Modelagem de Circuitos Elétricos no OpenDSS

Paulo Radatz
Mestrando EPUSP - Enerq

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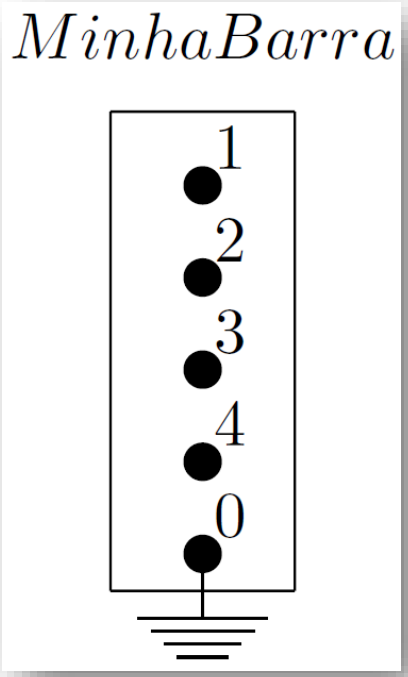
Visão Geral

- Modelos Básicos do OpenDSS
  - Barra
  - Terminal
  - Elemento de Transporte de Energia (PD)
  - Elemento de Conversão de Energia (PC)
- O Cálculo do Fluxo de Potência
  - Matriz Y dos Elementos
  - Matriz Y do Sistema
    - Elementos PDs
    - Elementos PCs (Parte Linear)
  - Corrente de Compensação dos PCs
  - Algoritmo de Fluxo de Potência do OpenDSS
- Elementos de Suporte
  - Elementos de Controle
  - Elementos Gerais
  - Elementos de Medição
- Referências

Modelos Básicos do OpenDSS

Barra

- Elemento de circuito que contém *N* nós
- Conecta em seus nós os terminais dos componentes elétricos
- O nó de referência 0 apresenta tensão nula
- As barras são criadas a partir da inclusão dos componentes elétricos no sistema

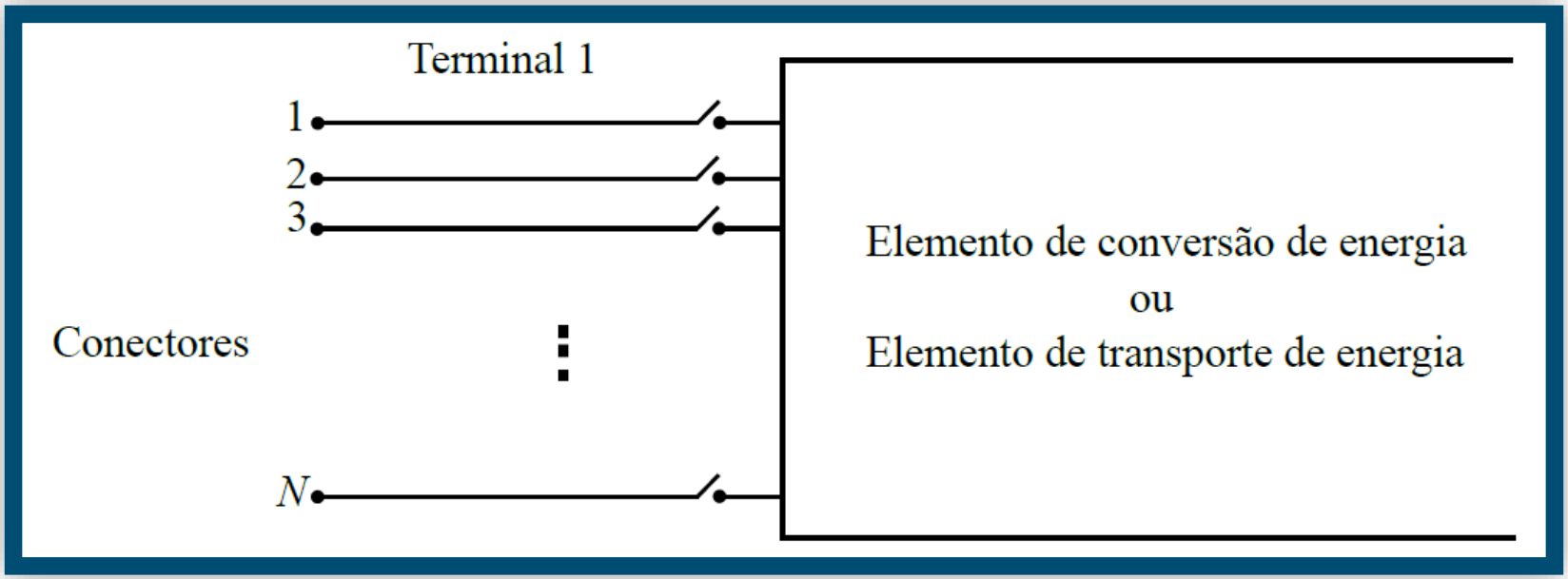



```
// Componente com 3 conectores
// Formas Equivalentes
bus1=MinhaBarra.1.2.3.0
bus1=MinhaBarra.1.2.3
bus1=MinhaBarra
```

```
// Componente com 4 conectores
bus1=MinhaBarra.1.2.3.4
// Componentes com 2 conectores
bus1=MinhaBarra.1.2
bus1=MinhaBarra.2.1
// Componente com 1 conector
bus1=MinhaBarra.3
```

Terminal

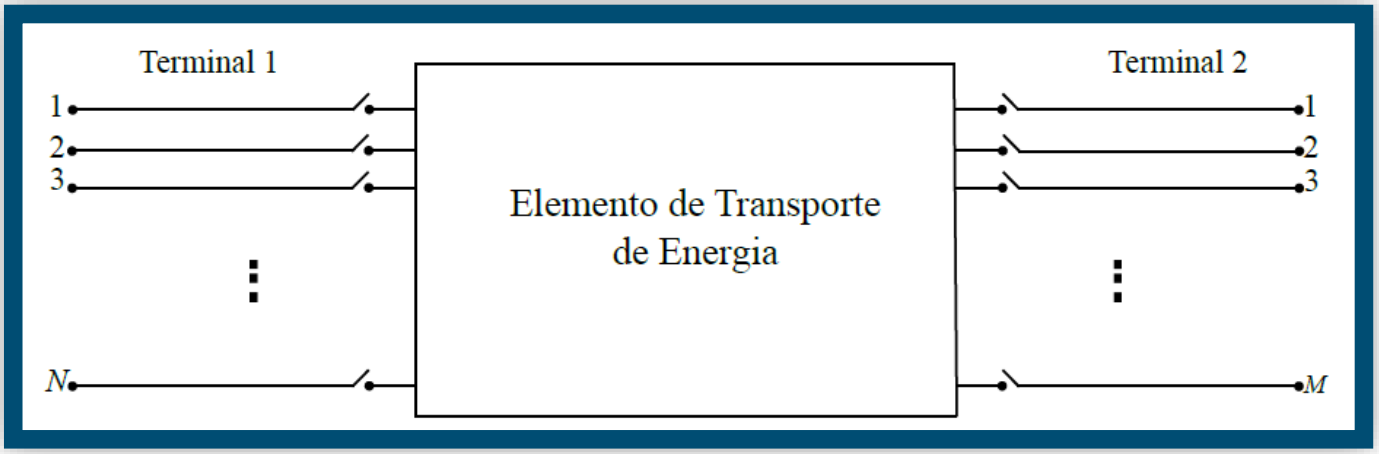
- Componentes elétricos possuem um ou mais terminais
- Terminais possuem conectores



- Cada terminal se conecta a uma barra
- Cada conector se conecta a um nó de uma barra

Elementos de Transporte de Energia (PD)

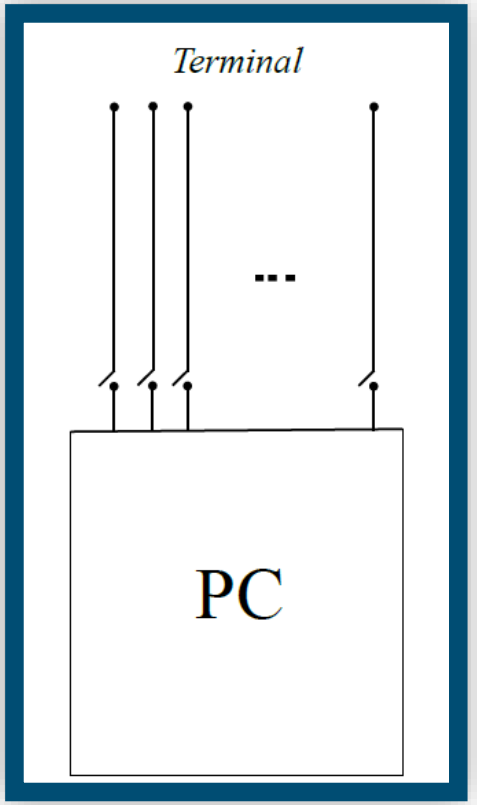
- Levam energia de um ponto para o outro
- Completamente caracterizados pela sua matriz de admitância nodal



- Possuem mais de um terminal:
  - Uma linha à 4 fios apresenta **2 terminais** com **4 conectores** cada
  - Um transformador monofásico de três enrolamentos apresenta **3 terminais** com **2 conectores** cada
  - Exceção: Um banco de capacitores trifásico conectados em shunt apresenta somente **1 terminal**

Elementos de Conversão de Energia (PC)

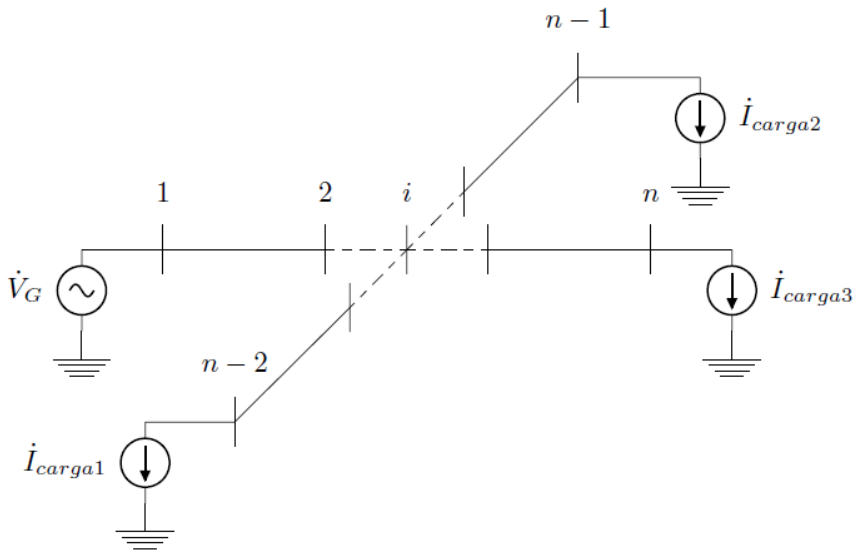
- Função de converter energia elétrica para outra forma de energia, ou vice-versa
- A corrente drenada/injetada é função da tensão aplicada
- Essa função pode ser não linear
- A sua operação depende do seu estado



O Cálculo do Fluxo de Potência

Matriz de Admitância Nodal

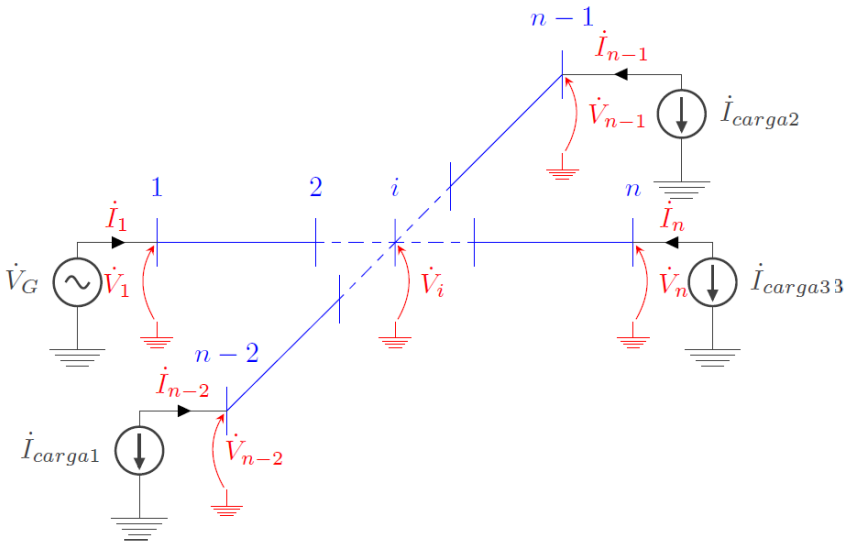
- Relaciona correntes injetadas com tensões nodais



$$\begin{bmatrix} \dot{I}_1 \\ \vdots \\ \dot{I}_i \\ \vdots \\ \dot{I}_n \end{bmatrix} = \begin{bmatrix} \bar{Y}_{11} & \dots & \bar{Y}_{1i} & \dots & \bar{Y}_{1n} \\ \vdots & \dots & \vdots & \dots & \vdots \\ \bar{Y}_{i1} & \dots & \bar{Y}_{ii} & \dots & \bar{Y}_{in} \\ \vdots & \dots & \vdots & \dots & \vdots \\ \bar{Y}_{n1} & \dots & \bar{Y}_{ni} & \dots & \bar{Y}_{nn} \end{bmatrix} \times \begin{bmatrix} \dot{V}_1 \\ \vdots \\ \dot{V}_i \\ \vdots \\ \dot{V}_n \end{bmatrix}$$

Matriz de Admitância Nodal

- Relaciona correntes injetadas com tensões nodais

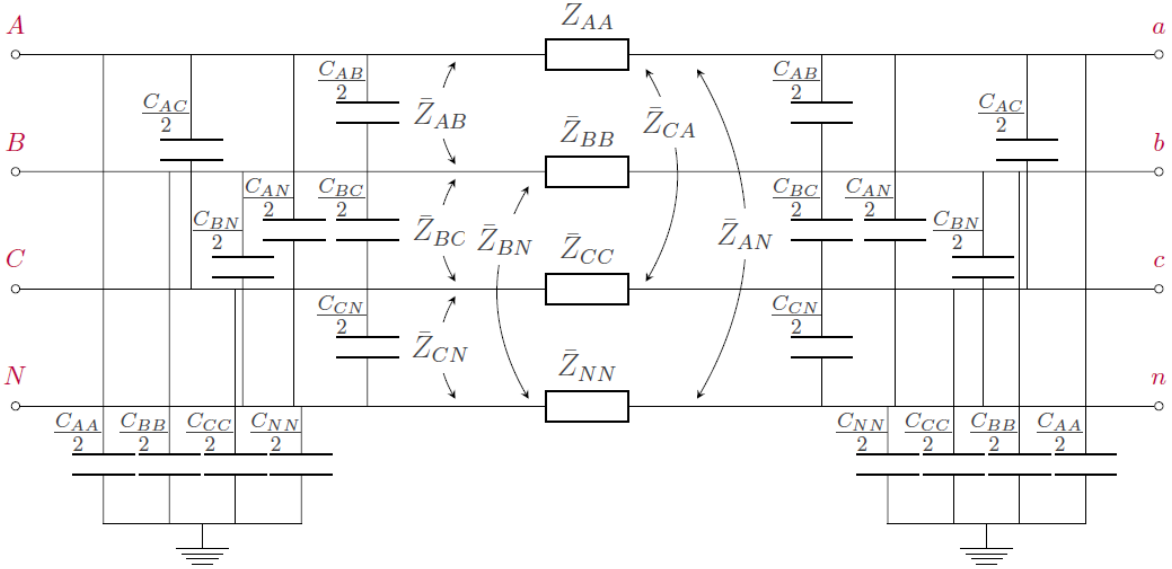


En

$$\begin{bmatrix} \dot{I}_1 \\ \vdots \\ \dot{I}_i \\ \vdots \\ \dot{I}_n \end{bmatrix} = \begin{bmatrix} \bar{Y}_{11} & \dots & \bar{Y}_{1i} & \dots & \bar{Y}_{1n} \\ \vdots & \dots & \vdots & \dots & \vdots \\ \bar{Y}_{i1} & \dots & \bar{Y}_{ii} & \dots & \bar{Y}_{in} \\ \vdots & \dots & \vdots & \dots & \vdots \\ \bar{Y}_{n1} & \dots & \bar{Y}_{ni} & \dots & \bar{Y}_{nn} \end{bmatrix} \times \begin{bmatrix} \dot{V}_1 \\ \vdots \\ \dot{V}_i \\ \vdots \\ \dot{V}_n \end{bmatrix}$$

