 \times Z_{k,k} + Z^0_{k,k}} - \frac{100,0 \times Z_{i,k}}{2 \times Z_{k,k} + Z^0_{k,k}} - \frac{100,0 \times Z^0_{i,k}}{2 \times Z_{k,k} + Z^0_{k,k}}$$

$$\hat{v}_{B_i} = a^2(100,0 - \frac{100,0 \times Z_{i,k}}{2 \times Z_{k,k} + Z^0_{k,k}}) - a(\frac{100,0 \times Z_{i,k}}{2 \times Z_{k,k} + Z^0_{k,k}}) - \frac{100,0 \times Z^0_{i,k}}{2 \times Z_{k,k} + Z^0_{k,k}}$$

$$\hat{v}_{C_i} = a(100,0 - \frac{100,0 \times Z_{i,k}}{2 \times Z_{k,k} + Z^0_{k,k}}) - a^2(\frac{100,0 \times Z_{i,k}}{2 \times Z_{k,k} + Z^0_{k,k}}) - \frac{100,0 \times Z^0_{i,k}}{2 \times Z_{k,k} + Z^0_{k,k}}$$

Tensões nas fases

$$\hat{v}_{A_i} = 100,0[1,0 - (\frac{2 \times Z_{i,k} + Z_{i,k}^0}{2 \times Z_{k,k} + Z_{k,k}^0})]$$

$$\hat{v}_{B_i} = 100,0[a^2 - (\frac{Z_{i,k}^0 - Z_{i,k}}{2 \times Z_{k,k} + Z_{k,k}^0})]$$

$$\hat{v}_{C_i} = 100,0[a - (\frac{Z_{i,k}^0 - Z_{i,k}}{2 \times Z_{k,k} + Z_{k,k}^0})]$$

Correntes nas linhas p-q

$$\hat{i}_{p,q_+} = \frac{\hat{v}^r_{p+} - \hat{v}^r_{q+}}{z_{p,q_+}}$$

$$\hat{i}_{p,q_+} = \frac{100,0 - \frac{100,0 \times Z_{p,k}}{2 \times Z_{k,k} + Z^0_{k,k}} - 100,0 + \frac{100,0 \times Z_{q,k}}{2 \times Z_{k,k} + Z^0_{k,k}}}{z_{p,q_+}}$$

$$\hat{i}_{p,q_-} = \frac{\hat{v}^r_{p-} - \hat{v}^r_{q-}}{z_{p,q_+}}$$

$$\hat{i}_{p,q_-} = \frac{\frac{100,0 \times Z_{p,k}}{2 \times Z_{k,k} + Z^0_{k,k}} - \frac{100,0 \times Z_{q,k}}{2 \times Z_{k,k} + Z^0_{k,k}}}{z_{p,q_+}}$$

$$\hat{i}_{p,q_o} = \frac{\hat{v}^r_{po} - \hat{v}^r_{qo}}{z_{p,q_o}}$$

$$\hat{i}_{p,q_o} = \frac{\frac{100,0 \times Z^0_{p,k}}{2 \times Z_{k,k} + Z^0_{k,k}} - \frac{100,0 \times Z^0_{q,k}}{2 \times Z_{k,k} + Z^0_{k,k}}}{z_{p,q_o}}$$

Correntes nas linhas p-q

$$\hat{i}_{p,q_+} = \left(\frac{Z_{q,k} - Z_{p,k}}{2 \times Z_{k,k} + Z^0_{k,k}}\right) \times \frac{100,0}{z_{p,q_+}}$$

$$\hat{i}_{p,q_-} = \left(\frac{Z_{q,k} - Z_{p,k}}{2 \times Z_{k,k} + Z^0_{k,k}}\right) \times \frac{100,0}{z_{p,q_+}}$$

