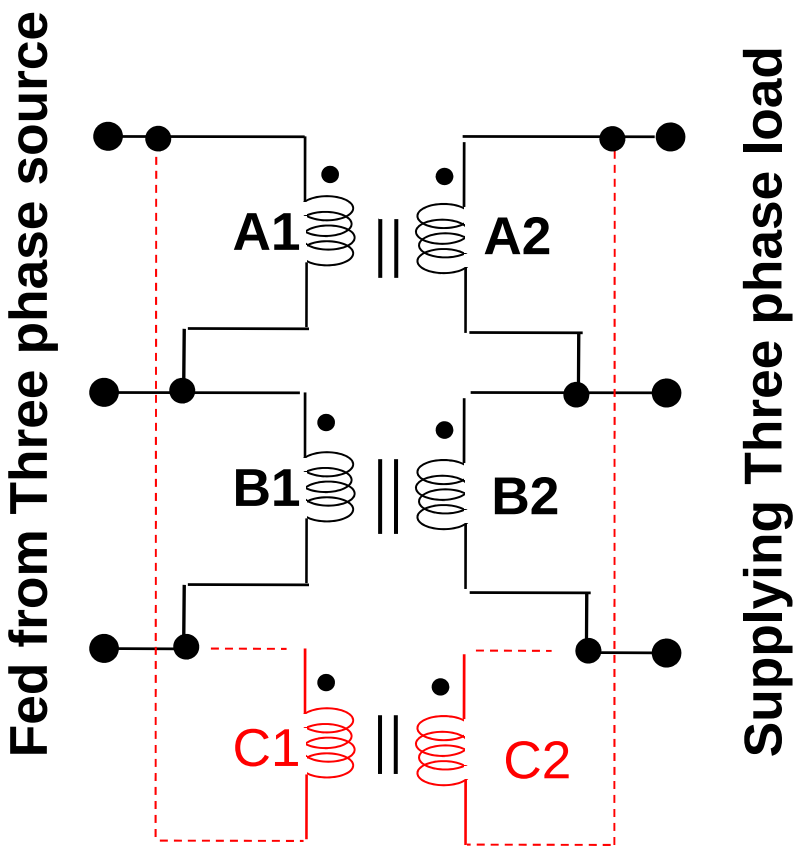
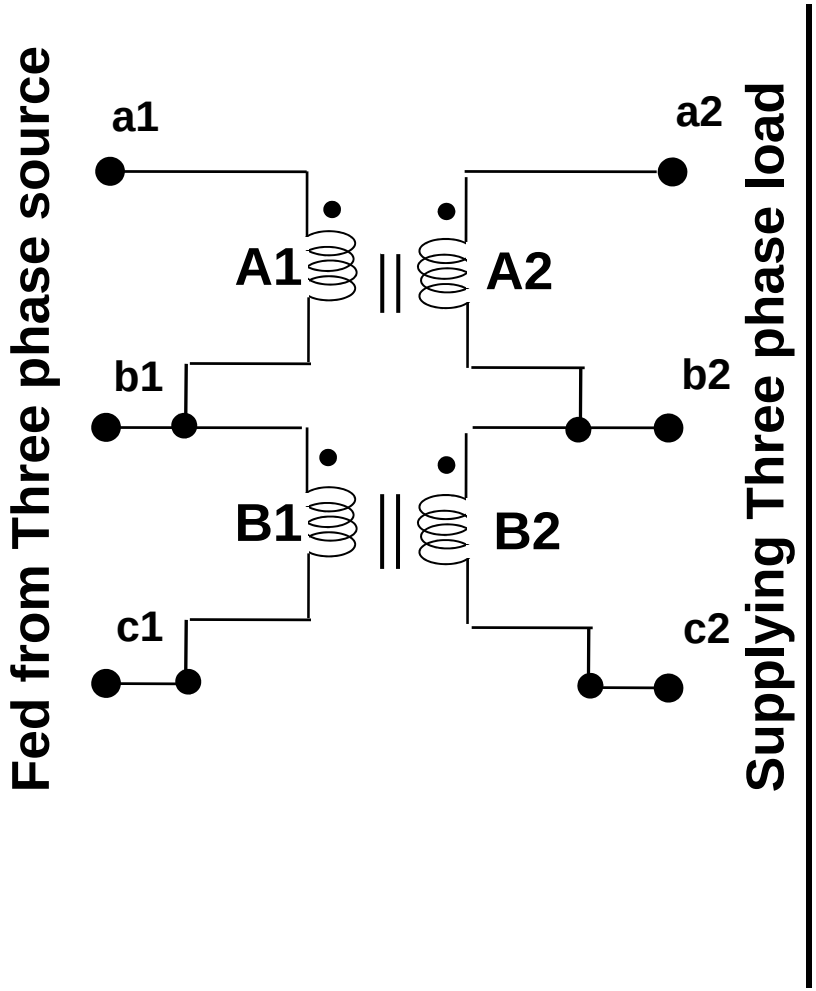
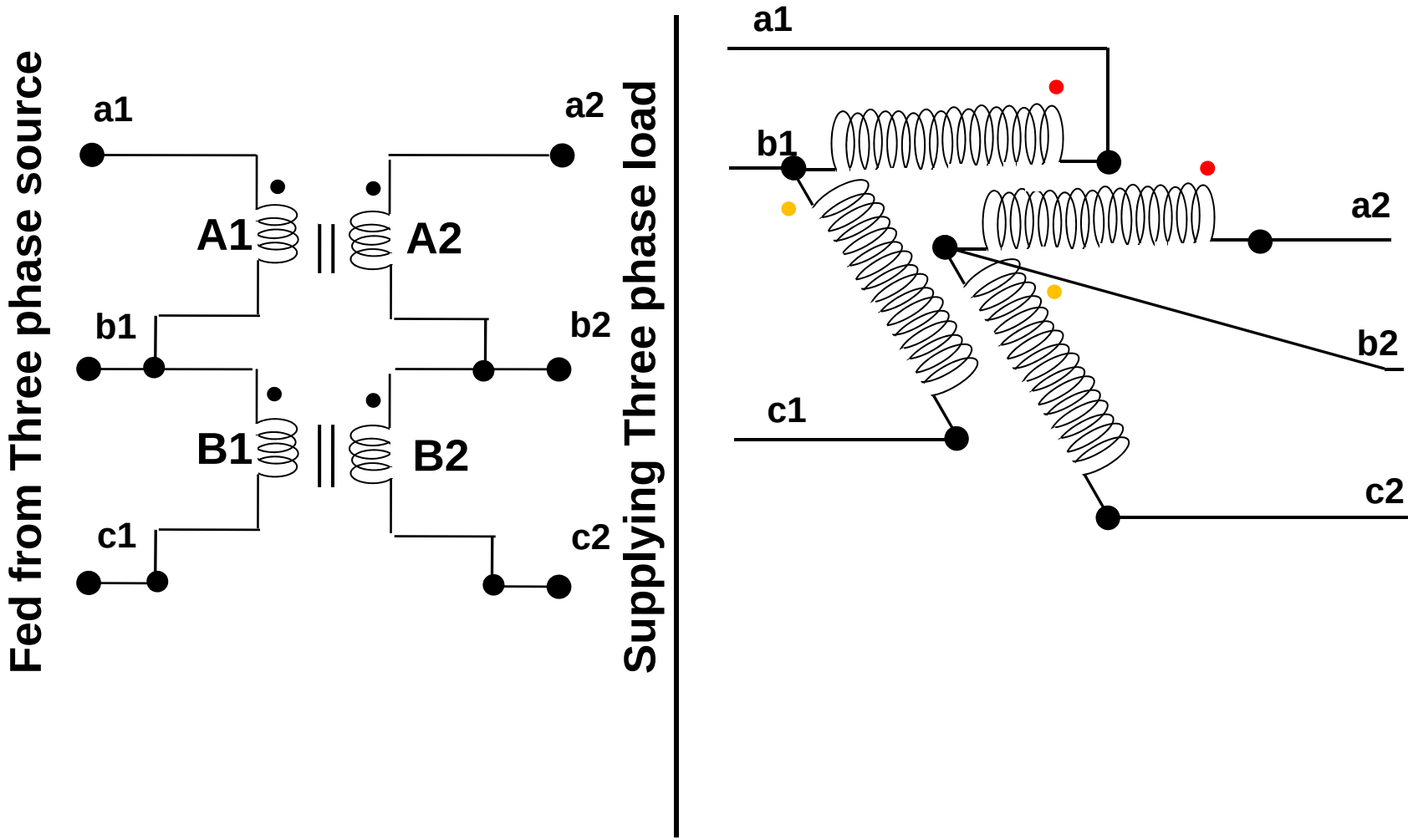
Open delta


