Course EE6-15: Modelling and Analysis of Stationary and Rotating Electrical Machines

Lesson 3:

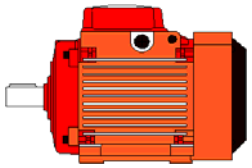
Phasor diagrams and winding polarity in transformers

Autotransformers

Three phase transformers

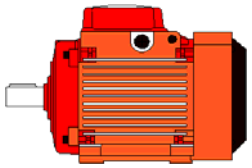
Instrument transformers

Per unit systems

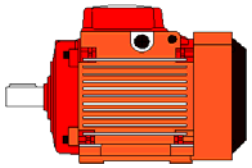


Agenda

- Phasor diagrams and winding polarity in transformers
- Autotransformers
- Three phase transformers
  - Three-phase connections of Single-phase transformers
  - Three-phase transformers
  - Harmonics and harmonic suppression in three-phase transformers
- Connection of three-phase transformers
- Instrument transformers
  - Voltage transformers
  - Current transformers



Phasor diagrams and winding polarity in transformers



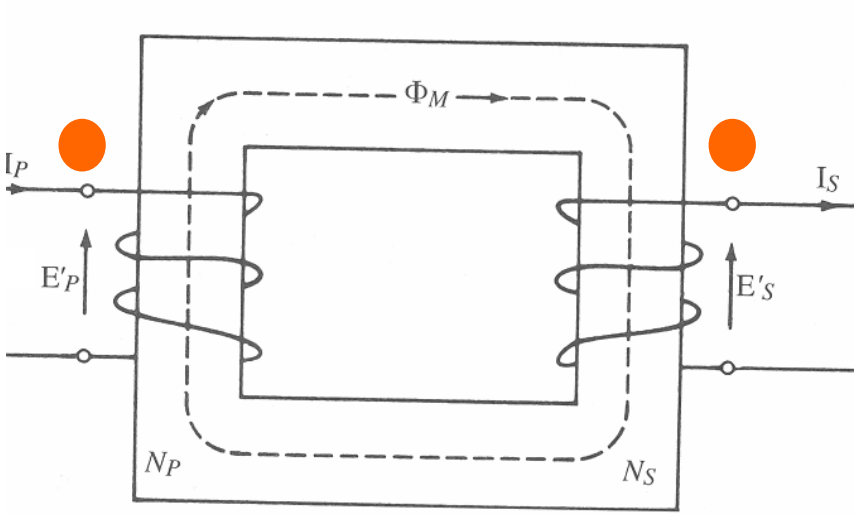
Phasor diagrams and winding polarity in transformers

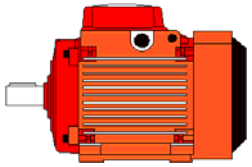
- The voltage generated by a winding is proportional to the derivative of the flux linkages
- It is important when connecting transformers to external circuits to know the direction of the voltage
- To show how the windings are to be connected, we mark each with a dot showing how the voltages follow one another
- This is known as the winding polarity of the transformer

$$e = \frac{d\lambda}{dt}$$

or more correctly :