$$\hat{i}_{p,q_o} = \left(\frac{Z^0_{q,k} - Z^0_{p,k}}{2 \times Z_{k,k} + Z^0_{k,k}}\right) \times \frac{100,0}{z_{p,q_o}}$$

$$\hat{i}_{p,q_A} = \hat{i}_{p,q_+} + \hat{i}_{p,q_-} + \hat{i}_{p,q_o}$$

$$\hat{i}_{p,q_B} = a^2\hat{i}_{p,q_+} + a\hat{i}_{p,q_-} + \hat{i}_{p,q_o}$$

$$\hat{i}_{p,q_C} = a\hat{i}_{p,q_+} + a^2\hat{i}_{p,q_-} + \hat{i}_{p,q_o}$$

Correntes nas linhas p-q

$$\hat{i}_{p,q_A} = 2 \times (\frac{Z_{q,k} - Z_{p,k}}{2 \times Z_{k,k} + Z^0_{k,k}}) \times \frac{100,0}{z_{p,q_+}} + (\frac{Z^0_{q,k} - Z^0_{p,k}}{2 \times Z_{k,k} + Z^0_{k,k}}) \times \frac{100,0}{z_{p,q_o}}$$

$$\hat{i}_{p,q_B} = -(\frac{Z_{q,k} - Z_{p,k}}{2 \times Z_{k,k} + Z^0_{k,k}}) \times \frac{100,0}{z_{p,q_+}} + (\frac{Z^0_{q,k} - Z^0_{p,k}}{2 \times Z_{k,k} + Z^0_{k,k}}) \times \frac{100,0}{z_{p,q_o}}$$

$$\hat{i}_{p,q_C} = -(\frac{Z_{q,k} - Z_{p,k}}{2 \times Z_{k,k} + Z^0_{k,k}}) \times \frac{100,0}{z_{p,q_+}} + (\frac{Z^0_{q,k} - Z^0_{p,k}}{2 \times Z_{k,k} + Z^0_{k,k}}) \times \frac{100,0}{z_{p,q_o}}$$

