MODEL RANGKAIAN

MODEL RANGKAIAN GENERATOR SINKRON

KUTUB SILINDRIS

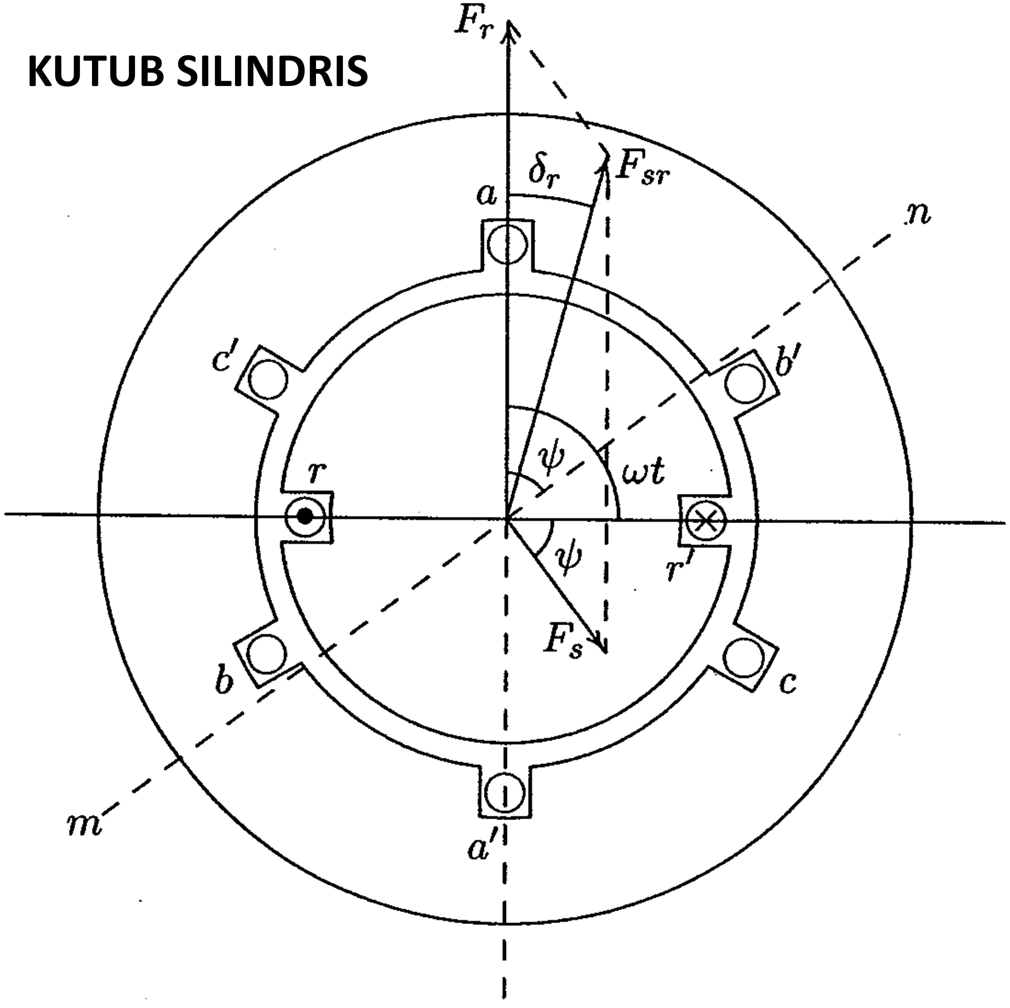


FIGURE 3.1
Elementary two-pole three-phase synchronous generator.

$$E = 4.44 f N \phi$$

$$E = 4.44 K_w f N \phi$$

$$f = \frac{P}{2}\frac{n}{60}$$

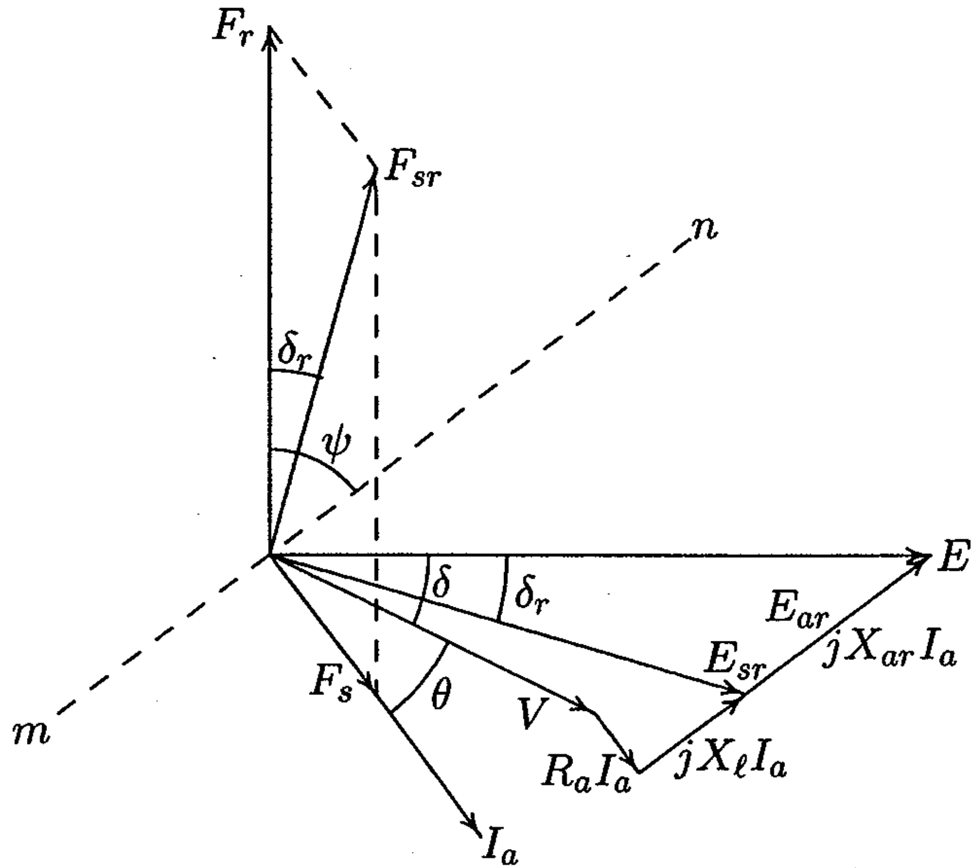


FIGURE 3.2
Combined phasor/vector diagram for one phase of a cylindrical rotor generator.

$$E = E_{sr} + jX_{ar}I_a$$

$$E = V + [R_a + j(X_\ell + X_{ar})]I_a$$

$$E = V + [R_a + jX_s]I_a$$

$$X_s = (X_\ell + X_{ar})$$

Xs = Reaktansi sinkron

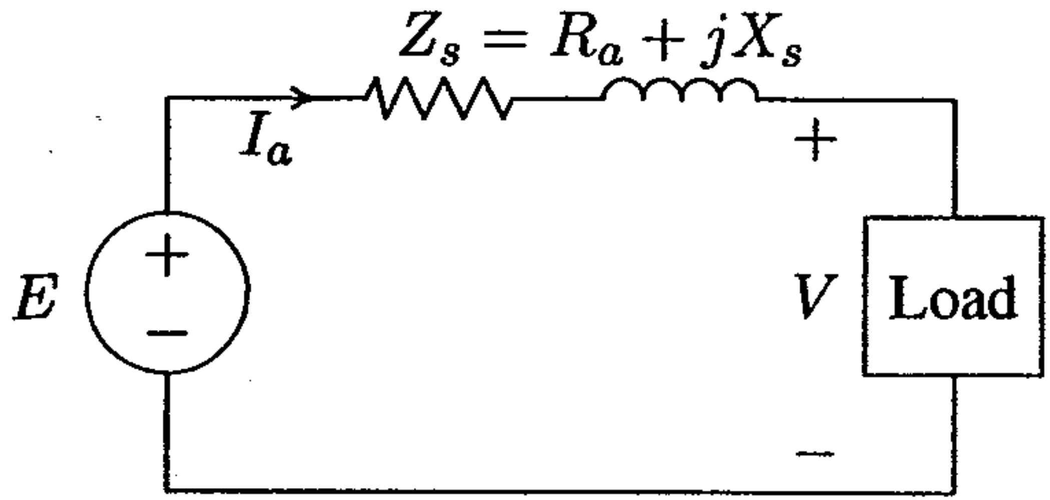


FIGURE 3.3
Synchronous machine equivalent circuit.

