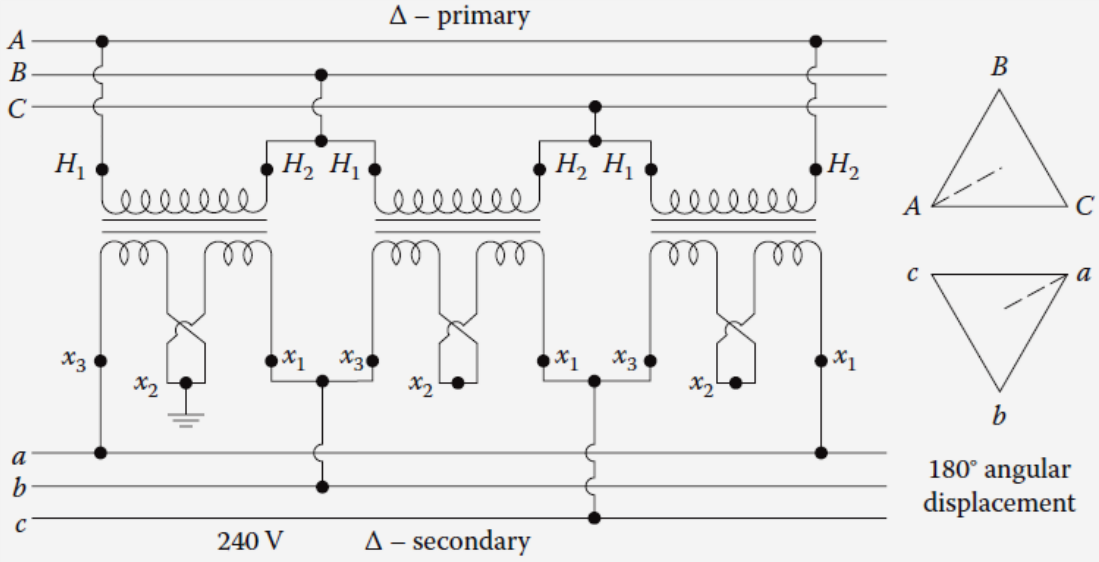
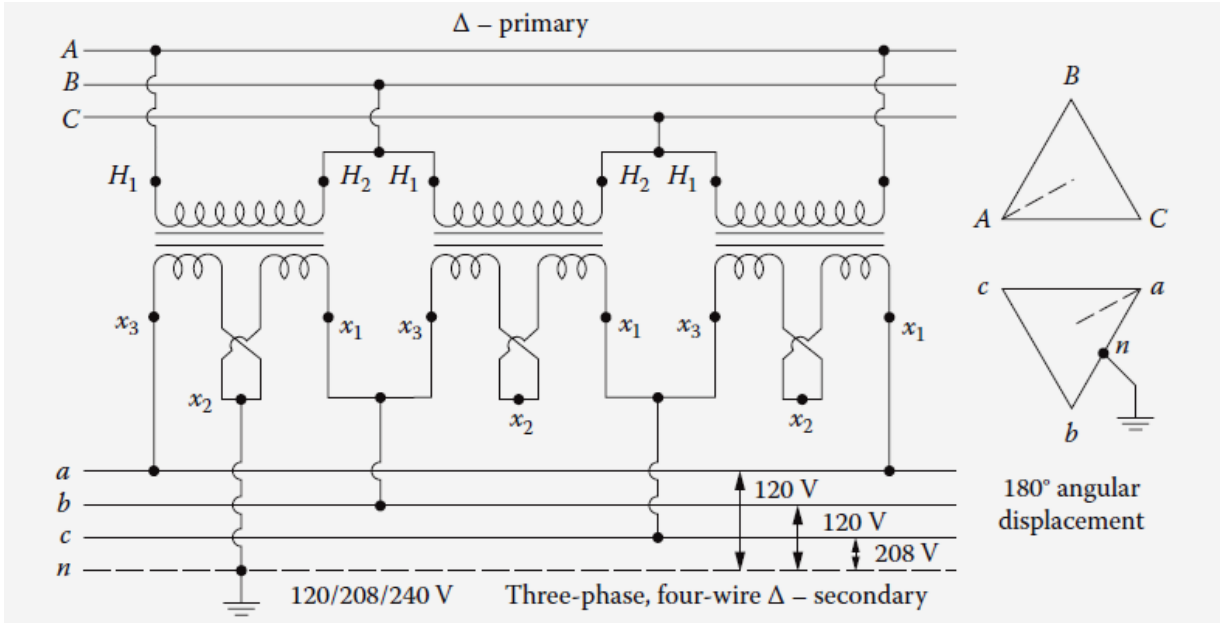
ECG 741
Power Transformers II

