Summer 2025

ENERGY CONVERSION-I
EEE 221
LECTURE-04

TGN

Transformers

BRAC UNIVERSITY

Inspiring Excellence

Chapter 2 Transformers

- Types and construction of transformers
- The ideal transformer
- Theory of operation of real single-phase transformers
- Equivalent circuit of a transformer
- **Transformer voltage regulation and efficiency**
- **Transformer taps and voltage regulation**
- **The autotransformer**
- Three-phase transformer
- Instrument transformers

Transformer phasor diagram

- Use the phasor relation to obtain the voltage regulation

$$\frac{\mathbf{V}_P}{a} = \mathbf{V}_S + R_{eq}\mathbf{I}_S + jX_{eq}\mathbf{I}_S \qquad (2\text{-}64)$$

Phasor diagram – lagging Power factor

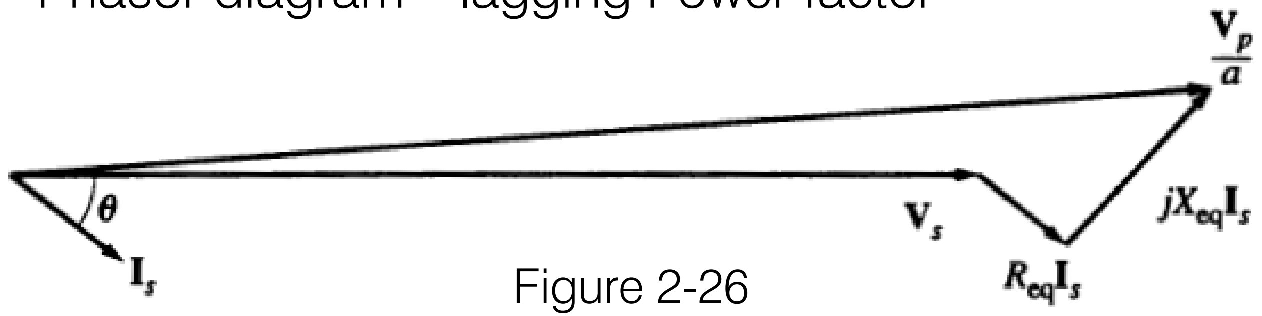

Figure 2-26

Phasor diagram – unity power factor

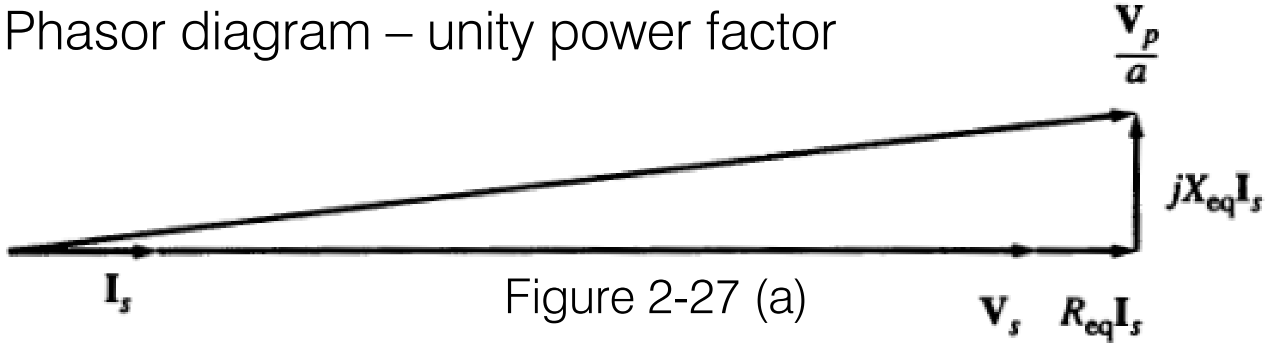

Figure 2-27 (a)