Matriz de Admitância Nodal de um Elemento

- O OpenDSS nomeia essa matriz de ***Yprimitive***

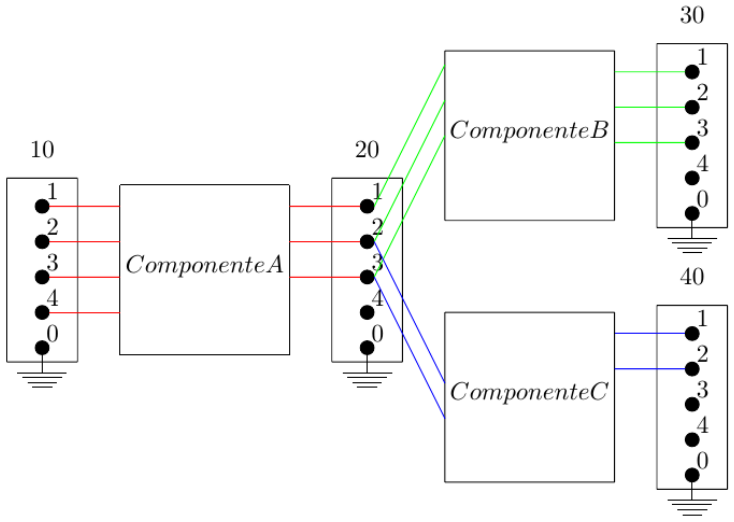


$$\begin{bmatrix} \dot{I}_A \\ \dot{I}_B \\ \dot{I}_C \\ \dot{I}_N \\ \dot{I}_a \\ \dot{I}_b \\ \dot{I}_c \\ \dot{I}_n \end{bmatrix} = \bar{\mathbf{Y}}_{\mathbf{prim}} \times \begin{bmatrix} \dot{V}_A \\ \dot{V}_B \\ \dot{V}_C \\ \dot{V}_N \\ \dot{V}_a \\ \dot{V}_b \\ \dot{V}_c \\ \dot{V}_n \end{bmatrix}$$

$$\bar{\mathbf{Y}}_{\mathbf{prim}} = \left[\begin{array}{c|c} \bar{\mathbf{z}}_{4\times4}^{-1} + j\frac{w}{2} \times \mathbf{C}_{4\times4} & -\bar{\mathbf{z}}_{4\times4}^{-1} \\ \hline -\bar{\mathbf{z}}_{4\times4}^{-1} & \bar{\mathbf{z}}_{4\times4}^{-1} + j\frac{w}{2} \times \mathbf{C}_{4\times4} \end{array}\right]_{8\times8}$$

Matriz de Admitância Nodal de um Sistema

- O OpenDSS nomeia essa matriz de ***Ymatrix***



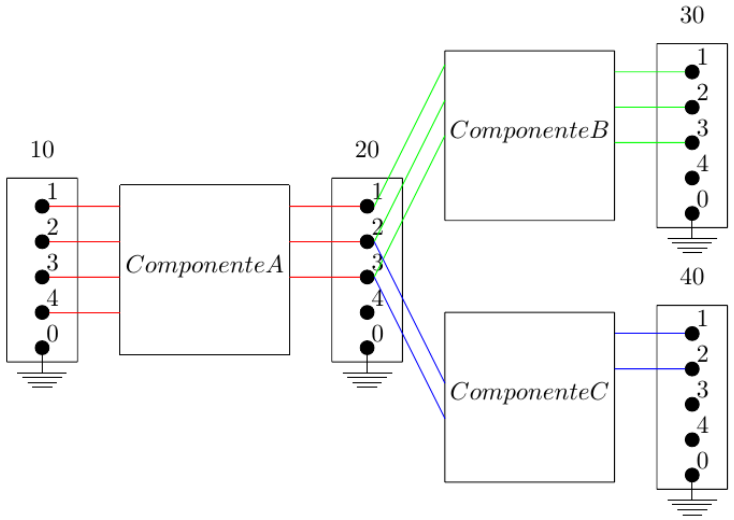
$$\bar{\mathbf{Y}}^{\mathbf{A}}_{\mathbf{prim}_{7\times7}} = \begin{array}{c} \\ 10.1 \\ 10.2 \\ 10.3 \\ 10.4 \\ 20.1 \\ 20.2 \\ 20.3 \end{array} \begin{array}{c} \begin{array}{ccccccc} 10.1 & 10.2 & 10.3 & 10.4 & 20.1 & 20.2 & 20.3 \end{array} \\ \left[\begin{array}{ccccccc} \bar{Y}_{a11} & \bar{Y}_{a12} & \bar{Y}_{a13} & \bar{Y}_{a14} & \bar{Y}_{a15} & \bar{Y}_{a16} & \bar{Y}_{a17} \\ \bar{Y}_{a21} & \bar{Y}_{a22} & \bar{Y}_{a23} & \bar{Y}_{a24} & \bar{Y}_{a25} & \bar{Y}_{a26} & \bar{Y}_{a27} \\ \bar{Y}_{a31} & \bar{Y}_{a32} & \bar{Y}_{a33} & \bar{Y}_{a34} & \bar{Y}_{a35} & \bar{Y}_{a36} & \bar{Y}_{a37} \\ \bar{Y}_{a41} & \bar{Y}_{a42} & \bar{Y}_{a43} & \bar{Y}_{a44} & \bar{Y}_{a45} & \bar{Y}_{a46} & \bar{Y}_{a47} \\ \bar{Y}_{a51} & \bar{Y}_{a52} & \bar{Y}_{a53} & \bar{Y}_{a54} & \bar{Y}_{a55} & \bar{Y}_{a56} & \bar{Y}_{a57} \\ \bar{Y}_{a61} & \bar{Y}_{a62} & \bar{Y}_{a63} & \bar{Y}_{a64} & \bar{Y}_{a65} & \bar{Y}_{a66} & \bar{Y}_{a67} \\ \bar{Y}_{a71} & \bar{Y}_{a72} & \bar{Y}_{a73} & \bar{Y}_{a74} & \bar{Y}_{a75} & \bar{Y}_{a76} & \bar{Y}_{a77} \end{array}\right] \end{array}$$

$$\bar{\mathbf{Y}}^{\mathbf{B}}_{\mathbf{prim}_{6\times6}} = \begin{array}{c} \\ 20.1 \\ 20.2 \\ 20.3 \\ 30.1 \\ 30.2 \\ 30.3 \end{array} \begin{array}{c} \begin{array}{ccccccc} 20.1 & 20.2 & 20.3 & 30.1 & 30.2 & 30.3 \end{array} \\ \left[\begin{array}{ccccccc} \bar{Y}_{b11} & \bar{Y}_{b12} & \bar{Y}_{b13} & \bar{Y}_{b14} & \bar{Y}_{b15} & \bar{Y}_{b16} \\ \bar{Y}_{b21} & \bar{Y}_{b22} & \bar{Y}_{b23} & \bar{Y}_{b24} & \bar{Y}_{b25} & \bar{Y}_{b26} \\ \bar{Y}_{b31} & \bar{Y}_{b32} & \bar{Y}_{b33} & \bar{Y}_{b34} & \bar{Y}_{b35} & \bar{Y}_{b46} \\ \bar{Y}_{b41} & \bar{Y}_{b42} & \bar{Y}_{b43} & \bar{Y}_{b44} & \bar{Y}_{b45} & \bar{Y}_{b46} \\ \bar{Y}_{b51} & \bar{Y}_{b52} & \bar{Y}_{b53} & \bar{Y}_{b54} & \bar{Y}_{b55} & \bar{Y}_{b56} \\ \bar{Y}_{b61} & \bar{Y}_{b62} & \bar{Y}_{b63} & \bar{Y}_{b64} & \bar{Y}_{b65} & \bar{Y}_{b66} \end{array}\right] \end{array}$$

$$\bar{\mathbf{Y}}^{\mathbf{C}}_{\mathbf{prim}_{4\times4}} = \begin{array}{c} \\ 20.2 \\ 20.3 \\ 40.1 \\ 40.2 \end{array} \begin{array}{c} \begin{array}{cccc} 20.2 & 20.3 & 40.1 & 40.2 \end{array} \\ \left[\begin{array}{cccc} \bar{Y}_{c11} & \bar{Y}_{c12} & \bar{Y}_{c13} & \bar{Y}_{c14} \\ \bar{Y}_{c21} & \bar{Y}_{c22} & \bar{Y}_{c23} & \bar{Y}_{c24} \\ \bar{Y}_{c31} & \bar{Y}_{c32} & \bar{Y}_{c33} & \bar{Y}_{c34} \\ \bar{Y}_{c41} & \bar{Y}_{c42} & \bar{Y}_{c43} & \bar{Y}_{c44} \end{array}\right] \end{array}$$

Matriz de Admitância Nodal de um Sistema

- O OpenDSS nomeia essa matriz de ***Ymatrix***



$$\bar{\mathbf{Y}}_{\mathbf{system}_{12\times12}} =$$

	10.1	10.2	10.3	10.4	20.1	20.2	20.3	30.1	30.2	30.3	40.1	40.2
10.1	$\bar{Y}_{a11}$	$\bar{Y}_{a12}$	$\bar{Y}_{a13}$	$\bar{Y}_{a14}$	$\bar{Y}_{a15}$	$\bar{Y}_{a16}$	$\bar{Y}_{a17}$	0	0	0	0	0
10.2	$\bar{Y}_{a21}$	$\bar{Y}_{a22}$	$\bar{Y}_{a23}$	$\bar{Y}_{a24}$	$\bar{Y}_{a25}$	$\bar{Y}_{a26}$	$\bar{Y}_{a27}$	0	0	0	0	0
10.3	$\bar{Y}_{a31}$	$\bar{Y}_{a32}$	$\bar{Y}_{a33}$	$\bar{Y}_{a34}$	$\bar{Y}_{a35}$	$\bar{Y}_{a36}$	$\bar{Y}_{a37}$	0	0	0	0	0
10.4	$\bar{Y}_{a41}$	$\bar{Y}_{a42}$	$\bar{Y}_{a43}$	$\bar{Y}_{a44}$	$\bar{Y}_{a45}$	$\bar{Y}_{a46}$	$\bar{Y}_{a47}$	0	0	0	0	0
20.1	$\bar{Y}_{a51}$	$\bar{Y}_{a52}$	$\bar{Y}_{a53}$	$\bar{Y}_{a54}$	$\bar{Y}_{a55}+\bar{Y}_{b11}$	$\bar{Y}_{a56}+\bar{Y}_{b12}$	$\bar{Y}_{a57}+\bar{Y}_{b13}$	$\bar{Y}_{b14}$	$\bar{Y}_{b15}$	$\bar{Y}_{b16}$	0	0
20.2	$\bar{Y}_{a61}$	$\bar{Y}_{a62}$	$\bar{Y}_{a63}$	$\bar{Y}_{a64}$	$\bar{Y}_{a65}+\bar{Y}_{b21}$	$\bar{Y}_{a66}+\bar{Y}_{b22}+\bar{\mathbf{Y}}_{\mathbf{c11}}$	$\bar{Y}_{a67}+\bar{Y}_{b23}+\bar{\mathbf{Y}}_{\mathbf{c12}}$	$\bar{Y}_{b24}$	$\bar{Y}_{b25}$	$\bar{Y}_{b26}$	$\bar{\mathbf{Y}}_{\mathbf{c13}}$	$\bar{\mathbf{Y}}_{\mathbf{c14}}$
20.3	$\bar{Y}_{a71}$	$\bar{Y}_{a72}$	$\bar{Y}_{a73}$	$\bar{Y}_{a74}$	$\bar{Y}_{a75}+\bar{Y}_{b31}$	$\bar{Y}_{a76}+\bar{Y}_{b32}+\bar{\mathbf{Y}}_{\mathbf{c21}}$	$\bar{Y}_{a77}+\bar{Y}_{b33}+\bar{\mathbf{Y}}_{\mathbf{c22}}$	$\bar{Y}_{b34}$	$\bar{Y}_{b35}$	$\bar{Y}_{b36}$	$\bar{\mathbf{Y}}_{\mathbf{c23}}$	$\bar{\mathbf{Y}}_{\mathbf{c24}}$
30.1	0	0	0	0	$\bar{Y}_{b41}$	$\bar{Y}_{b42}$	$\bar{Y}_{b43}$	$\bar{Y}_{b44}$	$\bar{Y}_{b45}$	$\bar{Y}_{b46}$	0	0
30.2	0	0	0	0	$\bar{Y}_{b51}$	$\bar{Y}_{b52}$	$\bar{Y}_{b53}$	$\bar{Y}_{b54}$	$\bar{Y}_{b55}$	$\bar{Y}_{b56}$	0	0
30.3	0	0	0	0	$\bar{Y}_{b61}$	$\bar{Y}_{b62}$	$\bar{Y}_{b63}$	$\bar{Y}_{b64}$	$\bar{Y}_{b65}$	$\bar{Y}_{b66}$	0	0
40.1	0	0	0	0	0	$\bar{\mathbf{Y}}_{\mathbf{c31}}$	$\bar{\mathbf{Y}}_{\mathbf{c32}}$	0	0	0	$\bar{\mathbf{Y}}_{\mathbf{c33}}$	$\bar{\mathbf{Y}}_{\mathbf{c34}}$
40.2	0	0	0	0	0	$\bar{\mathbf{Y}}_{\mathbf{c41}}$	$\bar{\mathbf{Y}}_{\mathbf{c42}}$	0	0	0	$\bar{\mathbf{Y}}_{\mathbf{c43}}$	$\bar{\mathbf{Y}}_{\mathbf{c44}}$