$$e = -\frac{d\lambda}{dt}$$



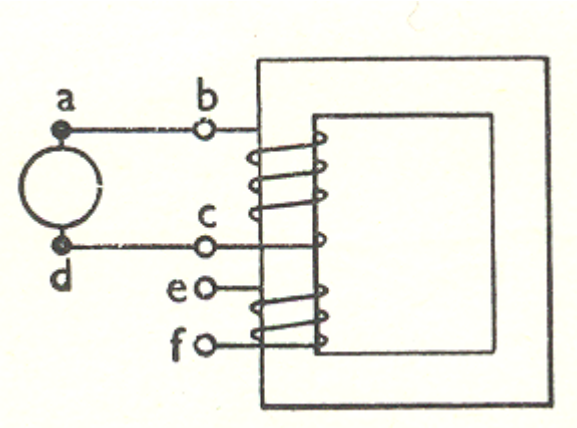


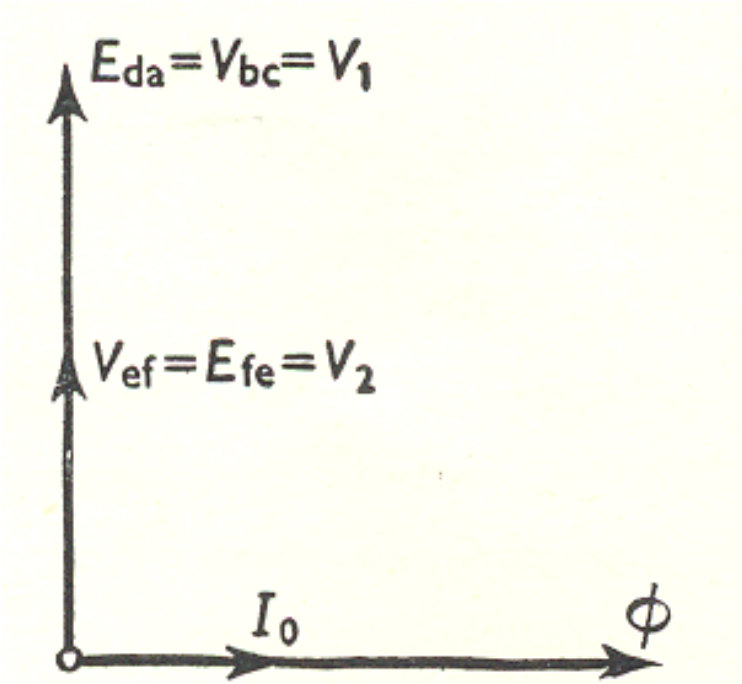
Phasor diagram of a transformer

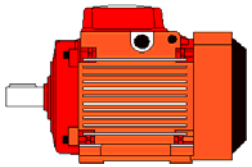
- Any transformer on No-load
  - (rms) phasor diagram

