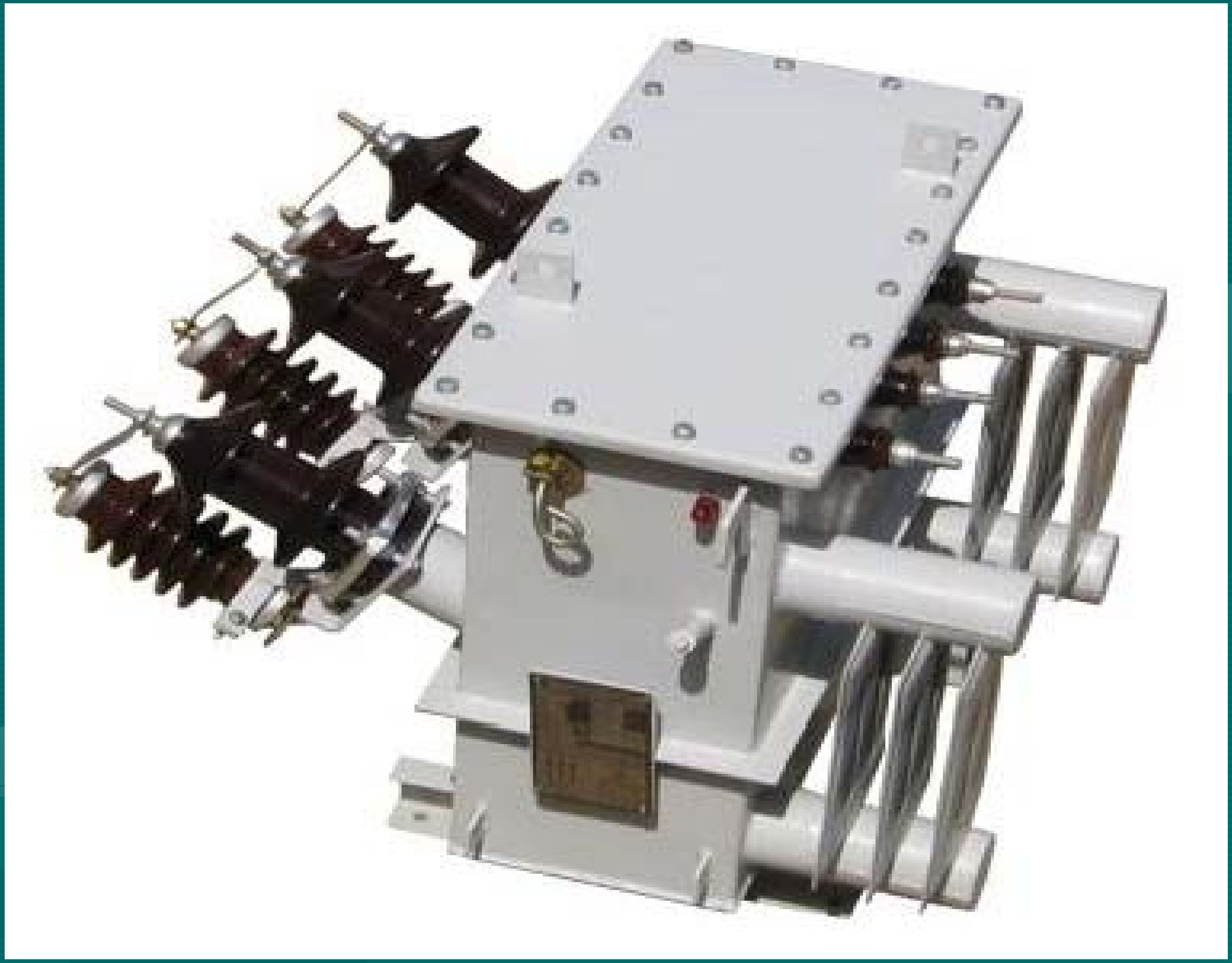
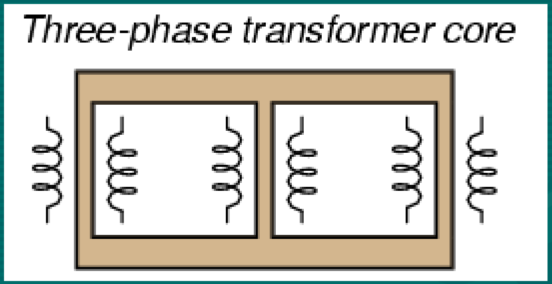
Three Phase Transformer