Matriz de Admitância Nodal de um Sistema

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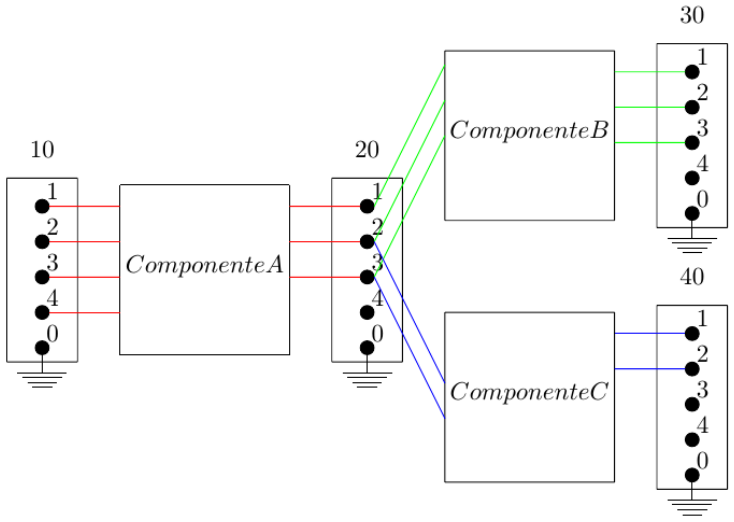
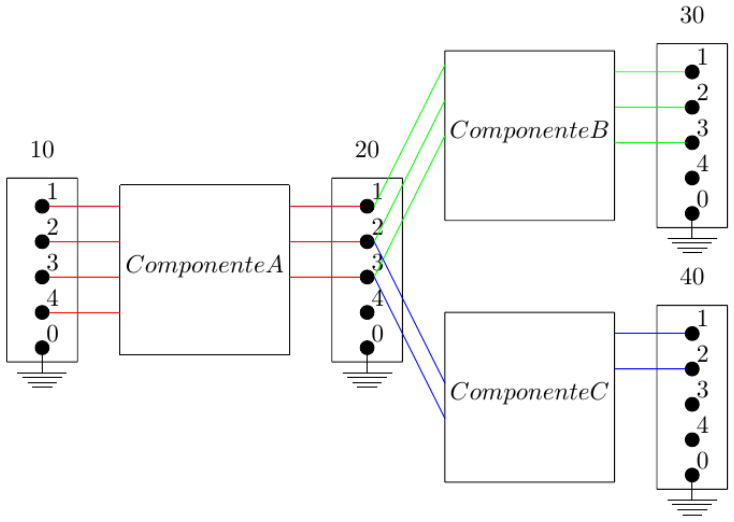


$$\bar{\mathbf{Y}}^{\mathbf{A}}_{\mathbf{prim}_{7\times 7}} = \begin{array}{c} \\ 10.1 \\ 10.2 \\ 10.3 \\ 10.4 \\ 20.1 \\ 20.2 \\ 20.3 \end{array} \begin{array}{c} \begin{array}{ccccccc} 10.1 & 10.2 & 10.3 & 10.4 & 20.1 & 20.2 & 20.3 \end{array} \\ \left[\begin{array}{ccc:ccc:c} \bar{Y}_{a11} & \bar{Y}_{a12} & \bar{Y}_{a13} & \bar{Y}_{a14} & \bar{Y}_{a15} & \bar{Y}_{a16} & \bar{Y}_{a17} \\ \bar{Y}_{a21} & \bar{Y}_{a22} & \bar{Y}_{a23} & \bar{Y}_{a24} & \bar{Y}_{a25} & \bar{Y}_{a26} & \bar{Y}_{a27} \\ \bar{Y}_{a31} & \bar{Y}_{a32} & \bar{Y}_{a33} & \bar{Y}_{a34} & \bar{Y}_{a35} & \bar{Y}_{a36} & \bar{Y}_{a37} \\ \bar{Y}_{a41} & \bar{Y}_{a42} & \bar{Y}_{a43} & \bar{Y}_{a44} & \bar{Y}_{a45} & \bar{Y}_{a46} & \bar{Y}_{a47} \\ \hdashline \bar{Y}_{a51} & \bar{Y}_{a52} & \bar{Y}_{a53} & \bar{Y}_{a54} & \bar{Y}_{a55} & \bar{Y}_{a56} & \bar{Y}_{a57} \\ \bar{Y}_{a61} & \bar{Y}_{a62} & \bar{Y}_{a63} & \bar{Y}_{a64} & \bar{Y}_{a65} & \bar{Y}_{a66} & \bar{Y}_{a67} \\ \bar{Y}_{a71} & \bar{Y}_{a72} & \bar{Y}_{a73} & \bar{Y}_{a74} & \bar{Y}_{a75} & \bar{Y}_{a76} & \bar{Y}_{a77} \end{array}\right] \end{array}$$

$$\bar{\mathbf{Y}}_{\mathbf{system}_{12\times 12}} = \begin{array}{c} \\ 10.1 \\ 10.2 \\ 10.3 \\ 10.4 \\ 20.1 \\ 20.2 \\ 20.3 \\ 30.1 \\ 30.2 \\ 30.3 \\ 40.1 \\ 40.2 \end{array} \begin{array}{c} \begin{array}{ccccccc:ccccc} 10.1 & 10.2 & 10.3 & 10.4 & 20.1 & 20.2 & 20.3 & 30.1 & 30.2 & 30.3 & 40.1 & 40.2 \end{array} \\ \left[\begin{array}{ccccccc:ccccc} \bar{Y}_{a11} & \bar{Y}_{a12} & \bar{Y}_{a13} & \bar{Y}_{a14} & \bar{Y}_{a15} & \bar{Y}_{a16} & \bar{Y}_{a17} & 0 & 0 & 0 & 0 & 0 \\ \bar{Y}_{a21} & \bar{Y}_{a22} & \bar{Y}_{a23} & \bar{Y}_{a24} & \bar{Y}_{a25} & \bar{Y}_{a26} & \bar{Y}_{a27} & 0 & 0 & 0 & 0 & 0 \\ \bar{Y}_{a31} & \bar{Y}_{a32} & \bar{Y}_{a33} & \bar{Y}_{a34} & \bar{Y}_{a35} & \bar{Y}_{a36} & \bar{Y}_{a37} & 0 & 0 & 0 & 0 & 0 \\ \bar{Y}_{a41} & \bar{Y}_{a42} & \bar{Y}_{a43} & \bar{Y}_{a44} & \bar{Y}_{a45} & \bar{Y}_{a46} & \bar{Y}_{a47} & 0 & 0 & 0 & 0 & 0 \\ \hdashline \bar{Y}_{a51} & \bar{Y}_{a52} & \bar{Y}_{a53} & \bar{Y}_{a54} & \bar{Y}_{a55}+\bar{Y}_{b11} & \bar{Y}_{a56}+\bar{Y}_{b12} & \bar{Y}_{a57}+\bar{Y}_{b13} & \bar{Y}_{b14} & \bar{Y}_{b15} & \bar{Y}_{b16} & 0 & 0 \\ \bar{Y}_{a61} & \bar{Y}_{a62} & \bar{Y}_{a63} & \bar{Y}_{a64} & \bar{Y}_{a65}+\bar{Y}_{b21} & \bar{Y}_{a66}+\bar{Y}_{b22}+\bar{\mathbf{Y}}_{\mathbf{c11}} & \bar{Y}_{a67}+\bar{Y}_{b23}+\bar{\mathbf{Y}}_{\mathbf{c12}} & \bar{Y}_{b24} & \bar{Y}_{b25} & \bar{Y}_{b26} & \bar{\mathbf{Y}}_{\mathbf{c13}} & \bar{\mathbf{Y}}_{\mathbf{c14}} \\ \bar{Y}_{a71} & \bar{Y}_{a72} & \bar{Y}_{a73} & \bar{Y}_{a74} & \bar{Y}_{a75}+\bar{Y}_{b31} & \bar{Y}_{a76}+\bar{Y}_{b32}+\bar{\mathbf{Y}}_{\mathbf{c21}} & \bar{Y}_{a77}+\bar{Y}_{b33}+\bar{\mathbf{Y}}_{\mathbf{c22}} & \bar{Y}_{b34} & \bar{Y}_{b35} & \bar{Y}_{b36} & \bar{\mathbf{Y}}_{\mathbf{c23}} & \bar{\mathbf{Y}}_{\mathbf{c24}} \\ \hdashline 0 & 0 & 0 & 0 & \bar{Y}_{b41} & \bar{Y}_{b42} & \bar{Y}_{b43} & \bar{Y}_{b44} & \bar{Y}_{b45} & \bar{Y}_{b46} & 0 & 0 \\ 0 & 0 & 0 & 0 & \bar{Y}_{b51} & \bar{Y}_{b52} & \bar{Y}_{b53} & \bar{Y}_{b54} & \bar{Y}_{b55} & \bar{Y}_{b56} & 0 & 0 \\ 0 & 0 & 0 & 0 & \bar{Y}_{b61} & \bar{Y}_{b62} & \bar{Y}_{b63} & \bar{Y}_{b64} & \bar{Y}_{b65} & \bar{Y}_{b66} & 0 & 0 \\ \hdashline 0 & 0 & 0 & 0 & 0 & \bar{\mathbf{Y}}_{\mathbf{c31}} & \bar{\mathbf{Y}}_{\mathbf{c32}} & 0 & 0 & 0 & \bar{\mathbf{Y}}_{\mathbf{c33}} & \bar{\mathbf{Y}}_{\mathbf{c34}} \\ 0 & 0 & 0 & 0 & 0 & \bar{\mathbf{Y}}_{\mathbf{c41}} & \bar{\mathbf{Y}}_{\mathbf{c42}} & 0 & 0 & 0 & \bar{\mathbf{Y}}_{\mathbf{c43}} & \bar{\mathbf{Y}}_{\mathbf{c44}} \end{array}\right] \end{array}$$

Matriz de Admitância Nodal de um Sistema

- O OpenDSS nomeia essa matriz de ***Ymatrix***

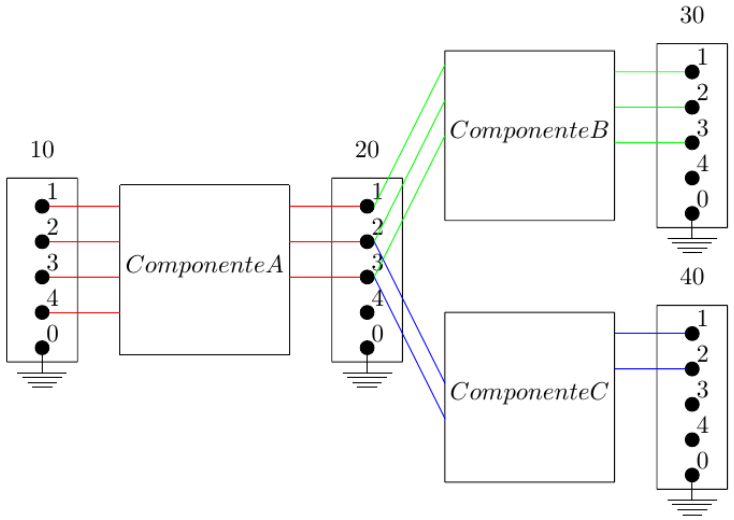


$$\bar{\mathbf{Y}}^{\mathbf{B}}_{\mathbf{prim}_{6\times6}} = \begin{array}{c} \\ 20.1 \\ 20.2 \\ 20.3 \\ 30.1 \\ 30.2 \\ 30.3 \end{array} \begin{array}{c} \begin{array}{cccccc} 20.1 & 20.2 & 20.3 & 30.1 & 30.2 & 30.3 \end{array} \\ \left[\begin{array}{cc|cc|cc} \bar{Y}_{b_{11}} & \bar{Y}_{b_{12}} & \bar{Y}_{b_{13}} & \bar{Y}_{b_{14}} & \bar{Y}_{b_{15}} & \bar{Y}_{b_{16}} \\ \bar{Y}_{b_{21}} & \bar{Y}_{b_{22}} & \bar{Y}_{b_{23}} & \bar{Y}_{b_{24}} & \bar{Y}_{b_{25}} & \bar{Y}_{b_{26}} \\ \bar{Y}_{b_{31}} & \bar{Y}_{b_{32}} & \bar{Y}_{b_{33}} & \bar{Y}_{b_{34}} & \bar{Y}_{b_{35}} & \bar{Y}_{b_{46}} \\ \hline \bar{Y}_{b_{41}} & \bar{Y}_{b_{42}} & \bar{Y}_{b_{43}} & \bar{Y}_{b_{44}} & \bar{Y}_{b_{45}} & \bar{Y}_{b_{46}} \\ \bar{Y}_{b_{51}} & \bar{Y}_{b_{52}} & \bar{Y}_{b_{53}} & \bar{Y}_{b_{54}} & \bar{Y}_{b_{55}} & \bar{Y}_{b_{56}} \\ \bar{Y}_{b_{61}} & \bar{Y}_{b_{62}} & \bar{Y}_{b_{63}} & \bar{Y}_{b_{64}} & \bar{Y}_{b_{65}} & \bar{Y}_{b_{66}} \end{array}\right] \end{array}$$

