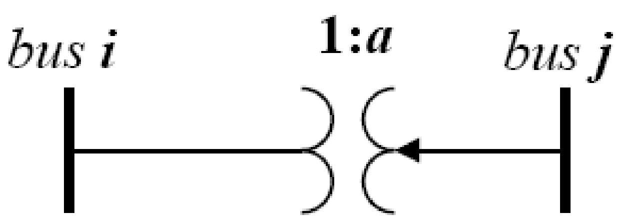
ELE-B7 Power Systems Engineering

Tap-Changing Transformers Modeling

Tap-Changing Transformers

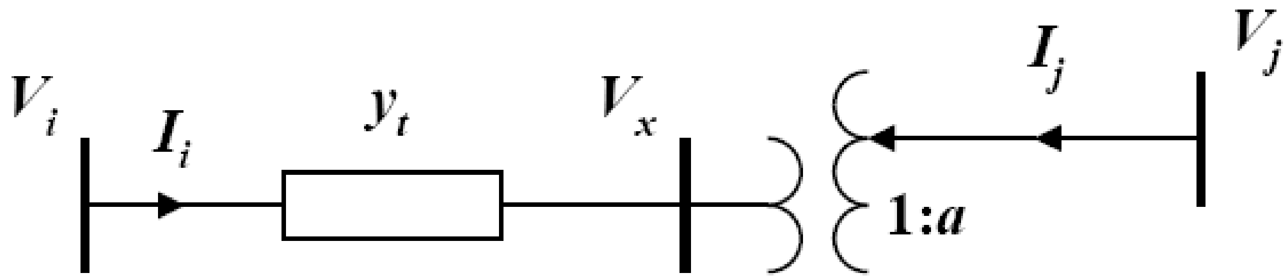
- **The tap-changing transform gives some control of the power network by changing the voltages and current magnitudes and angles by small amounts**
  - The flow of real power along a network branch is controlled by the angular difference of the terminal voltages
  - The flow of reactive power along a network branch is controlled by the magnitude difference of the terminal voltages
  - Real and reactive powers can be adjusted by voltage-regulating transformers and by phase-shifting transformers



a can be a complex number

Modeling of Tap-Changers

- the off-nominal tap ratio is given as 1:a
- the nominal turns-ratio (N_1/N_2) was addressed with the conversion of the network to per unit
- the transformer is modeled as two elements joined together at a fictitious bus x



- basic circuit equations:

$$V_x = \tfrac{1}{a} V_j \qquad I_i = -a^* \cdot I_j \qquad I_i = y_t (V_i - V_x)$$

Modeling of Tap-Changers, cont'd

- **Making substitutions**

$$V_x = \tfrac{1}{a} V_j \qquad\qquad I_i = y_t \left(V_i - V_x \right)$$

$$I_i = y_t \left(V_i - \tfrac{1}{a} V_j \right)$$

$$I_i = -a^* \cdot I_j$$

$$I_j = -\tfrac{1}{a^*} I_i$$

$$I_j = -\frac{y_t}{a^*} \left(V_i - \tfrac{1}{a} V_j \right) = -\frac{y_t}{a^*} V_i + \frac{y_t}{|a|^2} V_j$$

YBus Formation of Tap-Changers

- **Matrix formation**

$$I_i = \{y_t\} V_i + \left\{ -\frac{y_t}{a} \right\} V_j$$

$$I_j = \left\{ -\frac{y_t}{a^*} \right\} V_i + \left\{ \frac{y_t}{|a|^2} \right\} V_j$$

$$\begin{bmatrix} I_i \\ I_j \end{bmatrix} = \begin{bmatrix} y_t & -y_t/a \\ -y_t/a^* & y_t/|a|^2 \end{bmatrix} \cdot \begin{bmatrix} V_i \\ V_j \end{bmatrix}$$

Pi-Circuit Model of Tap-Changers

- **Valid for real values of a**
- **Taking the y-bus formation, break the diagonal elements into two components**
  - the off-diagonal element represent the impedance across the two buses
  - the remainder form the shunt element