Ra << Xs

$$E = V + jX_s I_a$$

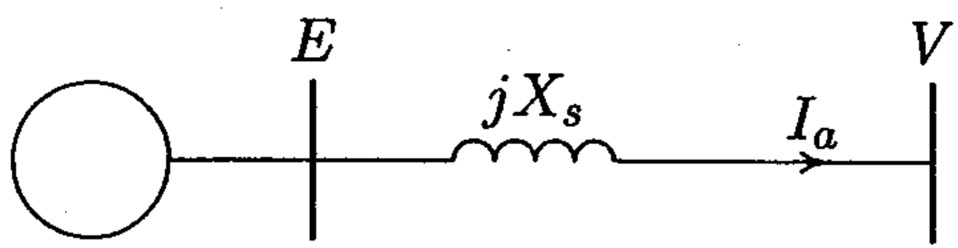


FIGURE 3.4
Synchronous machine connected to an infinite bus.

PENGATURAN EKSITASI

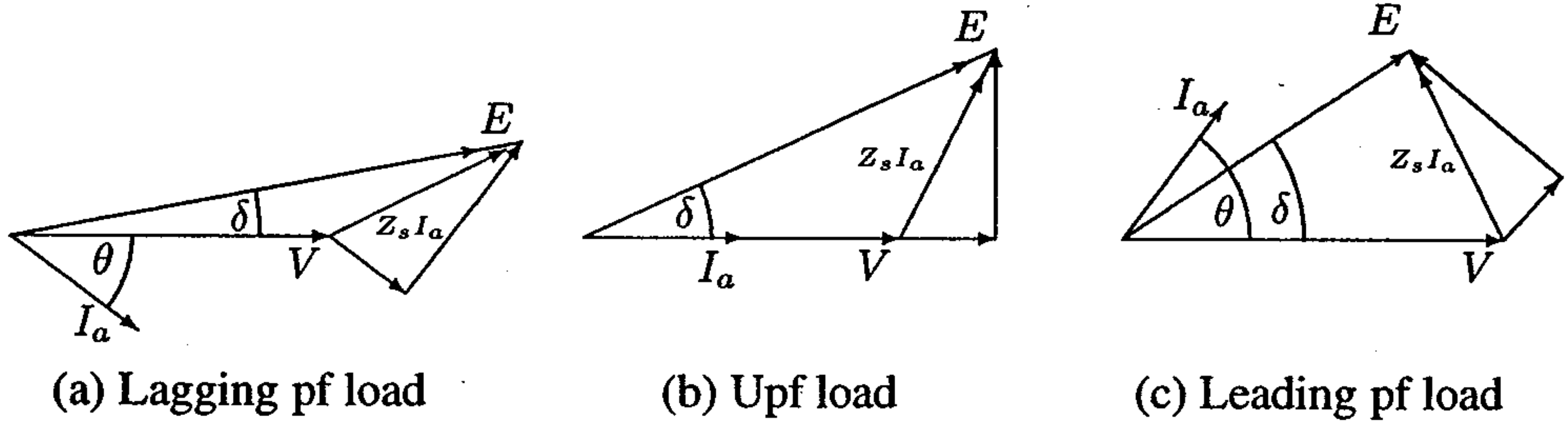


FIGURE 3.5
Synchronous generator phasor diagram.

PENGATUR TEGANGAN/VOLTAGE REGULATION

$$\mathrm{VR} = \frac{|V_{nl}| - |V_{rated}|}{|V_{rated}|} \times 100 = \frac{|E| - |V_{rated}|}{|V_{rated}|} \times 100$$

SALIENT-POLE SYNCHRONOUS GENERATORS

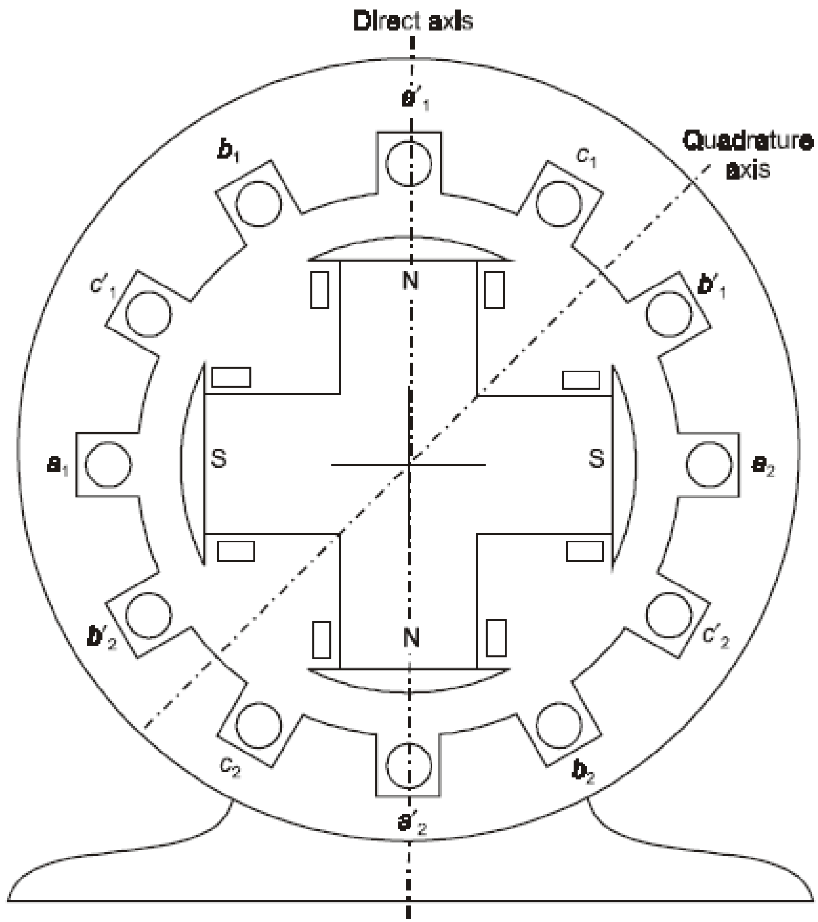


Fig. 4.5: Schematic representation of a salient pole synchronous generator (four poles).

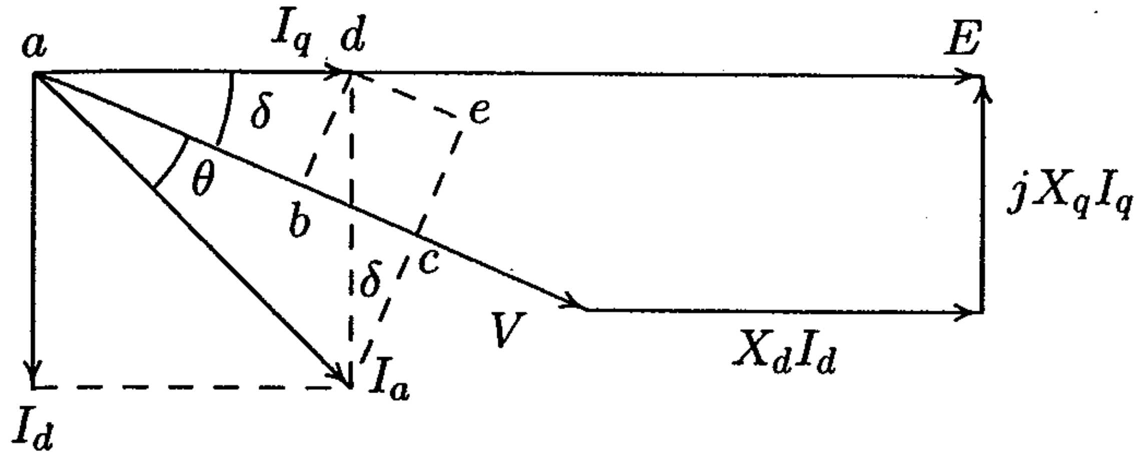


FIGURE 3.8
Phasor diagram for a salient-pole generator.