$$\bar{\mathbf{Y}}_{\mathbf{system}_{12\times12}} = \begin{array}{c} \\ 10.1 \\ 10.2 \\ 10.3 \\ 10.4 \\ 20.1 \\ 20.2 \\ 20.3 \\ 30.1 \\ 30.2 \\ 30.3 \\ 40.1 \\ 40.2 \end{array} \begin{array}{c} \begin{array}{cccccccccccc} 10.1 & 10.2 & 10.3 & 10.4 & 20.1 & 20.2 & 20.3 & 30.1 & 30.2 & 30.3 & 40.1 & 40.2 \end{array} \\ \left[\begin{array}{cccc|ccc|ccc|cc} \bar{Y}_{a_{11}} & \bar{Y}_{a_{12}} & \bar{Y}_{a_{13}} & \bar{Y}_{a_{14}} & \bar{Y}_{a_{15}} & \bar{Y}_{a_{16}} & \bar{Y}_{a_{17}} & 0 & 0 & 0 & 0 & 0 \\ \bar{Y}_{a_{21}} & \bar{Y}_{a_{22}} & \bar{Y}_{a_{23}} & \bar{Y}_{a_{24}} & \bar{Y}_{a_{25}} & \bar{Y}_{a_{26}} & \bar{Y}_{a_{27}} & 0 & 0 & 0 & 0 & 0 \\ \bar{Y}_{a_{31}} & \bar{Y}_{a_{32}} & \bar{Y}_{a_{33}} & \bar{Y}_{a_{34}} & \bar{Y}_{a_{35}} & \bar{Y}_{a_{36}} & \bar{Y}_{a_{37}} & 0 & 0 & 0 & 0 & 0 \\ \bar{Y}_{a_{41}} & \bar{Y}_{a_{42}} & \bar{Y}_{a_{43}} & \bar{Y}_{a_{44}} & \bar{Y}_{a_{45}} & \bar{Y}_{a_{46}} & \bar{Y}_{a_{47}} & 0 & 0 & 0 & 0 & 0 \\ \hline \bar{Y}_{a_{51}} & \bar{Y}_{a_{52}} & \bar{Y}_{a_{53}} & \bar{Y}_{a_{54}} & \bar{Y}_{a_{55}}+\bar{Y}_{b_{11}} & \bar{Y}_{a_{56}}+\bar{Y}_{b_{12}} & \bar{Y}_{a_{57}}+\bar{Y}_{b_{13}} & \bar{Y}_{b_{14}} & \bar{Y}_{b_{15}} & \bar{Y}_{b_{16}} & 0 & 0 \\ \bar{Y}_{a_{61}} & \bar{Y}_{a_{62}} & \bar{Y}_{a_{63}} & \bar{Y}_{a_{64}} & \bar{Y}_{a_{65}}+\bar{Y}_{b_{21}} & \bar{Y}_{a_{66}}+\bar{Y}_{b_{22}}+\bar{\mathbf{Y}}_{\mathbf{c_{11}}} & \bar{Y}_{a_{67}}+\bar{Y}_{b_{23}}+\bar{\mathbf{Y}}_{\mathbf{c_{12}}} & \bar{Y}_{b_{24}} & \bar{Y}_{b_{25}} & \bar{Y}_{b_{26}} & \bar{\mathbf{Y}}_{\mathbf{c_{13}}} & \bar{\mathbf{Y}}_{\mathbf{c_{14}}} \\ \bar{Y}_{a_{71}} & \bar{Y}_{a_{72}} & \bar{Y}_{a_{73}} & \bar{Y}_{a_{74}} & \bar{Y}_{a_{75}}+\bar{Y}_{b_{31}} & \bar{Y}_{a_{76}}+\bar{Y}_{b_{32}}+\bar{\mathbf{Y}}_{\mathbf{c_{21}}} & \bar{Y}_{a_{77}}+\bar{Y}_{b_{33}}+\bar{\mathbf{Y}}_{\mathbf{c_{22}}} & \bar{Y}_{b_{34}} & \bar{Y}_{b_{35}} & \bar{Y}_{b_{36}} & \bar{\mathbf{Y}}_{\mathbf{c_{23}}} & \bar{\mathbf{Y}}_{\mathbf{c_{24}}} \\ \hline 0 & 0 & 0 & 0 & \bar{Y}_{b_{41}} & \bar{Y}_{b_{42}} & \bar{Y}_{b_{43}} & \bar{Y}_{b_{44}} & \bar{Y}_{b_{45}} & \bar{Y}_{b_{46}} & 0 & 0 \\ 0 & 0 & 0 & 0 & \bar{Y}_{b_{51}} & \bar{Y}_{b_{52}} & \bar{Y}_{b_{53}} & \bar{Y}_{b_{54}} & \bar{Y}_{b_{55}} & \bar{Y}_{b_{56}} & 0 & 0 \\ 0 & 0 & 0 & 0 & \bar{Y}_{b_{61}} & \bar{Y}_{b_{62}} & \bar{Y}_{b_{63}} & \bar{Y}_{b_{64}} & \bar{Y}_{b_{65}} & \bar{Y}_{b_{66}} & 0 & 0 \\ \hline 0 & 0 & 0 & 0 & 0 & \bar{\mathbf{Y}}_{\mathbf{c_{31}}} & \bar{\mathbf{Y}}_{\mathbf{c_{32}}} & 0 & 0 & 0 & \bar{\mathbf{Y}}_{\mathbf{c_{33}}} & \bar{\mathbf{Y}}_{\mathbf{c_{34}}} \\ 0 & 0 & 0 & 0 & 0 & \bar{\mathbf{Y}}_{\mathbf{c_{41}}} & \bar{\mathbf{Y}}_{\mathbf{c_{42}}} & 0 & 0 & 0 & \bar{\mathbf{Y}}_{\mathbf{c_{43}}} & \bar{\mathbf{Y}}_{\mathbf{c_{44}}} \end{array}\right] \end{array}$$

Matriz de Admitância Nodal de um Sistema

- O OpenDSS nomeia essa matriz de ***Ymatrix***

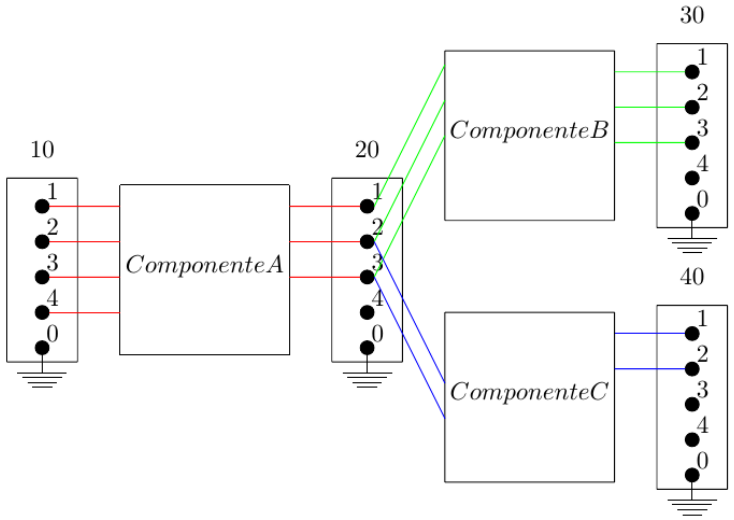


$$\bar{\mathbf{Y}}^{\mathbf{C}}_{\mathbf{prim}_{4\times4}} = \begin{array}{c} \\ 20.2 \\ 20.3 \\ 40.1 \\ 40.2 \end{array} \begin{array}{c} \begin{array}{cccc} 20.2 & 20.3 & 40.1 & 40.2 \end{array} \\ \begin{bmatrix} \bar{Y}_{c11} & \bar{Y}_{c12} & \bar{Y}_{c13} & \bar{Y}_{c14} \\ \bar{Y}_{c21} & \bar{Y}_{c22} & \bar{Y}_{c23} & \bar{Y}_{c24} \\ \bar{Y}_{c31} & \bar{Y}_{c32} & \bar{Y}_{c33} & \bar{Y}_{c34} \\ \bar{Y}_{c41} & \bar{Y}_{c42} & \bar{Y}_{c43} & \bar{Y}_{c44} \end{bmatrix} \end{array}$$

$$\bar{\mathbf{Y}}_{\mathbf{system}_{12\times12}} = \begin{array}{c} \\ 10.1 \\ 10.2 \\ 10.3 \\ 10.4 \\ 20.1 \\ 20.2 \\ 20.3 \\ 30.1 \\ 30.2 \\ 30.3 \\ 40.1 \\ 40.2 \end{array} \begin{array}{c} \begin{array}{cccccccccccc} 10.1 & 10.2 & 10.3 & 10.4 & 20.1 & 20.2 & 20.3 & 30.1 & 30.2 & 30.3 & 40.1 & 40.2 \end{array} \\ \begin{bmatrix} \bar{Y}_{a11} & \bar{Y}_{a12} & \bar{Y}_{a13} & \bar{Y}_{a14} & \bar{Y}_{a15} & \bar{Y}_{a16} & \bar{Y}_{a17} & 0 & 0 & 0 & 0 & 0 \\ \bar{Y}_{a21} & \bar{Y}_{a22} & \bar{Y}_{a23} & \bar{Y}_{a24} & \bar{Y}_{a25} & \bar{Y}_{a26} & \bar{Y}_{a27} & 0 & 0 & 0 & 0 & 0 \\ \bar{Y}_{a31} & \bar{Y}_{a32} & \bar{Y}_{a33} & \bar{Y}_{a34} & \bar{Y}_{a35} & \bar{Y}_{a36} & \bar{Y}_{a37} & 0 & 0 & 0 & 0 & 0 \\ \bar{Y}_{a41} & \bar{Y}_{a42} & \bar{Y}_{a43} & \bar{Y}_{a44} & \bar{Y}_{a45} & \bar{Y}_{a46} & \bar{Y}_{a47} & 0 & 0 & 0 & 0 & 0 \\ \bar{Y}_{a51} & \bar{Y}_{a52} & \bar{Y}_{a53} & \bar{Y}_{a54} & \bar{Y}_{a55}+\bar{Y}_{b11} & \bar{Y}_{a56}+\bar{Y}_{b12} & \bar{Y}_{a57}+\bar{Y}_{b13} & \bar{Y}_{b14} & \bar{Y}_{b15} & \bar{Y}_{b16} & 0 & 0 \\ \bar{Y}_{a61} & \bar{Y}_{a62} & \bar{Y}_{a63} & \bar{Y}_{a64} & \bar{Y}_{a65}+\bar{Y}_{b21} & \bar{Y}_{a66}+\bar{Y}_{b22}+\bar{\mathbf{Y}}_{\mathbf{c11}} & \bar{Y}_{a67}+\bar{Y}_{b23}+\bar{\mathbf{Y}}_{\mathbf{c12}} & \bar{Y}_{b24} & \bar{Y}_{b25} & \bar{Y}_{b26} & \bar{\mathbf{Y}}_{\mathbf{c13}} & \bar{\mathbf{Y}}_{\mathbf{c14}} \\ \bar{Y}_{a71} & \bar{Y}_{a72} & \bar{Y}_{a73} & \bar{Y}_{a74} & \bar{Y}_{a75}+\bar{Y}_{b31} & \bar{Y}_{a76}+\bar{Y}_{b32}+\bar{\mathbf{Y}}_{\mathbf{c21}} & \bar{Y}_{a77}+\bar{Y}_{b33}+\bar{\mathbf{Y}}_{\mathbf{c22}} & \bar{Y}_{b34} & \bar{Y}_{b35} & \bar{Y}_{b36} & \bar{\mathbf{Y}}_{\mathbf{c23}} & \bar{\mathbf{Y}}_{\mathbf{c24}} \\ 0 & 0 & 0 & 0 & \bar{Y}_{b41} & \bar{Y}_{b42} & \bar{Y}_{b43} & \bar{Y}_{b44} & \bar{Y}_{b45} & \bar{Y}_{b46} & 0 & 0 \\ 0 & 0 & 0 & 0 & \bar{Y}_{b51} & \bar{Y}_{b52} & \bar{Y}_{b53} & \bar{Y}_{b54} & \bar{Y}_{b55} & \bar{Y}_{b56} & 0 & 0 \\ 0 & 0 & 0 & 0 & \bar{Y}_{b61} & \bar{Y}_{b62} & \bar{Y}_{b63} & \bar{Y}_{b64} & \bar{Y}_{b65} & \bar{Y}_{b66} & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & \bar{\mathbf{Y}}_{\mathbf{c31}} & \bar{\mathbf{Y}}_{\mathbf{c32}} & 0 & 0 & 0 & \bar{\mathbf{Y}}_{\mathbf{c33}} & \bar{\mathbf{Y}}_{\mathbf{c34}} \\ 0 & 0 & 0 & 0 & 0 & \bar{\mathbf{Y}}_{\mathbf{c41}} & \bar{\mathbf{Y}}_{\mathbf{c42}} & 0 & 0 & 0 & \bar{\mathbf{Y}}_{\mathbf{c43}} & \bar{\mathbf{Y}}_{\mathbf{c44}} \end{bmatrix} \end{array}$$

Matriz de Admitância Nodal de um Sistema

- O OpenDSS nomeia essa matriz de ***Ymatrix***



- Por enquanto, só os PDs foram considerados

$$\bar{\mathbf{Y}}_{\mathbf{system}_{12\times12}} =$$

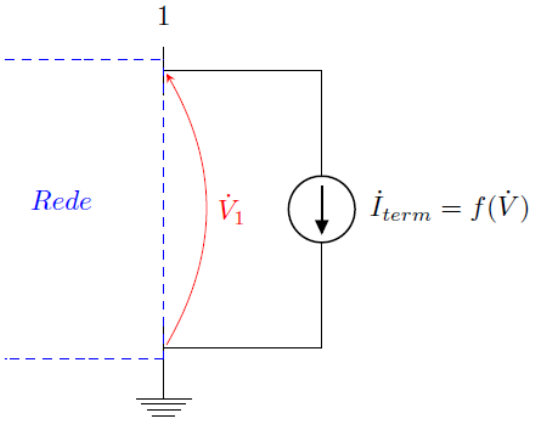
	10.1	10.2	10.3	10.4	20.1	20.2	20.3	30.1	30.2	30.3	40.1	40.2
10.1	$\bar{Y}_{a11}$	$\bar{Y}_{a12}$	$\bar{Y}_{a13}$	$\bar{Y}_{a14}$	$\bar{Y}_{a15}$	$\bar{Y}_{a16}$	$\bar{Y}_{a17}$	0	0	0	0	0
10.2	$\bar{Y}_{a21}$	$\bar{Y}_{a22}$	$\bar{Y}_{a23}$	$\bar{Y}_{a24}$	$\bar{Y}_{a25}$	$\bar{Y}_{a26}$	$\bar{Y}_{a27}$	0	0	0	0	0
10.3	$\bar{Y}_{a31}$	$\bar{Y}_{a32}$	$\bar{Y}_{a33}$	$\bar{Y}_{a34}$	$\bar{Y}_{a35}$	$\bar{Y}_{a36}$	$\bar{Y}_{a37}$	0	0	0	0	0
10.4	$\bar{Y}_{a41}$	$\bar{Y}_{a42}$	$\bar{Y}_{a43}$	$\bar{Y}_{a44}$	$\bar{Y}_{a45}$	$\bar{Y}_{a46}$	$\bar{Y}_{a47}$	0	0	0	0	0
20.1	$\bar{Y}_{a51}$	$\bar{Y}_{a52}$	$\bar{Y}_{a53}$	$\bar{Y}_{a54}$	$\bar{Y}_{a55}+\bar{Y}_{b11}$	$\bar{Y}_{a56}+\bar{Y}_{b12}$	$\bar{Y}_{a57}+\bar{Y}_{b13}$	$\bar{Y}_{b14}$	$\bar{Y}_{b15}$	$\bar{Y}_{b16}$	0	0
20.2	$\bar{Y}_{a61}$	$\bar{Y}_{a62}$	$\bar{Y}_{a63}$	$\bar{Y}_{a64}$	$\bar{Y}_{a65}+\bar{Y}_{b21}$	$\bar{Y}_{a66}+\bar{Y}_{b22}+\bar{\mathbf{Y}}_{\mathbf{c11}}$	$\bar{Y}_{a67}+\bar{Y}_{b23}+\bar{\mathbf{Y}}_{\mathbf{c12}}$	$\bar{Y}_{b24}$	$\bar{Y}_{b25}$	$\bar{Y}_{b26}$	$\bar{\mathbf{Y}}_{\mathbf{c13}}$	$\bar{\mathbf{Y}}_{\mathbf{c14}}$
20.3	$\bar{Y}_{a71}$	$\bar{Y}_{a72}$	$\bar{Y}_{a73}$	$\bar{Y}_{a74}$	$\bar{Y}_{a75}+\bar{Y}_{b31}$	$\bar{Y}_{a76}+\bar{Y}_{b32}+\bar{\mathbf{Y}}_{\mathbf{c21}}$	$\bar{Y}_{a77}+\bar{Y}_{b33}+\bar{\mathbf{Y}}_{\mathbf{c22}}$	$\bar{Y}_{b34}$	$\bar{Y}_{b35}$	$\bar{Y}_{b36}$	$\bar{\mathbf{Y}}_{\mathbf{c23}}$	$\bar{\mathbf{Y}}_{\mathbf{c24}}$
30.1	0	0	0	0	$\bar{Y}_{b41}$	$\bar{Y}_{b42}$	$\bar{Y}_{b43}$	$\bar{Y}_{b44}$	$\bar{Y}_{b45}$	$\bar{Y}_{b46}$	0	0
30.2	0	0	0	0	$\bar{Y}_{b51}$	$\bar{Y}_{b52}$	$\bar{Y}_{b53}$	$\bar{Y}_{b54}$	$\bar{Y}_{b55}$	$\bar{Y}_{b56}$	0	0
30.3	0	0	0	0	$\bar{Y}_{b61}$	$\bar{Y}_{b62}$	$\bar{Y}_{b63}$	$\bar{Y}_{b64}$	$\bar{Y}_{b65}$	$\bar{Y}_{b66}$	0	0
40.1	0	0	0	0	0	$\bar{\mathbf{Y}}_{\mathbf{c31}}$	$\bar{\mathbf{Y}}_{\mathbf{c32}}$	0	0	0	$\bar{\mathbf{Y}}_{\mathbf{c33}}$	$\bar{\mathbf{Y}}_{\mathbf{c34}}$
40.2	0	0	0	0	0	$\bar{\mathbf{Y}}_{\mathbf{c41}}$	$\bar{\mathbf{Y}}_{\mathbf{c42}}$	0	0	0	$\bar{\mathbf{Y}}_{\mathbf{c43}}$	$\bar{\mathbf{Y}}_{\mathbf{c44}}$