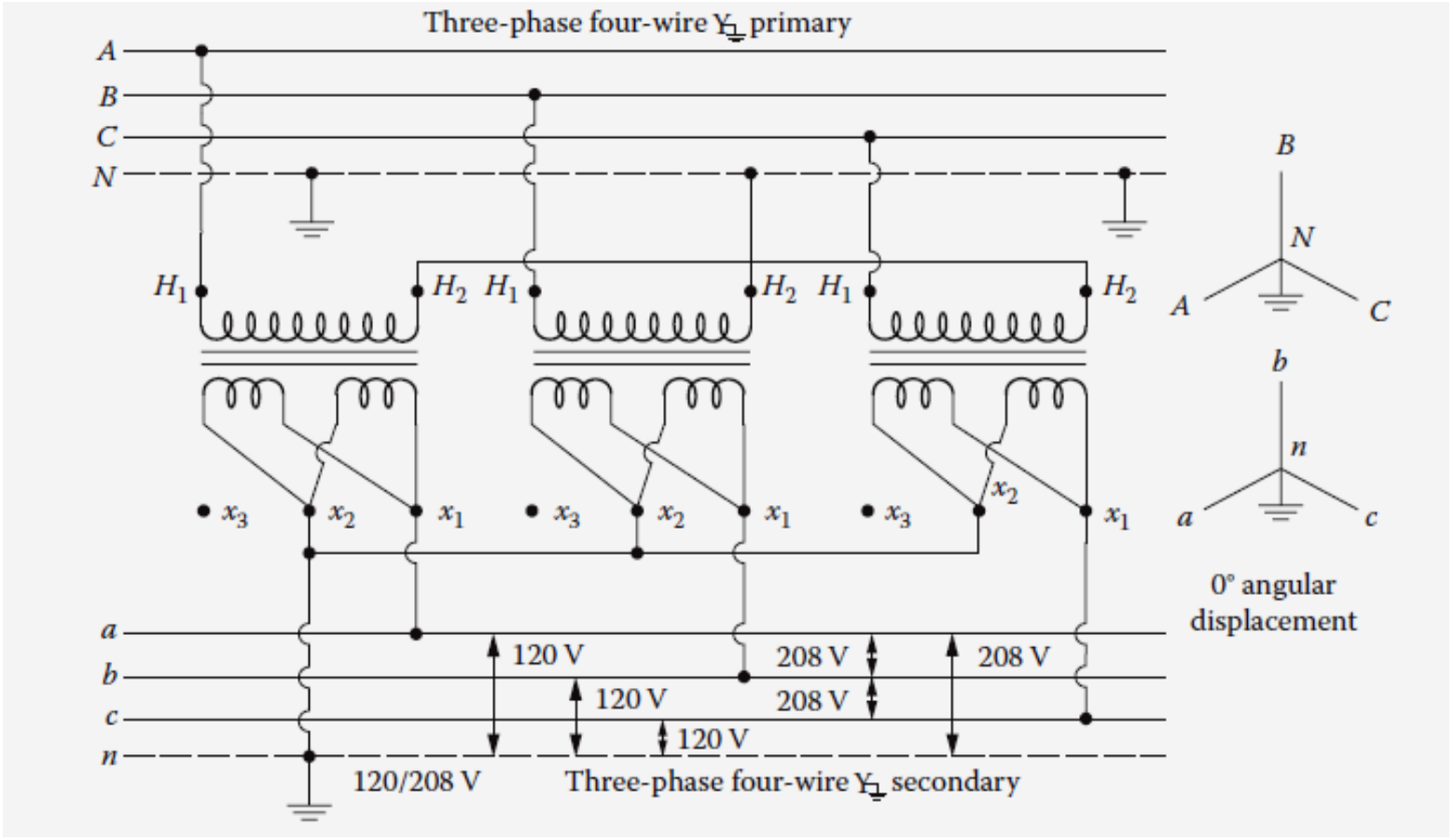
Spring 2014

Delta-Delta Connection

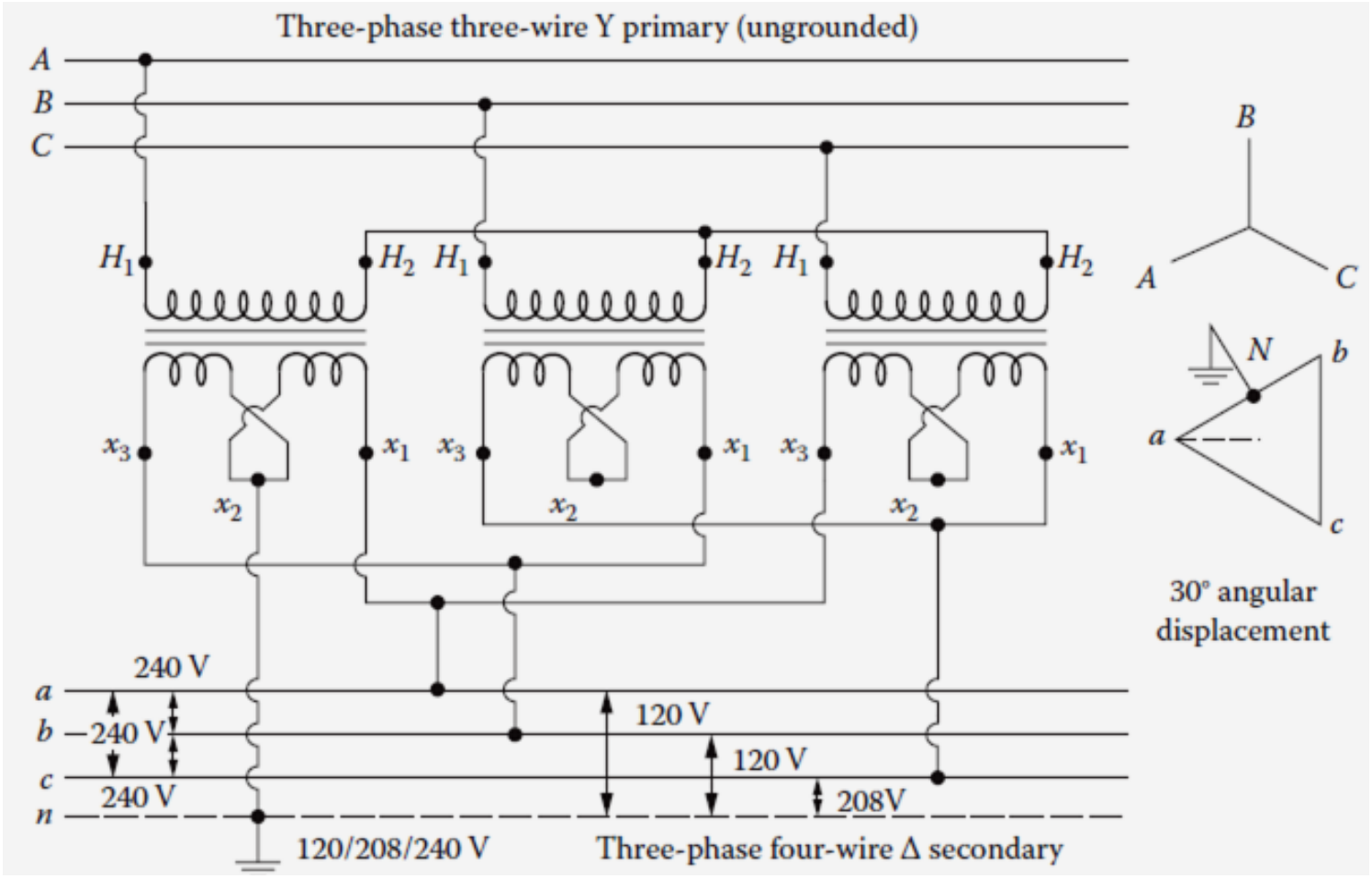




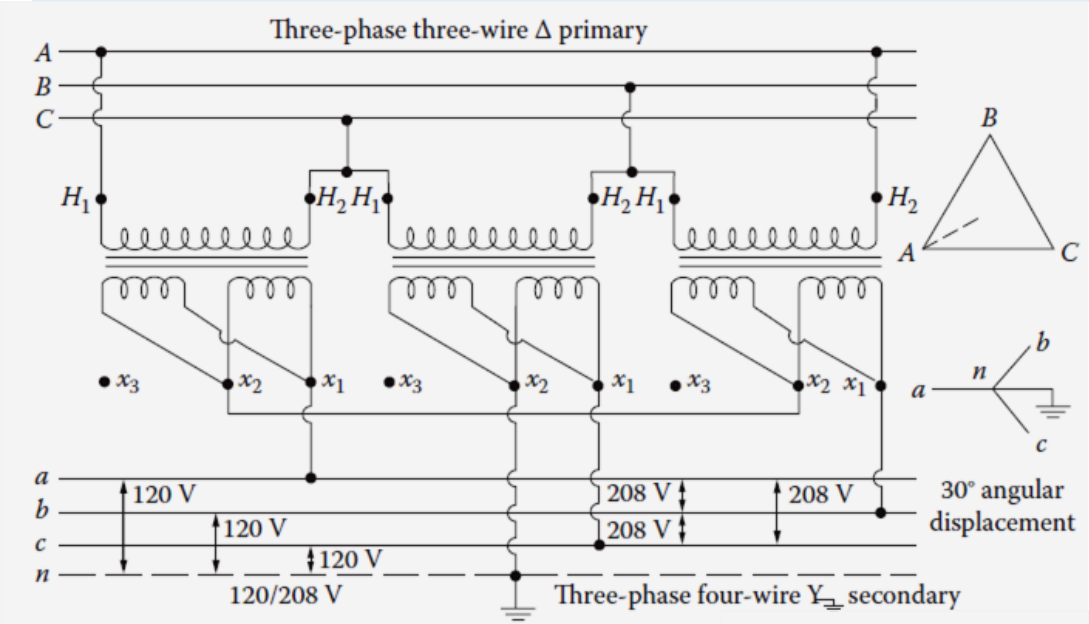
