Transformers – Dry & Liquid Filled

Milad Tannous   E.I.T.
Applications Engineering
Spectrum Power Systems Inc.
Why Transformers

600V from Utility

600V

120 VAC

120 VAC

600V

600V

AC Motor

Motor Starter
STI
55 Saltsman Drive
Cambridge
ON, N3H 4R7
Tel: 519-653-1847
Fax: 519-653-3658
www.stipower.ca

General Purpose Transformers
K-Rated Transformers
Harmonic Mitigation Transformers
UPS System’s Transformers
Auto & Drive Isolation Transformers
Power Transformers

Building Better Transformers
Product Scope

- **Low Voltage**
  - Any kVA any type

- **Medium Voltage**
  - Up to 27.6 kV
  - Up to 3000 kVA
    - With fans 4000 kVA
Transformer Basics

A transformer consists of a pair of windings primary and secondary, linked by a magnetic circuit or core.
Transformer Basics

Fig - B: Three Phase Transformer with Top View
Transformer Basics

A transformer consists of a pair of windings primary and secondary, linked by a magnetic circuit or core.

\[
\frac{V_1}{V_2} = \frac{N_1}{N_2}
\]
A transformer consists of a pair of windings primary and secondary, linked by a magnetic circuit or core.
A transformer consists of a pair of windings primary and secondary, linked by a magnetic circuit or core.

Windings: Copper or Alum. Windings can be rectangular or round.

Core: Cold rolled high grade steel
Core and Coil Assemblies – Multi Legged Cores

Fig. 8 Schematic of four-legged core-type transformer magnetic paths

Fig. 10 Schematic of five-legged core-type transformer magnetic paths
How long does a transformer last?

- 10 – 20 years
- 20 – 25 years
- 25 – 30 years
- 30 – 40 years
- 40 – 50 years
- 50 years plus
Why does a transformer fail?

- Over voltage
- Over current
Insulation
Insulation Class and Temp Rise

- **Class 105°C**
  - Maximum ambient temperature allowance: 40°C
  - Average Temperature rise: 30°C
  - Hot spot allowance: 10°C

- **Class 150°C**
  - Maximum ambient temperature allowance: 40°C
  - Average Temperature rise: 80°C
  - Hot spot allowance: 55°C

- **Class 180°C**
  - Maximum ambient temperature allowance: 40°C
  - Average Temperature rise: 40°C
  - Hot spot allowance: 25°C
  - Average Temperature rise with hot spot: 115°C

- **Class 220°C**
  - Maximum ambient temperature allowance: 40°C
  - Average Temperature rise: 40°C
  - Hot spot allowance: 30°C
  - Average Temperature rise with hot spot: 150°C
Temperature Rise

- Standard temp rise is 150 Deg. C.
- 115 and 80 Deg. C. rise units are available. These units will also have a continuous overload capacity of 15% for 115 Deg. C rise units and 30% for 80 Deg. C. rise units when operate at 150 Deg. C. rise.
- Since the insulation system is rated 220 Deg. C., this overload operation will not reduce the normal life expectancy of the transformers.
- Since operating in an overload condition results in higher temperatures and higher losses, the efficiency will decrease under these conditions.
Transformer Standards

Design, manufacture and test the dry type transformers in accordance with good industry practices and in accordance with the following standards:

- CSA C9
- CSA C22.2 No. 47
- CSA C802.00
- NEMA TP1
Transformer Impedance

- Transformation between primary and secondary is not perfect
- Not all of the flux produced by the secondary windings links the secondary
- The transformer is said to possess leakage reactance
- The combination of resistance and reactance is expressed in practical terms as impedance
- Normal method of expressing transformer impedance is as a % voltage drop in the transformer at full load current.
Percent Impedance Voltage Drop

- Inherent resistance and reactance in a transformer
- The transformer impedance assists in determining transformer contribution to the available fault current at the secondary terminations of the transformer.
- Important for over-current coordination and selecting secondary over-current protection.
Fault Current

- Calculating Maximum Available Fault Current on Transformer Secondary
- Full Load Current (I) ÷ %IZ

Example
- 3Ø Transformer Secondary Current:
  - $I = 500 \text{ kVA} ÷ .480 \text{ kV} ÷ 1.73 = 602\text{A}$
  - $IZ = 4.0\%$
- Maximum available fault current
  $= 602 \text{Amps} ÷ .04 = 15,050 \text{Amps}$
Regulation

