Thoughts on polarizing:

- $V_{LL}$
- $-3V_{ao}$, $3I_{ao}$

Also

- $V_{a2}$

\[
\begin{cases}
L-G \\
L-L \\
L-L-G
\end{cases}
\]
"Common mode failure"
If: CBI open
Fault on L1
Then CT on
CBI can sat

⇒ Larger meas. error
EE 5210 - Power Systems Protection  Spring 2001

87T - Overlapping Zones

Note: Typical scheme used by Consumer's Energy.
Overload (size fuses to blow on overload)

Sec. Fault prot/cood.

Int. Faults
<table>
<thead>
<tr>
<th>IEC/IEEE</th>
<th>OLD IEEE</th>
</tr>
</thead>
<tbody>
<tr>
<td>- ONAN</td>
<td>OA</td>
</tr>
<tr>
<td>- OFAF</td>
<td>FOA</td>
</tr>
<tr>
<td>- ONAF</td>
<td>FA</td>
</tr>
</tbody>
</table>

Large XFMRS
- 3 MVA rating

\[
\begin{align*}
\text{OA/EA/FA} & \quad 55^\circ C \\
\text{self} & \quad 3 \\
\text{Bank 1} & \quad 4 \\
\text{Banks} & \quad 5 \\
\text{Fans} & \quad 66^\circ C \\
+ & \quad Y_8
\end{align*}
\]

Air flow diagram:
- Oil flow
- Fans
- Radiator
- Air inlet
- Air outlet
5.1 Cooling classes of transformers

Transformers shall be identified according to the cooling method employed. For liquid-immersed transformers, this identification is expressed by a four-letter code as described below. These designations are consistent with IEC 60076-2: 1993.

First letter: Internal cooling medium in contact with the windings:

O mineral oil or synthetic insulating liquid with fire point\(^7\) \(\leq 300\) °C
K insulating liquid with fire point \(> 300\) °C
L insulating liquid with no measurable fire point

Second letter: Circulation mechanism for internal cooling medium:

N natural convection flow through cooling equipment and in windings
F forced circulation through cooling equipment (i.e., coolant pumps), natural convection flow in windings (also called nondirected flow)
D forced circulation through cooling equipment, directed from the cooling equipment into at least the main windings

Third letter: External cooling medium:

A air
W water

Fourth letter: Circulation mechanism for external cooling medium:

N natural convection
F forced circulation (fans (air cooling), pumps (water cooling))

NOTES:

1—In a transformer with forced, non-directed cooling, (second code letter F), the rate of coolant flow through all the windings vary with the loading, and are not directly controlled by the pumps. The pumped oil flows freely inside the tank and is not forced to flow through the windings.

2—In a transformer designated as having forced directed coolant circulation (second code letter D), the rate of coolant flow through the main windings is determined by the pumps and not by the loading. A minor fraction of the coolant flow through the cooling equipment may be directed outside the main windings to provide cooling for core and other parts. Regulating windings and/or other windings having relatively low power may also have non-directed coolant circulation.

A transformer may be specified with more than one power rating (also referred to as cooling stages). The transformer nameplate shall list the rated power and cooling class designation for each rating. The ratings shall be listed in order of increasing power. The cooling class designations are normally listed in order with a diagonal slash separating each one.

Examples:

ONAN/ONAF. The transformer has a set of fans which may be put in service as desired at high loading. The coolant circulation is by natural convection only.

ONAN/OPAF. The coolant circulation is by natural convection only at base loading. However, the transformer has cooling equipment with pumps and fans to increase the power-carrying capacity at high loading.

Examples of the cooling class designations used in IEEE Std C57.12.00-1993 and in previous revisions, and the corresponding new designations, are provided in Table 2.

\(^7\)Fire point—The lowest temperature at which a specimen will sustain burning for 5 s. (ASTM D92-1998. "Cleveland Open Cup" test method.)
Table 2—Cooling class designation

<table>
<thead>
<tr>
<th>Present designations</th>
<th>Previous designations</th>
</tr>
</thead>
<tbody>
<tr>
<td>ONAN</td>
<td>OA</td>
</tr>
<tr>
<td>ONAF</td>
<td>FA</td>
</tr>
<tr>
<td>ONAN/ONAF/ONAF</td>
<td>OA/FA/FA</td>
</tr>
<tr>
<td>ONAN/ONAF/OFAF</td>
<td>OA/FA/POA</td>
</tr>
<tr>
<td>ONAN/ODAF</td>
<td>OA/POA</td>
</tr>
<tr>
<td>ONAN/ODAF/OPOAF</td>
<td>OA/POA/POA</td>
</tr>
<tr>
<td>OFAF</td>
<td>POA</td>
</tr>
<tr>
<td>OFWF</td>
<td>POW</td>
</tr>
<tr>
<td>ODAF</td>
<td>POA</td>
</tr>
<tr>
<td>ODWF</td>
<td>POW</td>
</tr>
</tbody>
</table>

*Indicates directed oil flow per Table 9, NOTE 2 of IEEE Std C57.12.00-1993.*

5.2 Frequency

Unless otherwise specified, transformers shall be designed for operation at a frequency of 60 Hz.

5.3 Phases

5.3.1 General

Transformers described in this standard are either single-phase or three-phase. Standard ratings are included in the product standards for particular types of transformers. When specified, other phase arrangements may be provided.

5.3.2 Scott-connected or T-connected transformers

5.3.2.1 Phase transformation

These may be provided to accomplish three-phase to two-phase transformation, or vice versa; or to accomplish three-phase to three-phase transformation. Several arrangements commonly utilized to accomplish such transformations are described here.

5.3.2.2 Dissimilar single-phase transformers

Two single-phase transformers are assembled in an enclosure, and permanently interconnected, with the following characteristics:

a) Performance characteristics shall be based on bank operation of three-phase to two-phase transformation or vice versa.

b) The single-phase transformers may not be identical or interchangeable.
Heat: \( \frac{1}{R_c} \cdot \frac{1}{\ln} \)

Core: \( \frac{1}{R_c} \cdot \frac{1}{\ln} \)

Coils: \( \frac{R_c}{\text{REQ}} \)

\( P_{\text{core}} \cdot \frac{I^2}{R_c} \)

\( P_{\text{coil}} \cdot \frac{I^2}{\text{REQ}} \)

Top Oil Temp
Alarm - 26 H
Trip - 26 HH

Bank 1 - 49-1
Bank 2 - 49-2
alarm
trip
- 49 HH