$$e(t) = \hat{e} \cdot \sin(wt - \varphi)$$

$$E_{rms} = \sqrt{\frac{1}{2\pi}\int_0^{2\pi} e(t)^2\, dt}$$

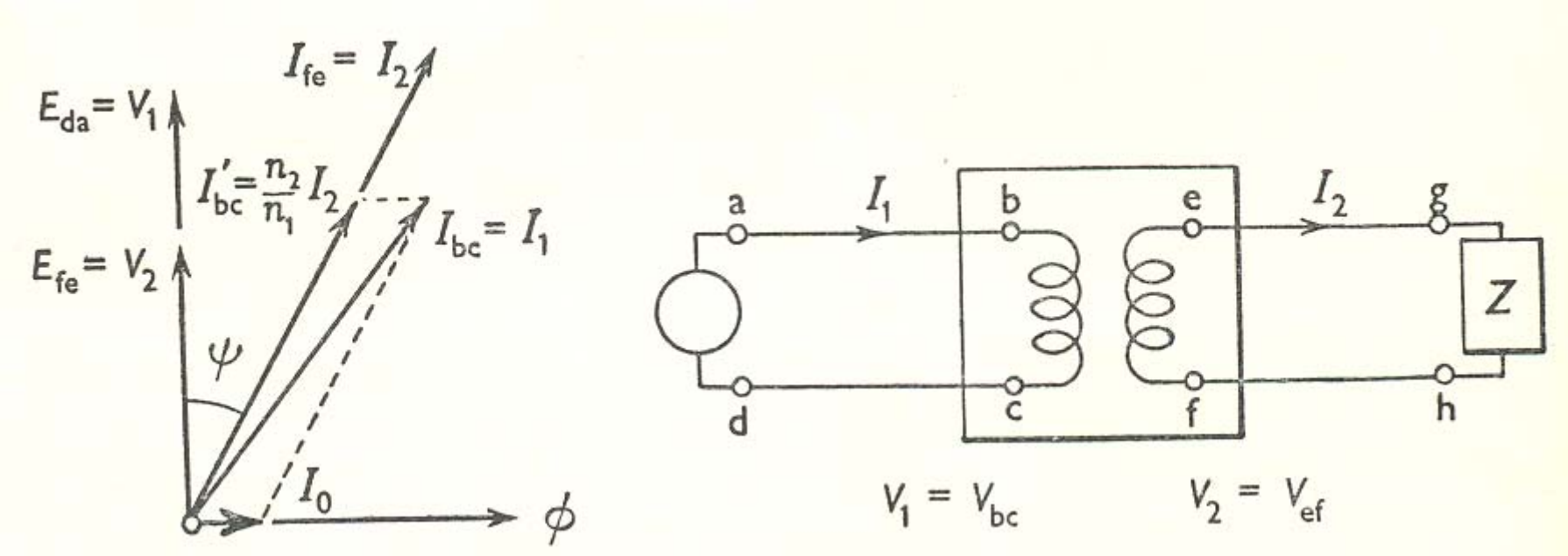


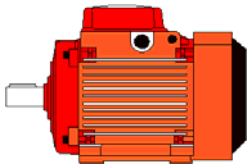




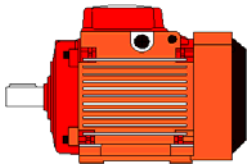
Phasor Diagram of A Transformer

- On Load





Autotransformers



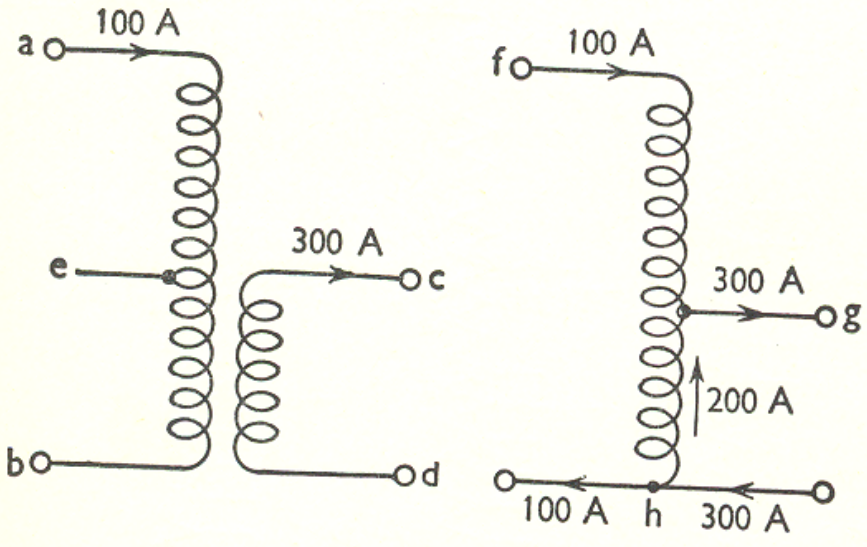
Autotransformer

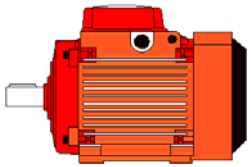
- Uses a single winding only

$$V_{ab} = 3V_{cd}$$

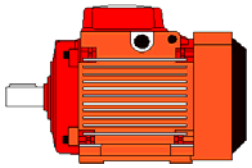
$$I_{dc} = 3I_{ab}.$$

$$I_{ab} = 100\ \text{A} \quad \text{and} \quad I_{dc} = 300\ \text{A}.$$