Fed from Three phase source
A1
A2
B1
B2
C1
C2
Supplying Three phase load

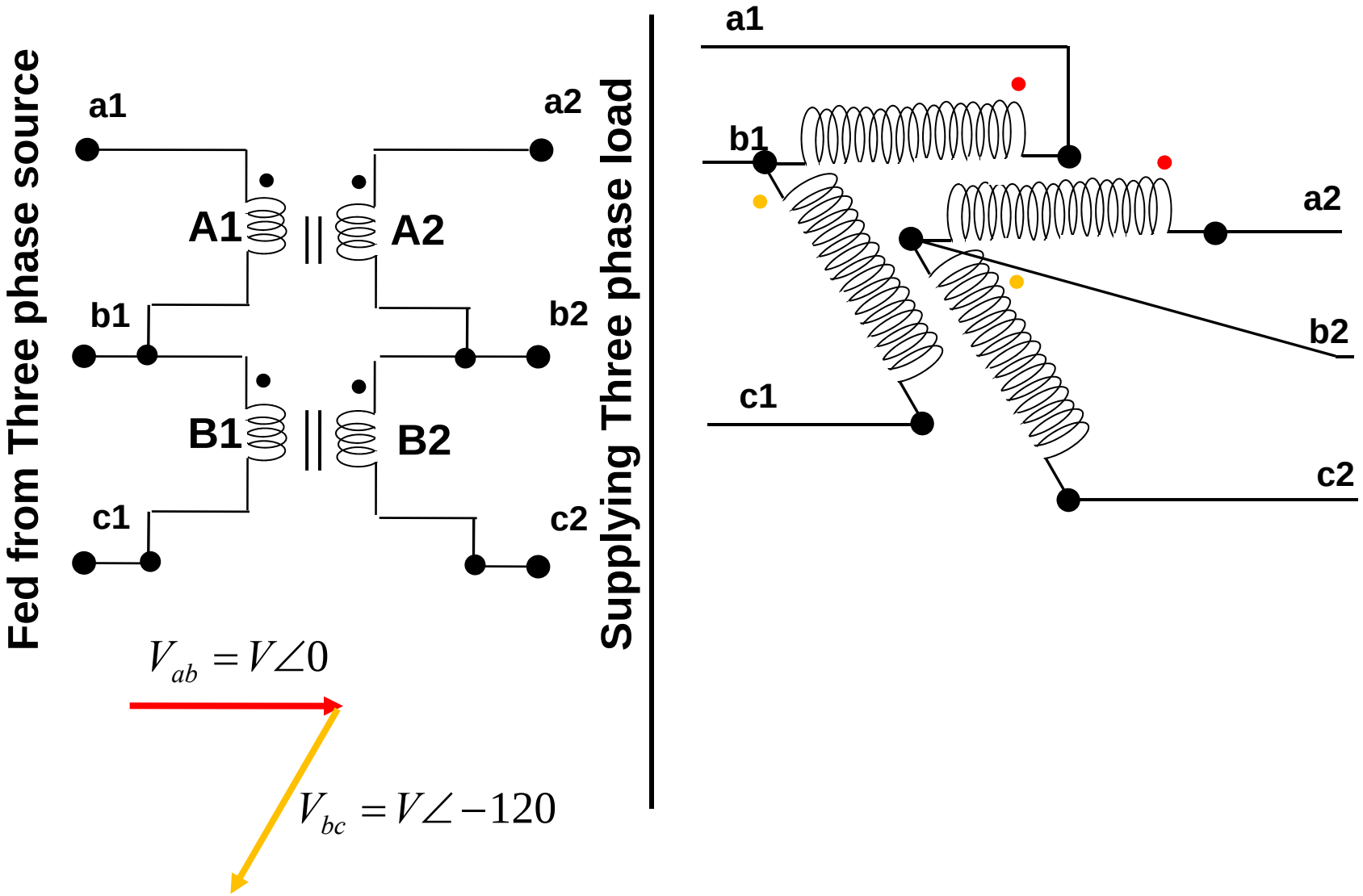
Open delta


Fed from Three phase source
a1
A1
b1
B1
c1
a2
A2
b2
B2
c2
Supplying Three phase load