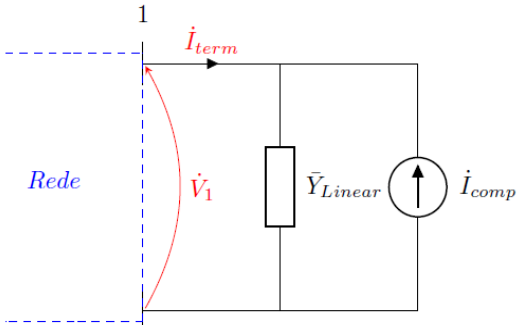
Matriz de Admitância Nodal de um Sistema

- Incluindo os PCs na ***Ymatrix***
  - Os PCs (cargas, geradores...) são separados em duas partes:
    - Uma linear que é representada por uma matriz de admitância calculada na condição nominal. Essa admitância é inserida na matriz ***Ymatrix***
    - A outra, não linear, é representada por uma corrente de compensação
- Incluindo fontes na ***Ymatrix***
  - Fontes de tensão são modeladas por Equivalentes de Thévenin. Elas são convertidas para Equivalentes de Norton, ou seja, uma fonte de corrente em paralelo a uma admitância. Essa admitância é inserida na matriz ***Ymatrix***

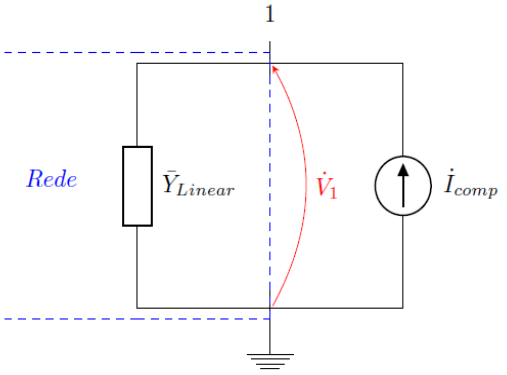
Matriz de Admitância Nodal de um Sistema

- Separação entre parte linear e não linear de uma carga monofásica conectada no nó 1 da barra 40





$$\dot{I}_{comp} = \dot{V}_1 \times \bar{Y}_{linear} - \dot{I}_{term}$$

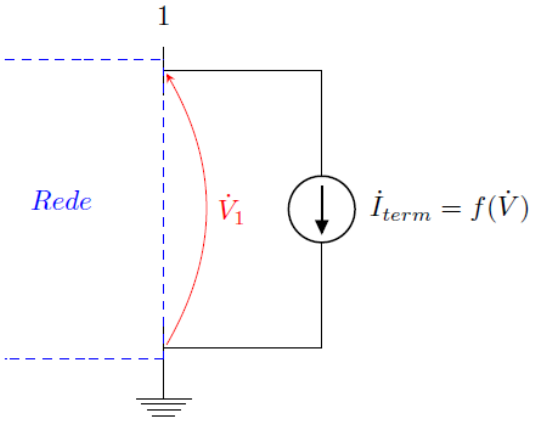


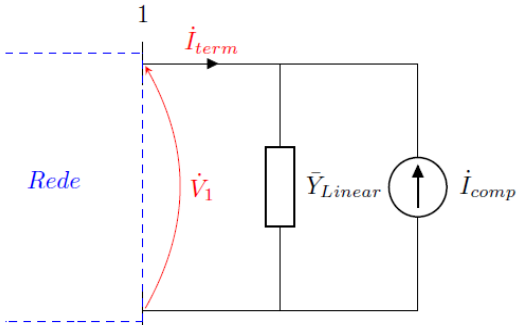
$$\bar{\mathbf{Y}}_{\mathbf{system_{12\times12}}} =$$

	10.1	10.2	10.3	10.4	20.1	20.2	20.3	30.1	30.2	30.3	40.1	40.2
10.1	$\bar{Y}_{a11}$	$\bar{Y}_{a12}$	$\bar{Y}_{a13}$	$\bar{Y}_{a14}$	$\bar{Y}_{a15}$	$\bar{Y}_{a16}$	$\bar{Y}_{a17}$	0	0	0	0	0
10.2	$\bar{Y}_{a21}$	$\bar{Y}_{a22}$	$\bar{Y}_{a23}$	$\bar{Y}_{a24}$	$\bar{Y}_{a25}$	$\bar{Y}_{a26}$	$\bar{Y}_{a27}$	0	0	0	0	0
10.3	$\bar{Y}_{a31}$	$\bar{Y}_{a32}$	$\bar{Y}_{a33}$	$\bar{Y}_{a34}$	$\bar{Y}_{a35}$	$\bar{Y}_{a36}$	$\bar{Y}_{a37}$	0	0	0	0	0
10.4	$\bar{Y}_{a41}$	$\bar{Y}_{a42}$	$\bar{Y}_{a43}$	$\bar{Y}_{a44}$	$\bar{Y}_{a45}$	$\bar{Y}_{a46}$	$\bar{Y}_{a47}$	0	0	0	0	0
20.1	$\bar{Y}_{a51}$	$\bar{Y}_{a52}$	$\bar{Y}_{a53}$	$\bar{Y}_{a54}$	$\bar{Y}_{a55} + \bar{Y}_{b11}$	$\bar{Y}_{a56} + \bar{Y}_{b12}$	$\bar{Y}_{a57} + \bar{Y}_{b13}$	$\bar{Y}_{b14}$	$\bar{Y}_{b15}$	$\bar{Y}_{b16}$	0	0
20.2	$\bar{Y}_{a61}$	$\bar{Y}_{a62}$	$\bar{Y}_{a63}$	$\bar{Y}_{a64}$	$\bar{Y}_{a65} + \bar{Y}_{b21}$	$\bar{Y}_{a66} + \bar{Y}_{b22} + \bar{\mathbf{Y}}_{\mathbf{c11}}$	$\bar{Y}_{a67} + \bar{Y}_{b23} + \bar{\mathbf{Y}}_{\mathbf{c12}}$	$\bar{Y}_{b24}$	$\bar{Y}_{b25}$	$\bar{Y}_{b26}$	$\bar{\mathbf{Y}}_{\mathbf{c13}}$	$\bar{\mathbf{Y}}_{\mathbf{c14}}$
20.3	$\bar{Y}_{a71}$	$\bar{Y}_{a72}$	$\bar{Y}_{a73}$	$\bar{Y}_{a74}$	$\bar{Y}_{a75} + \bar{Y}_{b31}$	$\bar{Y}_{a76} + \bar{Y}_{b32} + \bar{\mathbf{Y}}_{\mathbf{c21}}$	$\bar{Y}_{a77} + \bar{Y}_{b33} + \bar{\mathbf{Y}}_{\mathbf{c22}}$	$\bar{Y}_{b34}$	$\bar{Y}_{b35}$	$\bar{Y}_{b36}$	$\bar{\mathbf{Y}}_{\mathbf{c23}}$	$\bar{\mathbf{Y}}_{\mathbf{c24}}$
30.1	0	0	0	0	$\bar{Y}_{b41}$	$\bar{Y}_{b42}$	$\bar{Y}_{b43}$	$\bar{Y}_{b44}$	$\bar{Y}_{b45}$	$\bar{Y}_{b46}$	0	0
30.2	0	0	0	0	$\bar{Y}_{b51}$	$\bar{Y}_{b52}$	$\bar{Y}_{b53}$	$\bar{Y}_{b54}$	$\bar{Y}_{b55}$	$\bar{Y}_{b56}$	0	0
30.3	0	0	0	0	$\bar{Y}_{b61}$	$\bar{Y}_{b62}$	$\bar{Y}_{b63}$	$\bar{Y}_{b64}$	$\bar{Y}_{b65}$	$\bar{Y}_{b66}$	0	0
40.1	0	0	0	0	0	$\bar{\mathbf{Y}}_{\mathbf{c31}}$	$\bar{\mathbf{Y}}_{\mathbf{c32}}$	0	0	0	$\bar{\mathbf{Y}}_{\mathbf{c33}}$	$\bar{\mathbf{Y}}_{\mathbf{c34}}$
40.2	0	0	0	0	0	$\bar{\mathbf{Y}}_{\mathbf{c41}}$	$\bar{\mathbf{Y}}_{\mathbf{c42}}$	0	0	0	$\bar{\mathbf{Y}}_{\mathbf{c43}}$	$\bar{\mathbf{Y}}_{\mathbf{c44}}$

Matriz de Admitância Nodal de um Sistema

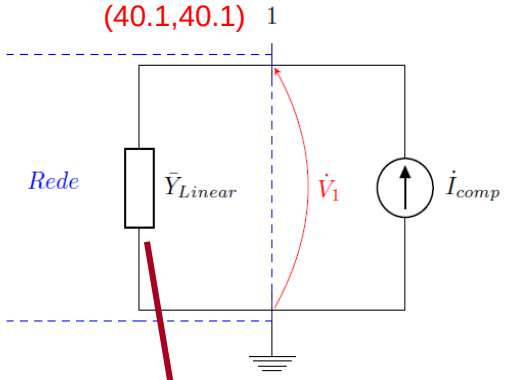
- Separação entre parte linear e não linear de uma carga monofásica conectada no nó 1 da barra 40





$$\dot{I}_{comp} = \dot{V}_1 \times \bar{Y}_{linear} - \dot{I}_{term}$$

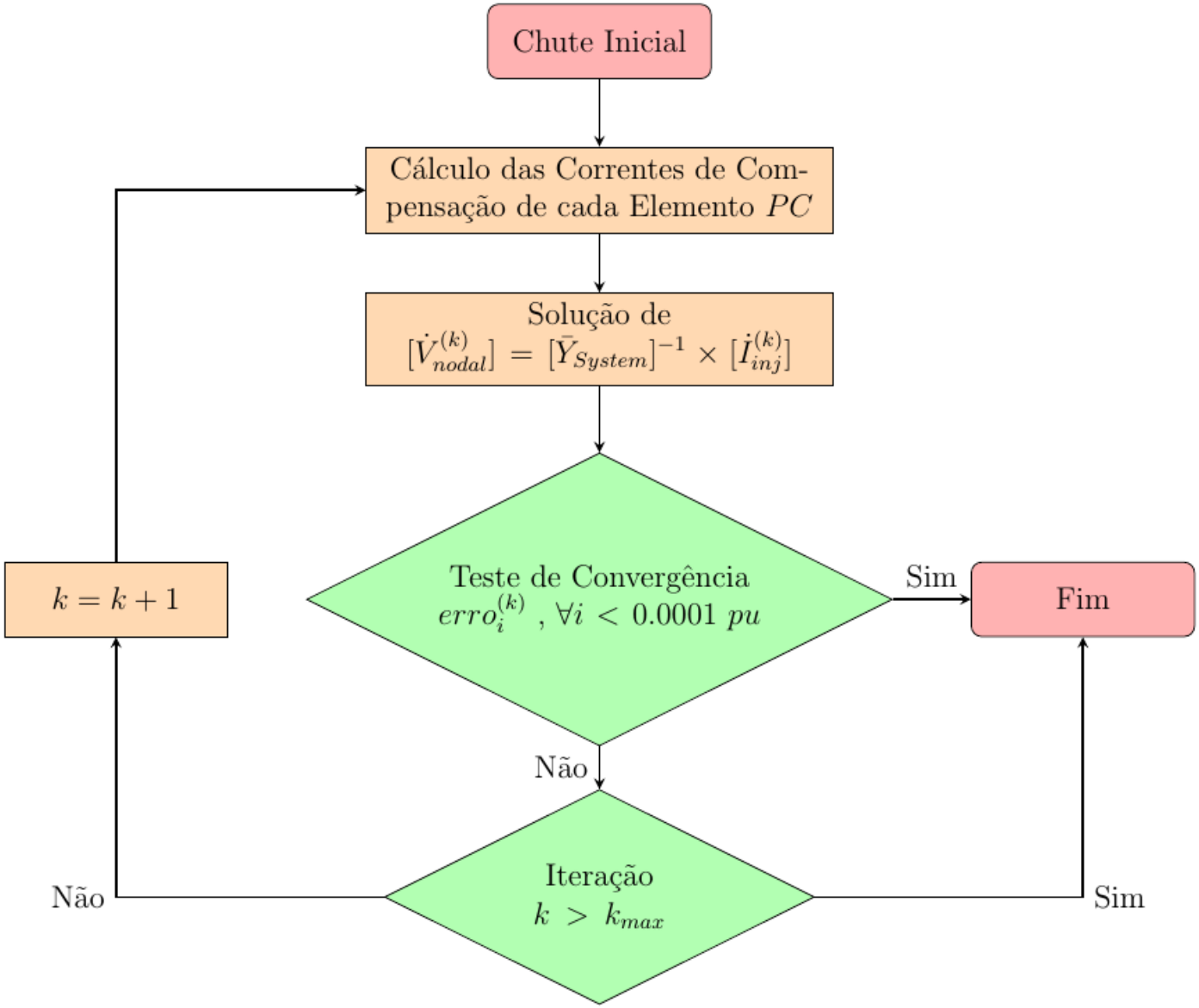
Essa admitância entra somando no elemento (40.1,40.1)