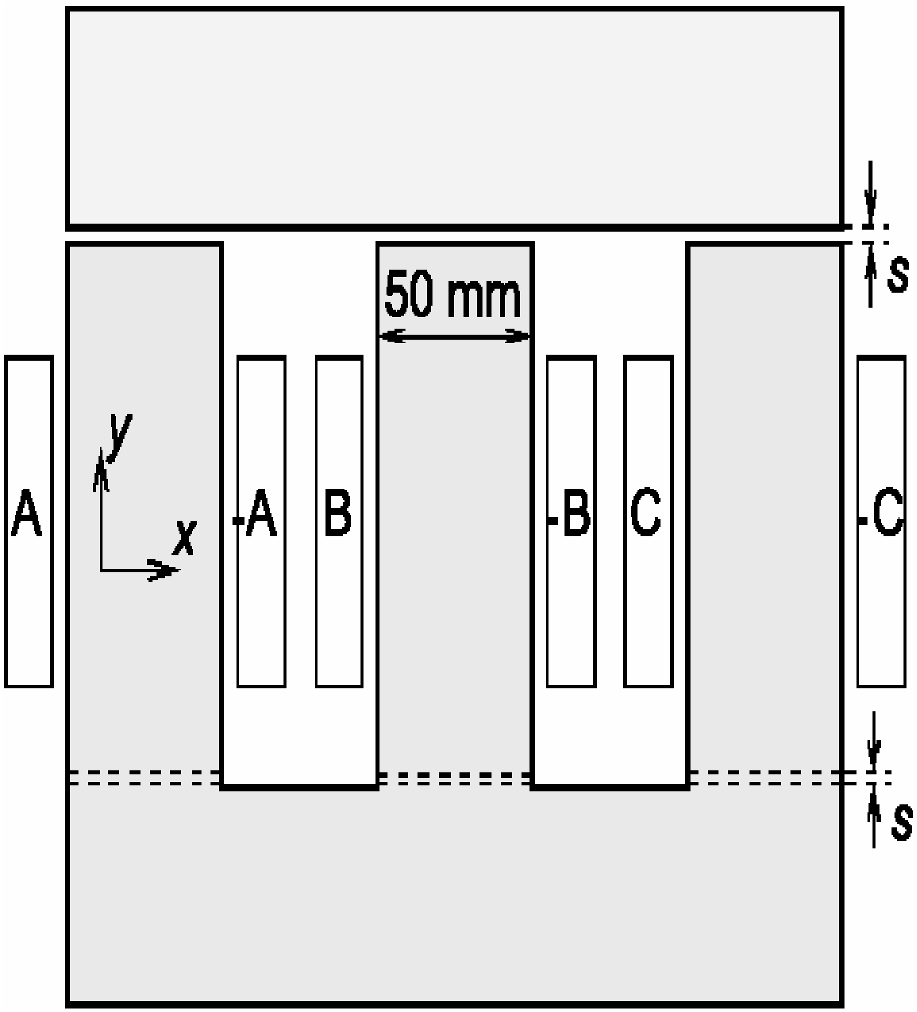


A three-phase transformer is made of three sets of primary and secondary windings, each set wound around one leg of an iron core assembly. Essentially it looks like three single-phase transformers sharing a joined core as in Figure below.

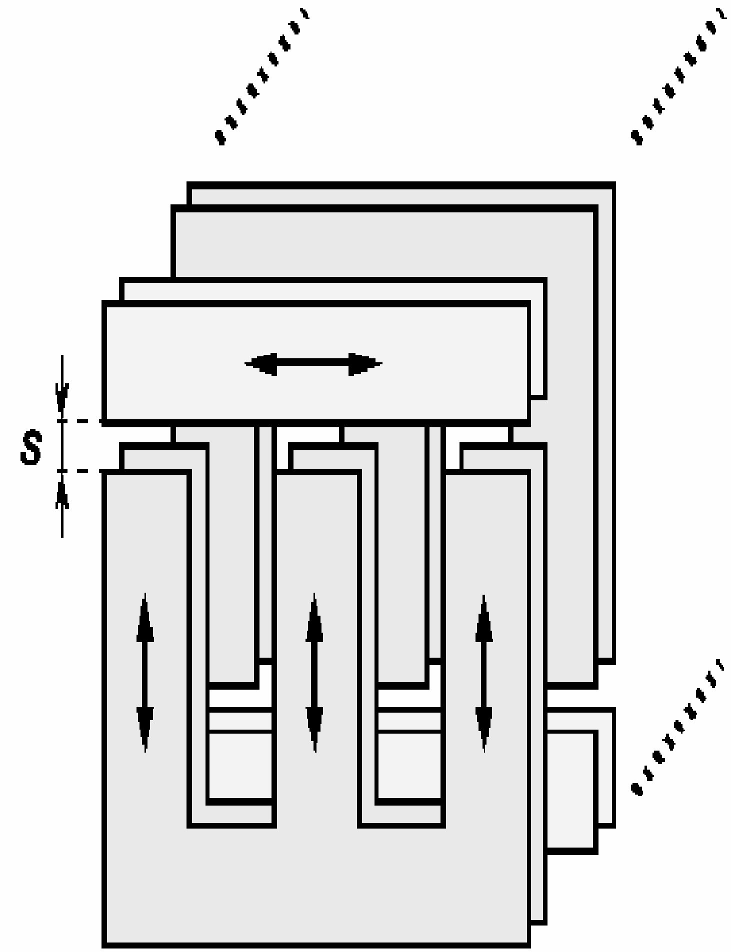


Three phase transformer core has three sets of windings.

Those sets of primary and secondary windings will be connected in either Δ or Y configurations to form a complete unit. The various combinations of ways that these windings can be connected together in will be the focus of this section.



(a) cross-section of the core and the three primary windings



(b) alternate stacking of E- and I-sheets in pairs (rolling direction indicated)

Figure 7 A diagram showing the three legs of a core type three-phase transformer.