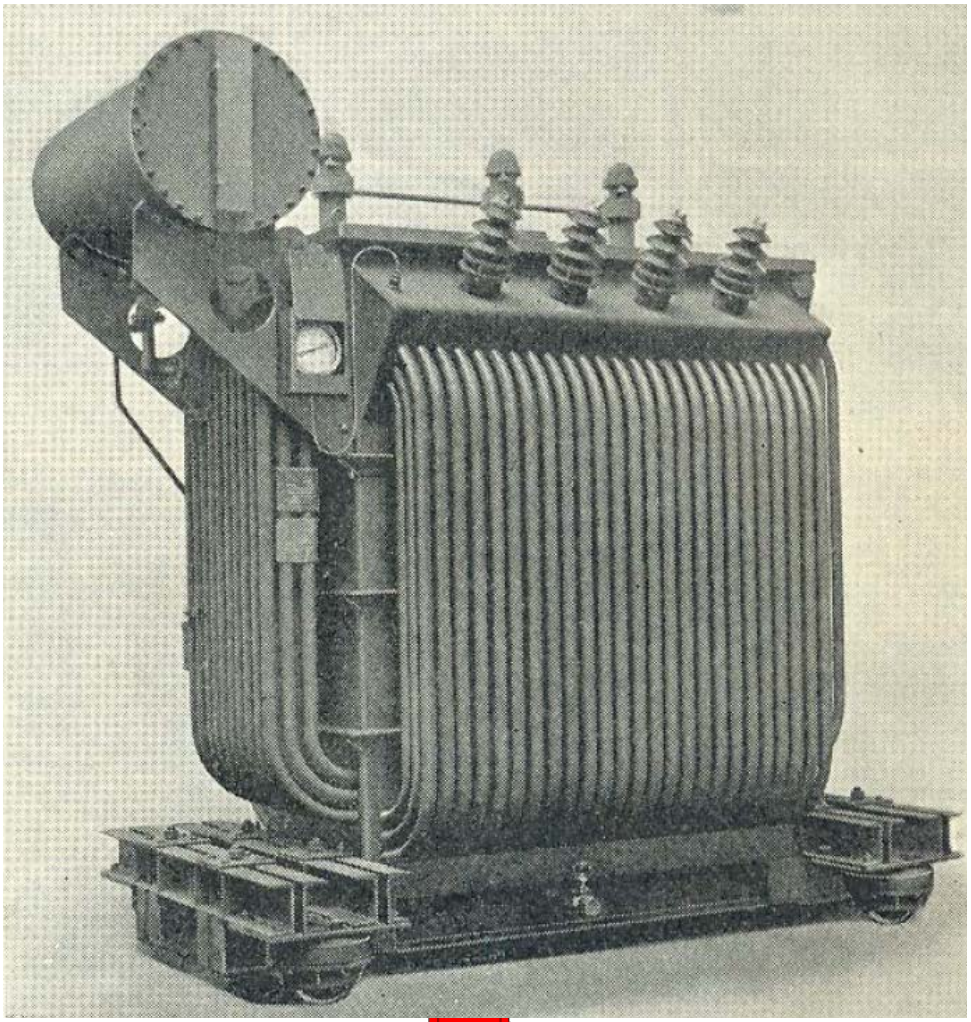


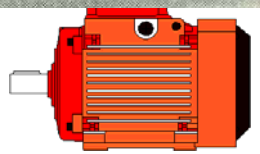


Three phase transformers

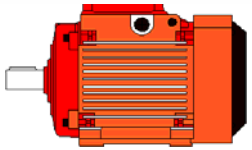


Three Phase Transformers





Three Phase Transformers



Three Phase Transformers

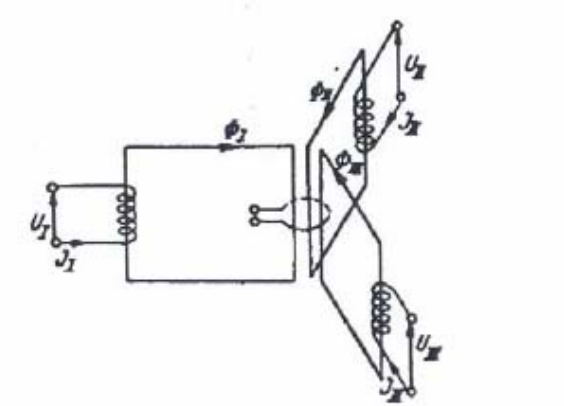


Figure 4 Showing a diagram of the fluxes in a three-phase transformer.

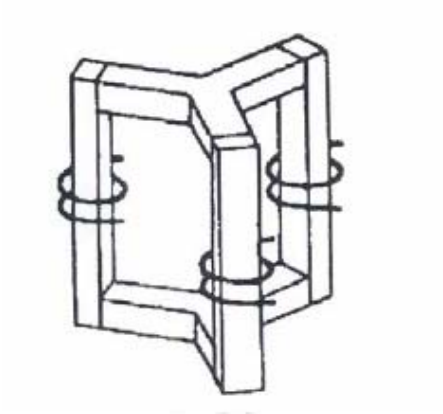
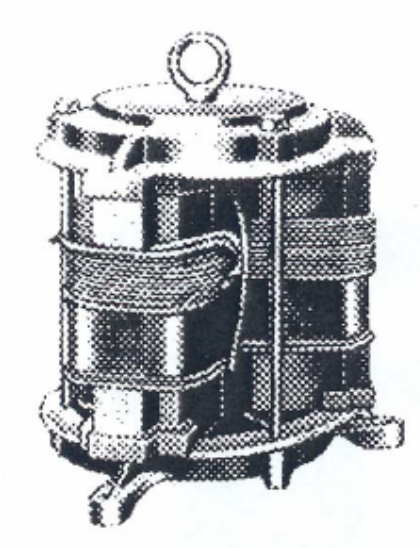


Figure 5 Showing the arrangement of the core legs, corresponding to the flux flowing in the leg.



