

Circle diagram at no load ($\Phi_r=0$)

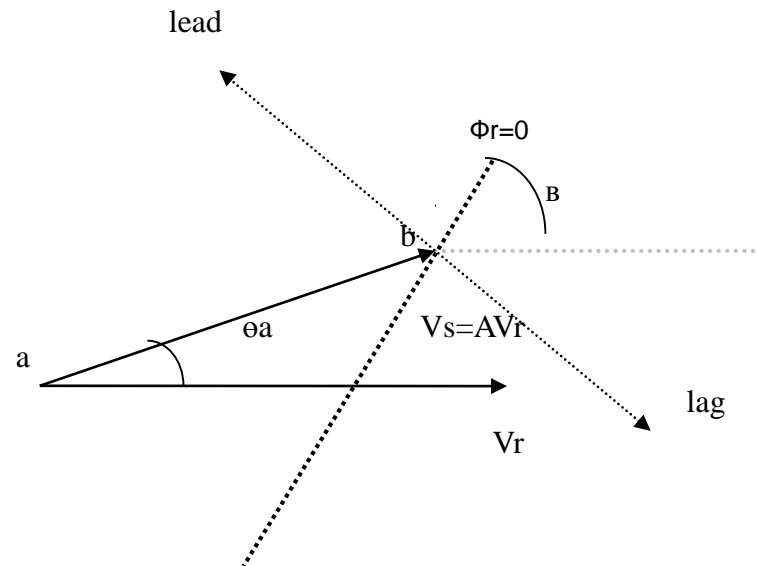
$$I_r = 0 \quad \phi_r = 0$$

$$V_s \angle \theta = A V_r \angle \theta_a + B I_r \angle \beta \pm \phi_r$$

$$V_s \angle \theta = A V_r \angle \theta_a$$

$$\theta = \theta_a$$

$$\overline{ab} = |V_s| = |A V_r|$$



Circle diagram at Lagging P.f ($\Phi_r = -ve$ value)

$$V_s \angle \theta = AV_r \angle \theta_a + BI_r \angle \beta - \phi_r$$

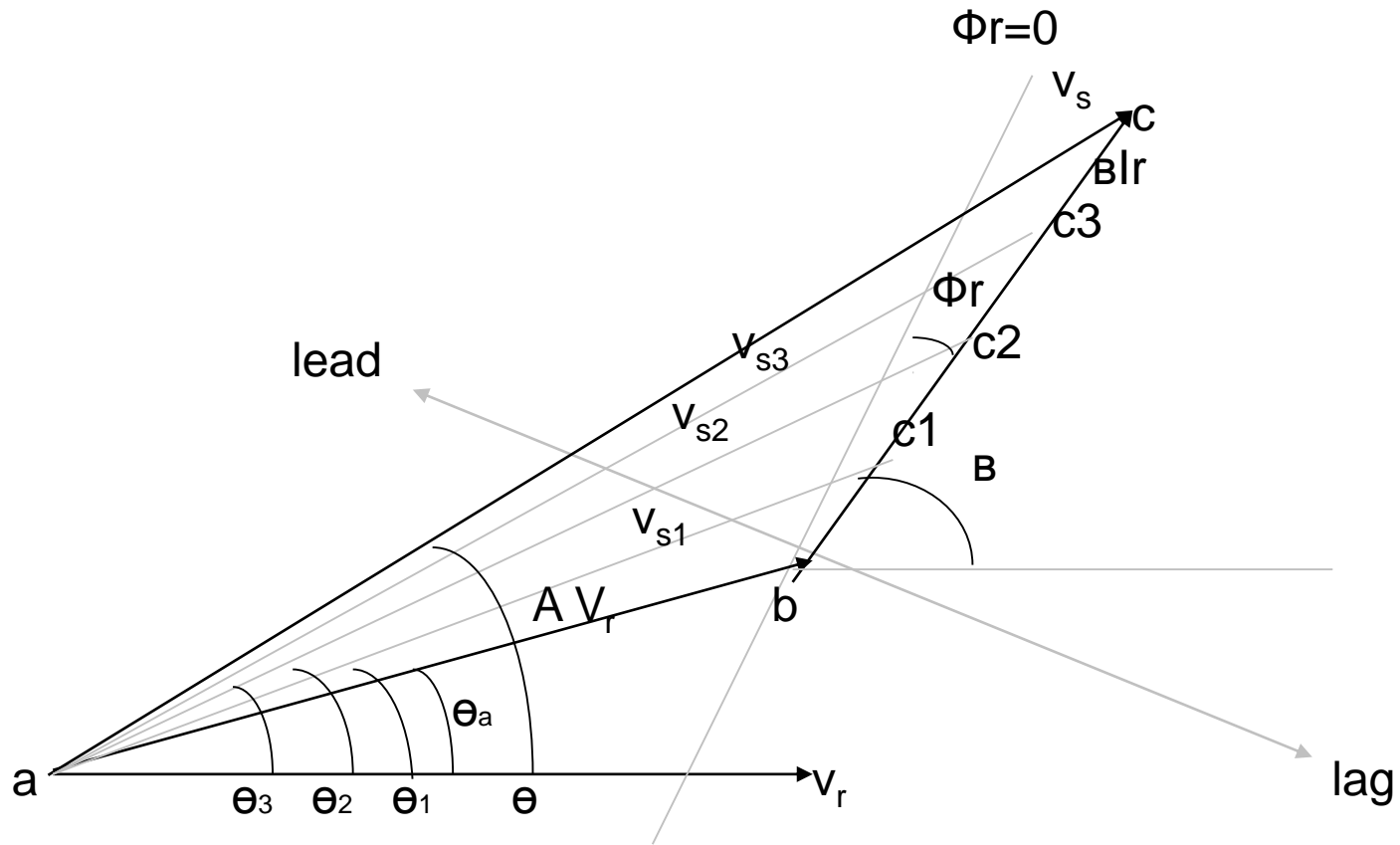
$$\overline{ac_1} = V_{s1} \quad \text{at } \frac{1}{4} \text{ load}$$