- When a transformer is energized with no load, the secondary voltage will be exactly the primary voltage divided by the turns ratio (NP/NS).
- When the transformer is loaded, the secondary voltage will be diminished by an amount determined by the impedance and the power factor of the load. This change in voltage is called regulation and is defined as the rise in voltage when the load is removed.
- % regulation can be specified to be a certain number at a certain power factor, usually 1.0 or 0.8 and is always a positive number.
Transformer Losses

- Eddy current loss
- Hysteresis loss
- Iron loss

Total losses

Load in kVA

Load Loss

Core Loss

Losses in Watts

0 100 200 300 400 500 600

0 5 10 15 20 25
Efficiency

- As with any other energy conversion device, the efficiency of a transformer is the ratio of energy delivered to the load divided by the total energy drawn from the source.
- Transformer efficiency in Canada is mandated by CSA Standard 802
## CSA vs. DOE Efficiencies

<table>
<thead>
<tr>
<th>kVA</th>
<th>DOE 10 CFR Part 431</th>
<th>CSA C802.1-00</th>
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<tr>
<td>15</td>
<td>98.36</td>
<td>97.89</td>
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<tr>
<td>30</td>
<td>98.62</td>
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<td>45</td>
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<td>75</td>
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<td>112.5</td>
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<tr>
<td>150</td>
<td>99.08</td>
<td>98.84</td>
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<tr>
<td>225</td>
<td>99.17</td>
<td>98.94</td>
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<td>99.23</td>
<td>98.94</td>
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<td>500</td>
<td>99.25</td>
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<td>99.32</td>
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<td>2000</td>
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<td>99.37</td>
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<tr>
<td>2500</td>
<td>99.49</td>
<td>99.37</td>
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</table>
Electrical distribution systems are subject to lightning surges.

The Basic Impulse Level (BIL) of the transformer measures its ability to withstand these surges.
Delta Wye Connected Transformers

- Primary
- Secondary
- 30 Deg
# 0 Degrees Transformer Connections

<table>
<thead>
<tr>
<th>Phasor Symbols</th>
<th>Marking of line terminals and phasor diagram of induced voltages</th>
<th>Winding Connections</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>H.V. Winding</td>
<td>L.V. Winding</td>
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<tr>
<td>( \text{Y}_0 )</td>
<td><img src="image1.png" alt="Diagram" /></td>
<td><img src="image2.png" alt="Diagram" /></td>
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<tr>
<td>( \text{D}_0 )</td>
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<td><img src="image5.png" alt="Diagram" /></td>
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<tr>
<td>( \text{Z}_0 )</td>
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</table>
# 30 Degrees Transformer Connections

<table>
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<th>Marking of line terminals and phasor diagram of induced voltages</th>
<th>Winding Connections</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>H.V. Winding</td>
<td>L.V. Winding</td>
</tr>
<tr>
<td>Dy1</td>
<td><img src="image1.png" alt="Diagram" /></td>
<td><img src="image2.png" alt="Diagram" /></td>
</tr>
<tr>
<td>Yd1</td>
<td><img src="image3.png" alt="Diagram" /></td>
<td><img src="image4.png" alt="Diagram" /></td>
</tr>
<tr>
<td>Yz1</td>
<td><img src="image5.png" alt="Diagram" /></td>
<td><img src="image6.png" alt="Diagram" /></td>
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<tr>
<td>Zyl</td>
<td><img src="image7.png" alt="Diagram" /></td>
<td><img src="image8.png" alt="Diagram" /></td>
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</table>
Phase Shift Issues
Connections

Delta Wye

600V - 120/208V

Delta Wye
Taps

- Transformers also provide the option of compensating for regulation
- Regulation which is system introduced or introduced by the transformer itself
Taps

If transformer voltage is 600V to 120/208V

- FCAN
  - 615V
  - 630V

- FCBN
  - 585V
  - 570V
Inrush Current

- When a transformer is taken off-line, there will be a certain amount of residual flux that can remain in the core due to the properties of the magnetic core material.
- The residual flux can be as much as 50 to 90% of the maximum operating flux, depending on the type of core steel.
- When voltage is reapplied to the transformer, the flux introduced by this source voltage will build upon that which already exists in the core.
- In order to maintain this level of flux in the core, which can be well into the saturation range of the core steel, the transformer can draw current well in excess of the transformer’s rated full load current.
Tests