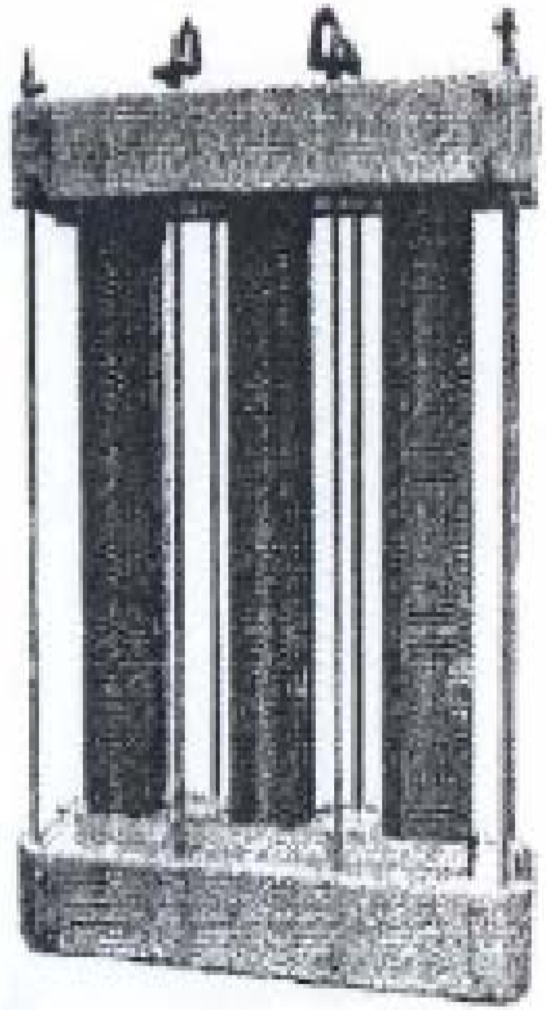


Figure 8 A photo of an early core type three-phase transformer.

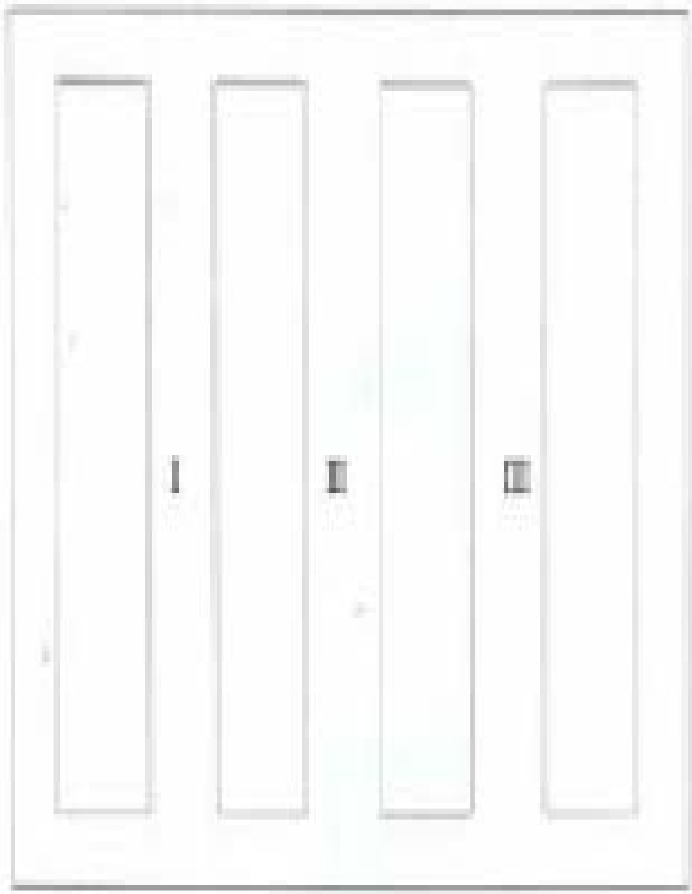
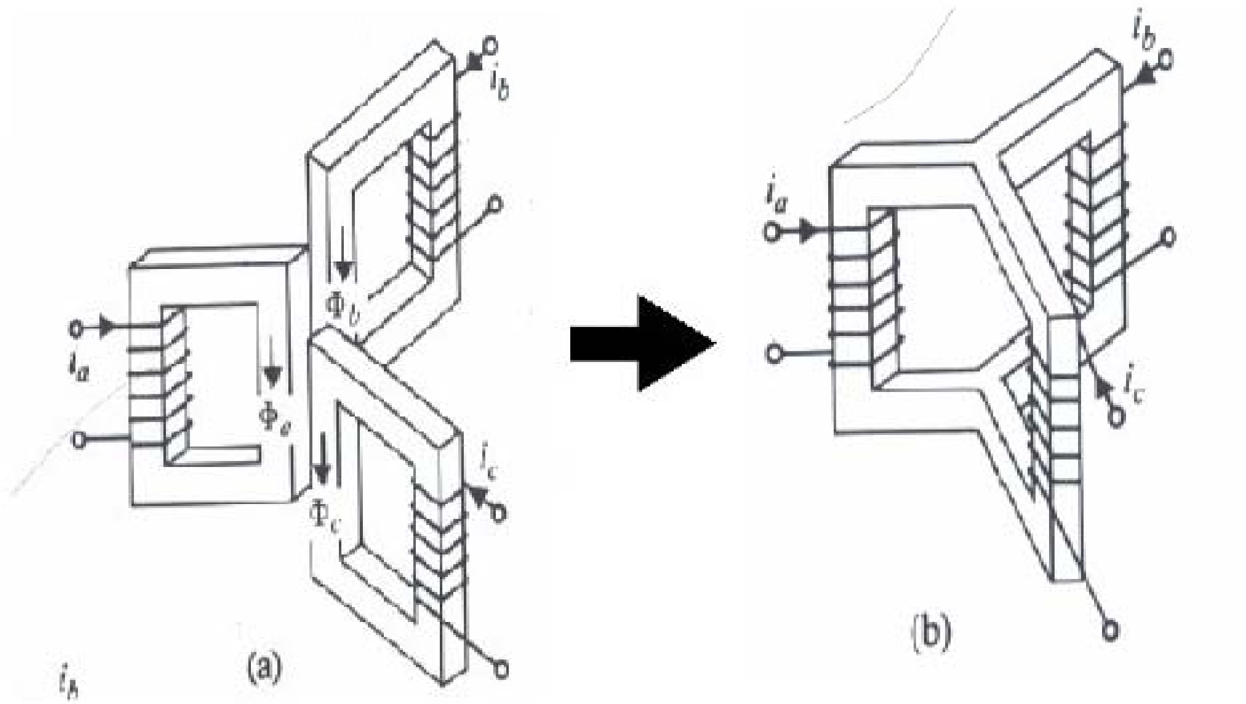