$$\overline{ac_2} = V_{s2} \quad \text{at } \frac{1}{2} \text{ load}$$

$$\overline{ac_3} = V_{s3} \quad \text{at } \frac{3}{4} \text{ load}$$

$$\overline{ac} = V_s \quad \text{at full load}$$

Continue



Circle diagram at Leading P.f ($\Phi_r = +ve$ value)

$$V_s \angle \theta = AV_r \angle \theta_a + BI_r \angle \beta + \phi_r$$

$$\overline{bc} = BI_r$$

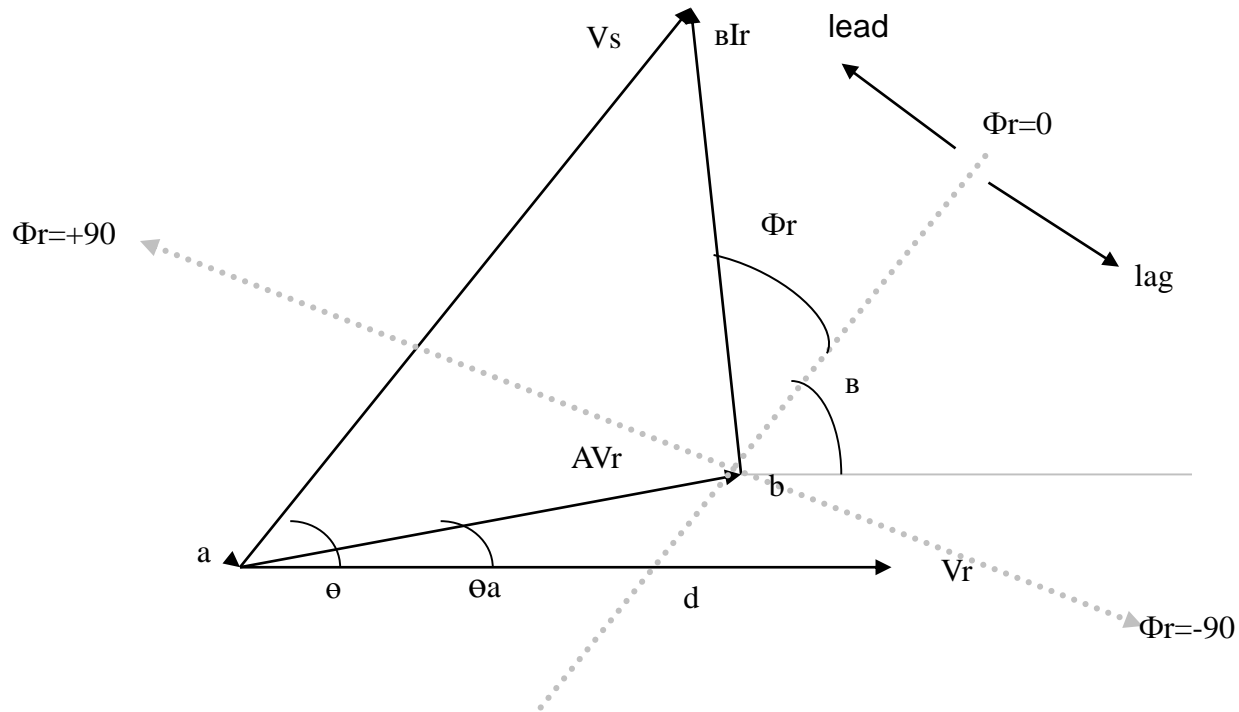
$$\overline{ac} = V_s$$

$$c\hat{a}d = \theta$$

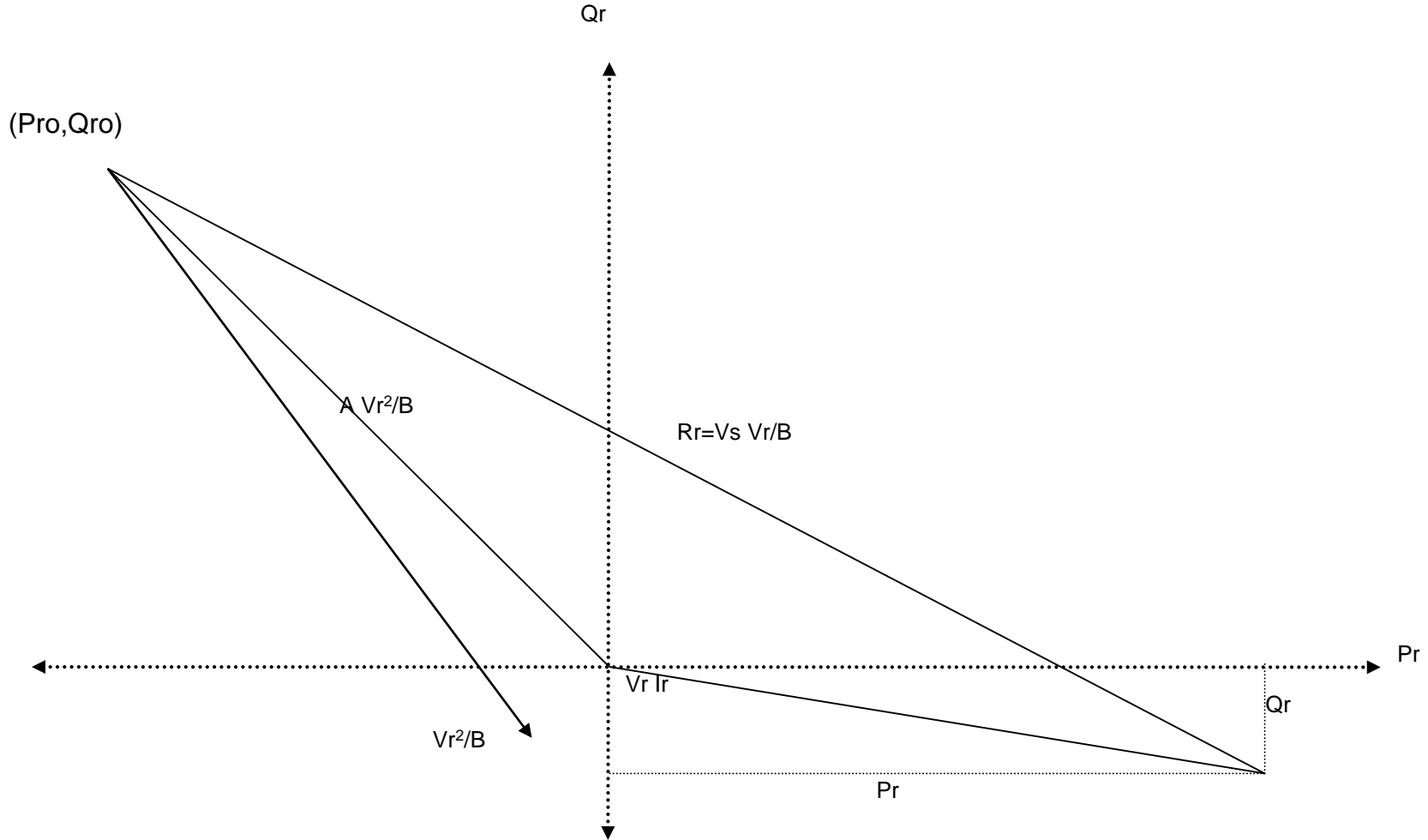
$$\overline{cD} = BI_r \sin \phi_r$$

$$\overline{bD} = BI_r \cos \phi_r$$

Continue



Receiving-End Power Circle Diagram



Continue

$$V_s = AV_r + BI_r \qquad I_r = \frac{V_s}{B} - \frac{AV_r}{B}$$

$$I_r^* = \frac{V_s^*}{B^*} - \frac{A^*V_r^*}{B^*}$$

$$P_r + jQ_r = V_r I_r^*$$