Three Phase Transformers

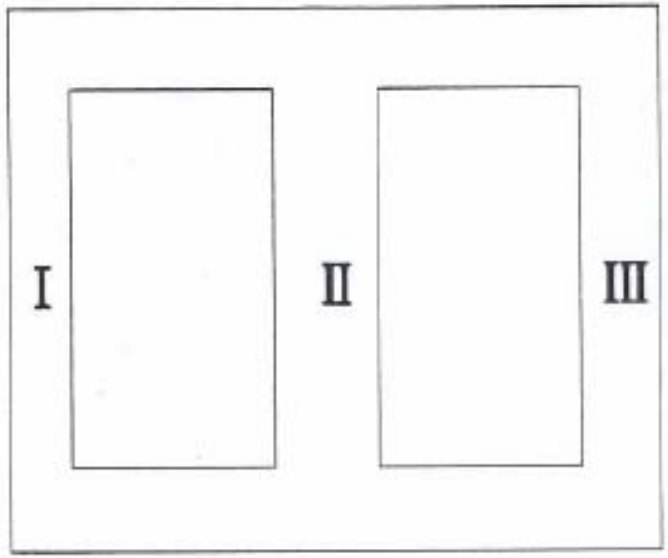


Figure 7 A diagram showing the three legs of a core type three-phase transformer.

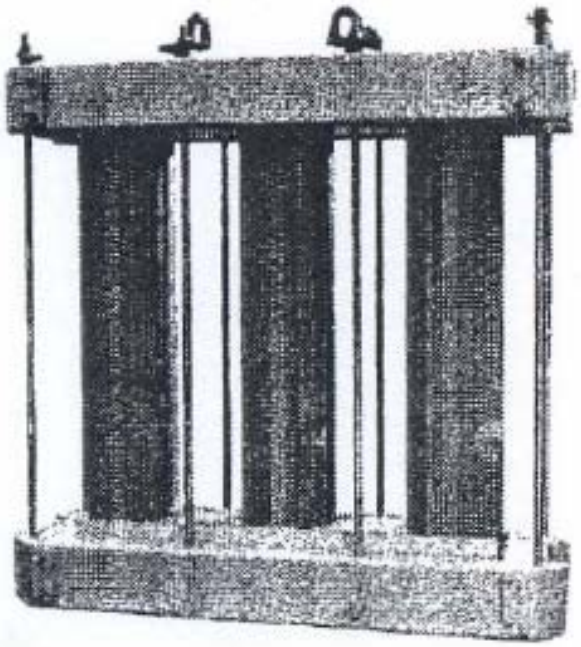
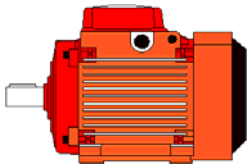


Figure 8 A photo of an early core type three-phase transformer.



Three Phase Transformers

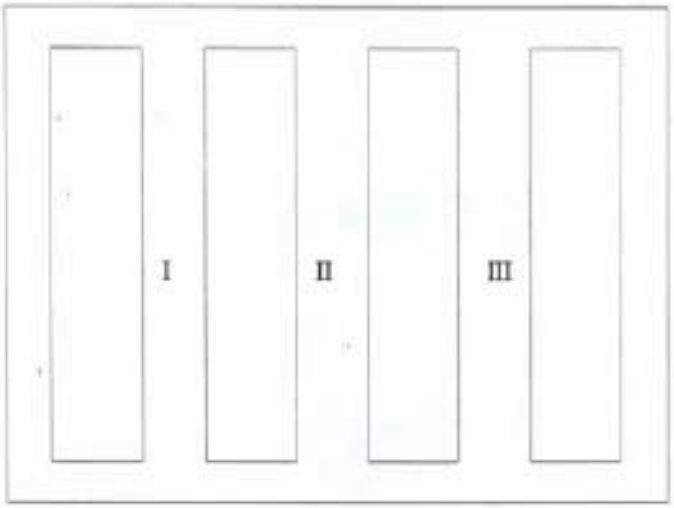


Figure 9 A diagram showing the five legs of a shell type three-phase transformer.

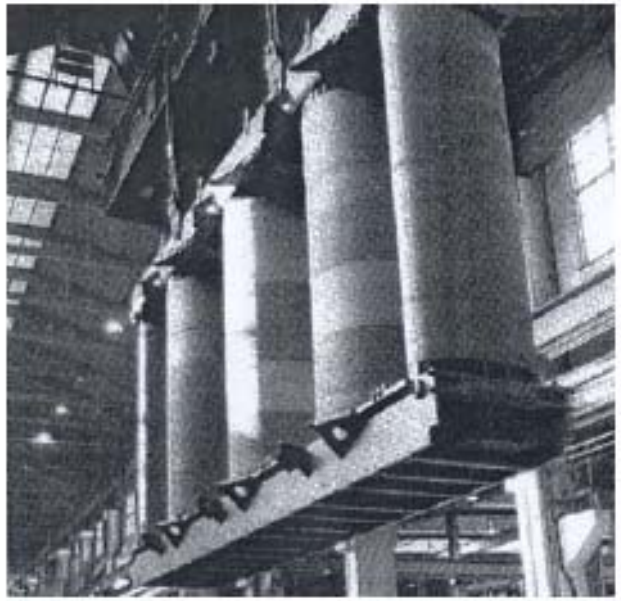
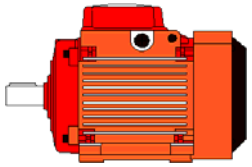
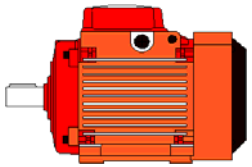


Figure 10 A photo of a shell-type three phase transformer.