Wye-Wye Transformer Connection

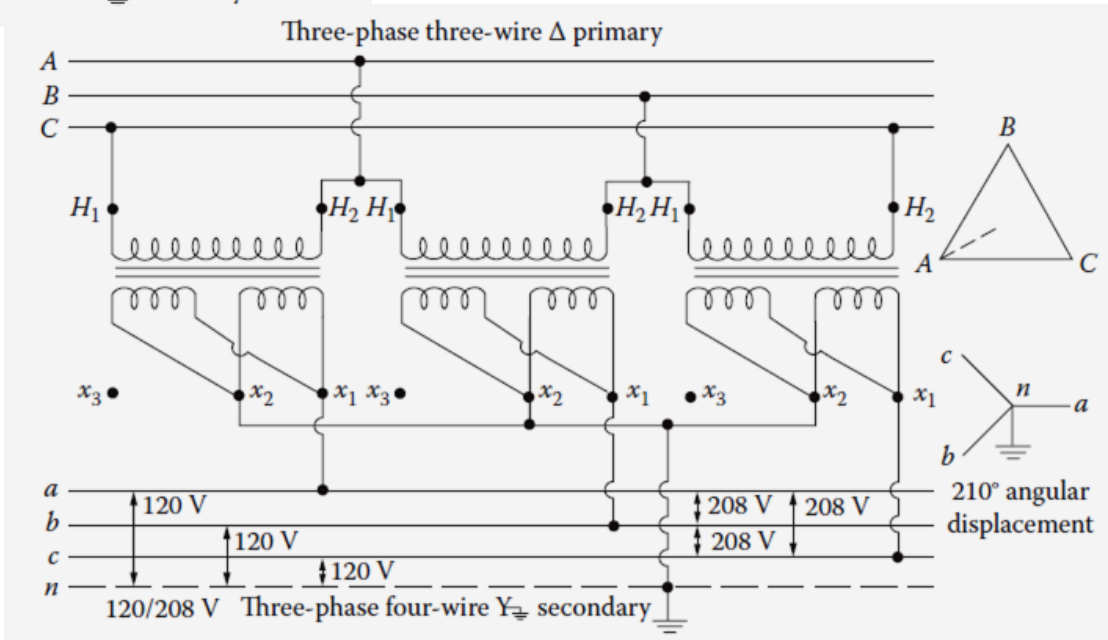


Wye-Delta Transformer Connection



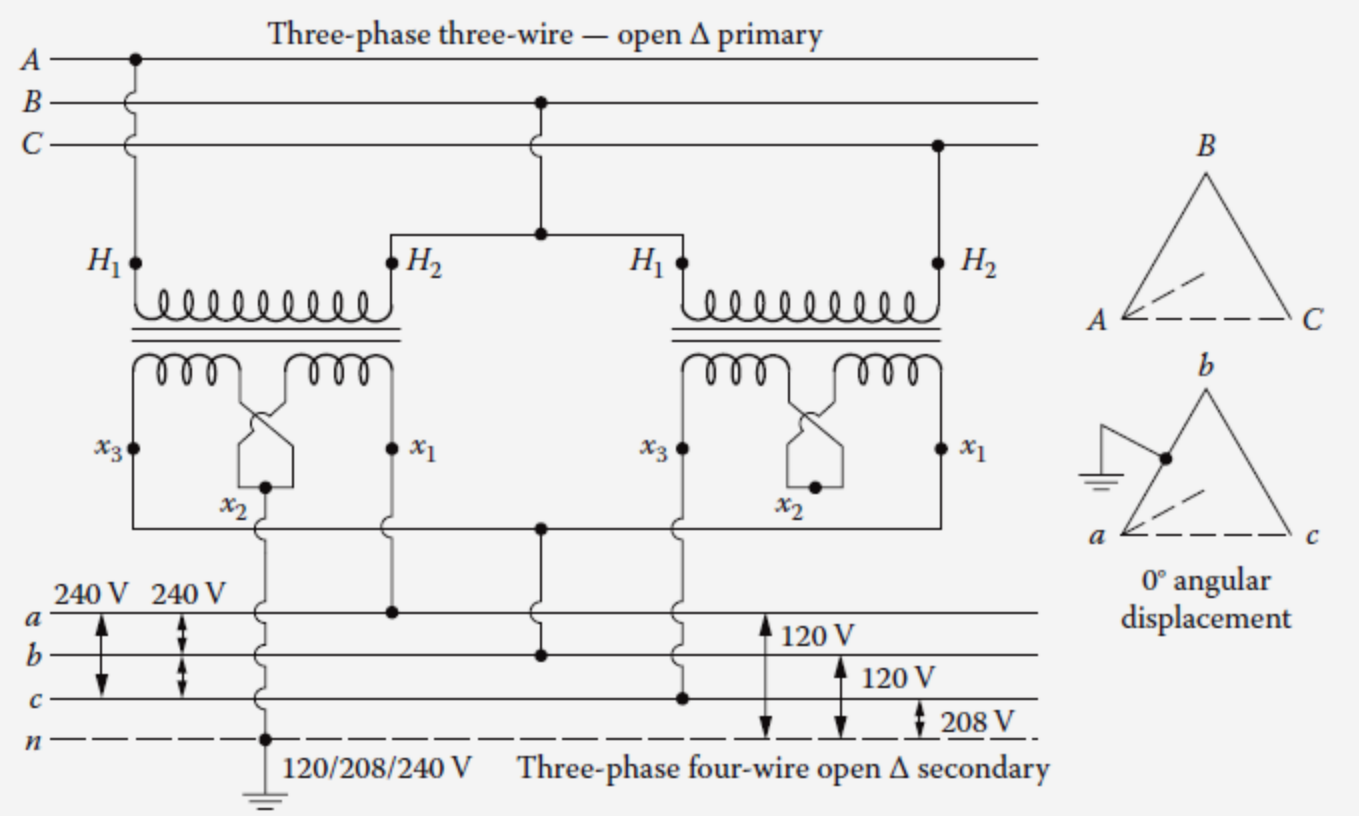
Delta-Wye Transformer Connection