Figure 9 A diagram showing the five legs of a shell type three phase transformer.

Figure 10 A photo of a shell-type three phase transformer.

Polyphase transformers



Three Phase Transformers

Can be formed as:

• 3 single phase transformers connected together

– Star/Delta winding arrangements

– Easy to replace failed units

• Common core device

▪save a great deal of iron (1/3 iron).

▪Less transformer oil is used.

▪Less floor space.

▪Cheaper (about 15% saving)

▪Installation and operational cost low

▪ Lighter and cheaper than 3 individual units

▪ 6 rather than 12 external connections

Disadvantage of single three phase

Whole transformer has to be replaced if single winding fails.

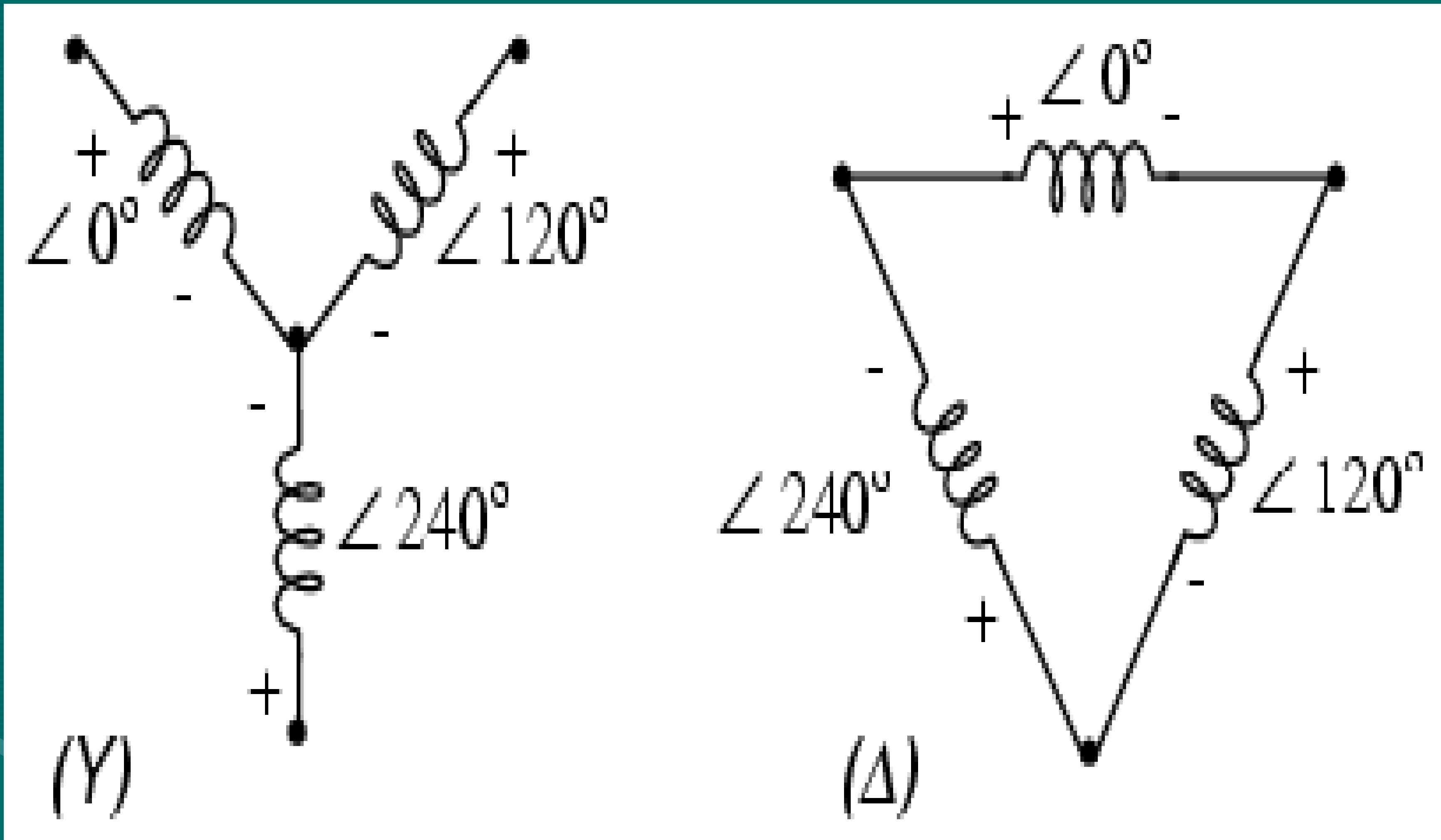
Larger and heavier

More difficult and costly to repair