$$|E| = |V|\cos\delta + X_d I_d$$

The three-phase real power at the generator terminal is

$$P = 3|V||I_a|\cos\theta$$

$$I_d = \frac{|E| - |V|\cos\delta}{X_d}$$

$$I_q = \frac{|V|\sin\delta}{X_q}$$

$$P = 3|V|(I_q\cos\delta + I_d\sin\delta)$$

$$P_{3\phi} = 3\frac{|E||V|}{X_d}\sin\delta + 3|V|^2\frac{X_d - X_q}{2X_dX_q}\sin 2\delta$$

MODEL TRANSFORMATOR

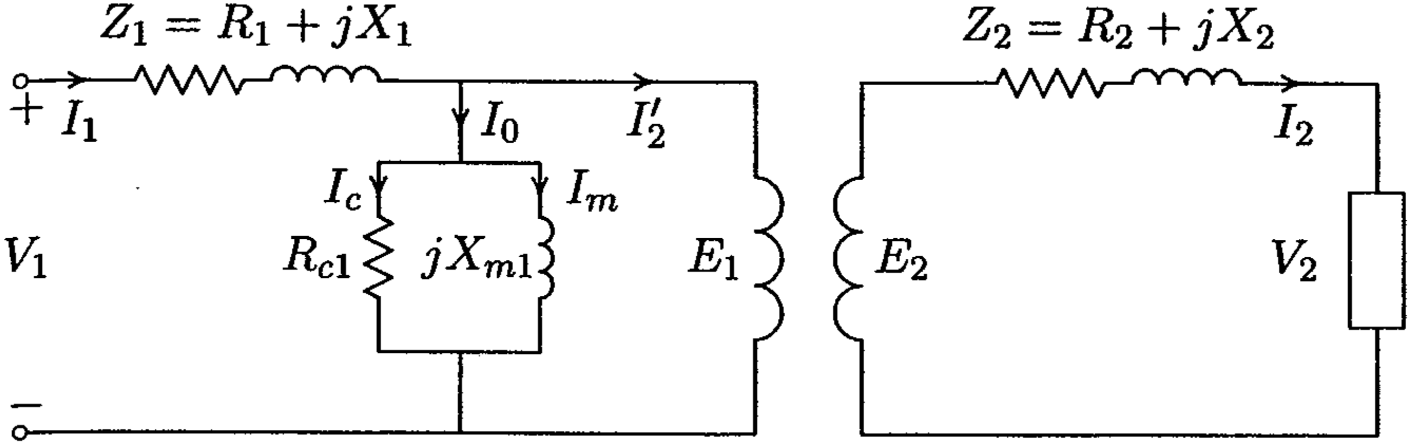


FIGURE 3.9
Equivalent circuit of a transformer.

$$E_1 = 4.44 f N_1 \Phi_{max} \qquad E_2 = 4.44 f N_2 \Phi_{max}$$

$$\frac{E_1}{E_2} = \frac{I_2}{I'_2} = \frac{N_1}{N_2}$$

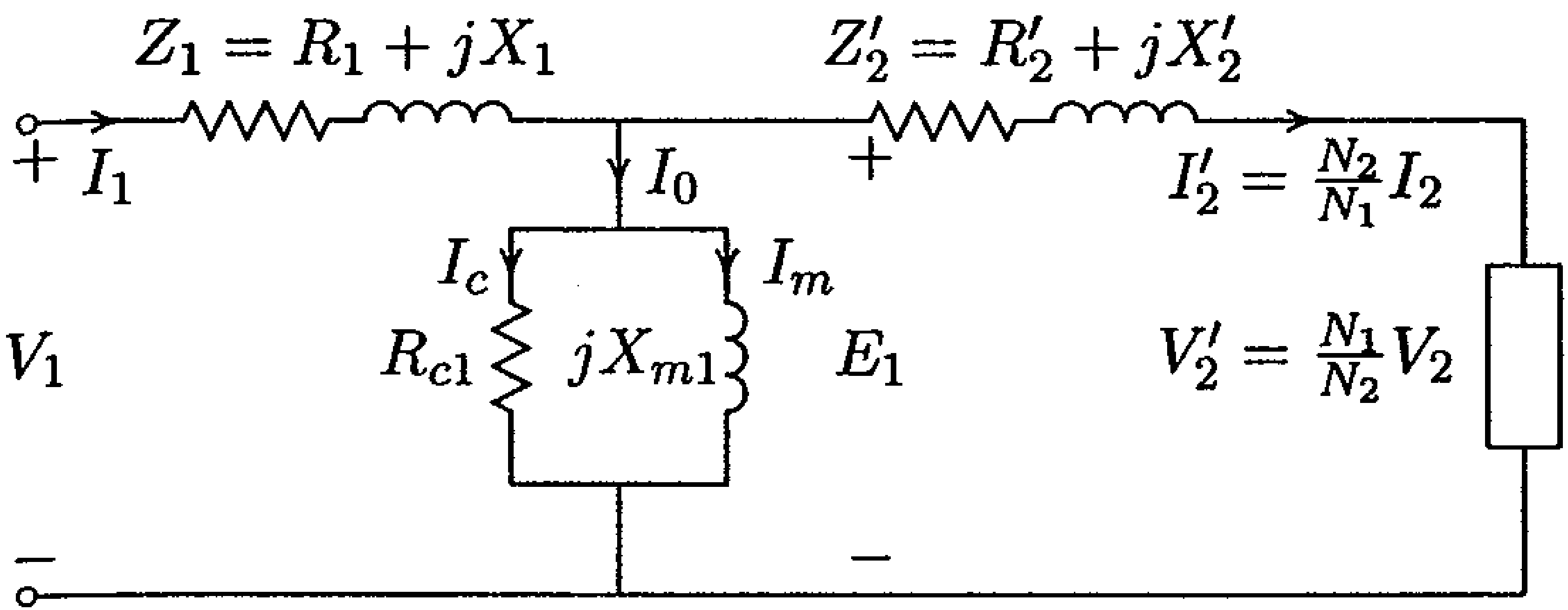


FIGURE 3.10
Exact equivalent circuit referred to the primary side.

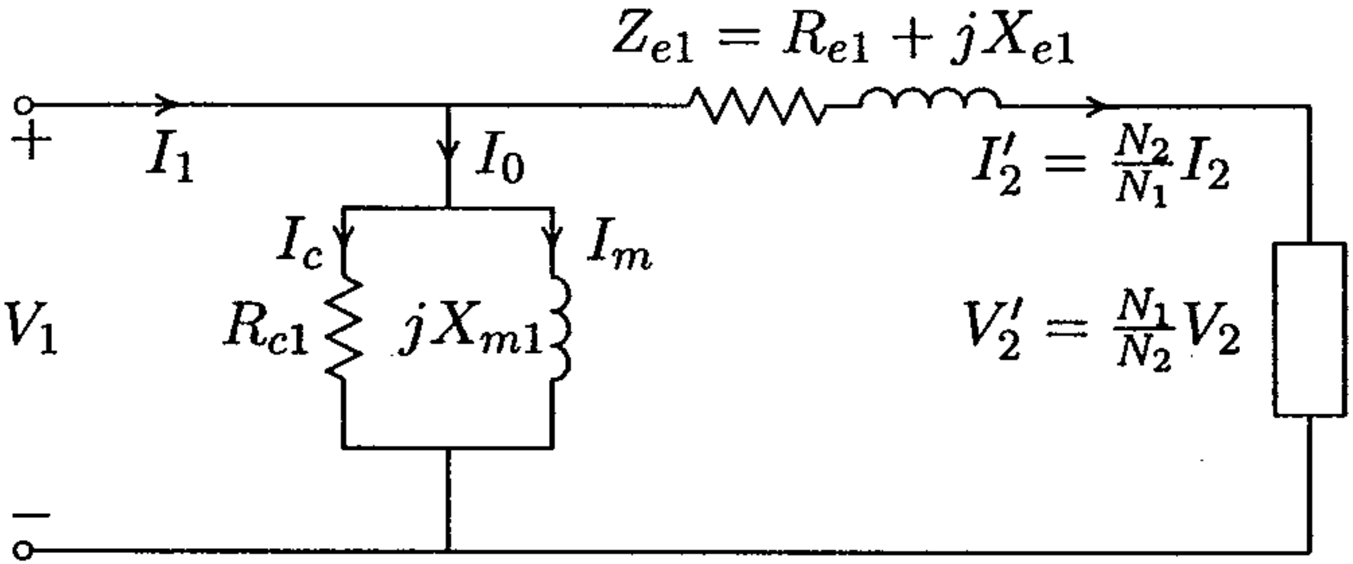


FIGURE 3.11
Approximate equivalent circuit referred to the primary.