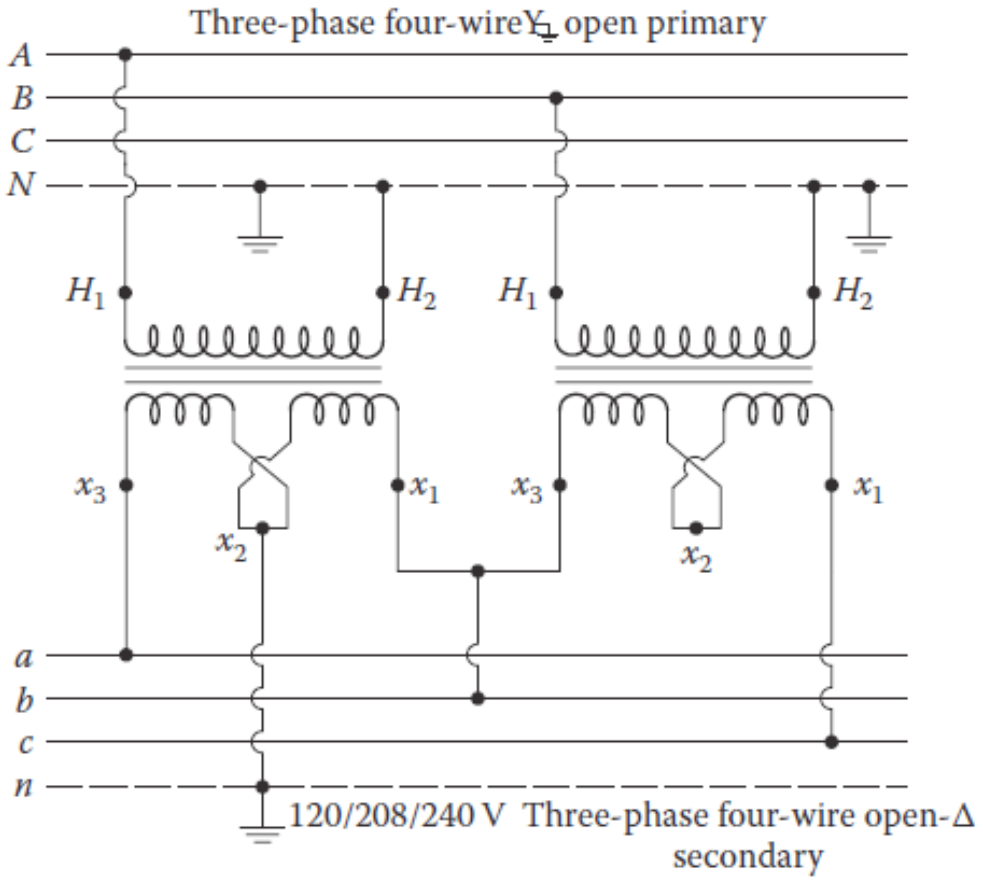


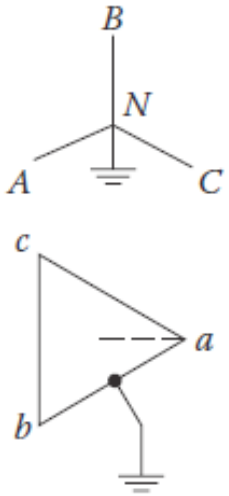
Open-Delta Open-Delta Connection

Capacity: 57.7% of Delta-Delta bank (not 66.7%)