Connection of three-phase transformers



Connection of Three-Phase Transformers

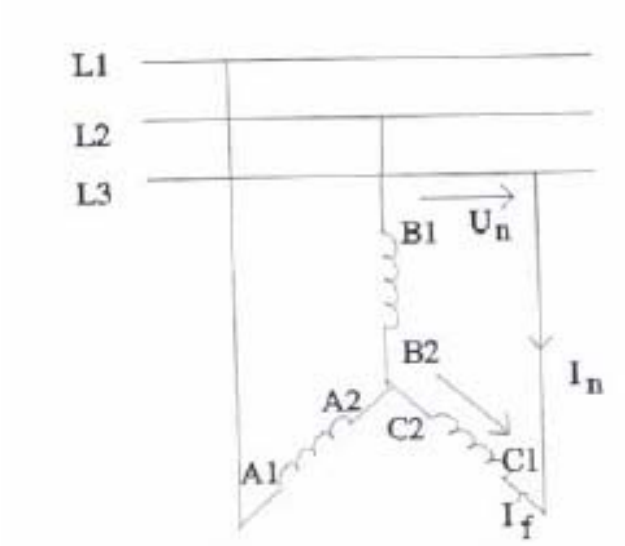


Figure 12 Star connected windings, version 1.

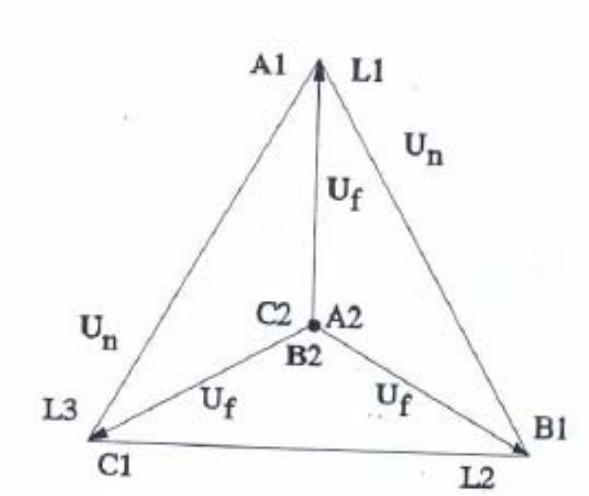
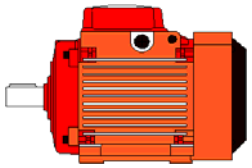


Figure 14 Phasor diagram for a star connected three-phase transformer.



Connection of Three-Phase Transformers

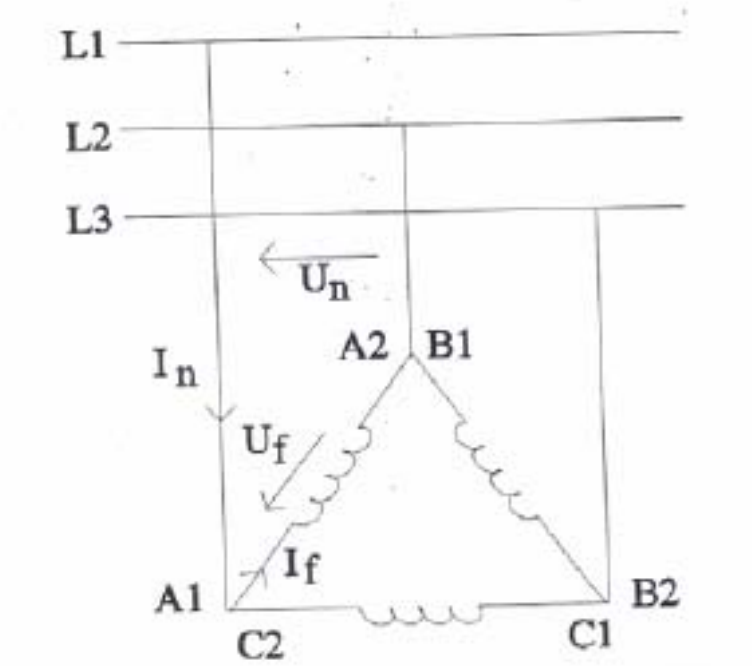


Figure 15 Circuit diagram for delta connected three-phase winding, version one.