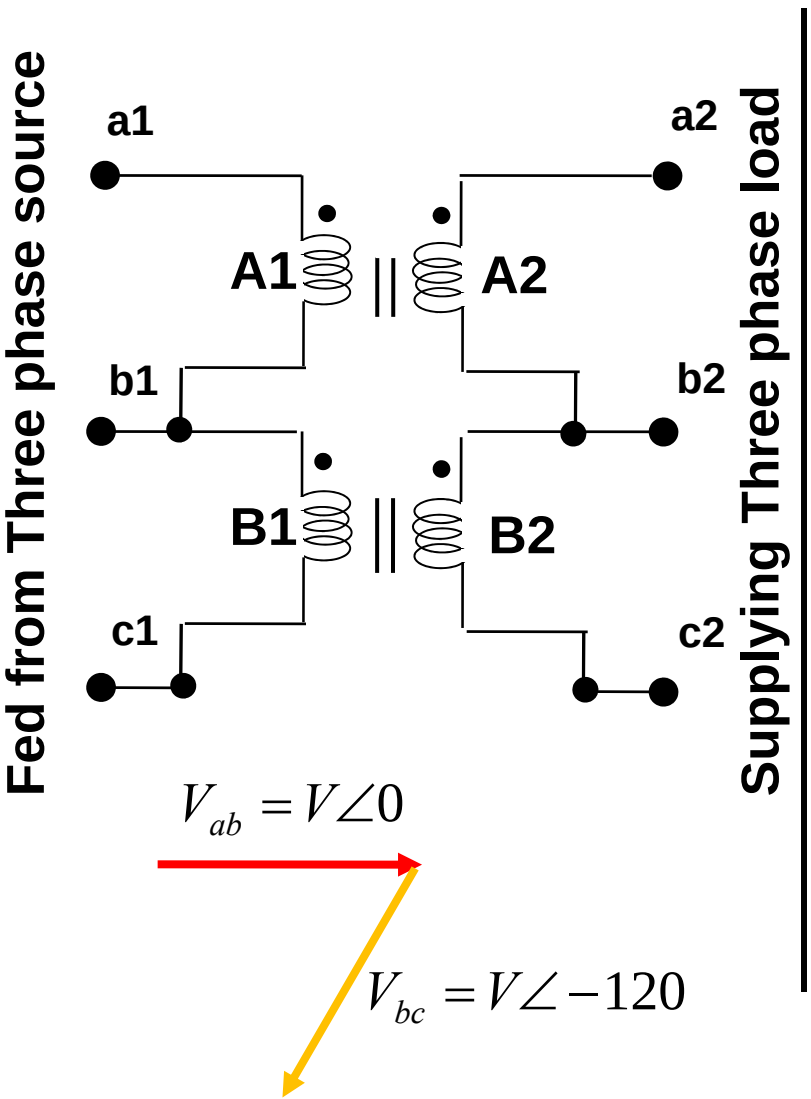
Open delta

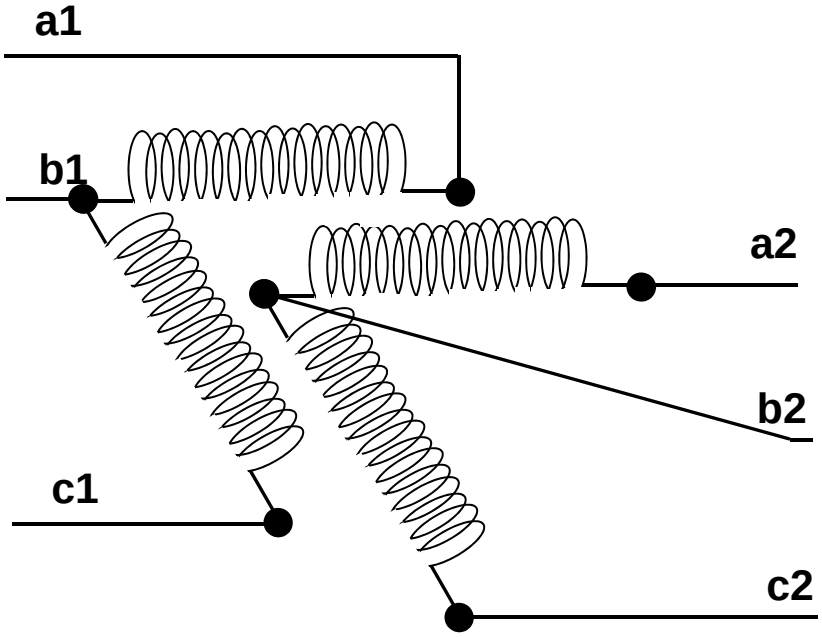

Fed from Three phase source
a1
a2
A1
A2
b1
b2
B1
B2
c1
c2
Supplying Three phase load
a1
b1
a2
b2
c1
c2

Open delta


Fed from Three phase source
a1
a2
A1
A2
b1
b2
B1
B2
c1
c2
$V_{ab} = V\angle 0$
$V_{bc} = V\angle -120$
Supplying Three phase load
a1
b1
a2
b2
c1
c2