Primary	-	**Secondary**
Y	-	Y
Y	-	Δ
Δ	-	Y
Δ	-	Δ

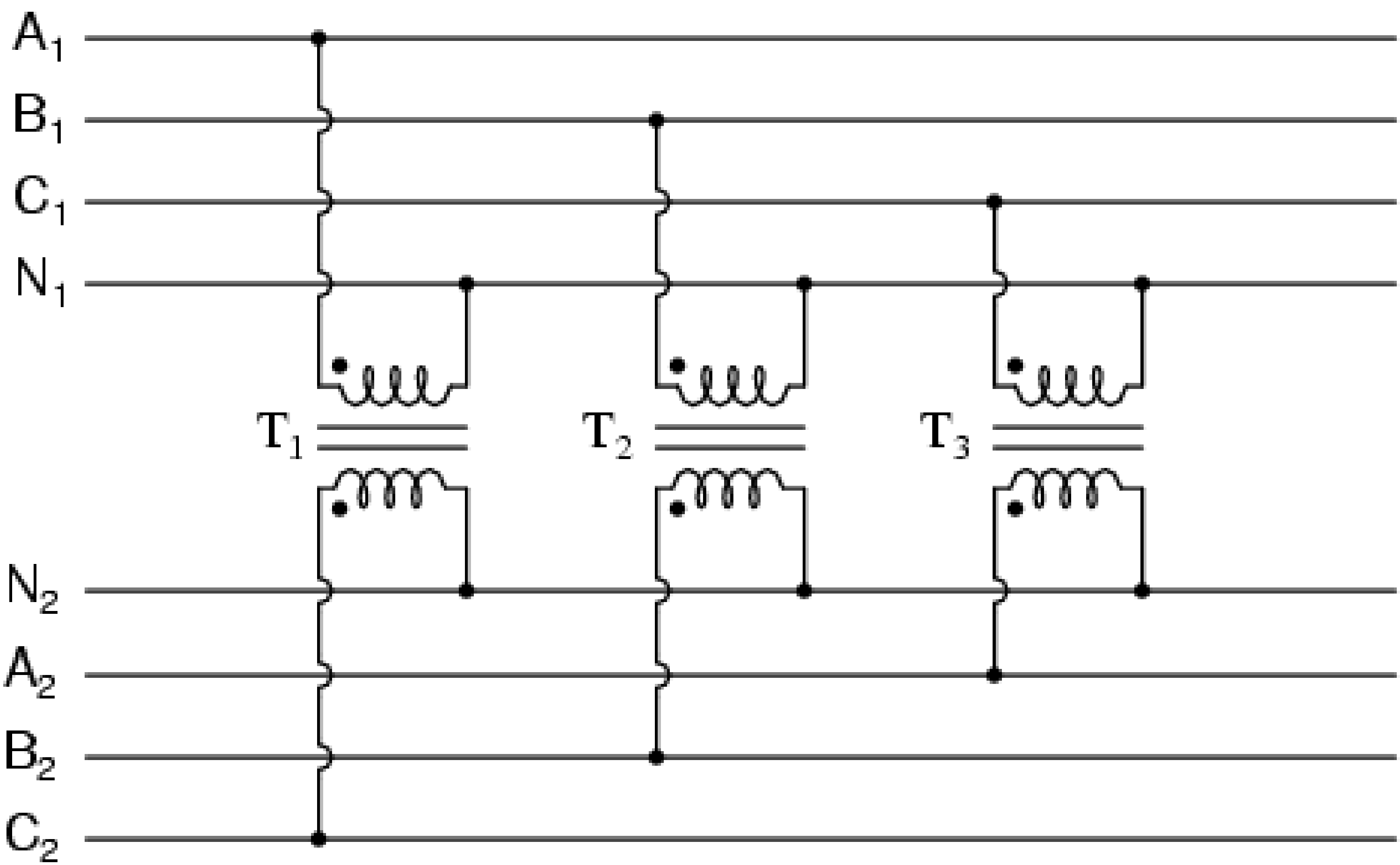
The reasons for choosing a Y or Δ configuration for transformer winding connections are the same as for any other three-phase application: Y connections provide the opportunity for multiple voltages, while Δ connections enjoy a higher level of reliability (if one winding fails open, the other two can still maintain full line voltages to the load).

Probably the most important aspect of connecting three sets of primary and secondary windings together to form a three-phase transformer bank is paying attention to proper winding phasing (the dots used to denote "polarity" of windings). Remember the proper phase relationships between the phase windings of Δ and Y: (Figure below)