Open-Wye Open-Delta Connection

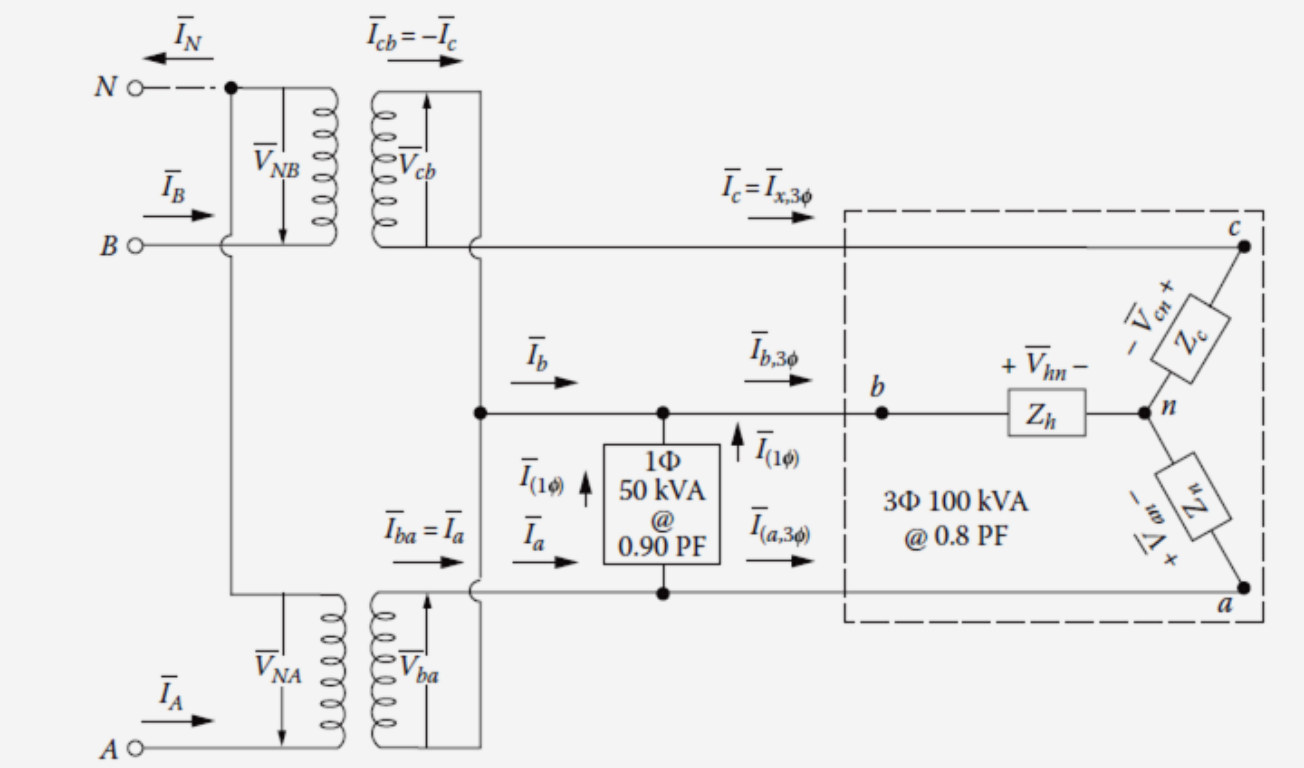




210° angular displacement

Example

Primary Voltage: 13,200/7,620 V
Secondary Voltage: 240 V

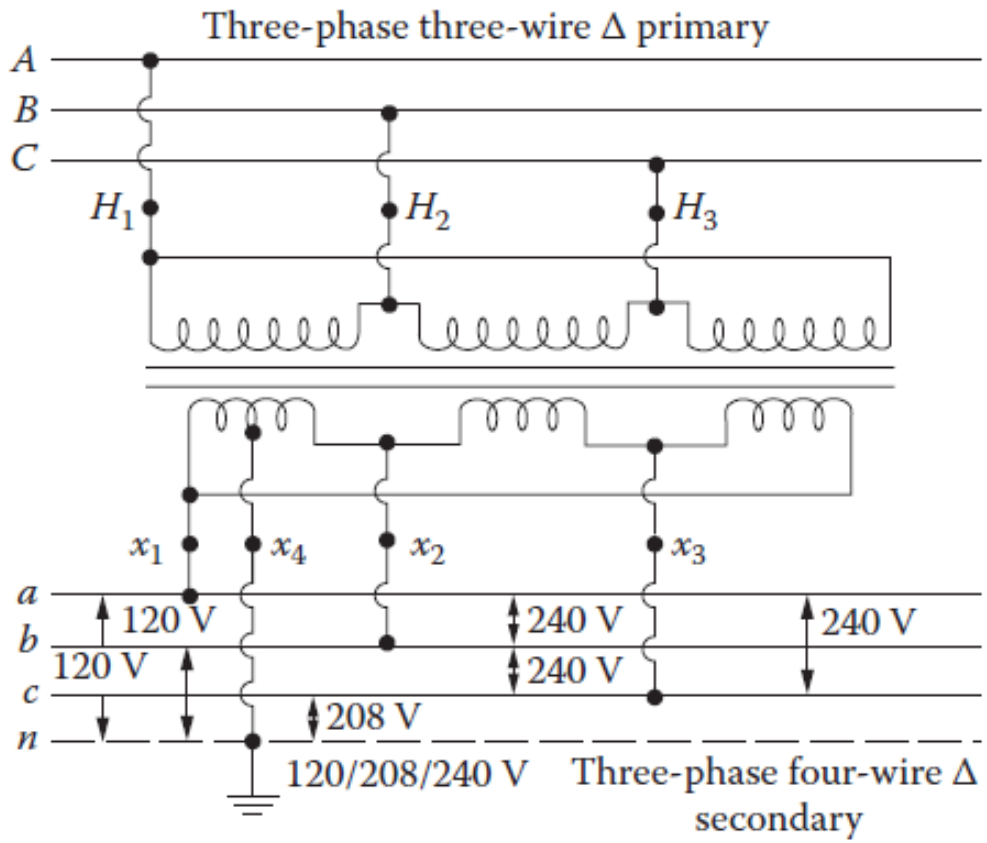


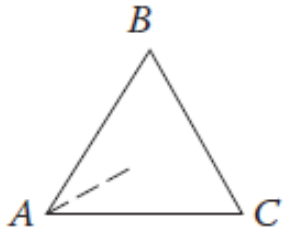
Ia = 421 ∟-18º A
Ib = 443 ∟-166º A
Ic = 241∟83º A