$$P_r + jQ_r = \left(-\frac{A^*V_r^*}{B^*} \right) V_r + \left(\frac{V_s^*}{B^*} \right) V_r$$

$$P_r + jQ_r = -\frac{A^*}{B^*} |V_r|^2 + \frac{|V_r V_s|}{B^*} e^{-j\theta}$$

Continue

$$P_{ro} = -\frac{AV_r^2}{B} \cos(\beta - \theta_a)$$

$$Q_{ro} = +\frac{AV_r^2}{B} \sin(\beta - \theta_a)$$

$$P_{ro} = -\frac{AV_r^2}{B} (\cos \beta \cos \theta_a + \sin \beta \sin \theta_a)$$

$$Q_{ro} = \frac{AV_r^2}{B} (\sin \beta \cos \theta_a - \cos \beta \sin \theta_a)$$

Continue

assume,

$$A = a_1 + ja_2 = A \angle \theta_a \quad , \quad B = b_1 + jb_2 = B \angle \beta$$

$$\sin \theta_a = \frac{a_2}{A} \quad \cos \theta_a = \frac{a_1}{A}$$

$$\sin \beta = \frac{b_2}{B} \quad \cos \beta = \frac{b_1}{B}$$

$$Q_{ro} = \frac{+AV_r^2}{B} \left[\frac{b_2a_1}{AB} - \frac{b_1a_2}{AB} \right] = \frac{+V_r^2}{B^2} [a_1b_2 - a_2b_1]$$