- Basic Impulse Level test
- Partial discharge test
- Heat run test
- Sound level test
- Ratio test
Winding Material

- Copper or aluminum
- Depends on application and individual preference
- Copper has higher electrical conductivity and cost
- Copper units are smaller
- Both oxidize over time
Dry type transformers can be manufactured with its windings separated by a grounded metal-foil shield.
Shielded Isolation Transformers
Transformer Sound

- The "hum" is due to the alternating flux in the core
- Transformer "hum", is commonly referred to as "noise"
- Noise is an inherent characteristic of the core and cannot be completely eliminated.
- Quality core steel will minimize audible sound levels.

<table>
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<tr>
<th>Transformer Sound Level Standards</th>
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<tbody>
<tr>
<td>Transformer kVA</td>
</tr>
<tr>
<td>-----------------</td>
</tr>
<tr>
<td>0-9</td>
</tr>
<tr>
<td>10-50</td>
</tr>
<tr>
<td>51-150</td>
</tr>
<tr>
<td>151-300</td>
</tr>
<tr>
<td>301-500</td>
</tr>
<tr>
<td>501-700</td>
</tr>
<tr>
<td>701-1000</td>
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# Enclosures Types

<table>
<thead>
<tr>
<th>Enclosure Rating</th>
<th>NEMA</th>
<th>UL</th>
<th>CSA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type 1</td>
<td>Enclosures are intended for indoor use primarily to provide a degree of protection against contact with the enclosed equipment or locations where unusual service conditions do not exist.</td>
<td>Indoor use primarily to provide protection against contact with the enclosed equipment and against a limited amount of falling dirt.</td>
<td>General purpose enclosure. Protects against accidental contact with live parts.</td>
</tr>
<tr>
<td>Type 2</td>
<td>Enclosures are intended for indoor use primarily to provide a degree of protection against limited amounts of falling water and dirt.</td>
<td>Indoor use to provide a degree of protection against limited amounts of falling water and dirt.</td>
<td>Indoor use to provide a degree of protection against dripping and light splashing of non-corrosive liquids and falling dirt.</td>
</tr>
<tr>
<td>Type 3</td>
<td>Enclosures are intended for outdoor use primarily to provide a degree of protection against windblown dust, rain, and sleet; undamaged by the formation of ice on the enclosure.</td>
<td>Outdoor use to provide a degree of protection against windblown dust and windblown rain; undamaged by the formation of ice on the enclosure.</td>
<td>Indoor or outdoor use; provides a degree of protection against rain, snow, and windblown dust; undamaged by the external formation of ice on the enclosure.</td>
</tr>
<tr>
<td>Type 3R</td>
<td>Enclosures are intended for outdoor use primarily to provide a degree of protection against falling rain and sleet; undamaged by the formation of ice on the enclosure.</td>
<td>Outdoor use to provide a degree of protection against falling rain; undamaged by the formation of ice on the enclosure.</td>
<td>Indoor or outdoor use; provides a degree of protection against rain, snow, and windblown dust; undamaged by the external formation of ice on the enclosure.</td>
</tr>
</tbody>
</table>
Enclosures

Type 1

Type 2

Type 3R
# STI Enclosure Dimensions

**Enclosure Specifications**

All dimensions in inches

<table>
<thead>
<tr>
<th>KVA</th>
<th>15-30</th>
<th>45-75</th>
<th>112-150</th>
<th>225-300</th>
<th>450-500</th>
<th>600-1000</th>
</tr>
</thead>
<tbody>
<tr>
<td>H</td>
<td>26</td>
<td>32</td>
<td>42</td>
<td>49</td>
<td>62</td>
<td>76</td>
</tr>
<tr>
<td>W</td>
<td>22</td>
<td>26</td>
<td>30</td>
<td>36</td>
<td>52</td>
<td>66</td>
</tr>
<tr>
<td>D</td>
<td>18</td>
<td>20</td>
<td>24</td>
<td>27</td>
<td>36</td>
<td>38</td>
</tr>
<tr>
<td>D+rs</td>
<td>23</td>
<td>25</td>
<td>31</td>
<td>37</td>
<td>42</td>
<td>44</td>
</tr>
</tbody>
</table>
Thermal Sensors – Single or 1 per coil