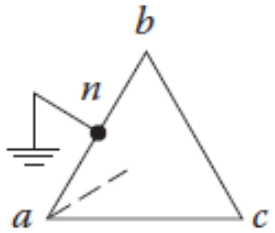
Sba = 101 kVA
Scb = 57.8 kVA

IA= 13.25 A
IB = 7.58 A
IN = 16.47 A

Three-Phase Transformer (Delta-Delta)

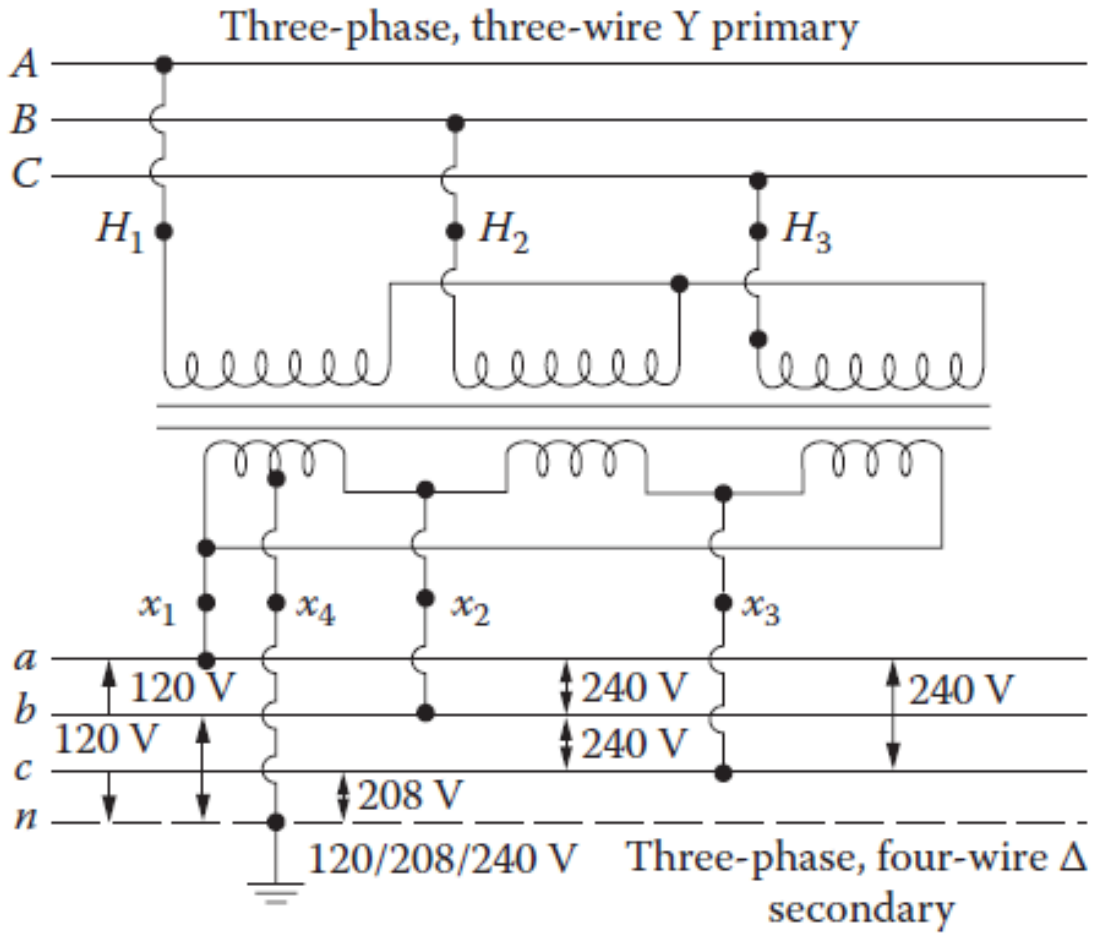


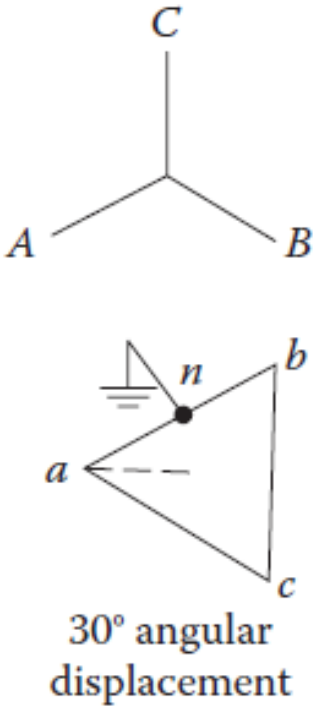




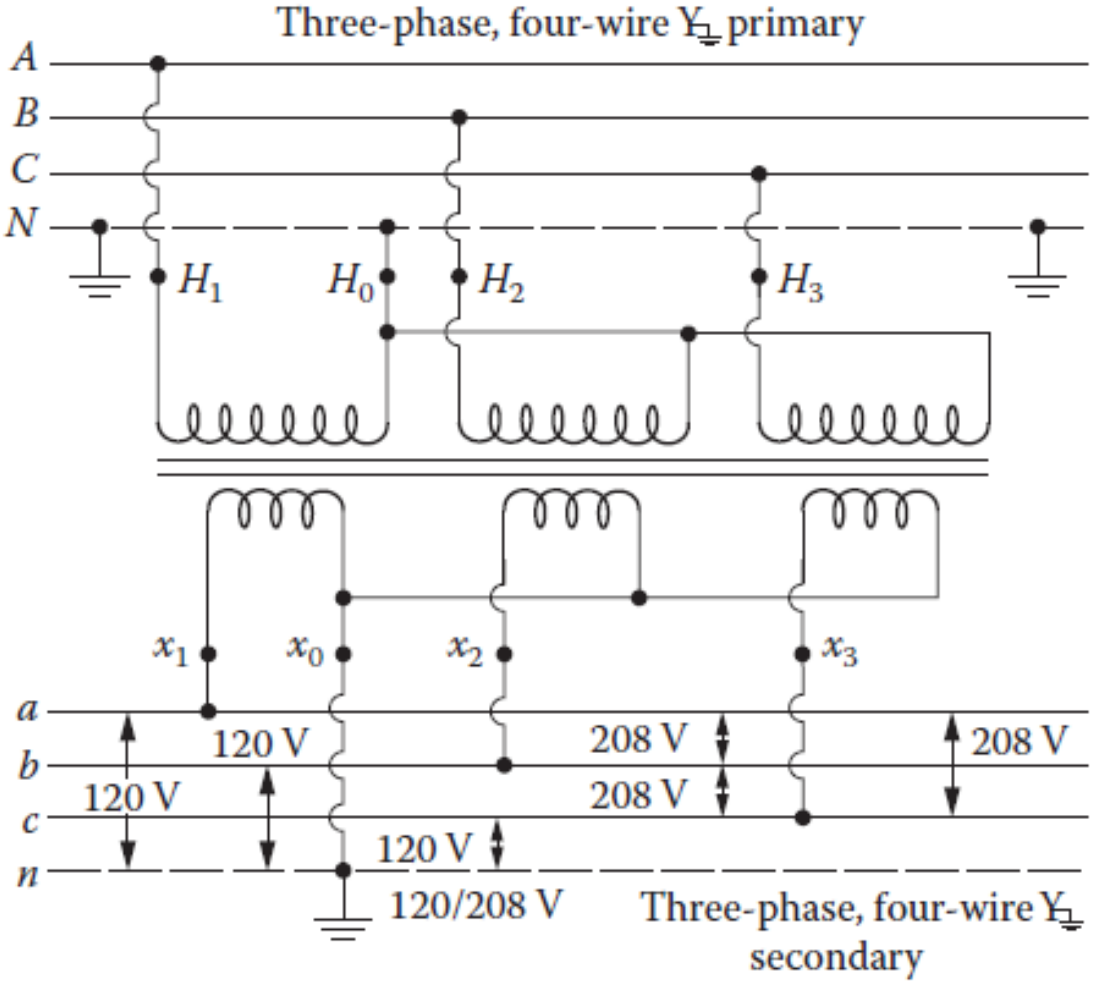
