Topics for Today:

- Announcements
  - Software: Matlab? Will begin using as early as next week.
  - Office hrs: 2pm, M,W,F
  - Office: EERC 614. Phone: 906.487.2857
  - Ch.2 Solutions posted on web page, go thru them for review.
  - XFMR exercises to be posted, due Sep 16th

- Chapter 2 - Review: Transformers and circuits w/transformers
  - Single phase transformers
  - Basic structure: winding R and Leakage, Core losses and saturation
  - 3-phase transformer banks and phase shifts (ANSI/IEEE vs. IEC)
  - Standard 30°shift transformers, non-standard connections
  - Pos/neg sequence phase shifts
  - Autotransformers
  - Load Tap Changing (LTC) transformers

- Comments on sequence networks
Waukesha Quality Inside
Means Reliability Is On Your Side

Load Tap Changer is designed to withstand up to a half-million operations without need for contact replacement.

Low no-load losses result from use of laser-scribed, super-grain-oriented steel.

Transformer exterior is coated to a minimum thickness of 3 mils. This coating has superior endurance characteristics and meets the ANSI C57.12.28 standard.

Material-stabilized coils are pressure-fit within the core frame.

Lamination width customized to achieve a near perfect-circle core cross section, resulting in the most efficient use of materials plus a lighter, more compact high-performance transformer.

Galvanized radiators provide excellent corrosion resistance and minimal maintenance.

De-energized tap changer features simple and compact in-line contact arrangement.

Coil assembly is rigidly braced in a high-strength frame that distributes clamping forces around the full circumference of the windings.

Submerged-arc process produces deep weld penetration, virtually eliminating leakage from welded tank joints.

Inside tank surfaces are painted white to facilitate internal inspection.

Waukesha Electric Systems offers component parts for transformer upgrades and repair, as well as extensive field service support that includes transformer moving, hauling and rigging, vacuum filling and oil processing, inspection, testing and customer training.

Waukesha Electric Systems
World Headquarters:
400 S. Prairie Avenue
Waukesha, WI 53186-5940
800.835.2732

U.S. Manufacturing:
Waukesha, WI  800.835.2732
Goldsboro, NC  800.758.4384

Service, Parts, Training:
High Voltage Supply
Dallas, TX  800.338.5526
Cooling
- Oil
- Heat exch
- Pumps, fans

Monitoring
- Temp: oil, coils
- Oil gases
- $N_2$

Coil Design
- Insulation:
  - coil-core; coil-coil; phase-phase
  - Higher V
  - BIL
  - BSK
How many possibilities are there for \( \Delta-Y \) or \( Y-\Delta \) phase shifts?

\[ \begin{align*}
  \pm 30^\circ, \\
  \pm 90^\circ, \\
  \pm 150^\circ
\end{align*} \]

6 each \( \Rightarrow 12 \) total.

Auto - \( \Delta \)
Zig - Zig
Extended \( \Delta \).
Three-Phase Transformers

All of these can and are used to indicate the same winding connections:

IEEE Stds:

Schematic

Circuit 3-line diagram

In Europe and much of the world:

IEC Stds: Dyn11

One-Line:

"old-down" diagram

One-Line:
Balanced 3-ph Voltages:

\[ |V_{abc}| = |V_{ba}| = |V_{ca}| \]
Transformer Phase Shifts

- See Δ-Y transformer nameplate

pos seg voltage
phrase shift
SEQUENCE NETWORKS
FOR TRANSFORMERS

Diagram showing a sequence network for transformers with nodes and connections labeled A, B, C, and others.
\[ I_{CO} \]

\[ I_{NO} \]

\[ I_N = 3I_{NO} \Rightarrow G \]

\[ V_{DROP} = 3I_{NO}Z_N = V_{NG} \]
triplen harmonics
buried tertiary
buried delta

Delta:
- trap triplen harmonics
- zero seq circ path
- Aux power (Station service)
- Protection
  - CTs