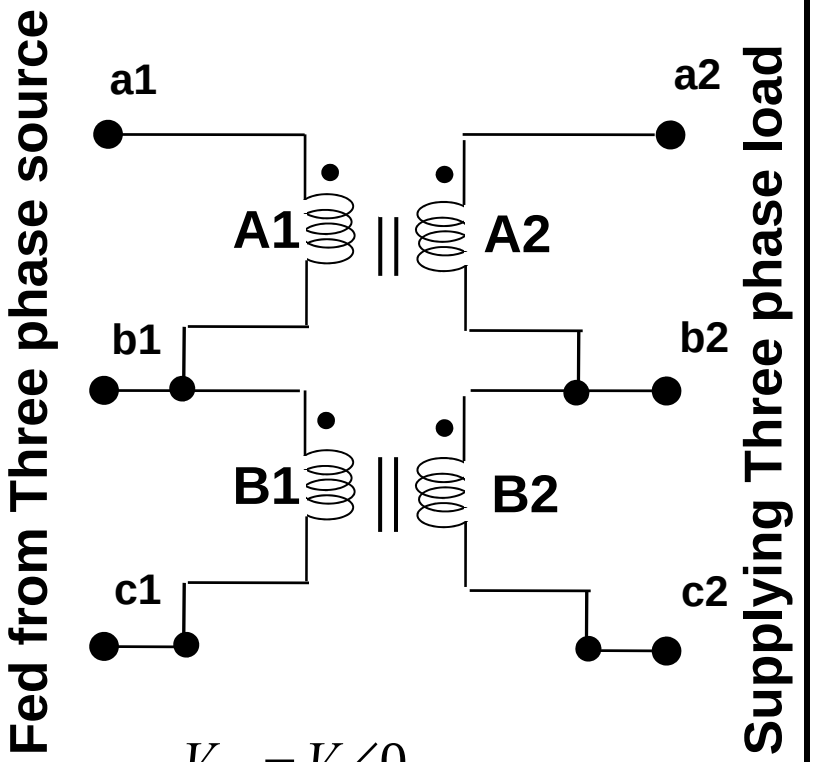
Open delta

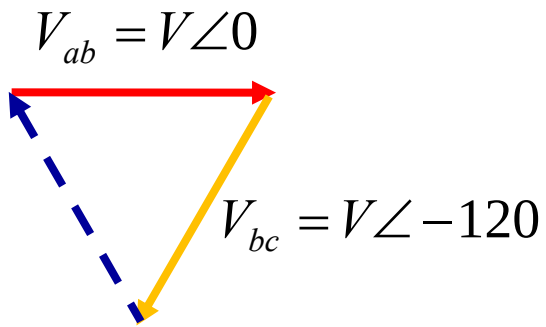


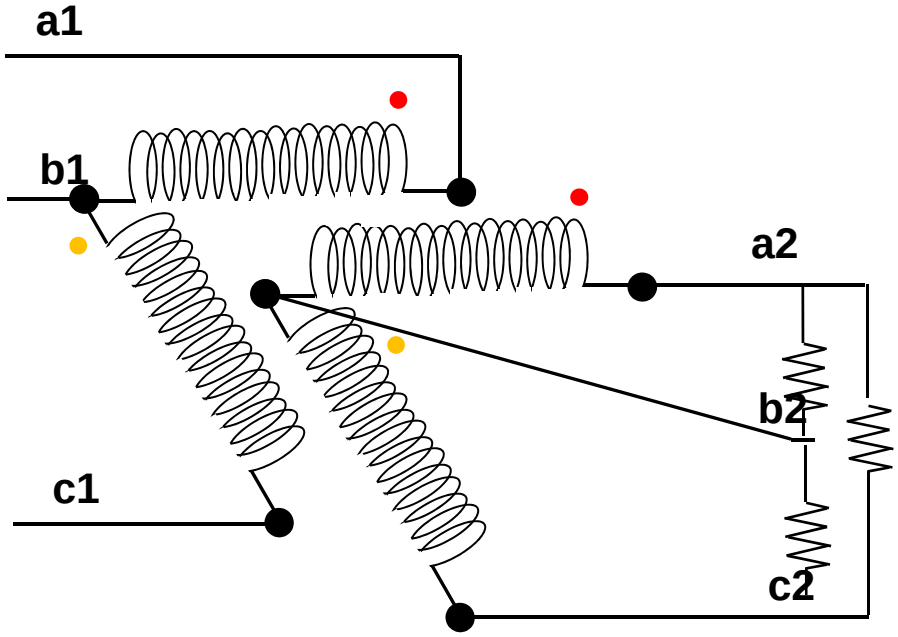


Applying KVL in loop $a_2b_2c_2a_2$:

Open delta



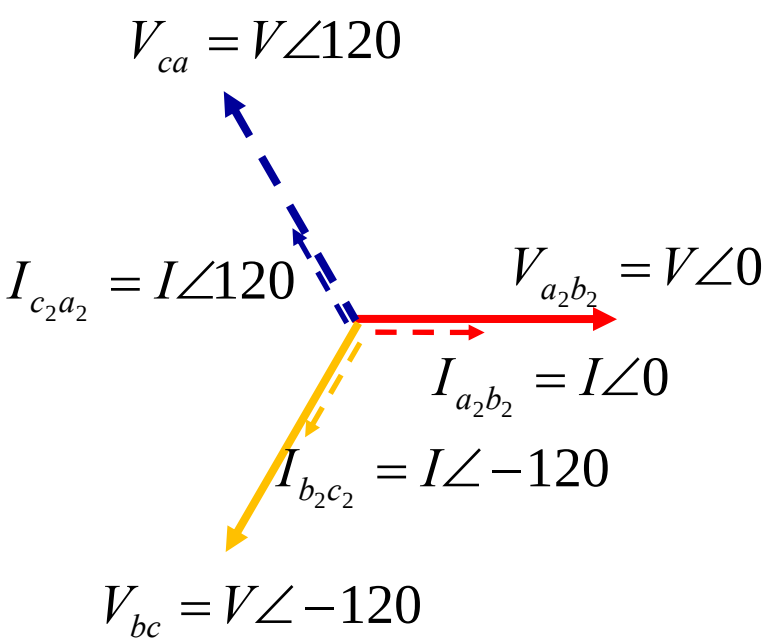


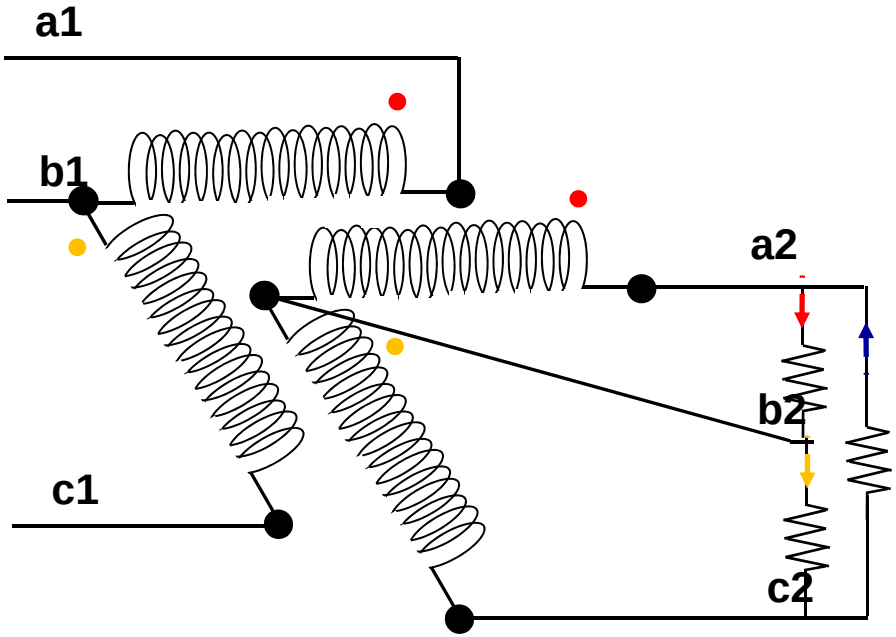


Applying KVL in loop $a_2b_2c_2a_2$:

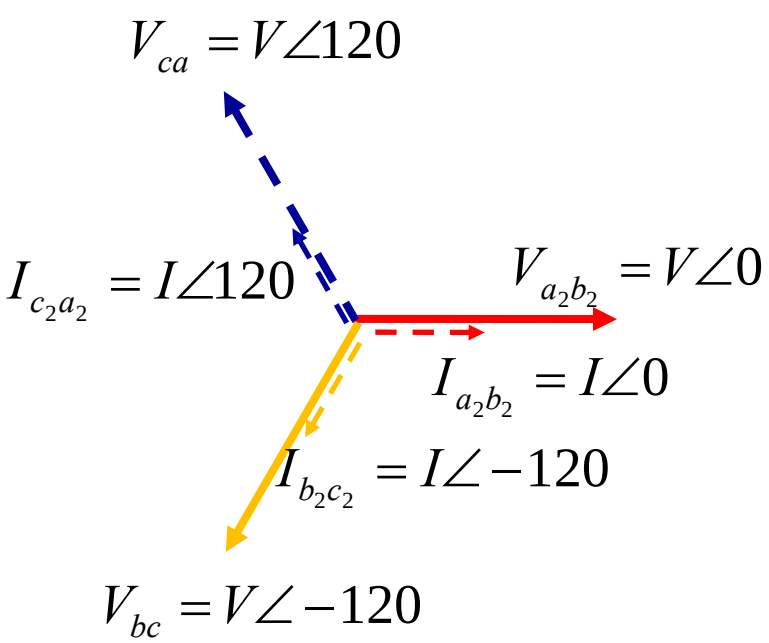
$$V_{ca} = -[V_{ab} + V_{bc}]$$
$$= -V\angle 0 - V\angle -120$$
$$= -V + 0.5V + j0.866V$$
$$= (0.5 + j0.866)V$$
$$= V\angle 120$$

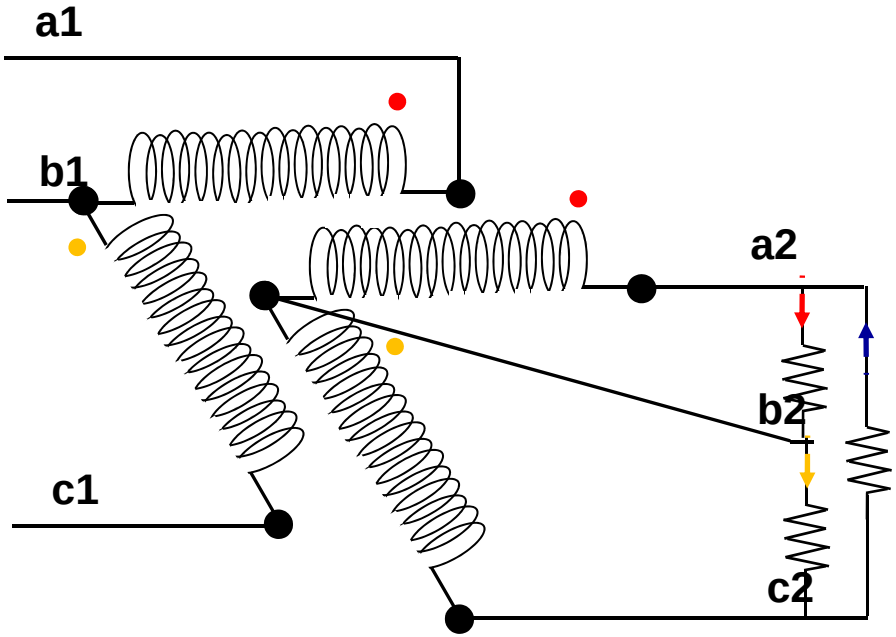
Phase load currents and line currents in open delta:



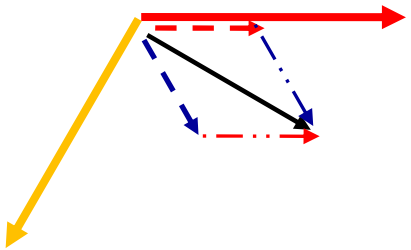


Phase load currents and line currents in open delta:





$$I_{a_2} = I_{a_2b_2} - I_{c_2a_2} = I\angle 0 - I\angle 120 = I\angle -30$$



Phase load currents and line currents in open delta:

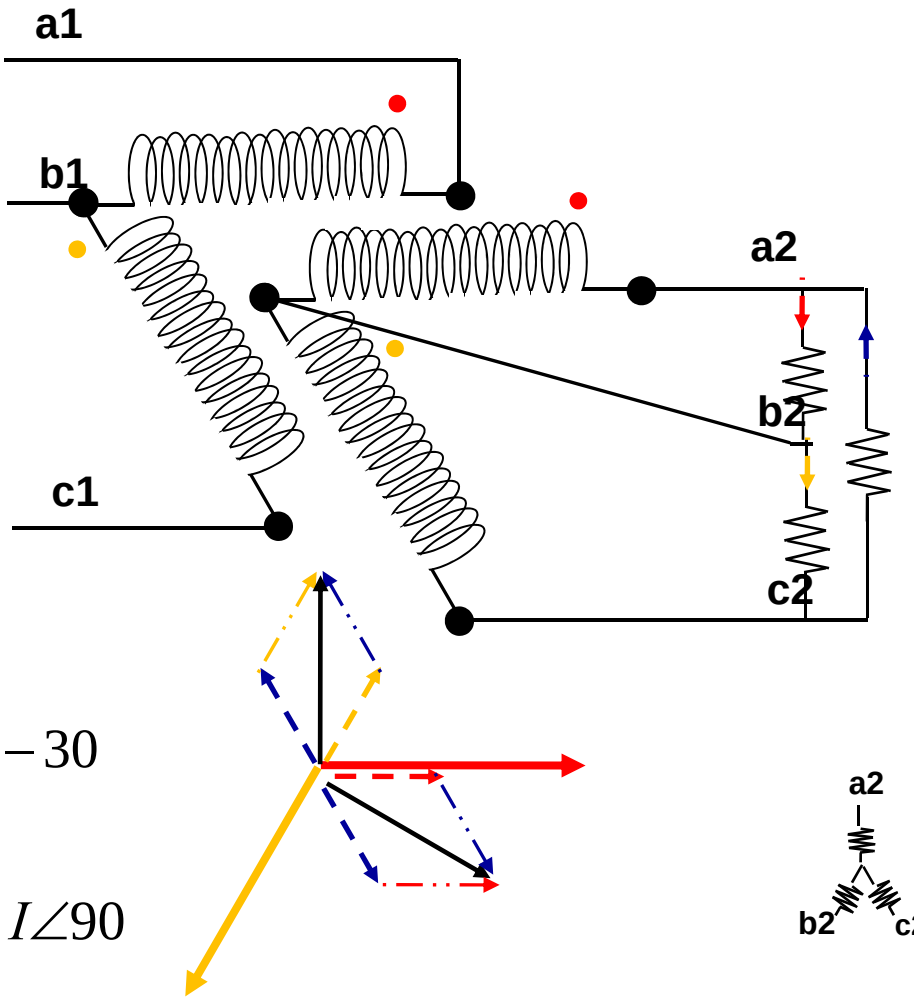
$$V_{ca} = V\angle 120$$

$$I_{c_2a_2} = I\angle 120 \qquad V_{a_2b_2} = V\angle 0$$

$$I_{a_2b_2} = I\angle 0$$

$$I_{b_2c_2} = I\angle -120$$

$$V_{b_2c_2} = V\angle -120$$

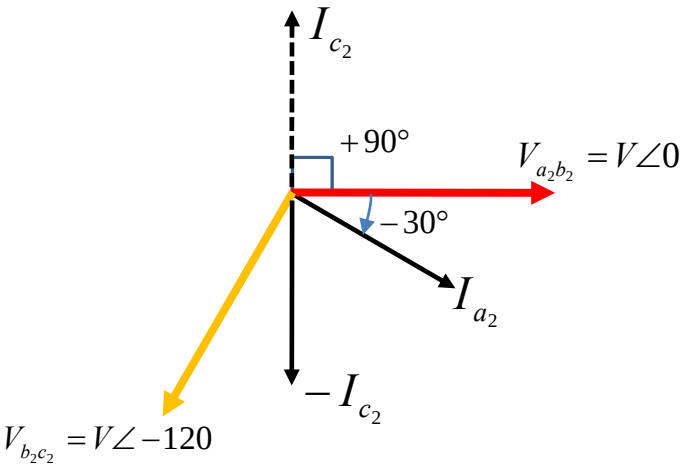


$$I_{a_2} = I_{a_2b_2} - I_{c_2a_2} = I\angle 0 - I\angle 120 = I\angle -30$$

$$I_{c_2} = I_{c_2a_2} - I_{b_2c_2} = I\angle 120 - I\angle -120 = I\angle 90$$

N.B.: Line currents have the same values and angles even if the load was star connected

Active & reactive power of open delta:



1^{st} *Transformer* :

$$V_{a_2b_2} = V\angle 0$$

$$I_{a_2} = I\angle -30$$

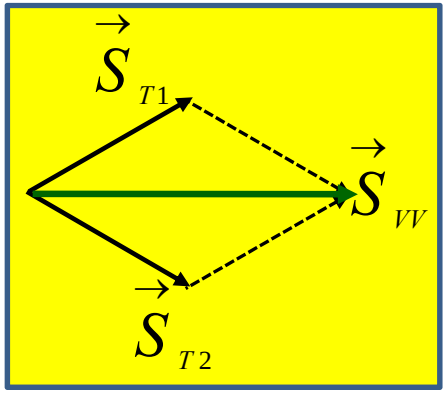
2^{nd} *Transformer* :

$$V_{bc} = V\angle -120$$

$$I_{c_2} = I\angle 90$$

$$-I_{c_2} = I\angle -90$$

$$S_{T1} = V_{a_2b_2} I_{a_2}^{*}$$
$$= (V\angle 0)(I\angle 30)$$
$$= VI\angle 30$$

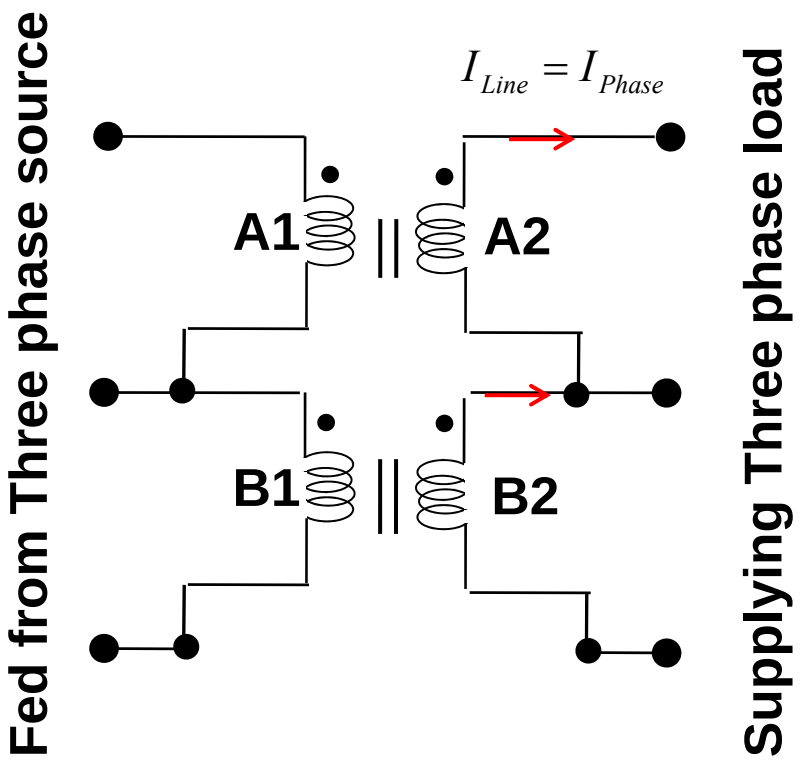


$$S_{T2} = V_{b_2c_2}(-I_{c_2})^{*}$$
$$= (V\angle -120)(I\angle 90)$$
$$= VI\angle -30$$

$$\vec{S}_{VV} = \vec{S}_{T1} + \vec{S}_{T2} = \sqrt{3}\, V_{Line} \times I_{Line}$$