0° angular displacement

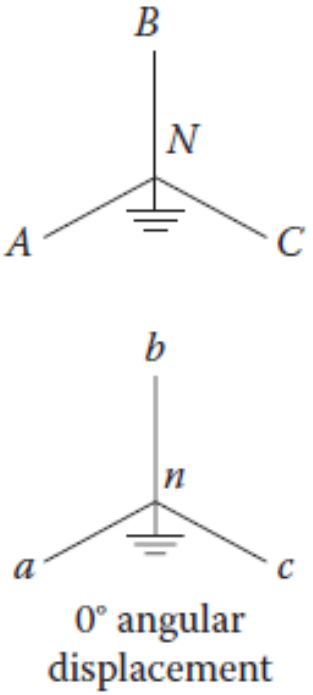
Three-Phase Transformer (Wye-Delta)



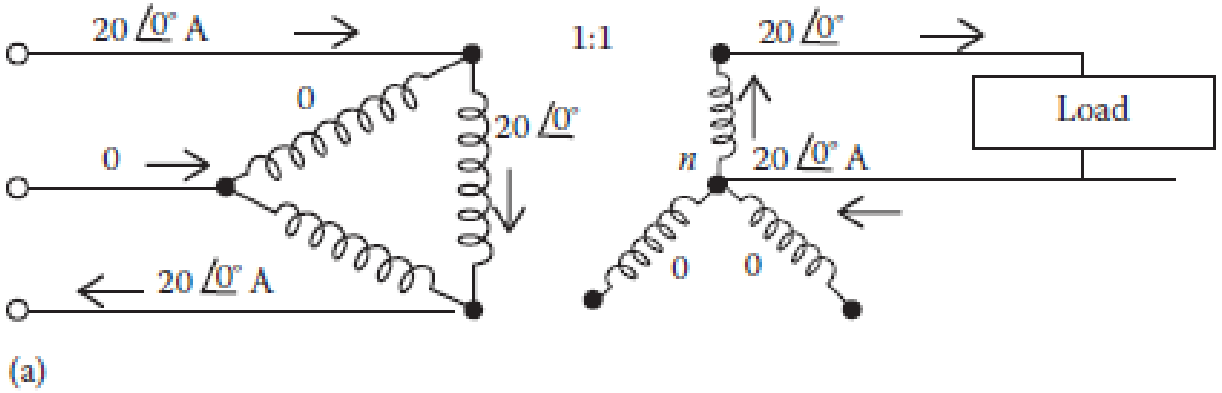


Three-Phase Transformer (Wye-Wye)

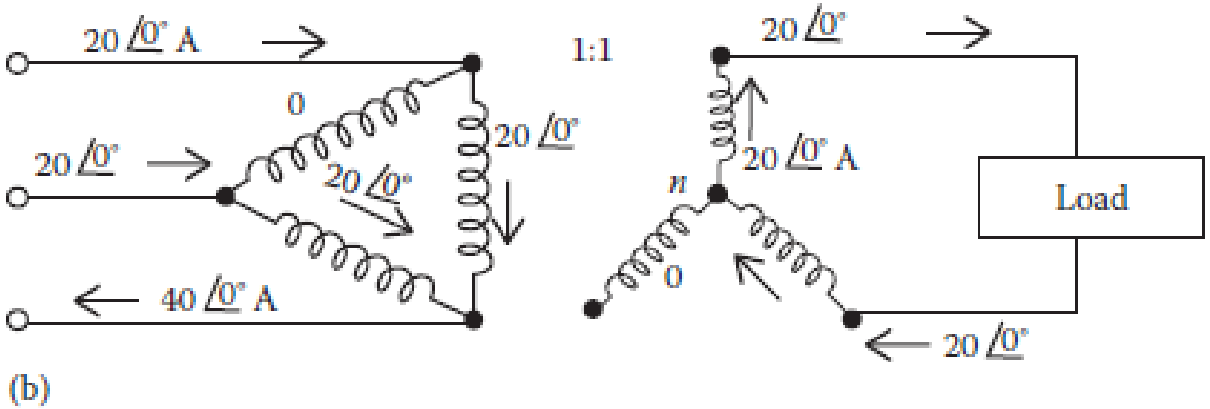




Example – Load Imbalance



(a)