$$V_1 = V_2' + (R_{e1} + jX_{e1})I_2'$$

where

$$R_{e1} = R_1 + \left(\frac{N_1}{N_2}\right)^2 R_2 \quad X_{e1} = X_1 + \left(\frac{N_1}{N_2}\right)^2 X_2 \text{ and } I_2' = \frac{S_L^*}{3V_2'^*}$$

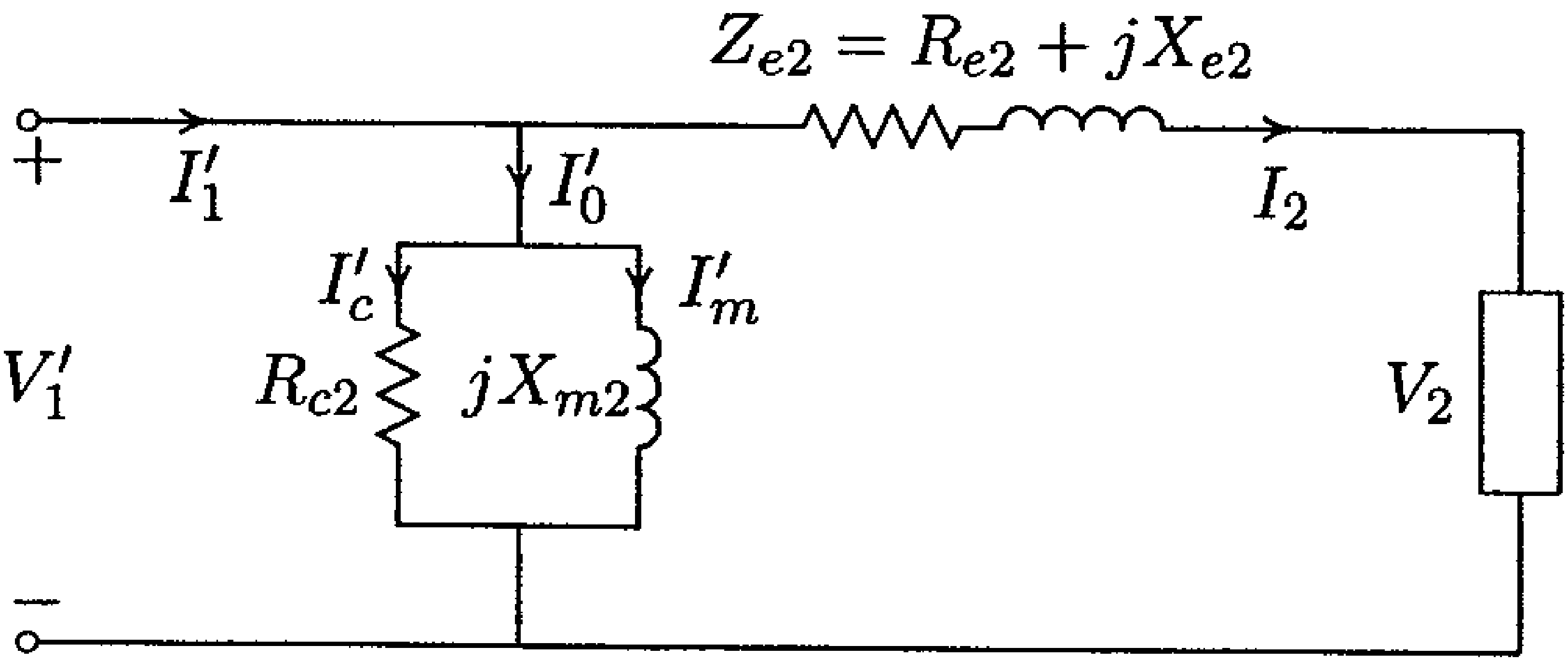


FIGURE 3.12
Approximate equivalent circuit referred to the secondary.

$$V_1' = V_2 + (R_{e2} + jX_{e2})I_2$$

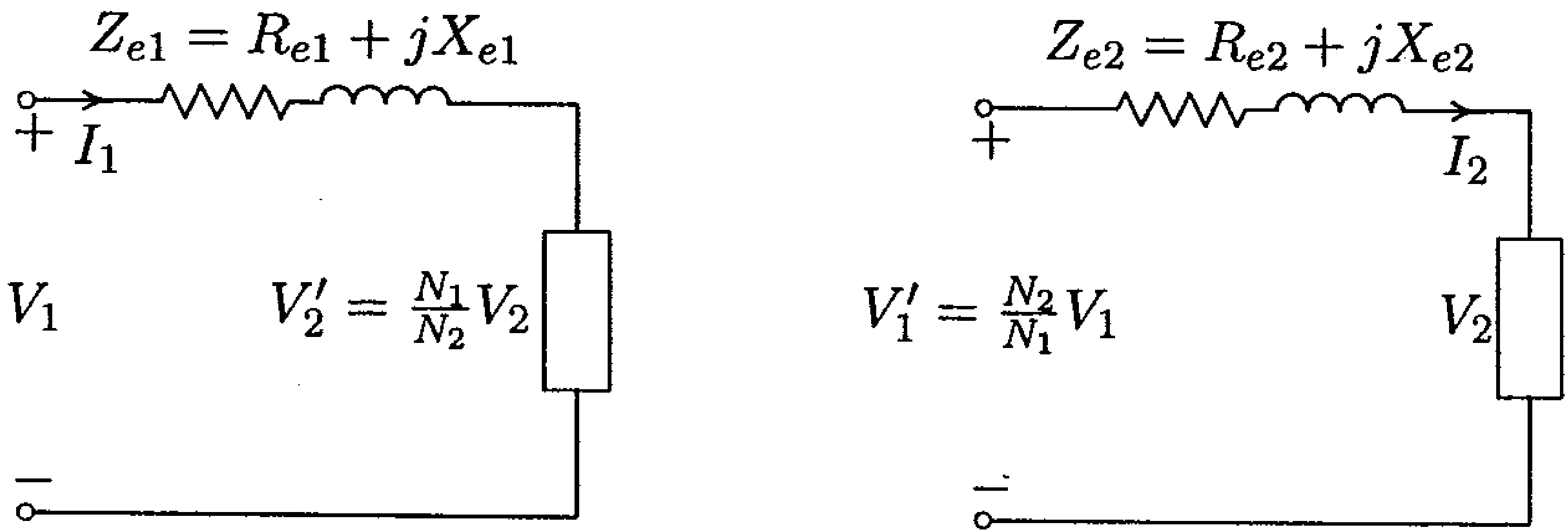


FIGURE 3.13
Simplified circuits referred to one side.

HUBUNGAN TRANFORMATOR TIGA PHASA

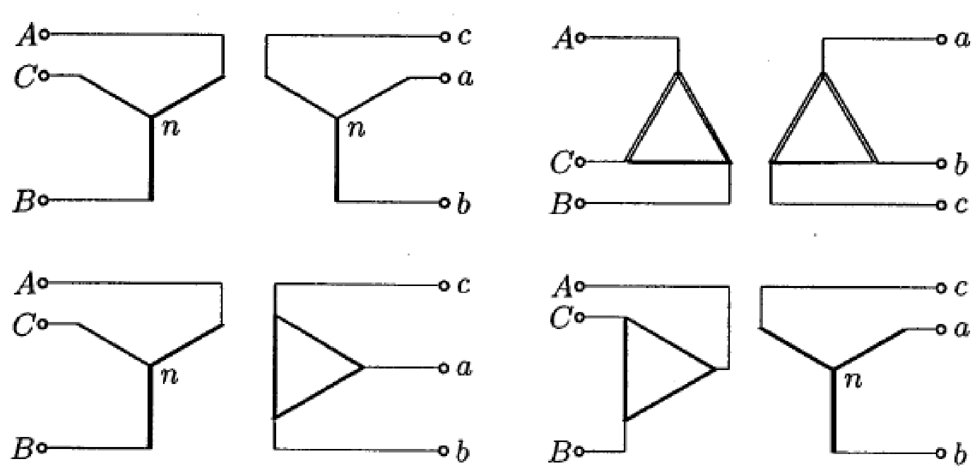


FIGURE 3.17
Three-phase transformer connections.