Phasor diagram – leading power factor

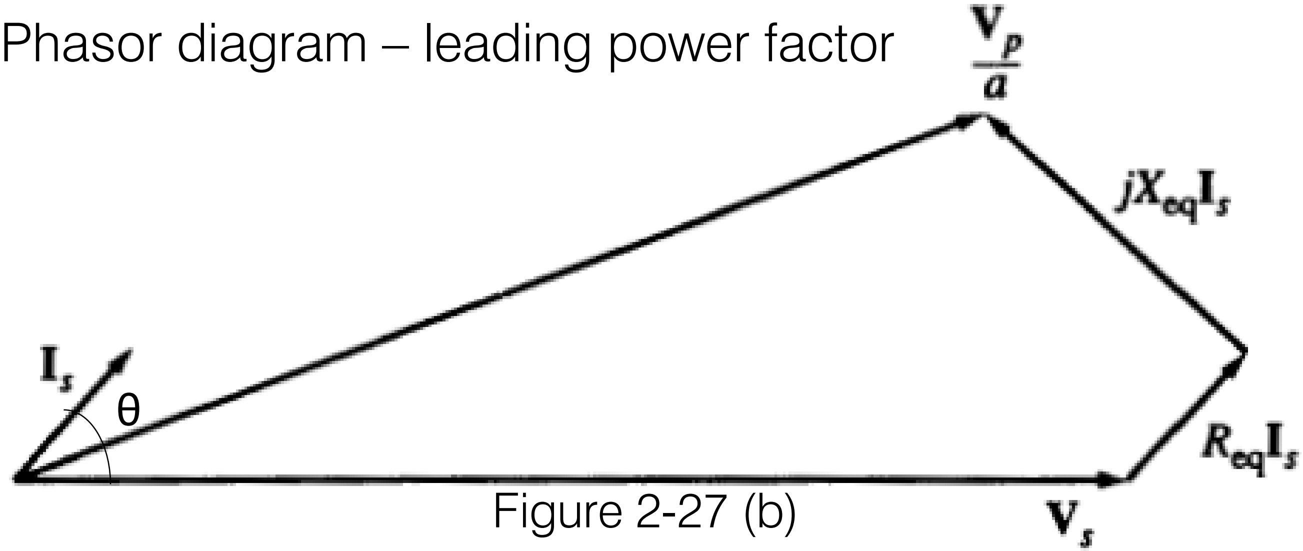

Figure 2-27 (b)

Transformer efficiency

$$\boxed{\eta = \frac{P_{out}}{P_{in}} \times 100\%} \qquad (2\text{-}65)$$

$$\boxed{\eta = \frac{P_{out}}{P_{out} + P_{loss}} \times 100\%} \qquad (2\text{-}66)$$

1. *Copper* (I^2R) *losses*. These losses are accounted for by the series resistance in the equivalent circuit.
2. *Hysteresis losses*. These losses were explained in Chapter 1 and are accounted for by resistor R_C.
3. *Eddy current losses*. These losses were explained in Chapter 1 and are accounted for by resistor R_C.

Transformer efficiency

To calculate the efficiency of a transformer at a given load, just add the losses from each resistor and apply Equation (2–67). Since the output power is given by

$$P_{\text{out}} = V_S I_S \cos \theta_S \tag{2–7}$$

the efficiency of the transformer can be expressed by

$$\boxed{\eta = \frac{V_S I_S \cos \theta}{P_{\text{Cu}} + P_{\text{core}} + V_S I_S \cos \theta} \times 100\%} \tag{2–67}$$

Assignment
Example 2-5

Example 2–5. A 15-kVA, 2300/230-V transformer is to be tested to determine its excitation branch components, its series impedances, and its voltage regulation. The following test data have been taken from the transformer:

Open-circuit test (low voltage side)	Short-circuit test (high voltage side)
$V_{OC} = 230$ V	$V_{SC} = 47$ V
$I_{OC} = 2.1$ A	$I_{SC} = 6.0$ A
Poc = 50 W	$P_{SC} = 160$ W

The data have been taken by using the connections shown in Figures 2–19 and 2–20.

(a) Find the equivalent circuit of this transformer referred to the high-voltage side.
(b) Find the equivalent circuit of this transformer referred to the low-voltage side.
(c) Calculate the full-load voltage regulation at 0.8 lagging power factor, 1.0 power factor, and at 0.8 leading power factor using the exact equation for $\mathbf{V}_P$.
(d) Plot the voltage regulation as load is increased from no load to full load at power factors of 0.8 lagging, 1.0, and 0.8 leading.
(e) What is the efficiency of the transformer at full load with a power factor of 0.8 lagging?

Transformer taps and voltage regulation

- The taps of transformer is used to change the effective turns ratio of transformer

Example 2–6. A 500-kVA, 13,200/480-V distribution transformer has four 2.5 percent taps on its primary winding. What are the voltage ratios of this transformer at each tap setting?

Solution

The five possible voltage ratings of this transformer are

+5.0% tap	13,860/480 V
+2.5% tap	13,530/480 V
Nominal rating	13,200/480 V
−2.5% tap	12,870/480 V
−5.0% tap	12,540/480 V

Thank You