(b)

Substation Transformer Rating

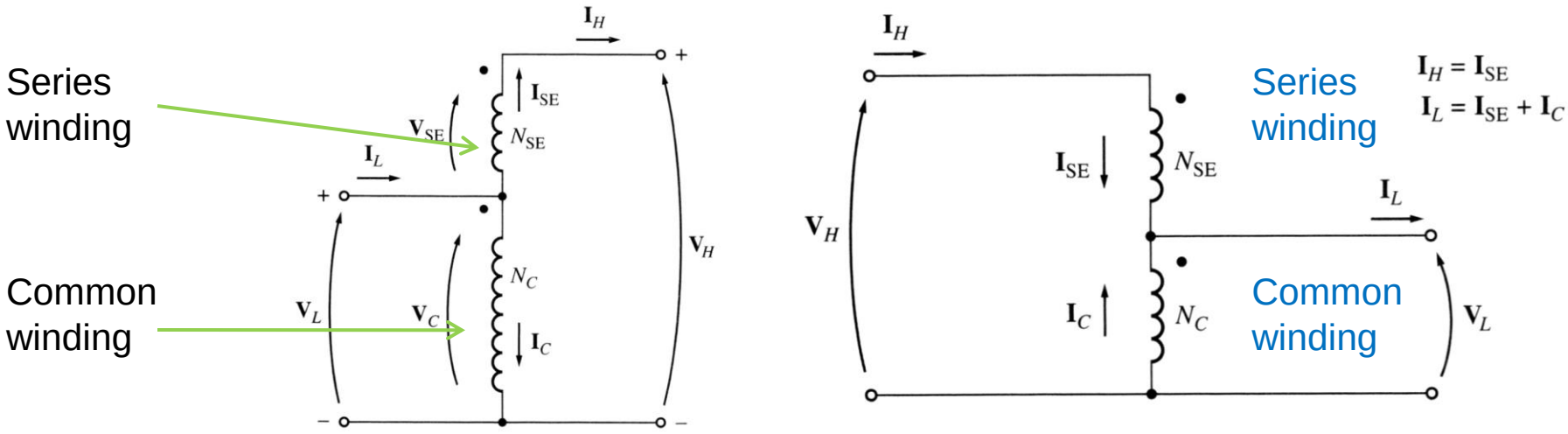
- 3 power ratings (e.g., 21/28/35 MVA)
  - OA: oil-immersed and self-cooled
  - FA: forced air cooled
  - FOA: forced oil cooled
- Above the hot-spot temperature of 110^{o}C, the life expectance decreases exponentially (it halves for every 8^{o}C increase in temperature.
- The transformer impedance is usually between 7%and 10% (based in OA rating)

The Autotransformer

Sometimes, it is desirable to change the voltage by a small amount (for instance, when the consumer is far away from the generator and it is needed to raise the voltage to compensate for voltage drops).

In such situations, it would be expensive to wind a transformer with two windings of approximately equal number of turns. An autotransformer (a transformer with only one winding) is used instead.

Diagrams of step-up and step-down autotransformers:



Output (up) or input (down) voltage is a sum of voltages across common and series windings.

The autotransformer

Since the autotransformer's coils are physically connected, a different terminology is used for autotransformers:

The voltage across the common winding is called a common voltage V_C, and the current through this coil is called a common current I_C. The voltage across the series winding is called a series voltage V_{SE}, and the current through that coil is called a series current I_{SE}.

The voltage and current on the low-voltage side are called V_L and I_L; the voltage and current on the high-voltage side are called V_H and I_H.

For the autotransformers:

$$\frac{V_C}{V_{SE}} = \frac{N_C}{N_{SE}}$$

$$N_C I_C = N_{SE} I_{SE}$$

$$\frac{V_L}{V_H} = \frac{N_C}{N_C + N_{SE}}$$

$$\frac{I_L}{I_H} = \frac{N_C + N_{SE}}{N_C}$$

The apparent power advantage

The ratio of the apparent power in the primary and secondary of the autotransformer to the apparent power **actually** traveling through its windings is

$$\frac{S_{IO}}{S_W} = \frac{N_{SE} + N_C}{N_{SE}}$$

The last equation described the apparent power rating advantage of an autotransformer over a conventional transformer.

S_W is the apparent power actually passing through the windings. The rest passes from primary to secondary parts without being coupled through the windings.

Note that the smaller the series winding, the greater the advantage!

The apparent power advantage

For example, a 5 MVA autotransformer that connects a 110 kV system to a 138 kV system would have a turns ratio (common to series) 110:28. Such an autotransformer would actually have windings rated at:

$$S_W = S_{IO}\frac{N_{SE}}{N_{SE}+N_C} = 5\cdot\frac{28}{28+110} = 1.015\ MVA$$

Therefore, the autotransformer would have windings rated at slightly over 1 MVA instead of 5 MVA, which makes is 5 times smaller and, therefore, considerably less expensive.

However, the construction of autotransformers is usually slightly different. In particular, the insulation on the smaller coil (the series winding) of the autotransformer is made as strong as the insulation on the larger coil to withstand the full output voltage.

The primary disadvantage of an autotransformer is that there is a direct physical connection between its primary and secondary circuits. Therefore, the electrical isolation of two sides is lost.

Chapter 3 Problems

6, 8, 9, 10.