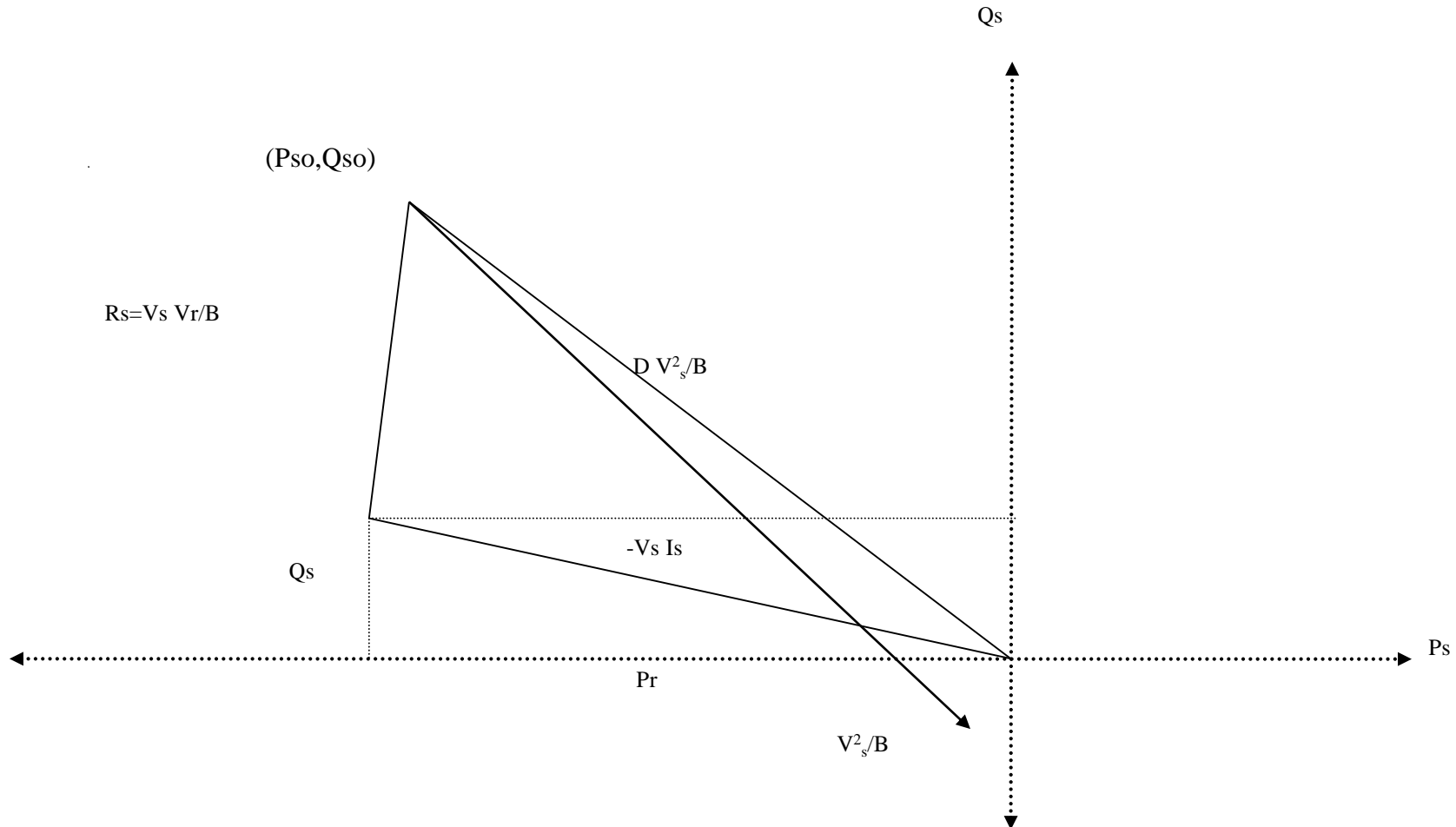
$$P_{ro} = \frac{-AV_r^2}{B} \left[\frac{b_1a_1}{AB} + \frac{b_2a_2}{AB} \right] = \frac{-V_r^2}{B^2} [a_1b_1 + a_2b_2]$$

Continue

$$(P_r - P_{r0})^2 + (Q_r - Q_{r0})^2 = R_r^2$$

$$\left(P_r + \frac{a_1 b_1 + a_2 b_2}{b_1^2 + b_2^2} V_r^2 \right)^2 + \left(Q_r - \frac{(a_1 b_2 - a_2 b_1)}{b_1^2 + b_2^2} V_r^2 \right)^2 = \frac{V_s^2 V_r^2}{b_1^2 + b_2^2}$$

Sending End Power Circle Diagram



Continue

$$\begin{aligned} DV_s - BI_s &= DAV_r - BCV_r + BDI_r - BDI_r \\ &= (DA - BC) = V_r \end{aligned}$$

$$\overline{oa} = \frac{DV_s^2}{B}$$

$$\overline{ab} = -\frac{BI_s V_s}{B} = -I_s V_s$$

$$\overline{ob} = \frac{V_s V_r}{B} = R_s$$

Continue

$$\overline{al} = I_s V_s \cos \phi_s = P_s$$

$$\overline{bl} = V_s I_s \sin \phi_s = Q_s$$

$$P_{so} = \overline{om} = \frac{D V_s^2}{B} \cos(\beta - \theta_a)$$

$$Q_{so} = \overline{on} = \frac{D V_s^2}{B} \sin(\beta - \theta_a)$$

Continue

$$V_r = DV_s - BI_s$$

$$= (d_1 + jd_2)V_s - (I_{sp} + jI_{sq})(b_1 + jb_2)$$

$$V_r = (d_1V_s - b_1I_{sp} + b_2I_{sq}) + j(d_2V_s - b_2I_{sp} - b_1I_{sq})$$

$$V_r^2 = (d_1^2 + d_2^2)V_s^2 + (b_1^2 + b_2^2)(I_{SP}^2 + I_{SQ}^2) \\ - 2(d_1b_1 + d_2b_2)V_sI_{sp} - 2(d_2b_1 - d_1b_2)V_sI_{sq}$$