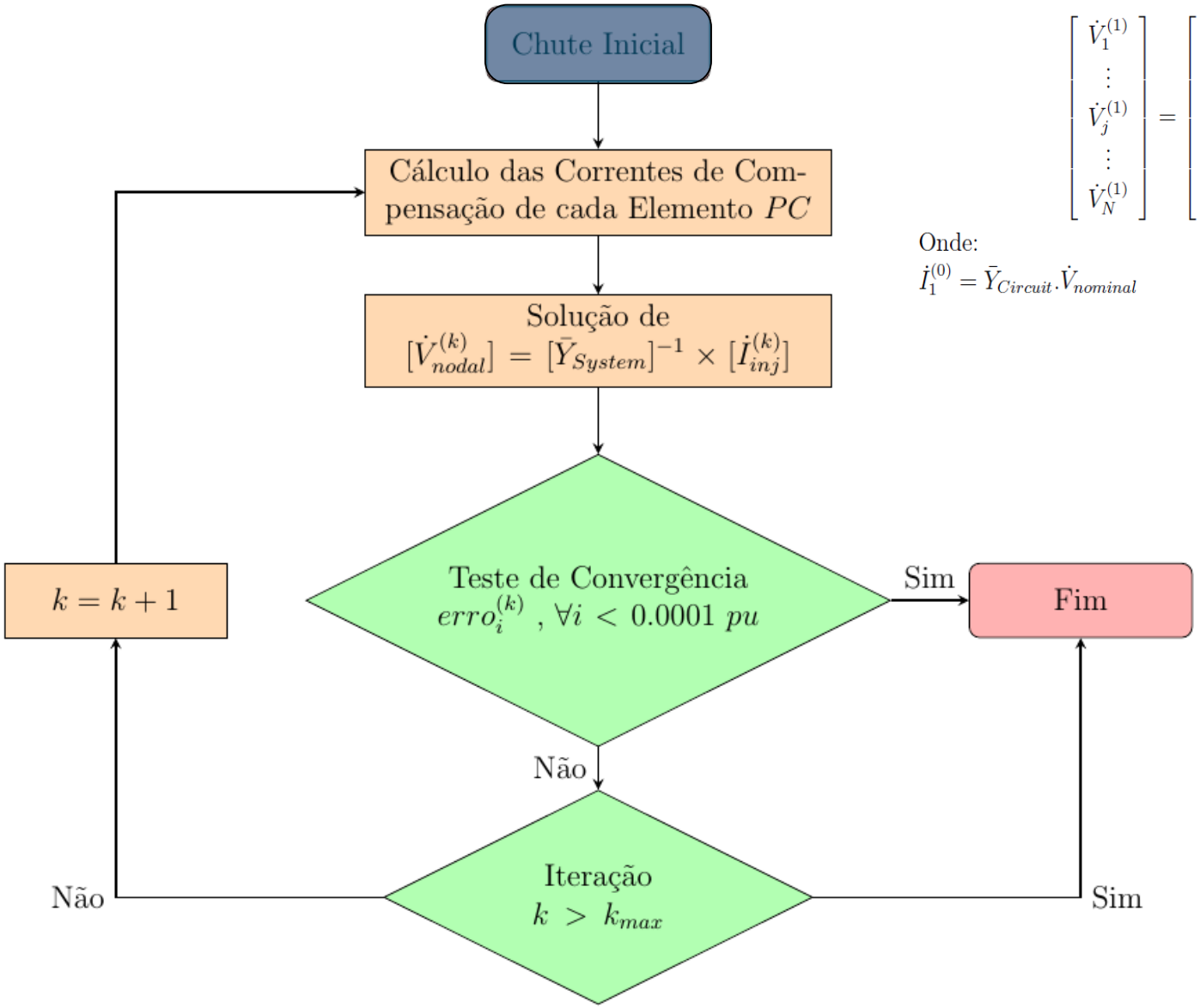
$$\bar{\mathbf{Y}}_{\mathbf{system_{12\times12}}} =$$

	10.1	10.2	10.3	10.4	20.1	20.2	20.3	30.1	30.2	30.3	40.1	40.2
10.1	$\bar{Y}_{a11}$	$\bar{Y}_{a12}$	$\bar{Y}_{a13}$	$\bar{Y}_{a14}$	$\bar{Y}_{a15}$	$\bar{Y}_{a16}$	$\bar{Y}_{a17}$	0	0	0	0	0
10.2	$\bar{Y}_{a21}$	$\bar{Y}_{a22}$	$\bar{Y}_{a23}$	$\bar{Y}_{a24}$	$\bar{Y}_{a25}$	$\bar{Y}_{a26}$	$\bar{Y}_{a27}$	0	0	0	0	0
10.3	$\bar{Y}_{a31}$	$\bar{Y}_{a32}$	$\bar{Y}_{a33}$	$\bar{Y}_{a34}$	$\bar{Y}_{a35}$	$\bar{Y}_{a36}$	$\bar{Y}_{a37}$	0	0	0	0	0
10.4	$\bar{Y}_{a41}$	$\bar{Y}_{a42}$	$\bar{Y}_{a43}$	$\bar{Y}_{a44}$	$\bar{Y}_{a45}$	$\bar{Y}_{a46}$	$\bar{Y}_{a47}$	0	0	0	0	0
20.1	$\bar{Y}_{a51}$	$\bar{Y}_{a52}$	$\bar{Y}_{a53}$	$\bar{Y}_{a54}$	$\bar{Y}_{a55} + \bar{Y}_{b11}$	$\bar{Y}_{a56} + \bar{Y}_{b12}$	$\bar{Y}_{a57} + \bar{Y}_{b13}$	$\bar{Y}_{b14}$	$\bar{Y}_{b15}$	$\bar{Y}_{b16}$	0	0
20.2	$\bar{Y}_{a61}$	$\bar{Y}_{a62}$	$\bar{Y}_{a63}$	$\bar{Y}_{a64}$	$\bar{Y}_{a65} + \bar{Y}_{b21}$	$\bar{Y}_{a66} + \bar{Y}_{b22} + \bar{\mathbf{Y}}_{\mathbf{c11}}$	$\bar{Y}_{a67} + \bar{Y}_{b23} + \bar{\mathbf{Y}}_{\mathbf{c12}}$	$\bar{Y}_{b24}$	$\bar{Y}_{b25}$	$\bar{Y}_{b26}$	$\bar{\mathbf{Y}}_{\mathbf{c13}}$	$\bar{\mathbf{Y}}_{\mathbf{c14}}$
20.3	$\bar{Y}_{a71}$	$\bar{Y}_{a72}$	$\bar{Y}_{a73}$	$\bar{Y}_{a74}$	$\bar{Y}_{a75} + \bar{Y}_{b31}$	$\bar{Y}_{a76} + \bar{Y}_{b32} + \bar{\mathbf{Y}}_{\mathbf{c21}}$	$\bar{Y}_{a77} + \bar{Y}_{b33} + \bar{\mathbf{Y}}_{\mathbf{c22}}$	$\bar{Y}_{b34}$	$\bar{Y}_{b35}$	$\bar{Y}_{b36}$	$\bar{\mathbf{Y}}_{\mathbf{c23}}$	$\bar{\mathbf{Y}}_{\mathbf{c24}}$
30.1	0	0	0	0	$\bar{Y}_{b41}$	$\bar{Y}_{b42}$	$\bar{Y}_{b43}$	$\bar{Y}_{b44}$	$\bar{Y}_{b45}$	$\bar{Y}_{b46}$	0	0
30.2	0	0	0	0	$\bar{Y}_{b51}$	$\bar{Y}_{b52}$	$\bar{Y}_{b53}$	$\bar{Y}_{b54}$	$\bar{Y}_{b55}$	$\bar{Y}_{b56}$	0	0
30.3	0	0	0	0	$\bar{Y}_{b61}$	$\bar{Y}_{b62}$	$\bar{Y}_{b63}$	$\bar{Y}_{b64}$	$\bar{Y}_{b65}$	$\bar{Y}_{b66}$	0	0
40.1	0	0	0	0	0	$\bar{\mathbf{Y}}_{\mathbf{c31}}$	$\bar{\mathbf{Y}}_{\mathbf{c32}}$	0	0	0	$\bar{\mathbf{Y}}_{\mathbf{c33}}$	$\bar{\mathbf{Y}}_{\mathbf{c34}}$
40.2	0	0	0	0	0	$\bar{\mathbf{Y}}_{\mathbf{c41}}$	$\bar{\mathbf{Y}}_{\mathbf{c42}}$	0	0	0	$\bar{\mathbf{Y}}_{\mathbf{c43}}$	$\bar{\mathbf{Y}}_{\mathbf{c44}}$

Algoritmo de Fluxo de Potência do OpenDSS



Algoritmo de Fluxo de Potência do OpenDSS

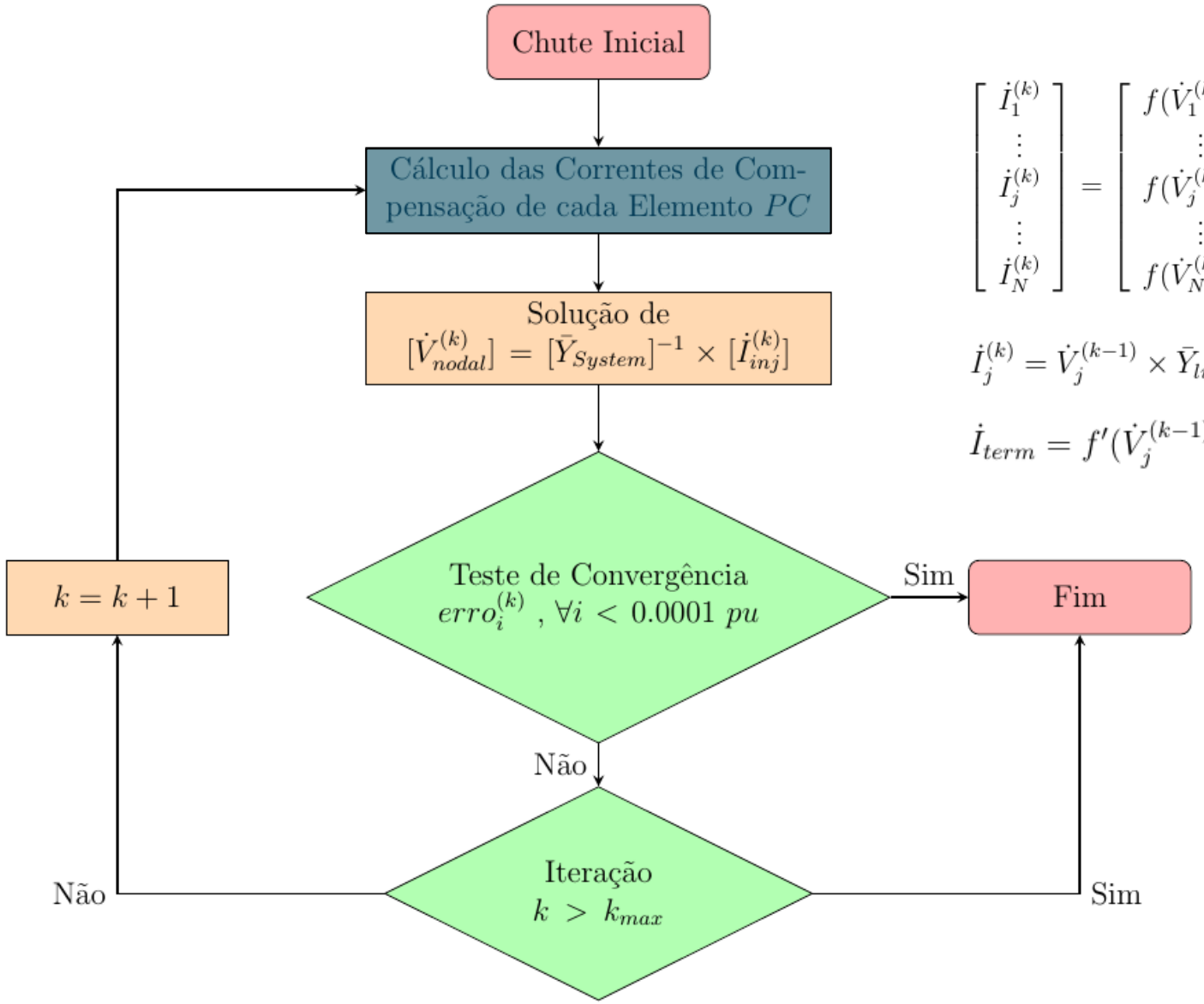


$$\begin{bmatrix} \dot{V}_1^{(1)} \\ \vdots \\ \dot{V}_j^{(1)} \\ \vdots \\ \dot{V}_N^{(1)} \end{bmatrix} = \begin{bmatrix} \bar{Y}_{11} & \dots & \bar{Y}_{1j} & \dots & \bar{Y}_{1N} \\ \vdots & \dots & \vdots & \dots & \vdots \\ \bar{Y}_{j1} & \dots & \bar{Y}_{jj} & \dots & \bar{Y}_{jN} \\ \vdots & \dots & \vdots & \dots & \vdots \\ \bar{Y}_{N1} & \dots & \bar{Y}_{Nj} & \dots & \bar{Y}_{NN} \end{bmatrix}^{-1} \cdot \begin{bmatrix} \dot{I}_1^{(0)} \\ \vdots \\ 0 \\ \vdots \\ 0 \end{bmatrix}$$

Onde:

$\dot{I}_1^{(0)} = \bar{Y}_{Circuit}.\dot{V}_{nominal}$

Algoritmo de Fluxo de Potência do OpenDSS

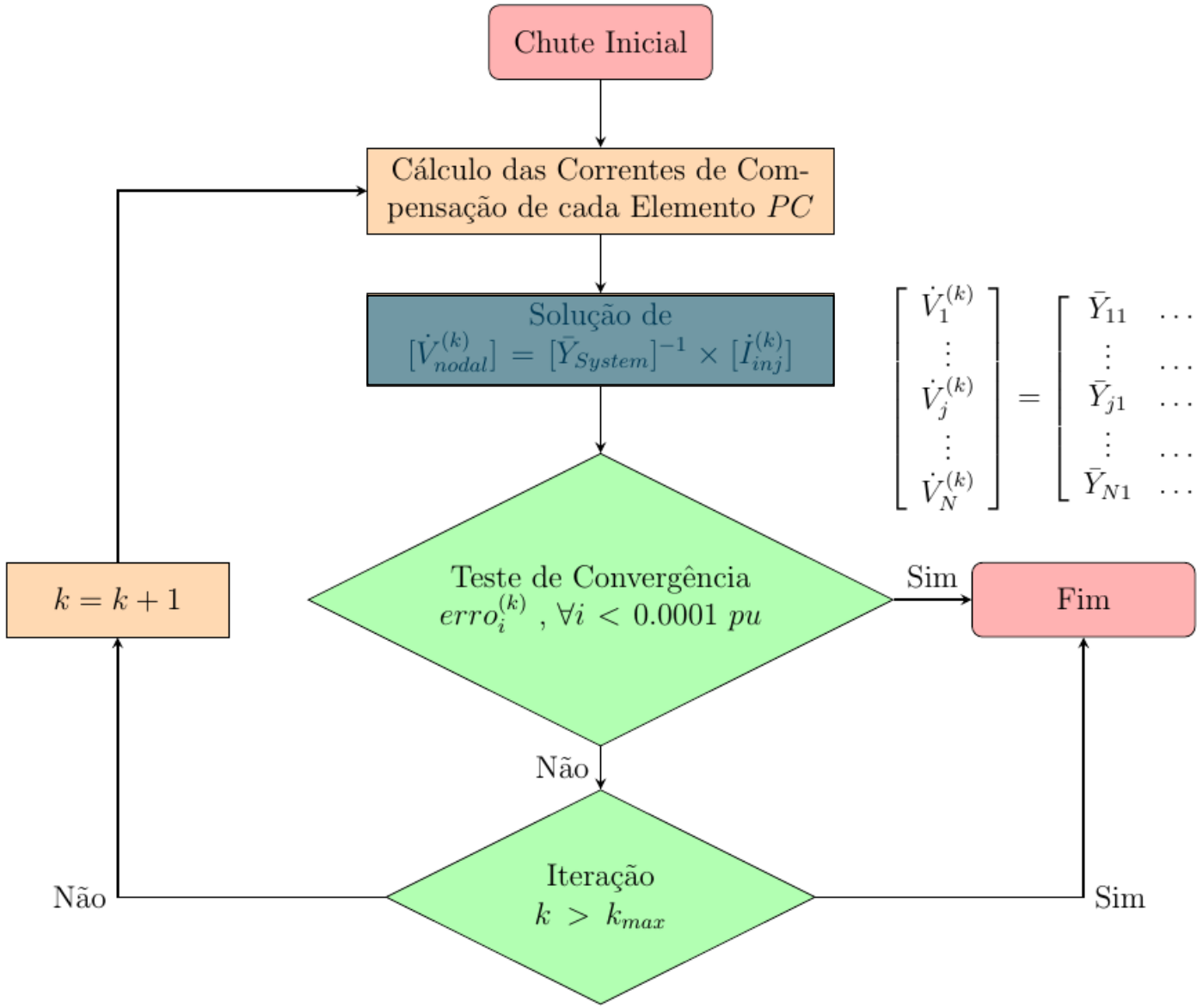


$$\begin{bmatrix} \dot{I}_1^{(k)} \\ \vdots \\ \dot{I}_j^{(k)} \\ \vdots \\ \dot{I}_N^{(k)} \end{bmatrix} = \begin{bmatrix} f(\dot{V}_1^{(k-1)}) \\ \vdots \\ f(\dot{V}_j^{(k-1)}) \\ \vdots \\ f(\dot{V}_N^{(k-1)}) \end{bmatrix}$$