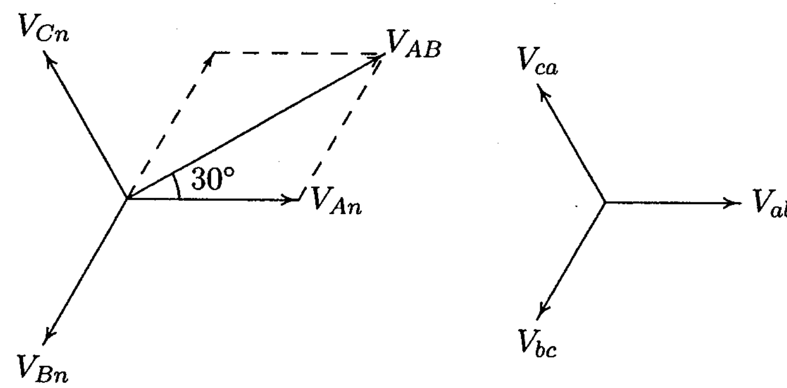


FIGURE 3.18
30° phase shift in line-to-line voltages of Y–Δ connection.

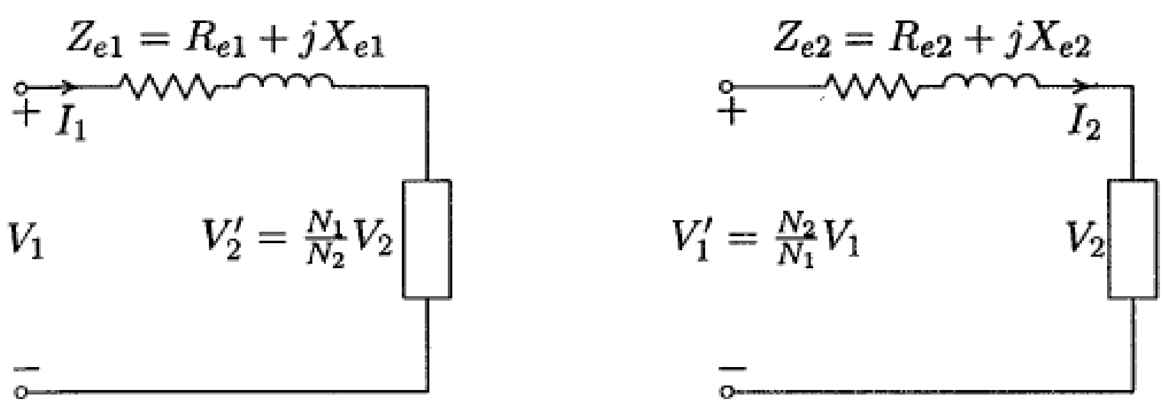
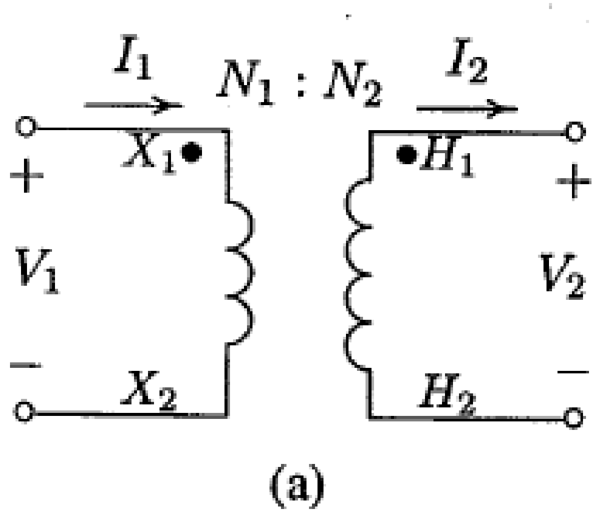


FIGURE 3.19
The per phase equivalent circuit.

AUTOTRANSFORMER



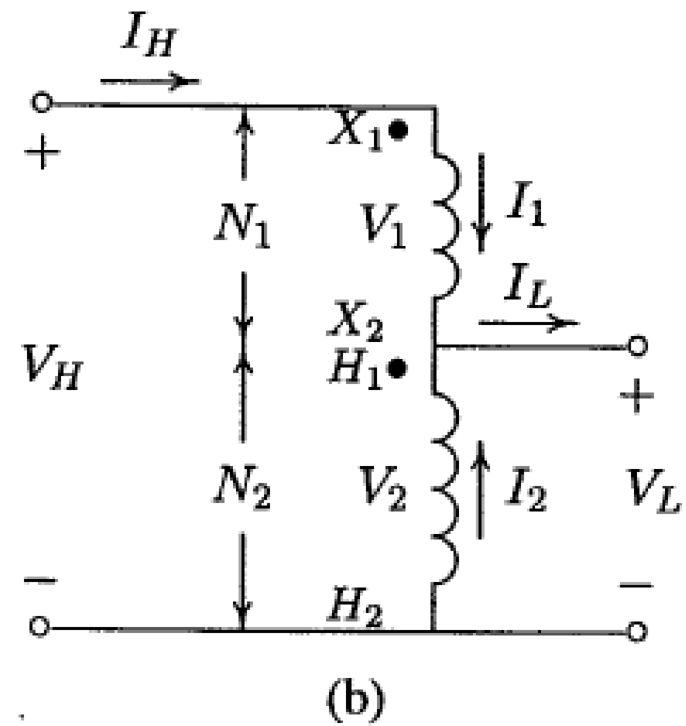


FIGURE 3.20
(a) Two-winding transformer, (b) reconnected as an autotransformer.

$$\frac{V_1}{V_2} = \frac{N_1}{N_2} = a$$

$$V_H = V_2 + V_1$$

$$V_H = V_L + \frac{N_1}{N_2} V_L = (1 + a) V_L$$

$$\frac{I_2}{I_1} = \frac{N_1}{N_2} = a$$

$$V_H = V_2 + \frac{N_1}{N_2} V_2$$

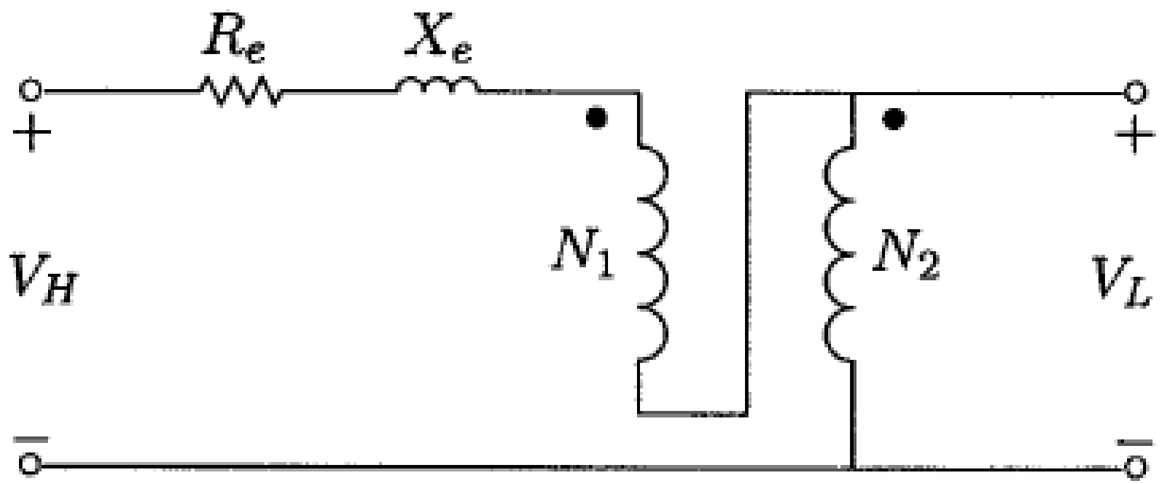


FIGURE 3.22
Autotransformer equivalent circuit.