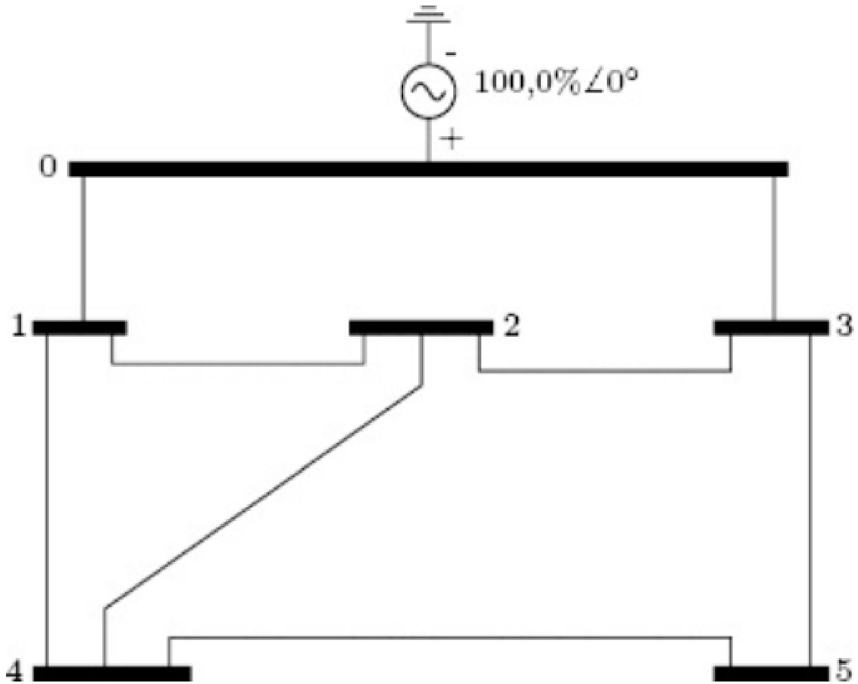
Correntes nas linhas p-q

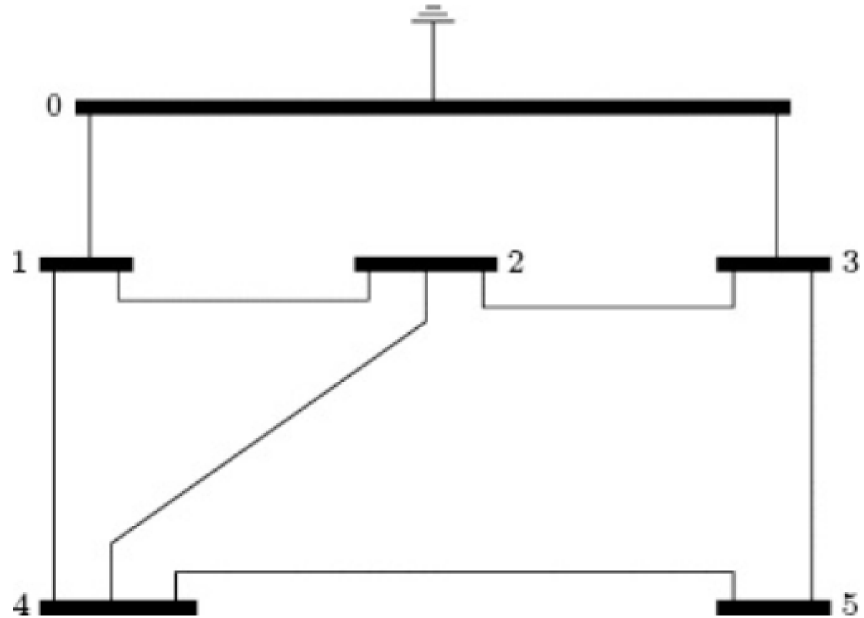
$$\hat{i}_{p,q_A} = \frac{100,0}{2 \times Z_{k,k} + Z^0_{k,k}}[2 \times \frac{(Z_{q,k} - Z_{p,k})}{z_{p,q_+}} + \frac{(Z^0_{q,k} - Z^0_{p,k})}{z_{p,q_o}}]$$

$$\hat{i}_{p,q_B} = \frac{100,0}{2 \times Z_{k,k} + Z^0_{k,k}}[\frac{(Z_{p,k} - Z_{q,k})}{z_{p,q_+}} + \frac{(Z^0_{q,k} - Z^0_{p,k})}{z_{p,q_o}}]$$

$$\hat{i}_{p,q_C} = \hat{i}_{p,q_B}$$

Hipóteses simplificadoras





Hipóteses simplificadoras

$$[Z^{+}_{BARRA}] = \begin{bmatrix} j1{,}7295 & j1{,}4072 & j0{,}9905 & j1{,}4690 & j1{,}2161 \\ j1{,}4072 & j2{,}4659 & j1{,}5811 & j1{,}8702 & j1{,}7174 \\ j0{,}9905 & j1{,}5811 & j2{,}3447 & j1{,}4679 & j1{,}9313 \\ j1{,}4690 & j1{,}8702 & j1{,}4679 & j2{,}6420 & j2{,}0215 \\ j1{,}2161 & j1{,}7174 & j1{,}9313 & j2{,}0215 & j3{,}4166 \end{bmatrix} \%$$

$$[Z^{0}_{BARRA}] = \begin{bmatrix} j0{,}7308 & j0{,}4346 & j0{,}0534 & j0{,}4913 & j0{,}2605 \\ j0{,}4346 & j4{,}6660 & j0{,}4574 & j2{,}1644 & j1{,}2647 \\ j0{,}0534 & j0{,}4574 & j0{,}9771 & j0{,}3801 & j0{,}6948 \\ j0{,}4913 & j2{,}1644 & j0{,}3801 & j5{,}4898 & j2{,}7966 \\ j0{,}2605 & j1{,}2647 & j0{,}6948 & j2{,}7966 & j7{,}8556 \end{bmatrix} \%$$