$$\dot{I}_j^{(k)} = \dot{V}_j^{(k-1)} \times \bar{Y}_{linear} - \dot{I}_{term}$$

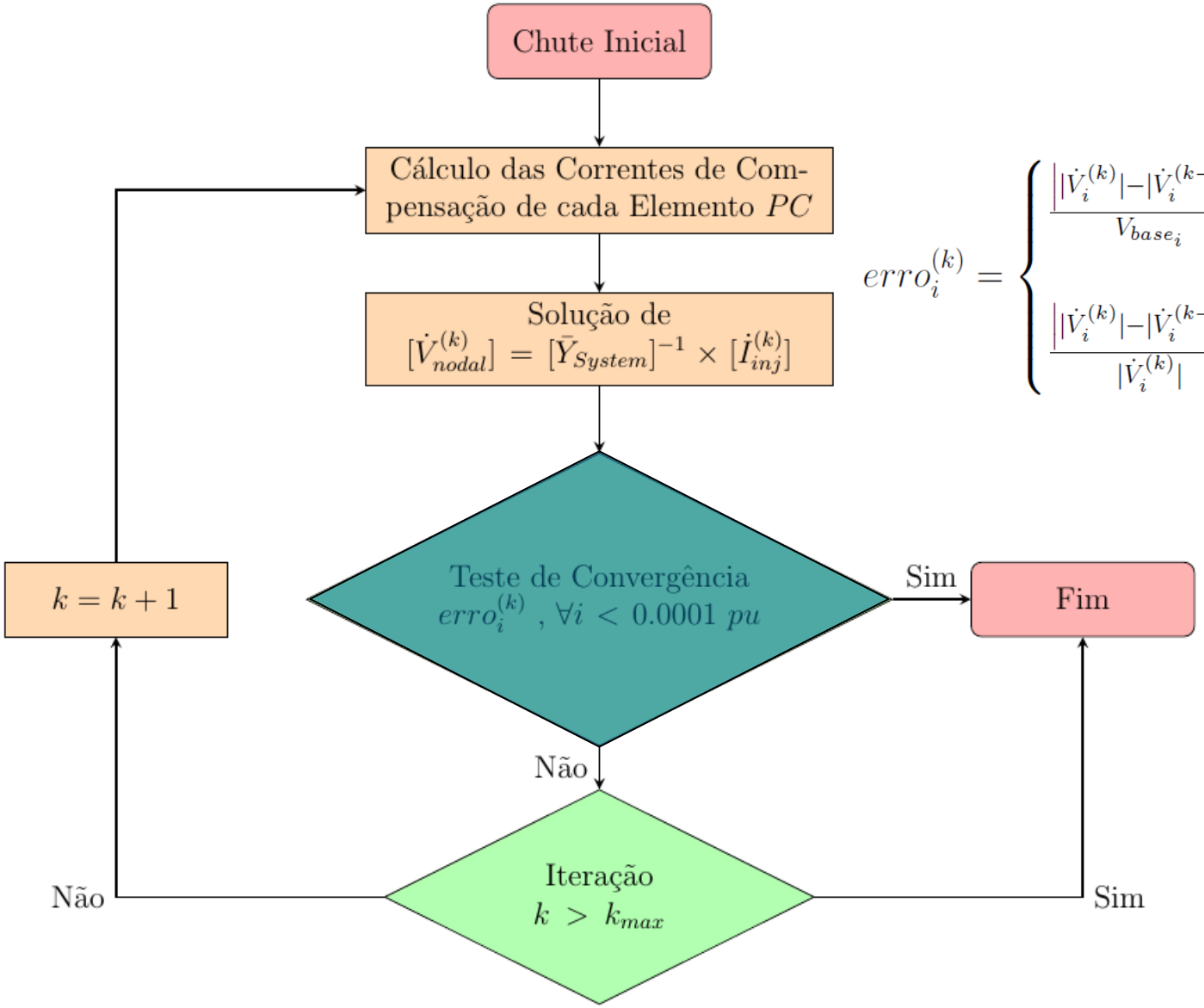
$$\dot{I}_{term} = f'(\dot{V}_j^{(k-1)})$$

Algoritmo de Fluxo de Potência do OpenDSS



$$\begin{bmatrix} \dot{V}_1^{(k)} \\ \vdots \\ \dot{V}_j^{(k)} \\ \vdots \\ \dot{V}_N^{(k)} \end{bmatrix} = \begin{bmatrix} \bar{Y}_{11} & \dots & \bar{Y}_{1j} & \dots & \bar{Y}_{1N} \\ \vdots & \dots & \vdots & \dots & \vdots \\ \bar{Y}_{j1} & \dots & \bar{Y}_{jj} & \dots & \bar{Y}_{jN} \\ \vdots & \dots & \vdots & \dots & \vdots \\ \bar{Y}_{N1} & \dots & \bar{Y}_{Nj} & \dots & \bar{Y}_{NN} \end{bmatrix}^{-1} \cdot \begin{bmatrix} \dot{I}_1^{(k)} \\ \vdots \\ \dot{I}_j^{(k)} \\ \vdots \\ \dot{I}_N^{(k)} \end{bmatrix}$$

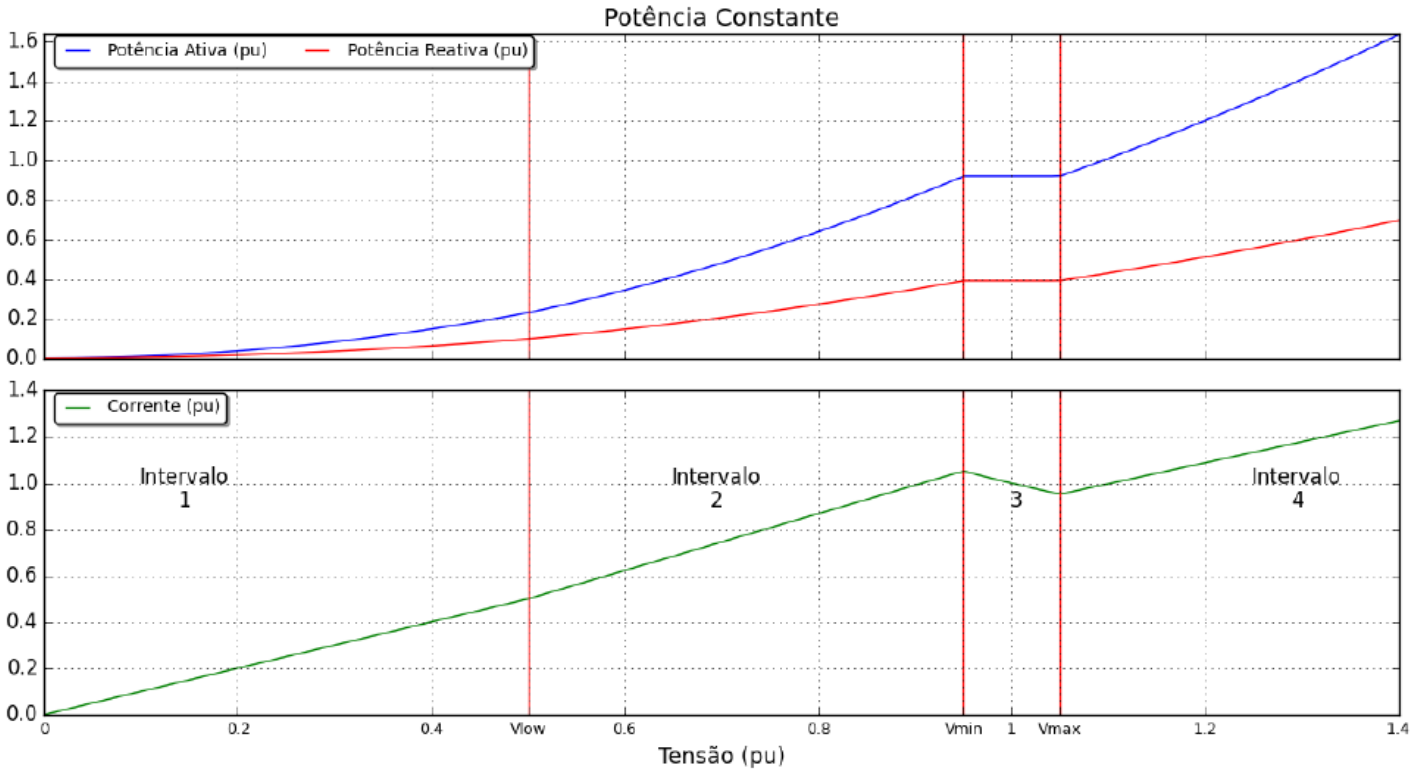
Algoritmo de Fluxo de Potência do OpenDSS



$$erro_i^{(k)} = \begin{cases} \dfrac{\left||\dot{V}_i^{(k)}|-|\dot{V}_i^{(k-1)}|\right|}{V_{base_i}}, & \text{se a barra a qual o nó } i \text{ pertence possui } V_{base} \\ \dfrac{\left||\dot{V}_i^{(k)}|-|\dot{V}_i^{(k-1)}|\right|}{|\dot{V}_i^{(k)}|}, & \text{senão} \end{cases}$$

Melhorando a Convergência

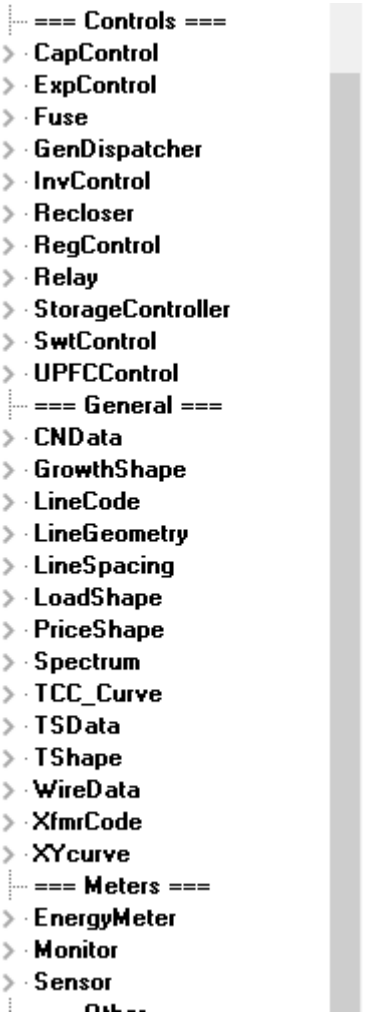
- A função que relaciona corrente drenada e tensão aplicada em um PC se altera dependendo do nível dessa tensão
- Exemplo de uma carga caracterizada pelo modelo de potência constante:



Elementos de Suporte

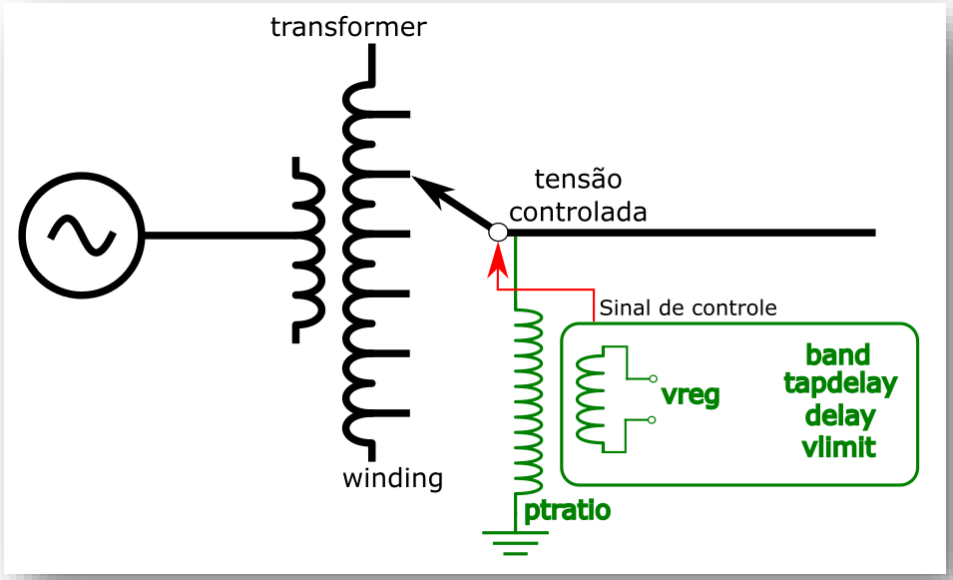
Elementos de Suporte

- São associados aos PDs e aos PCs.
- São separados em 3 grupos:
  - Controle: associam funcionalidades de controle a alguns elementos
  - Geral: armazenam informações de parâmetros que serão associados a outros elementos
  - Medição: monitoram parâmetros, fornecendo resultados de análises temporais