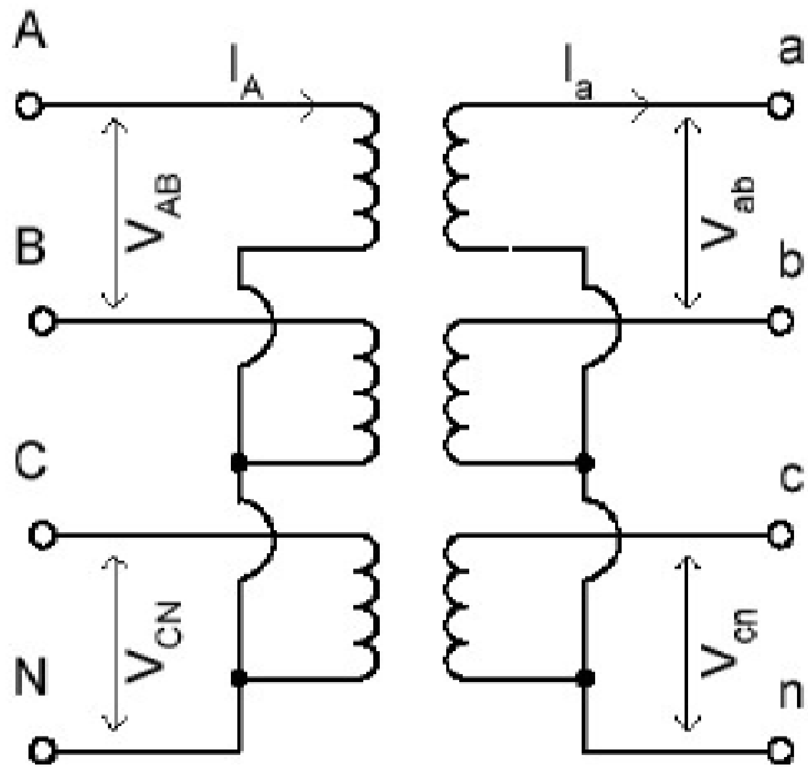
(Y) The center point of the "Y" must tie either all the "-" or all the "+" winding points together. (Δ) The winding polarities must stack together in a complementary manner (+ to -).

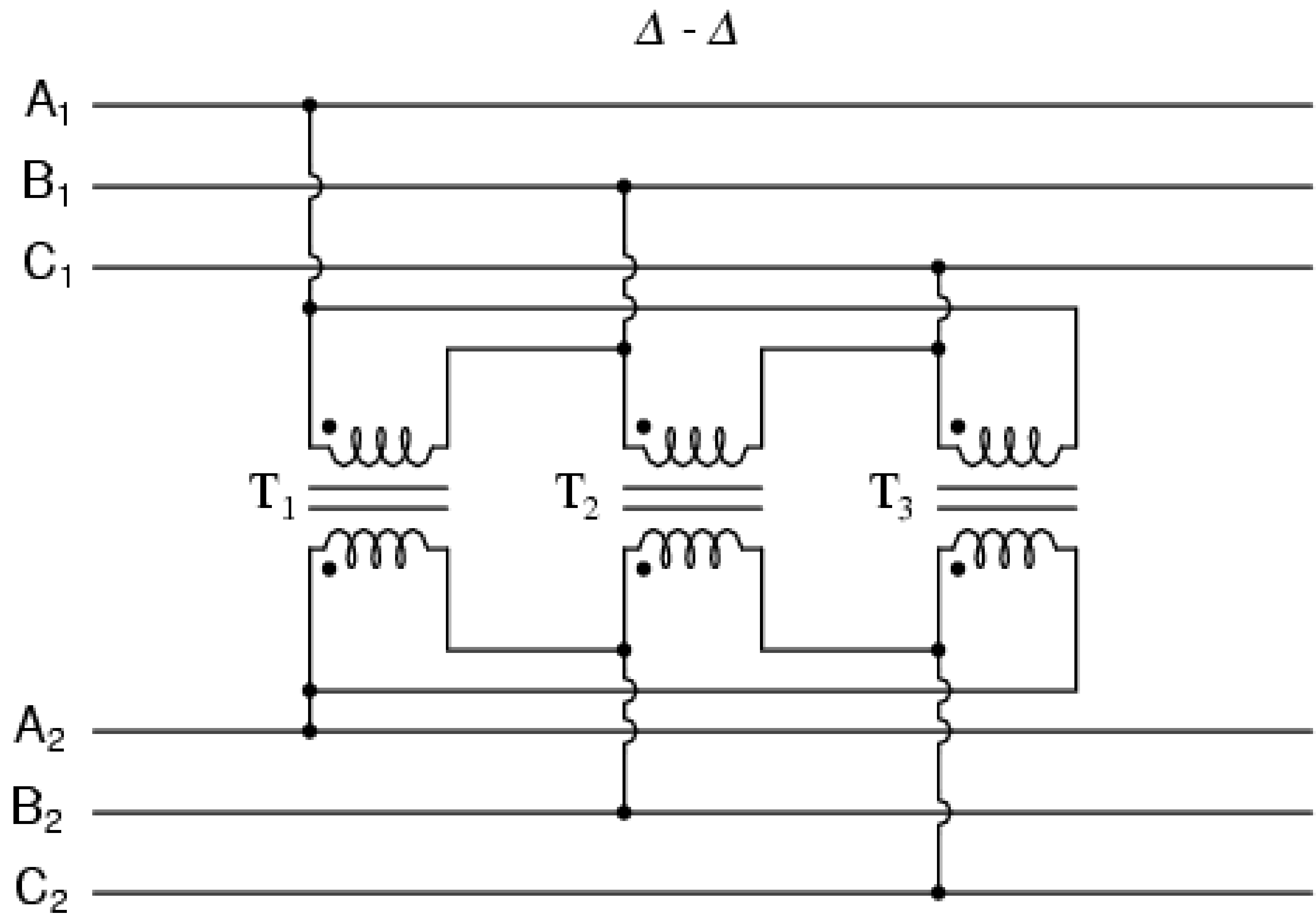
Y - Y



Wye – wye connection

- Each single phase transformer winding controls ratio of phase – neutral voltages and phase currents
  E.g
  $$|V_{AN}|/|V_{an}| = N_1/N_2$$
  $$|I_{AN}|/|I_{an}| = N_2/N_1$$
- Ratio of line-line voltages
  $$|V_{AB}|/|V_{ab}| = \sqrt{3}|V_{AN}|/\sqrt{3}|V_{an}| = N_1/N_2$$
- Ratio of line – currents
  $$|I_A|/|I_a| = |I_{AN}|/|I_{an}| = N_2/N_1$$

