Power Systems I

EE342

Applications of Transformers on Power Systems Control

Outline

- Tap Changing Transformers

  (Voltage Control)

- Phase Shifting Transformers

  (Power Control)

Tap Changing Transformers

3.12.1 TAP CHANGING TRANSFORMERS

Practically all power transformers and many distribution transformers have taps in one or more windings for changing the turns ratio. This method is the most popular since it can be used for controlling voltages at all levels. Tap changing, by altering the voltage magnitude, affects the distribution of vars and may therefore be used to control the flow of reactive power. There are two types of tap changing transformers

(i) Off-load tap changing transformers.
(ii) Tap changing under load (TCUL) transformers.

Off- load Tap Changing Transformers

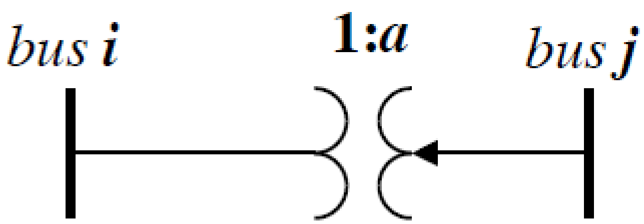
The off-load tap changing transformer requires the disconnection of the transformer when the tap setting is to be changed. Off-load tap changers are used when it is expected that the ratio will need to be changed only infrequently, because of load growth or some seasonal change. A typical transformer might have four taps in addition to the nominal setting, with spacing of 2.5 percent of full-load voltage between them. Such an arrangement provides for adjustments of up to 5 percent above or below the nominal voltage rating of the transformer.

Tap Changing Under Load

Tap changing under load (TCUL) is used when changes in ratio may be frequent or when it is undesirable to de-energize the transformer to change a tap. A large number of units are now being built with load tap changing equipment. It is used on transformers and autotransformers for transmission tie, for bulk distribution units, and at other points of load service. Basically, a TCUL transformer is a transformer with the ability to change taps while power is connected. A TCUL transformer may have built-in voltage sensing circuitry that automatically changes taps to keep the system voltage constant. Such special transformers are very common in modern power systems.

Tap-Changing Transformers

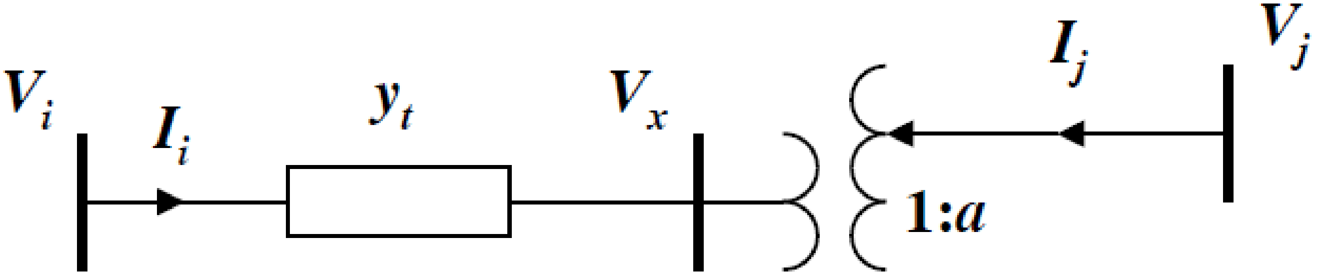
- **The tap-changing transform gives some control of the power network by changing the voltages and current magnitudes and angles by small amounts**
  - The flow of real power along a network branch is controlled by the angular difference of the terminal voltages
  - The flow of reactive power along 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:

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

Modeling of Tap-Changers

- **Making substitutions**

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

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

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

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

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

YBus Formation of Tap-Changers

Matrix formation

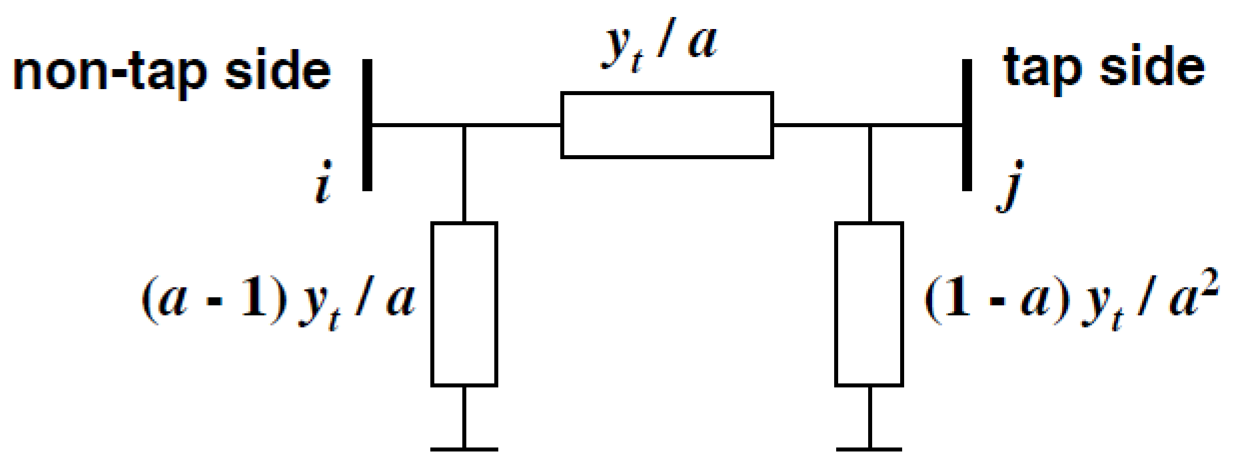
$$I_i = \{y_t\}V_i + \left\{-\frac{y_t}{a}\right\}V_j$$

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

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

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



Phase Shifting Transformers

- **Assignment** ??????????????????????????????????

- **Ref.**: IEEE C57.135™ (IEC 62032) Guide for the application, specification, and testing of phase-shifting transformers.
- **Due date** for submission: Week 13 !!!!!!!!!!!!!

- **5 Marks bonus**


Thanks


Any Questions...
Just Ask!