TRANSFORMATOR TIGA BELITAN

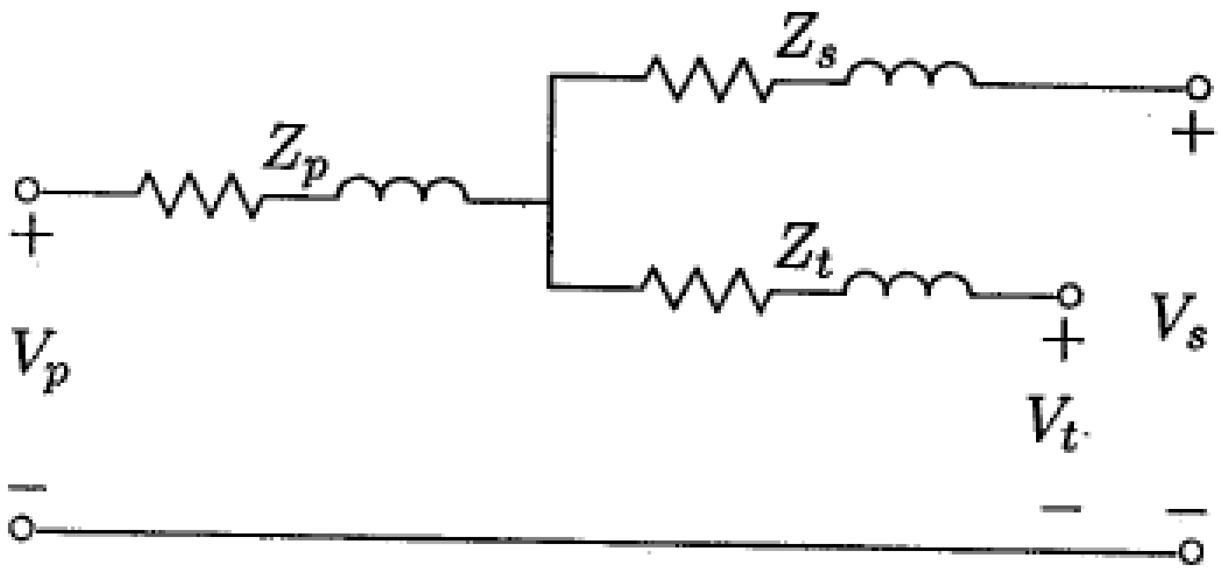


FIGURE 3.23
Equivalent circuit of three-winding transformer.

Z_{ps} = impedance measured in the primary circuit with the secondary short-circuited and the tertiary open.

Z_{pt} = impedance measured in the primary circuit with the tertiary short-circuited and the secondary open.

Z'_{st} = impedance measured in the secondary circuit with the tertiary short-circuited and the primary open.

Referring Z'_{st} to the primary side, we obtain

$$Z_{st} = \left(\frac{N_p}{N_s}\right)^2 Z'_{st}$$

If Z_p, Z_s, and Z_t are the impedances of the three separate windings referred to the primary side, then

$$\begin{aligned} Z_{ps} &= Z_p + Z_s \\ Z_{pt} &= Z_p + Z_t \\ Z_{st} &= Z_s + Z_t \end{aligned} \tag{3.68}$$

Solving the above equations, we have

$$\begin{aligned} Z_p &= \frac{1}{2}(Z_{ps} + Z_{pt} - Z_{st}) \\ Z_s &= \frac{1}{2}(Z_{ps} + Z_{st} - Z_{pt}) \\ Z_t &= \frac{1}{2}(Z_{pt} + Z_{st} - Z_{ps}) \end{aligned}$$

VOLTAGE CONTROL OF TRANSFORMERS

There are two types of tap changing transformers

(i) Off-load tap changing transformers.

(ii) Tap changing under load (TCUL) transformers.

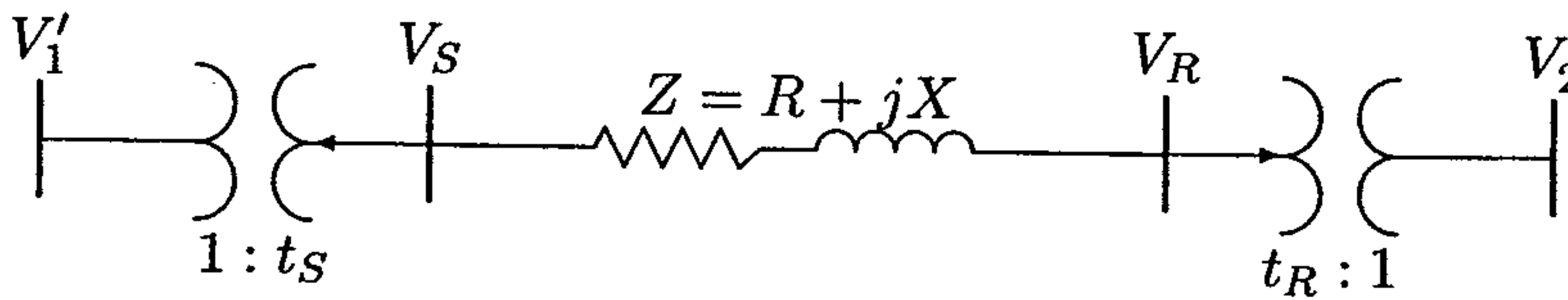


FIGURE 3.24
A radial line with tap changing transformers at both ends.

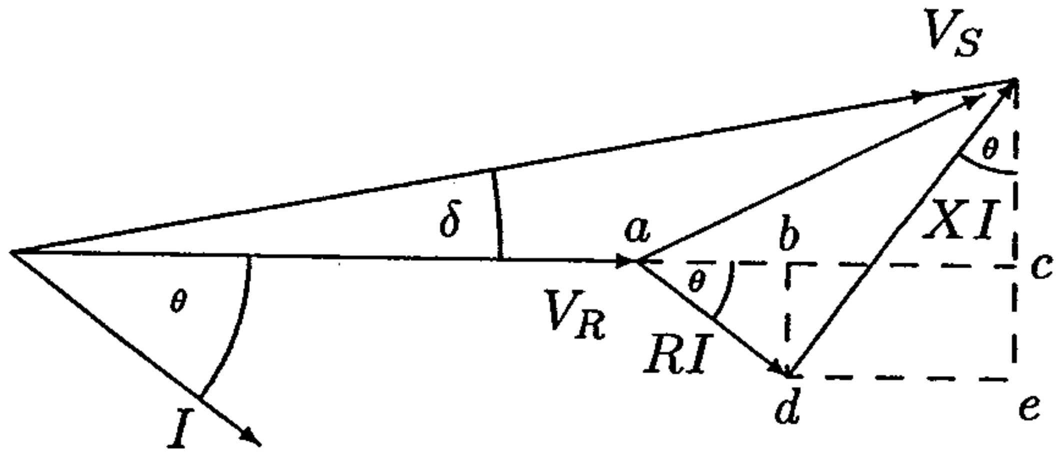


FIGURE 3.25
Voltage phasor diagram.

$$V_R = V_S + (R + jX)I$$

$$t_S = \sqrt{\frac{\frac{|V_2'|}{|V_1'|}}{1 - \frac{RP_\phi + XQ_\phi}{|V_1'||V_2'|}}}$$