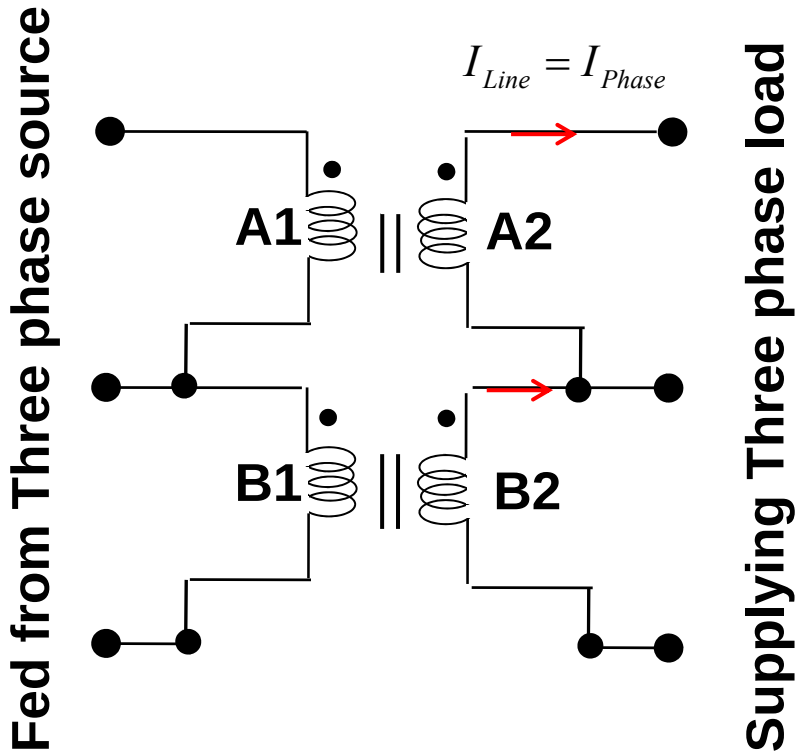
$$\vec{Q}_{T1} = -\vec{Q}_{T2} = \frac{1}{2}\,(V_{Line} \times I_{Line})$$

De-rating of open delta



$$S_{\Delta\Delta} = 3V_{phase} \times I_{Phase}$$

De-rating of open delta



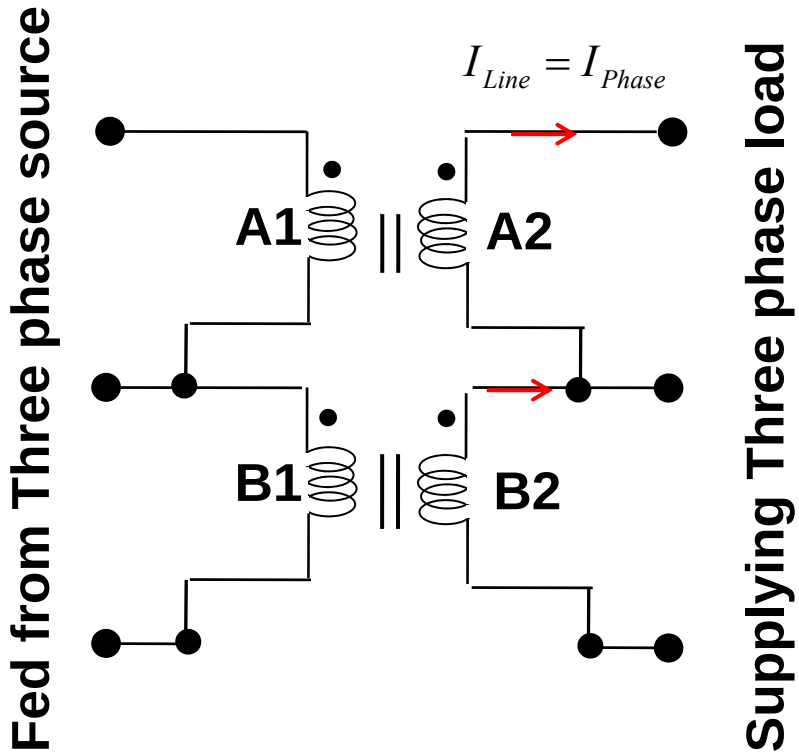
$$S_{\Delta\Delta} = 3V_{phase} \times I_{Phase}$$

$$\vec{S}_{VV} = \vec{S}_{T1} + \vec{S}_{T2} = \sqrt{3}\, V_{Line} \times I_{Line}$$

$$= \sqrt{3}\, V_{Line} \times (I_{Phase})$$

$$= \sqrt{3}\, V_{Line} \times I_{Phase}$$

De-rating of open delta



$$S_{\Delta\Delta} = 3V_{phase} \times I_{Phase}$$

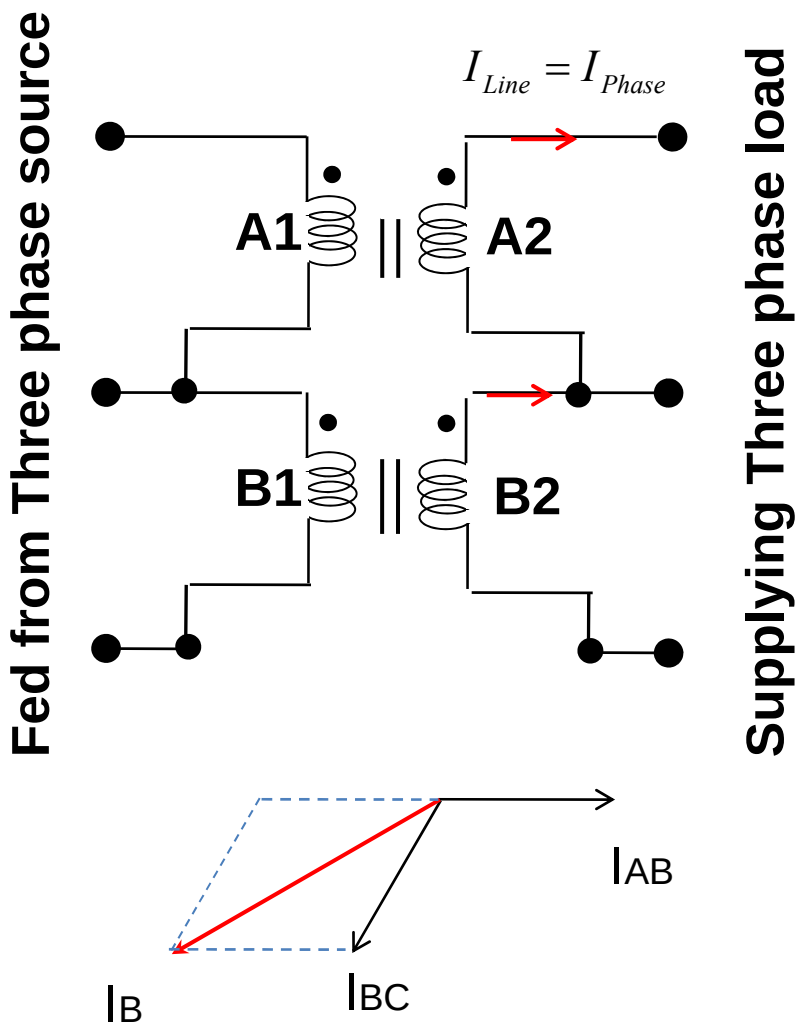
$$\vec{S}_{VV} = \vec{S}_{T1} + \vec{S}_{T2} = \sqrt{3}\, V_{Line} \times I_{Line}$$

$$= \sqrt{3}\, V_{Line} \times (I_{Phase})$$

$$= \sqrt{3}\, V_{Line} \times I_{Phase}$$

$$\therefore \frac{S_{VV}}{S_{\Delta\Delta}} \approx \frac{1}{\sqrt{3}} \approx 57.7\%$$