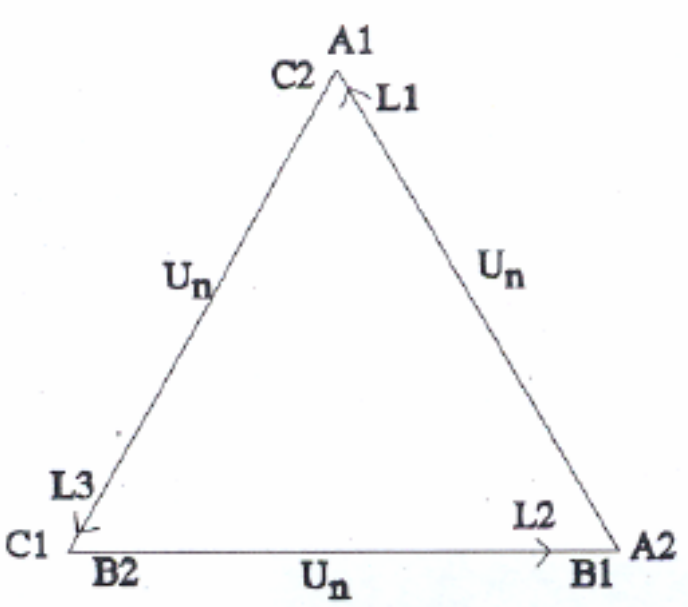
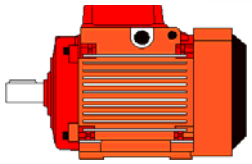


Figure 17 Phasor diagram for a star connected three-phase transformer.



Connection of Three-Phase Transformers

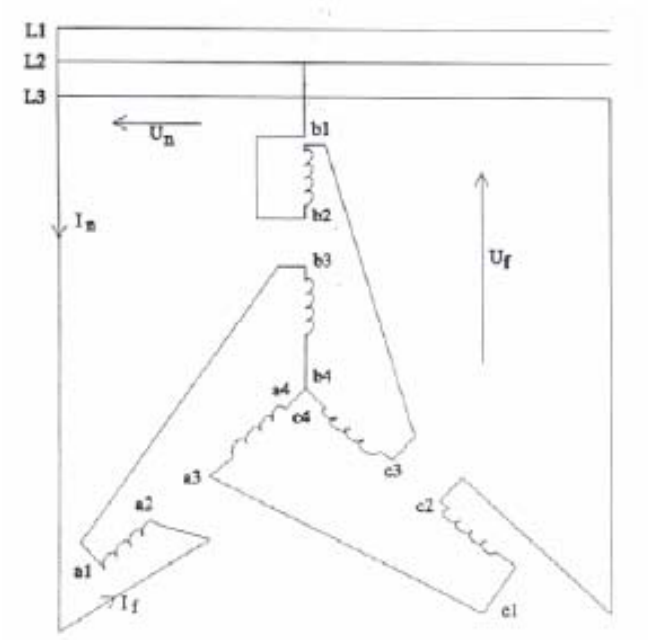


Figure 19 Circuit diagram for z connected three-phase winding, version one.

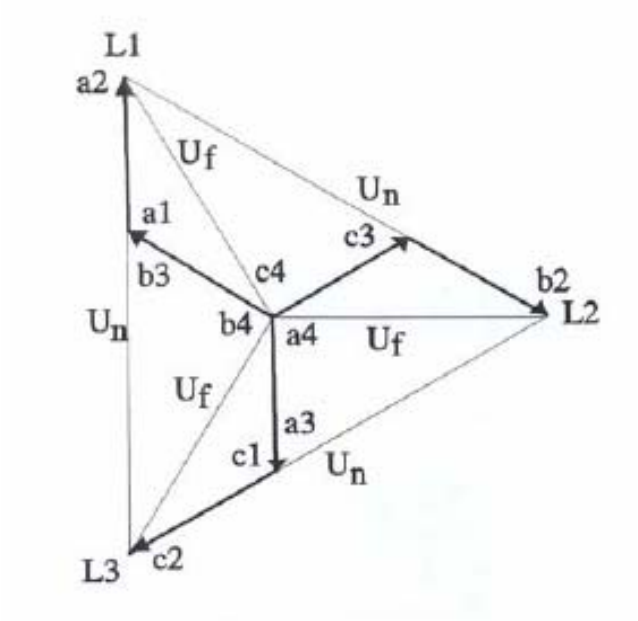
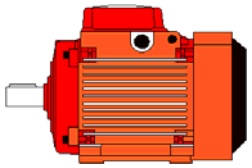
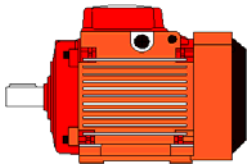