MODEL TRANSMISI

- TRANSMIMISI PENDEK (< 80 km)

$$Z = (r + j\omega L)\ell$$
$$= R + jX$$

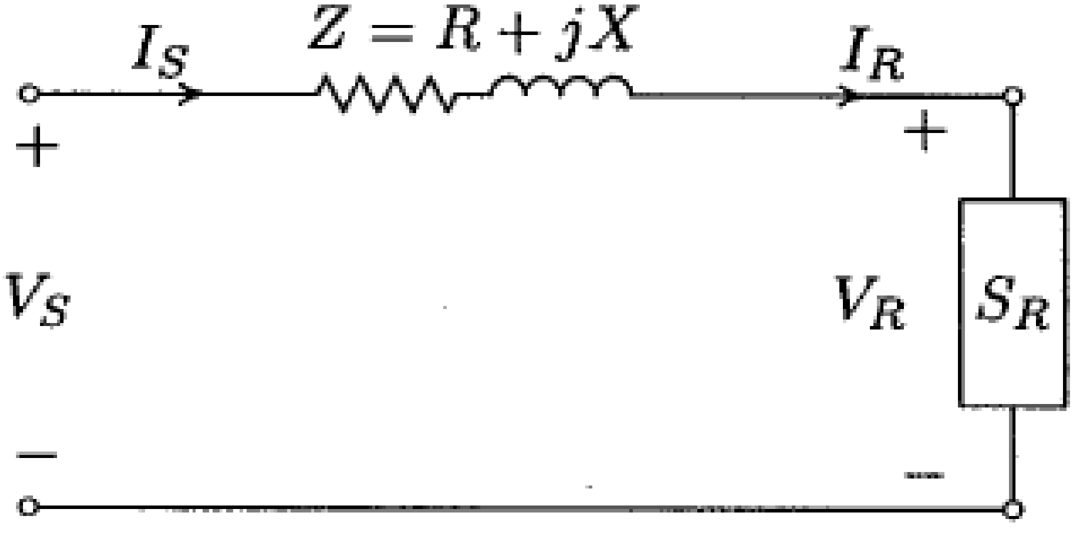


FIGURE 5.1
Short line model.

$$I_R = \frac{S^*_{R(3\phi)}}{3V^*_R}$$

$$V_S = V_R + ZI_R$$

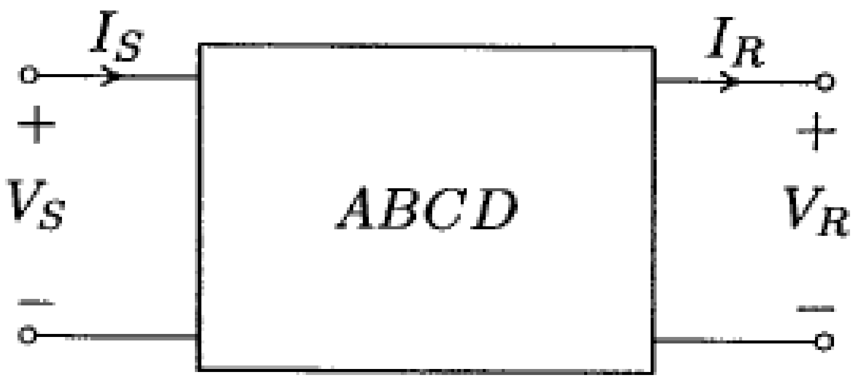


FIGURE 5.2
Two-port representation of a transmission line.

$$V_S = AV_R + BI_R \tag{5.5}$$
$$I_S = CV_R + DI_R \tag{5.6}$$

or in matrix form

$$\begin{bmatrix} V_S \\ I_S \end{bmatrix} = \begin{bmatrix} A & B \\ C & D \end{bmatrix} \begin{bmatrix} V_R \\ I_R \end{bmatrix} \tag{5.7}$$

According to (5.3) and (5.4), for short line model

$$A = 1 \qquad B = Z \qquad C = 0 \qquad D = 1 \tag{5.8}$$

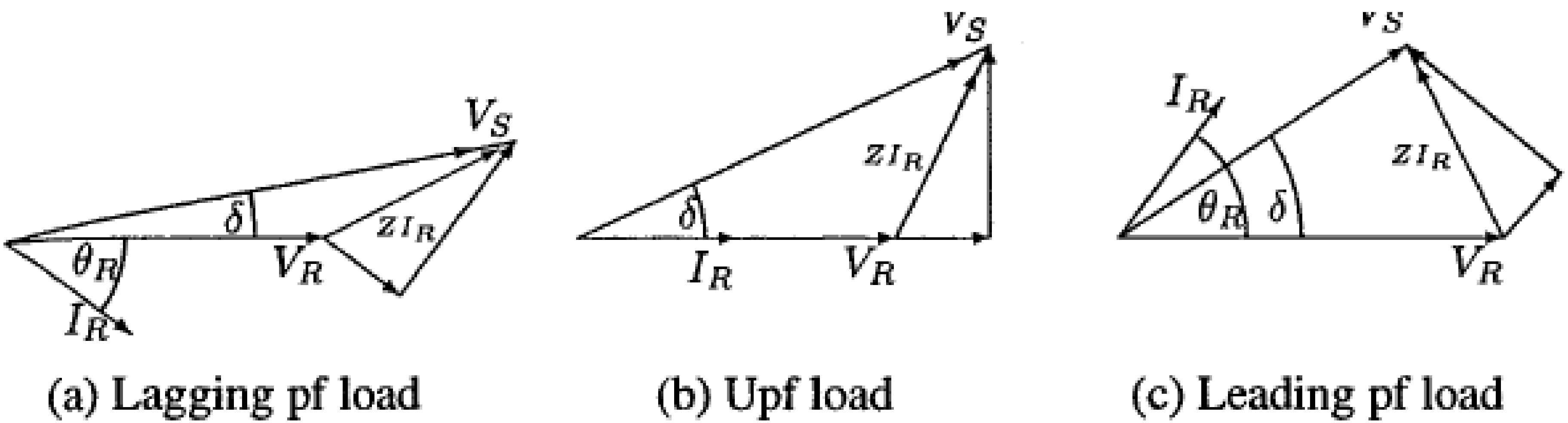


FIGURE 5.3
Phasor diagram for short line.

TRANSMISI MENENGAH (80km<L<250 km)

ADMITANSI SHUNT : $Y = (g + j\omega C)\ell$

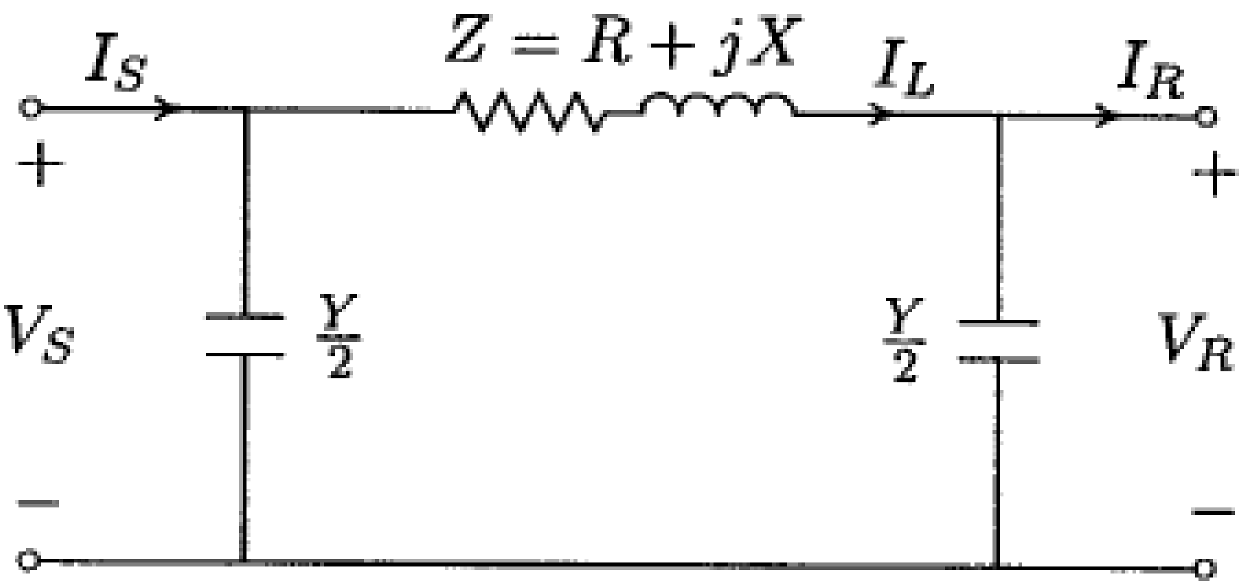


FIGURE 5.4
Nominal π model for medium length line.