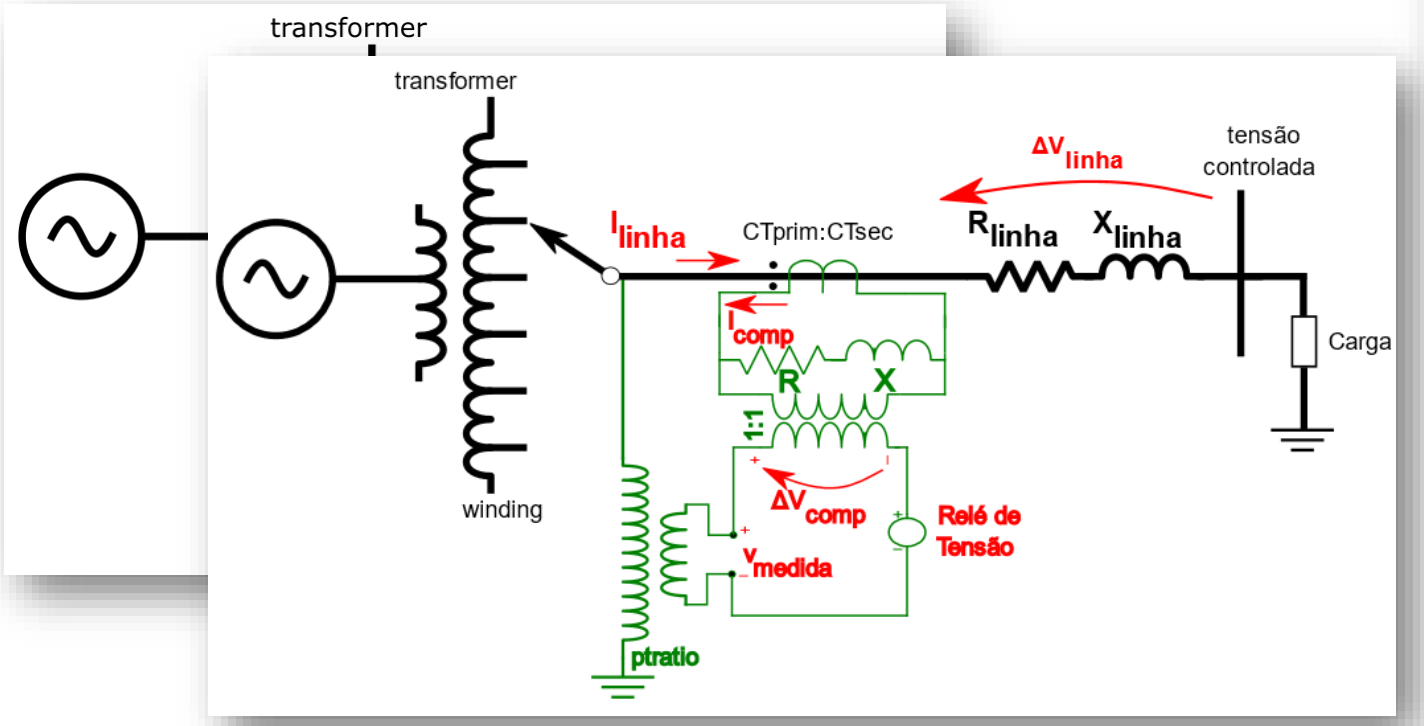
Elementos de Controle

- RegControl: controla o tap ou taps de um PD *transformer*



Elementos de Controle

- RegControl: controla o tap ou taps de um PD *transformer*



Elementos Gerais

- LineCode: Armazena as informações de um arranjo de linha específico

```
// Dados dos Arranjos
New Linecode.MeuArranjo4 nphases=4 basefreq=60 units=km
~ rmatrix = [0.249 |0.059 0.249 |0.059 0.059 0.249 |0.059 0.059 0.059 0.427]      !ohm/km
~ xmatrix = [0.878 |0.529 0.878 |0.451 0.484 0.878 |0.467 0.488 0.476 0.960]      !ohm/km
~ cmatrix = [9.353 |-3.028 9.858 |-1.160 -1.928 8.891 |-1.393 -1.772 -1.782 8.809] !nF/km
~ neutral=4 kron=No

// Dados dos Trechos
New Line.LinhaBC bus1=B.1.2.3.0 bus2=C.1.2.3.4 length=0.8 units=km linecode=MeuArranjo4
```

Elementos Gerais

- LineCode: Armazena as informações de um arranjo de linha específico

```
// Dados dos Arranjos
New Linecode.MeuArranjo4 nphases=4 basefreq=60 units=km
~ rmatrix = [0.249 |0.059 0.249 |0.059 0.059 0.249 |0.059 0.059 0.059 0.427]      !ohm/km
~ xmatrix = [0.878 |0.529 0.878 |0.451 0.484 0.878 |0.467 0.488 0.476 0.960]      !ohm/km
~ cmatrix = [9.353 |-3.028 9.858 |-1.160 -1.928 8.891 |-1.393 -1.772 -1.782 8.809] !nF/km
~ neutral=4 kron=No

// Dados dos Trechos
New Line.LinhaBC bus1=B.1.2.3.0 bus2=C.1.2.3.4 length=0.8 units=km linecode=MeuArranjo4
```

- Spectrum: Inclui um espectro harmônico a um PC

```
// Dados dos Espectros Harmonicos das Cargas
New Spectrum.spCargaC NumHarm=3 harmonic=(1 3 5) %mag=(100 5 1) angle=(0 180 90)
New Spectrum.spCargaD NumHarm=2 harmonic=(1 5) %mag=(100 2) angle=(0 30)

// Dados das Cargas
// Model=1 -> Potencia Constante
New Load.CargaC phases=1 bus1=C.1.4 kv=7.9674 kw=500 pf=0.92 model=1 spectrum=spCargaC
New Load.CargaD phases=3 bus1=D conn=wye kv=13.8 kw=2000 pf=0.92 model=1 spectrum=spCargaD
```

Elementos Gerais

- LineGeometry e WireData: Armazenam as informações geométricas do poste e dos condutores, respectivamente

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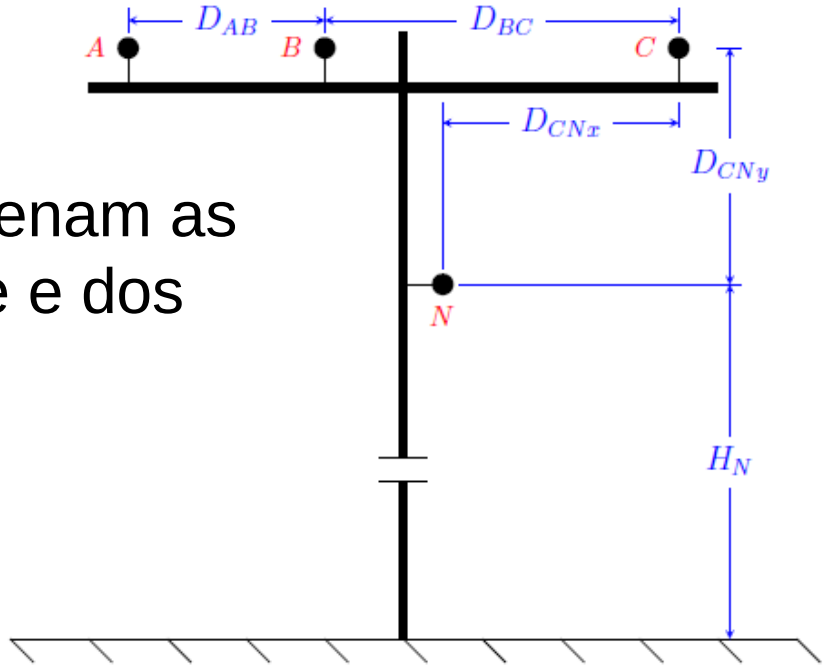
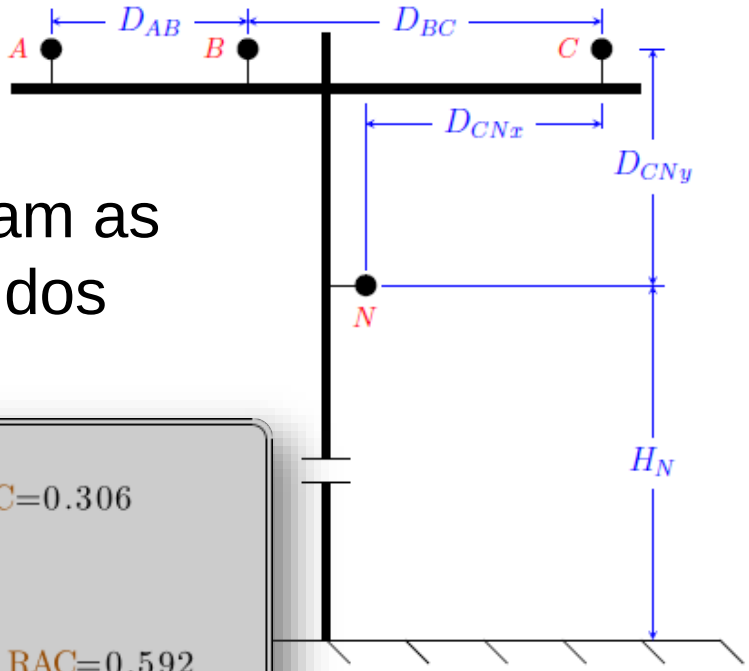
- LineGeometry e WireData: Armazenam as informações geométricas do poste e dos condutores, respectivamente



Elementos Gerais



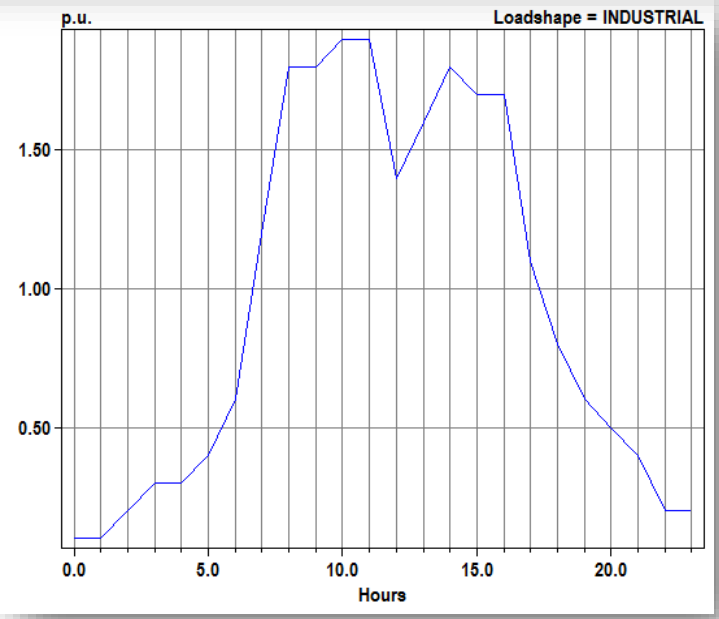
- LineGeometry e WireData: Armazenam as informações geométricas do poste e dos condutores, respectivamente

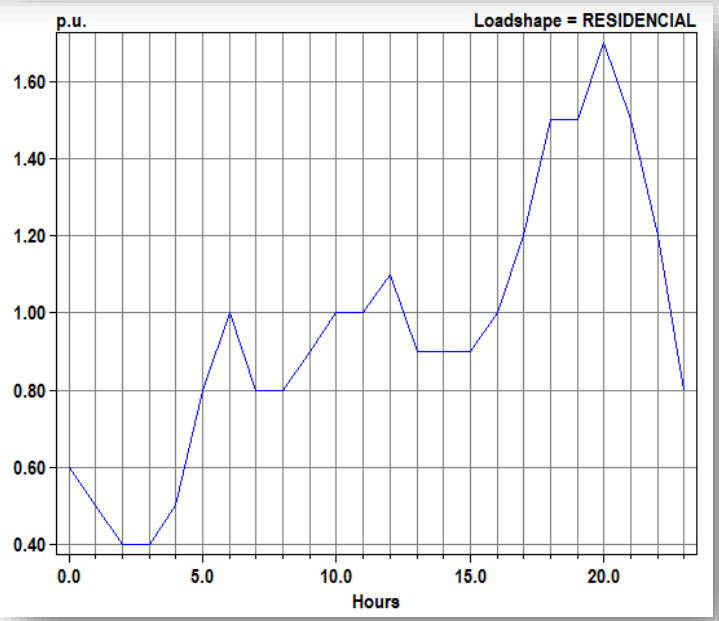
```
// Dados dos cabos e do poste
New Wiredata.CondutorFase GMR=0.0244 DIAM=0.721 RAC=0.306
~ normamps=530
~ Runits=mi RADunits=in GMRunits=ft

New Wiredata.CondutorNeutro GMR=0.00814 DIAM=0.563 RAC=0.592
~ normamps=340
~ Runits=mi RADunits=in GMRunits=ft

New Linegeometry.Poste nconds=4 nphases=3 reduce=No
~ cond=1 wire=CondutorFase     x= -4     h=29    units=ft
~ cond=2 wire=CondutorFase     x= -1.5   h=29    units=ft
~ cond=3 wire=CondutorFase     x= 3      h=29    units=ft
~ cond=4 wire=CondutorNeutro   x= 0      h=25    units=ft

New Line.MinhaLinha bus1=A.1.2.3.0 bus2=B.1.2.3.4
~ geometry=Poste
~ length=1 units=km
~ earthmodel=Carson
```

Elementos Gerais

- LoadShape: Corresponde a curvas que podem ser associadas a PCs, por exemplo:

```
// Dados das Curvas de Carga
New LoadShape.industrial npts=24 interval=1
~ mult=(0.1 0.1 0.2 0.3 0.3 0.4 0.6 1.2 1.8 1.8 1.9 1.9 1.4 1.6 1.8 1.7 1.7 1.1 0.8 0.6 0.5 0.4 0.2 0.2)
New LoadShape.residencial npts=24 interval=1
~ mult=(0.6 0.5 0.4 0.4 0.5 0.8 1.0 0.8 0.8 0.9 1.0 1.0 1.1 0.9 0.9 0.9 1.0 1.2 1.5 1.5 1.7 1.5 1.2 0.8)

// Dados das Cargas
// Model=1 -> Potencia Constante
New Load.CargaC phases=1 bus1=C.1.4 conn=wye kv=7.9674 kw=500 pf=0.92 model=1 daily=residencial
New Load.CargaD phases=3 bus1=D conn=wye kv=13.8 kw=2000 pf=0.92 model=1 daily=industrial
```





Elementos de Medição

- EnergyMeter: São conectados a PDs e armazenam diversos resultados sobre a sua área de medição
- Exemplos:
  - kWh, kvarh, max kW, max kvar, perdas em energia e em potência

```
// Medidor
New EnergyMeter.MedidorSub element=Transformer.Trafo terminal=1
```

Elementos de Medição

- Monitor: São conectados e armazenam grandezas ao longo do tempo.
- Exemplo:
  - Tensão, Corrente, Potência, Variáveis de Estado de PCs, etc..
  - No modo de simulação Harmonic, o monitor armazena as grandezas selecionadas para cada harmônica considerada

```
// Monitores
New Monitor.PotenciaSub element=Transformer.Trafo terminal=1 mode=1 ppolar=no
New Monitor.TensaoSub element=Transformer.Trafo terminal=1 mode=0
```

Referências

- Dugan, Roger: Slides de Treinamentos. http://sourceforge.net/p/electricdss/code/HEAD/tree/trunk/Training/. [Online; acessado emn11/09/2017].
- Sexauer, Jason: OpenDSS Primer, versão em português. https://sourceforge.net/p/electricdss/code/HEAD/tree/trunk/Distrib/Doc/OpenDSSPrimer_Portuguese.pdf.[Online; acessado em 11/09/2017].

Comentários Adicionais

Esse material foi disponibilizado gratuitamente, porém, ao utilizá-lo, pedimos que as devidas referências sejam feitas.

Se você possui alguma dúvida ou encontrou algum erro nesse material, por favor, entre em contato conosco através do e-mail opendss.brasil@gmail.com.

Obrigado!
Dúvidas?