Continue

$$\frac{V_r^2}{b_1^2 + b_2^2} = \frac{d_1^2 + d_2^2}{b_1^2 + b_2^2} V_s^2$$
$$+ \left[I_{sp}^2 - 2 \frac{(d_1 b_1 + d_2 b_2)}{b_1^2 + b_2^2} V_s I_{sp} \right] + \left[I_{sq}^2 - 2 \frac{(d_2 b_1 - d_1 b_2)}{b_1^2 + b_2^2} V_s I_{sq} \right]$$
$$\frac{V_r^2 V_s^2}{b_1^2 + b_2^2} = \left[I_{sp} V_s - \frac{(d_1 b_1 + d_2 b_2)}{b_1^2 + b_2^2} V_s^2 \right]^2$$
$$+ \left[I_{sq} V_s + \frac{(-d_2 b_1 + d_1 b_2)}{b_1^2 + b_2^2} V_s^2 \right]^2$$

Continue

$$R_s^2 = (P_s - P_{so})^2 + (Q_s - Q_{so})^2$$

$$P_{so} = + \frac{(d_1 b_1 + d_2 b_2)}{b_1^2 + b_2^2} V_s^2$$

$$Q_{so} = - \frac{(d_2 b_1 + d_1 b_2)}{b_1^2 + b_2^2} V_s^2$$

$$R_s = \frac{V_s V_r}{B}$$

Continue

from R.E. PCD:

$$\left[P_r + \frac{a_1 b_1 + a_2 b_2}{b_1^2 + b_2^2} V_r^2 \right]^2 + \left[Q_r - \frac{(a_1 b_2 - a_2 b_1)}{b_1^2 + b_2^2} V_r^2 \right]^2 = \frac{V_s^2 V_r^2}{B^2}$$

from S.E. PCD:

$$\left[P_s - \frac{d_1 b_1 + d_2 b_2}{b_1^2 + b_2^2} V_s^2 \right]^2 + \left[Q_s + \frac{(d_1 b_2 - d_2 b_1)}{b_1^2 + b_2^2} V_s^2 \right]^2 = \frac{V_s^2 V_r^2}{B^2}$$

$$\left[P_r \left(\frac{V_b}{V_r} \right)^2 + \frac{a_1 b_1 + a_2 b_2}{b_1^2 + b_2^2} V_b^2 \right]^2 + \left[Q_r \left(\frac{V_b}{V_r} \right)^2 - \frac{(a_1 b_2 - a_2 b_1)}{b_1^2 + b_2^2} V_b^2 \right]^2 = \frac{V_s^2 V_b^4}{V_r^2 B^2}$$

Continue

$$\left[P_s \left(\frac{V_b}{V_s} \right)^2 - \frac{a_1 b_1 + a_2 b_2}{b_1^2 + b_2^2} V_b^2 \right]^2 + \left[Q_s \left(\frac{V_b}{V_s} \right)^2 + \frac{(a_1 b_2 - a_2 b_1)}{b_1^2 + b_2^2} V_b^2 \right]^2$$
$$= \frac{V_b^4 V_r^2}{V_s^2 B^2}$$

$$\left(\bar{P}_r + \bar{P}_{ro} \right)^2 + \left(\bar{Q}_r - \bar{Q}_{ro} \right)^2 = \bar{R}_r^2$$

$$\left(\bar{P}_s - \bar{P}_{so} \right)^2 + \left(\bar{Q}_s + \bar{Q}_{so} \right)^2 = \bar{R}_s^2$$

Continue

It is noted that :

$$\bar{P}_{ro} = -\bar{P}_{so} = \frac{a_1 b_1 + a_2 b_2}{b_1^2 + b_2^2} V_b^2$$

$$\bar{Q}_{ro} = -\bar{Q}_{so} = \frac{a_1 b_2 - a_2 b_1}{b_1^2 + b_2^2} V_b^2$$

$$\bar{R}_r = \frac{V_s V_b^2}{V_r B}$$

$$\bar{R}_s = \frac{V_r V_b^2}{V_s B}$$

$$\bar{P}_r = P_r \left(\frac{V_b}{V_r} \right)^2$$

$$\bar{Q}_r = Q_r \left(\frac{V_b}{V_r} \right)^2$$

$$\bar{P}_s = P_s \left(\frac{V_b}{V_s} \right)^2$$

$$\bar{Q}_s = Q_s \left(\frac{V_b}{V_s} \right)^2$$