From KCL the current in the series impedance designated by I_L is

$$I_L = I_R + \frac{Y}{2} V_R$$

From KVL the sending end voltage is

$$V_S = V_R + Z I_L$$

Substituting for I_L from (5.15), we obtain

$$V_S = \left(1 + \frac{ZY}{2}\right) V_R + Z I_R$$

The sending end current is

$$I_S = I_L + \frac{Y}{2} V_S$$

Substituting for I_L and V_S

$$I_S = Y\left(1+\frac{ZY}{4}\right)V_R + \left(1+\frac{ZY}{2}\right)I_R \tag{5.19}$$

Comparing (5.17) and (5.19) with (5.5) and (5.6), the $ABCD$ constants for the nominal π model are given by

$$A = \left(1+\frac{ZY}{2}\right) \qquad B = Z \tag{5.20}$$

$$C = Y\left(1+\frac{ZY}{4}\right) \qquad D = \left(1+\frac{ZY}{2}\right) \tag{5.21}$$

$$\begin{bmatrix} V_R \\ I_R \end{bmatrix} = \begin{bmatrix} D & -B \\ -C & A \end{bmatrix} \begin{bmatrix} V_S \\ I_S \end{bmatrix}$$

TRANSMISI PANJANG (>250 KM)

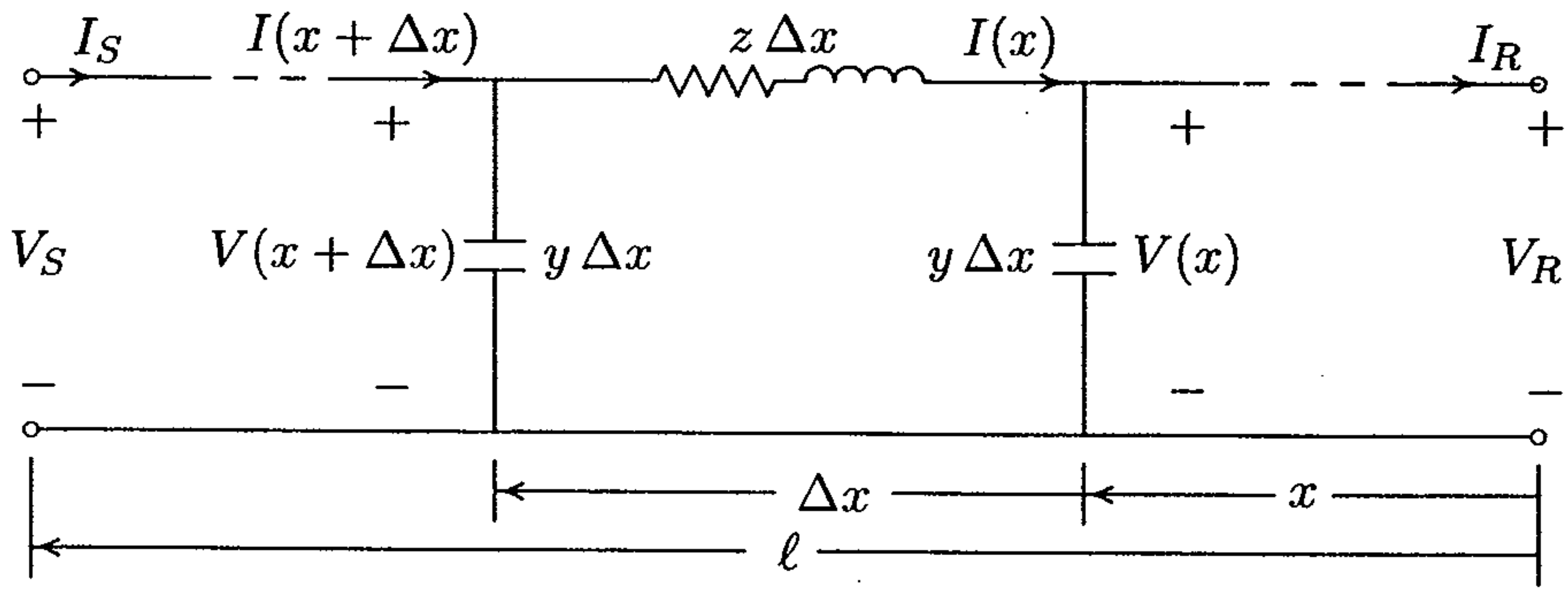


FIGURE 5.5
Long line with distributed parameters.

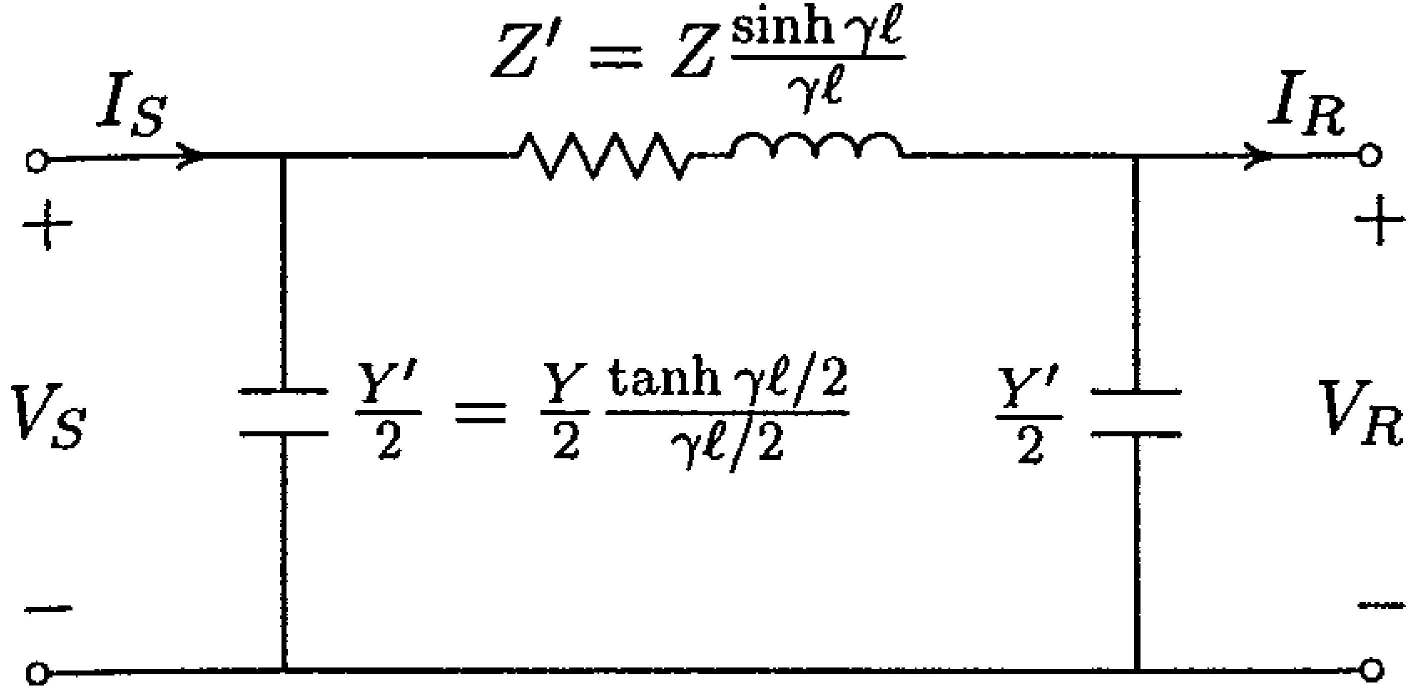


FIGURE 5.6
Equivalent π model for long length line.

$$Z' = Z_c \sinh \gamma\ell = Z\frac{\sinh \gamma\ell}{\gamma\ell}$$

$$\frac{Y'}{2} = \frac{1}{Z_c}\tanh\frac{\gamma\ell}{2} = \frac{Y}{2}\frac{\tanh \gamma\ell/2}{\gamma\ell/2}$$