DE	PARA	x_+ %	x_0 %
0	1	$j2{,}27$	$j0{,}77$
0	3	$j4{,}16$	$j1{,}05$
1	2	$j2{,}47$	$j10{,}63$
2	4	$j2{,}47$	$j10{,}63$
2	3	$j2{,}68$	$j11{,}48$
1	4	$j2{,}42$	$j10{,}40$
4	5	$j3{,}06$	$j13{,}04$
3	5	$j2{,}73$	$j11{,}70$

Corrente de curto Monofásico na barra 5

$$\hat{i}_{+k} = \hat{i}_{-k} = \hat{i}_{0k} = \frac{100}{2Z_{k,k}^{+} + Z_{k,k}^{0}}$$

$$\hat{i}_{+5} = \hat{i}_{-5} = \hat{i}_{05} = \frac{100}{2 \times j3{,}4166 + j7{,}8556} = -j6{,}81\ pu$$

$$[Z_{BARRA}^{+}] = \begin{bmatrix} j1{,}7295 & j1{,}4072 & j0{,}9905 & j1{,}4690 & j1{,}2161 \\ j1{,}4072 & j2{,}4659 & j1{,}5811 & j1{,}8702 & j1{,}7174 \\ j0{,}9905 & j1{,}5811 & j2{,}3447 & j1{,}4679 & j1{,}9313 \\ j1{,}4690 & j1{,}8702 & j1{,}4679 & j2{,}6420 & j2{,}0215 \\ j1{,}2161 & j1{,}7174 & j1{,}9313 & j2{,}0215 & j3{,}4166 \end{bmatrix} \%$$

$$i_{ccA5}^{1\emptyset} = 3(-j6{,}81) = -j20{,}424$$

$$[Z_{BARRA}^{0}] = \begin{bmatrix} j0{,}7308 & j0{,}4346 & j0{,}0534 & j0{,}4913 & j0{,}2605 \\ j0{,}4346 & j4{,}6660 & j0{,}4574 & j2{,}1644 & j1{,}2647 \\ j0{,}0534 & j0{,}4574 & j0{,}9771 & j0{,}3801 & j0{,}6948 \\ j0{,}4913 & j2{,}1644 & j0{,}3801 & j5{,}4898 & j2{,}7966 \\ j0{,}2605 & j1{,}2647 & j0{,}6948 & j2{,}7966 & j7{,}8556 \end{bmatrix} \%$$

$$I_{base} = \frac{100 \times 10^{6}}{\sqrt{3} \times 500 \times 10^{3}} = 115{,}47\ A$$

$$I_{ccA5}^{1\emptyset} = -j20{,}424 \times 115{,}47 = -j\,2.358{,}3A$$

Tensão na barra 4

$$\hat{v}_{Ai} = 1{,}0 - \left(\frac{2Z_{i,k}^{+} + Z_{i,k}^{0}}{2Z_{k,k}^{+} + Z_{k,k}^{0}}\right)$$

$$\hat{v}_{Bi} = a^2 - \left(\frac{Z_{i,k}^{0} - Z_{i,k}^{+}}{2Z_{k,k}^{+} + Z_{k,k}^{0}}\right)$$

$$\hat{v}_{Ci} = a - \left(\frac{Z_{i,k}^{0} - Z_{i,k}^{+}}{2Z_{k,k}^{+} + Z_{k,k}^{0}}\right)$$

$$\hat{v}_{A4} = 1{,}0 - \left(\frac{2 \times j2{,}0215 + j2{,}7966}{2 \times j3{,}4166 + j7{,}8556}\right) = 0{,}534\angle 0° \, pu$$