Figure 21 Phasor diagram for a z connected three-phase transformer.



Instrument transformers



Instrument Transformers

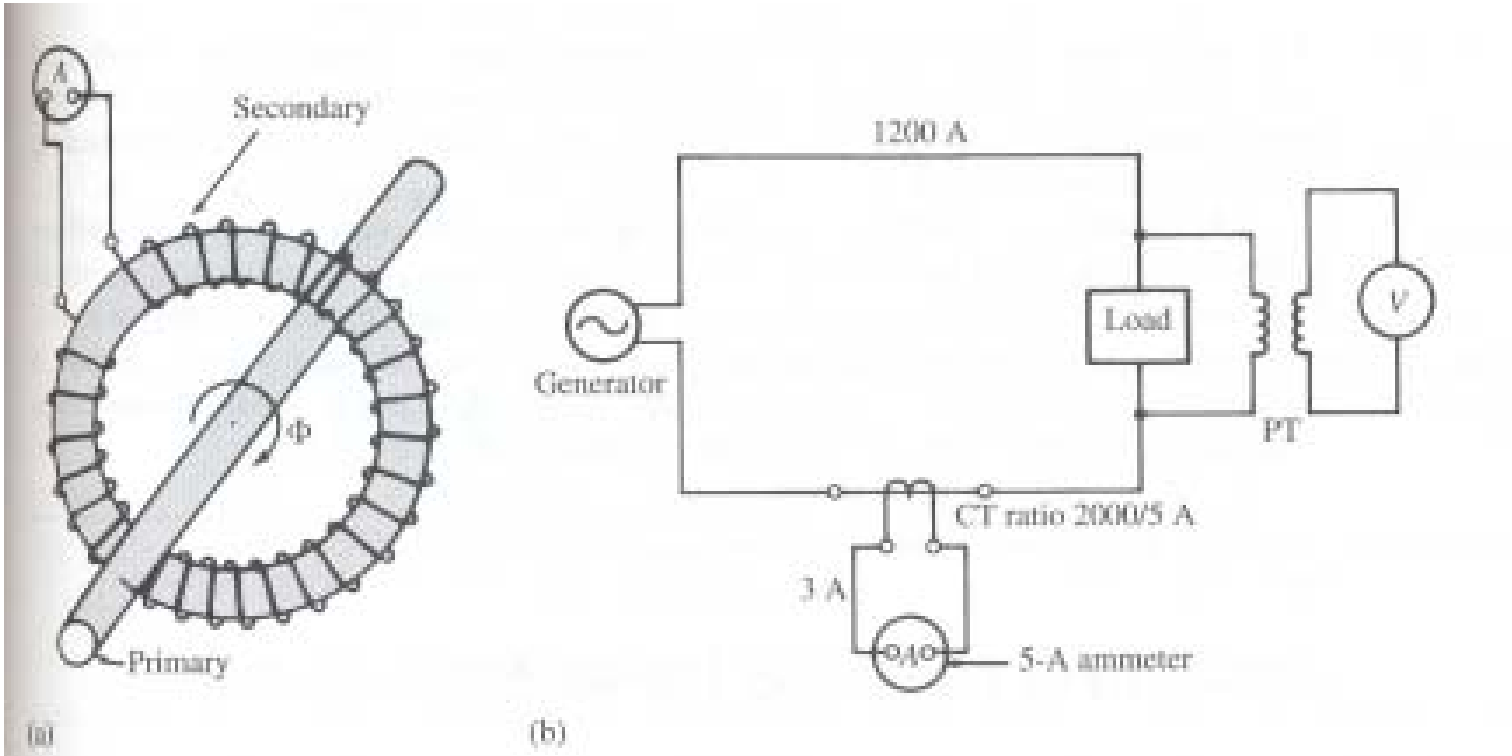


FIGURE 3.18
Current transformer: (a) window type; (b) circuit connections.