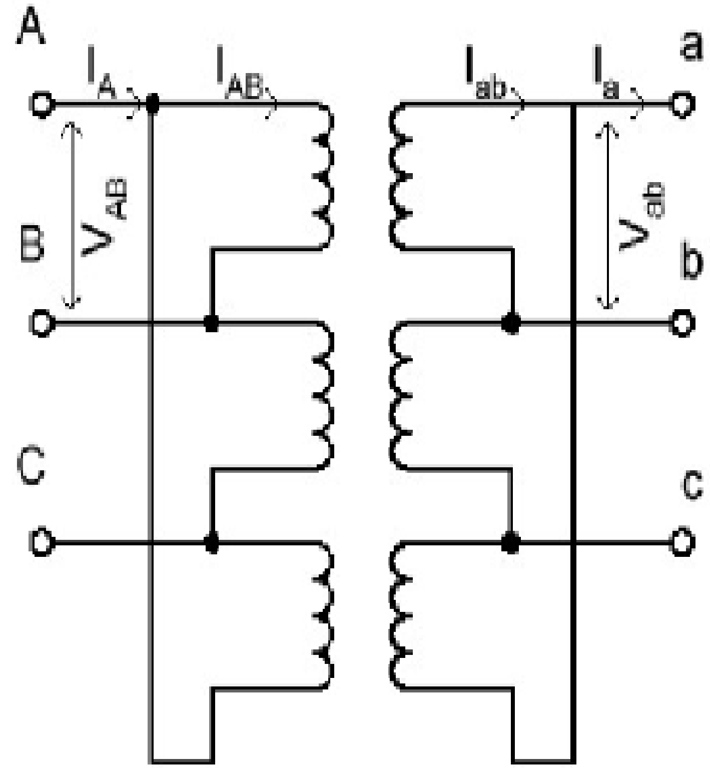


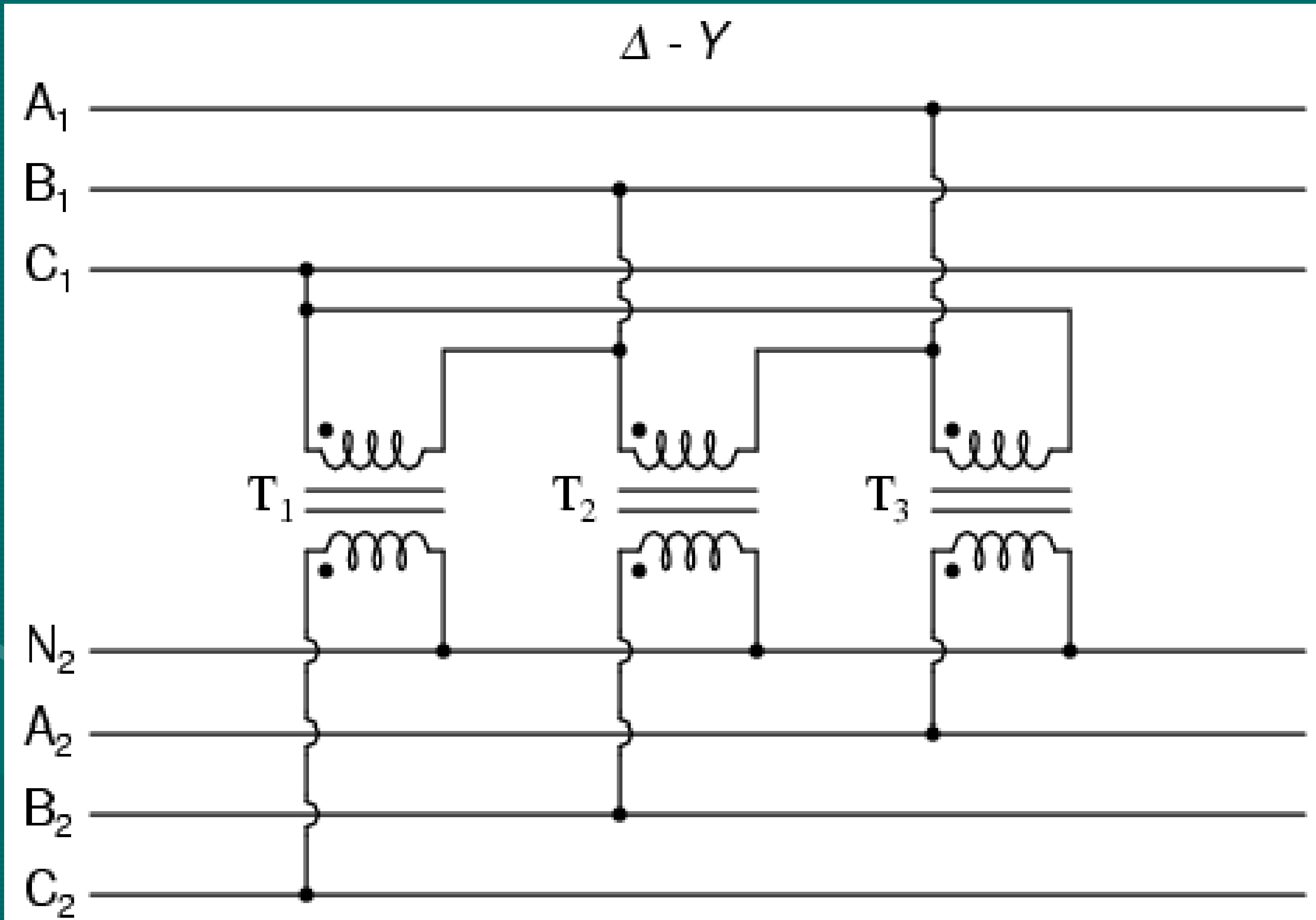

Δ - Δ
A1
B1
C1
T1
T2
T3
A2
B2
C2

Delta – delta connection

- Each single phase transformer winding controls ratio of line – line voltages and phase currents
  E.g
  $$|V_{AB}|/|V_{ab}| = N_1/N_2$$
  $$|I_{AB}|/|I_{ab}| = N_2/N_1$$

- Ratio of line – currents
  $$|I_A|/|I_a| = \sqrt{3}|I_{AB}|/\sqrt{3}|I_{ab}| = N_2/N_1$$




Δ - Y
A1
B1
C1
T1
T2
T3
N2
A2
B2
C2

Delta – wye connection

- Each single phase transformer winding controls ratio of line – line voltage (HV) to phase – neutral voltage (LV) and ratios of currents through each single phase winding E.g

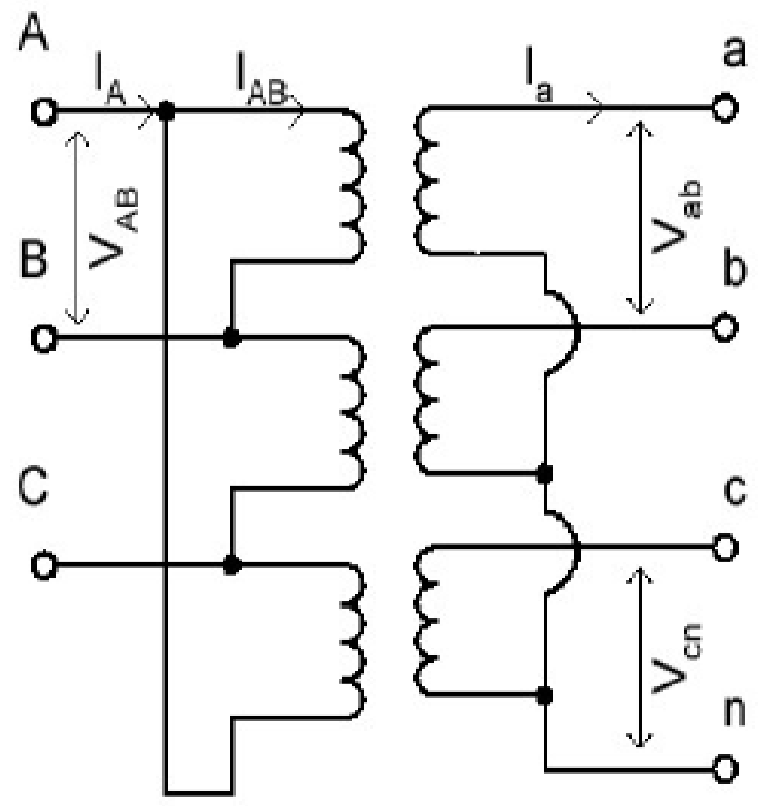
  $|V_{AB}|/|V_{an}| = N_1/N_2$
  $|I_{AB}|/|I_{an}| = N_2/N_1$

- Ratio of line-line voltages

  $|V_{AB}|/|V_{ab}| = |V_{AB}|/\sqrt{3}|V_{an}|$
  $= N_1/\sqrt{3}N_2$

- Ratio of line – currents

  $|I_A|/|I_a| = \sqrt{3}|I_{AB}|/|I_{an}|$
  $= \sqrt{3}N_2/N_1$



Choice of transformer connections

<u>Star-star</u>

Economical for small current and high voltage transformer

No.of turns per phase and amount of insulation rqd. Minnimum Vp = 1/1.732

Neutral is available

If load is unbalance, neutral shifts it's position

Delta-Delta

Large currents and low voltage

Continuity of service even though one phase develop faults

Cross section of conductor is reduced as Ip = 1/1.732

More insulation reqd. as compared to Y-Y

Star-Delta

Where voltage is to be stepped down, placed at the end of transmission line

Delta-star connection

Where voltage is to be stepped up (placed at the beginning of transmission line)

ADVANTAGES

- Delta to Delta - use: industrial applications
- Delta to Wye - use : most common; commercial and industrial
- Wye to Delta - use : high voltage transmissions
- Wye to Wye - use : rare, don't use causes harmonics and balancing problems

Parallel operation of single phase transformer

- Polarities of transformer are same
- Voltage ratings of primary and secondaries are same
- Phase sequence of the transformers are same
- Percent impedance be same (X/R)
- Phase displacement between primary and secondary be same

Distribution transformer