$$\hat{v}_{B4} = a^2 - \left(\frac{j2{,}7966 - j2{,}0215}{2 \times j3{,}4166 + j7{,}8556}\right) = 1{,}027\angle 237{,}5° \, pu$$

$$\hat{v}_{C4} = a - \left(\frac{j2{,}7966 - j2{,}0215}{2 \times j3{,}4166 + j7{,}8556}\right) = 1{,}027\angle 122{,}5° \, pu$$

$$\hat{V}_{A4} = 0{,}534\left(\frac{500}{\sqrt{3}}\right) = 154{,}2\angle 0° \, kV$$

$$\hat{V}_{B4} = 1{,}027\left(\frac{500}{\sqrt{3}}\right) = 296{,}5\angle 237{,}5° \, kV$$

$$\hat{V}_{C4} = 1{,}027\left(\frac{500}{\sqrt{3}}\right) = 296{,}5\angle 122{,}5° \, kV$$

Corrente na linha 2-4

$$\hat{\imath}_{A\ p,q} = \frac{100}{2Z_{k,k}^{+} + Z_{k,k}^{0}} \left(\frac{2\left(Z_{q,k}^{+} - Z_{p,k}^{+}\right)}{z_{p,q}^{+}} + \frac{\left(Z_{q,k}^{0} - Z_{p,k}^{0}\right)}{z_{p,q}^{o}} \right)$$

$$\hat{\imath}_{B\ p,q} = \frac{100}{2Z_{k,k}^{+} + Z_{k,k}^{0}} \left(\frac{\left(Z_{p,k}^{+} - Z_{q,k}^{+}\right)}{z_{p,q}^{+}} + \frac{\left(Z_{q,k}^{0} - Z_{p,k}^{0}\right)}{z_{p,q}^{o}} \right)$$

$$\hat{\imath}_{C\ p,q} = \hat{\imath}_{B\ p,q}$$

$$\hat{\imath}_{A\ 2,4} = \frac{100}{2 \times j3{,}4166 + j7{,}8556} \left(\frac{2(j2{,}0215 - j1{,}7174)}{j2{,}47} + \frac{(j2{,}7966 - j1{,}2647)}{j10{,}63} \right)$$

$$\hat{\imath}_{B\ 2,4} = \frac{100}{2 \times j3{,}4166 + j7{,}8556} \left(\frac{(j1{,}7174 - j2{,}0215)}{j2{,}47} + \frac{(j2{,}7966 - j1{,}2647)}{j10{,}63} \right)$$

$$\hat{\imath}_{C\ 2,4} = \hat{\imath}_{B\ 2,4}$$

Corrente na linha 2-4

$$\hat{i}_{A\ 2,4} = -j2{,}657\ pu$$

$$\hat{i}_{B\ 2,4} = -j0{,}143\ pu$$

$$\hat{i}_{C\ 2,4} = -j0{,}143\ pu$$

$$I_{base} = \frac{100 \times 10^6}{\sqrt{3} \times 500 \times 10^3} = 115{,}47\ A$$

$$\hat{I}_{A\ 2,4} = -j2{,}657 \times 115{,}47 = -j306{,}8\ A$$

$$\hat{I}_{B\ 2,4} = -j0{,}143 \times 115{,}47 = -j16{,}5\ A$$

$$\hat{I}_{C\ 2,4} = -j0{,}143 \times 115{,}47 = -j16{,}5\ A$$

www.gesep.ufv.br

Gesep

gesep_vicosa

Gesep UFV

EStimate - Sistemas Fotovoltaicos

Google Play

https://play.google.com/store/apps/details?id=br.developer.gesep.estimate

Obrigado!

Heverton Augusto Pereira
Prof. Departamento de Engenheira Eletrica | UFV
Coordenador da Gerência de Especialistas em Sistemas Elétricos de Potência |Gesep
Membro do Programa de Pós-Graduaçao em Engenharia Elétrica | PPGEL/CEFET-MG
E-mail: heverton.pereira@ufv.br