Open delta



Disadvantages:

- De-rated operation, 57.7% of ΔΔ bank; × (3/2) = 86.6% of the capacity of the remaining two transformers

-Average P.F. of V bank < Load P.F. (~ 86.6% of balanced load P.F.);
The two transformers operate at different power factors; for a balanced load P.F. of *cosϕ*, one transformer has a P.F. of *cos(30-ϕ)* while the other has a P.F. of *cos(30+ϕ)*, accordingly voltage regulation differs.

- Accordingly, increasing load (even if perfectly balanced), causes terminal secondary voltages to be unbalanced

Two single phase 150 kVA, 7200/600 V transformers are connected in open delta configuration. Find the maximum three phase load supplied.

Rated Secondary current of either transformer = 150 000 / 600 = 250 A
This current should not be exceeded whatever was the type of connection, Accordingly:

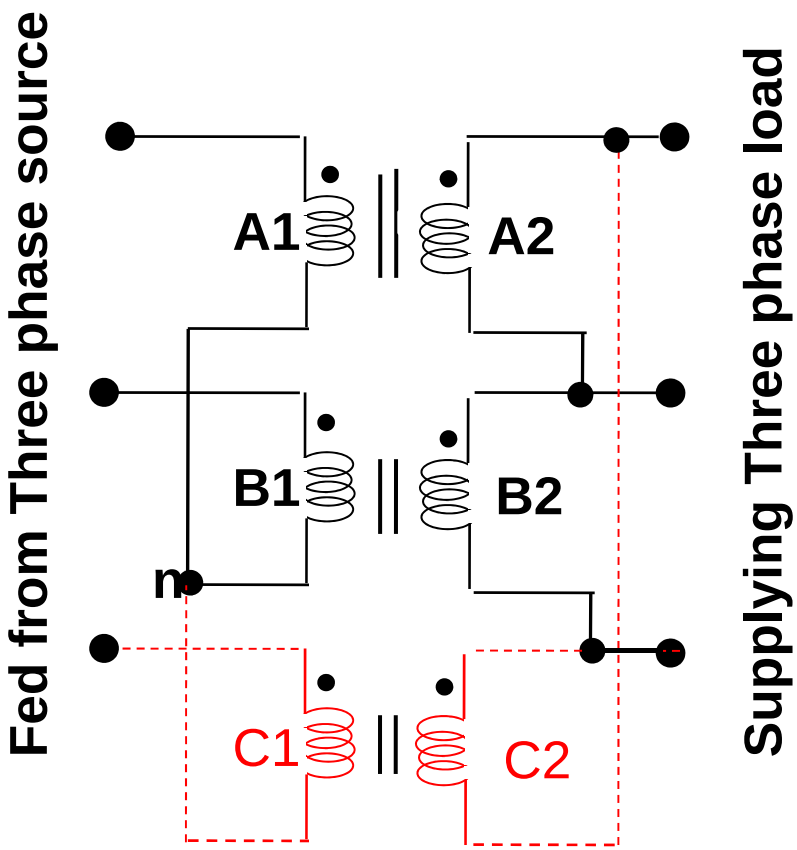
$$\left(S_{Load}\right)_{\text{maximum}} = \sqrt{3}VI = \sqrt{3} \times 600 \times 250 = 260kVA$$

$$Available\ rating\ of\ two\ transformers = 2 \times 150 = 300kVA$$

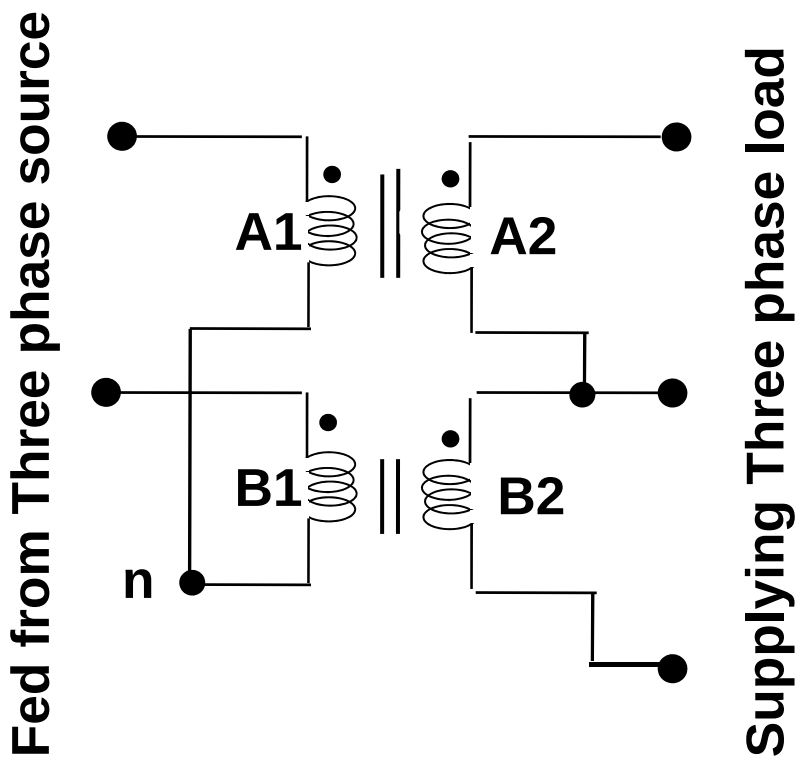
$$\%\ Derating = 260/300 = 86.6\%$$

One transformer is producing reactive power, while the other is consuming reactive power. This energy exchange between the two transformers is the reason for limited power output of 57.7% instead of an expected 66.7%

Open Y – Open Delta



Open Y –Open Delta



Disadvantages:

- Very large return current flow in neutral of primary