Isolation Transformer with Thermal Sensor Switch in Center Coil

<table>
<thead>
<tr>
<th>Switch Type</th>
<th>Normally closed (normally open also available)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature Setting</td>
<td>180°C non-adjustable (other temperatures also available)</td>
</tr>
</tbody>
</table>
IR Window
Epoxy Vacuum Impregnation

- Increased mechanical strengths
- Enhanced performance in heavily contaminated environments
- Comparable with cast coil performance
- Reduced noise
- Improved winding insulation
- No air pockets
Auto Transformers

- Designed for linear loads
- Common primary and secondary winding
- Light and compact
- More cost effective
- 600-480V, 10 to 1,000 kVA
- 3 windings, 3-phase
Power Transformers

- 150 kVA onwards
- 5 kV to 27.6 kV,
- Provision for close coupling to either new or existing switchgear equipment
Dual Output Transformer - LV

TRANSFORMER IN ACCORDANCE WITH CSA C22.2. 47–M50 AND UL1561
MEETS OR EXCEEDS EFFICIENCY REQUIREMENT OF C802.2–06

21 KVA, 3 PHASE, 60 Hz
INPUT: 360 VOLTS WITH 2–2.5% FCAN & 2–2.5% FCBN
OUTPUT 1: 15 KVA 208Y/120
OUTPUT 2: 6 KVA 400V/230
CONDUCTOR: ALUM/COPPER WINDINGS

AUDIBLE NOISE: 48 dB
ENCLOSURE TYPE: NEMA 1
WEIGHT: 265 LBS.

INSULATION CLASS: 220°C
TEMPERATURE RISE: 150°C AMBIENT: 40°C

NO-LOAD LOSSES: 120 WATTS
FULL-LOAD LOSSES: 975 WATTS

THD: 3.58%
TIX: 2.66%
TIZ: 4.46%

PEAK INFLUSH CURRENT: 330 AMPS

EFFICIENCY:
25% LOAD: 97.24%
50% LOAD: 97.53%
75% LOAD: 96.87%
FULL LOAD: 96.03%

INPUT TERMINALS: 25x0.75 CU Ø .281 HOLE
OUTPUT TERMINALS: 25x0.75 CU Ø .281 HOLE
X0 TERMINAL: 25x0.75 CU Ø .281 HOLE
GND TERMINAL: AL LUG FOR 2–14 AWG WIRE
Dual Output Transformer - MV

1500 KVA, 3 PHASE, 60 Hz
INPUT: 13800 VOLTS
WITH 2–2.5% FCAN & 2–2.5% FCBN
OUTPUT 1: 208Y/120 AT 750 KVA
OUTPUT 2: 600Y/346 AT 750 KVA
SHIELD BETWEEN PRIMARY AND SECONDARY
AUDIBLE NOISE: 68 db
ENCLOSURE TYPE: NEMA 3R
WEIGHT: 9080 LBS.

COPPER WINDINGS

PRIMARY RATING: 95 KV
INSULATION CLASS: 220°C
TEMPERATURE RISE: 150°C

AMBIENT: 40°C
NO-LOAD LOSSES: 3186 WATTS
FULL-LOAD LOSSES: 20,710 WATTS
%X: 7.20 %Z: 7.30 IR: 1.17
EFFICIENCY:
25% LOAD: 98.95% 50% LOAD: 99.14%
75% LOAD: 98.93% FULL LOAD: 98.64%
Dual Output Transformer

- Dual output transformer diagram with labeled inputs and outputs.
- Connections from X0, X1, X2, X3 to H1, H2, H3, and Y0.
- Ground connection indicated between Y0 and PP2.
Dry Type Cooling

- ANN – Air Natural Convection Cooled
  - kVA is name plates rated kVA, single rating only
- ANF – Forced Air Cooled
# Eaton’s Cooper Power Systems

## Transformers
- Single-Phase Poles
- Single & Three-Phase Pads
- Substations

## Voltage Regulators
- Voltage Regulators
- Auto Boosters
- Variable Power Regulators

## Switchgear
- Overhead switchgear
- Pad-mount switchgear

## Capacitors
- HV capacitor Unit
- Capacitor banks
- Filter banks

## Arresters, Fuses, Switches & Connectors
- Fuses/Surge Arrestors
- Cable connectors
- Transformer Components
- Service parts

## Energy Automation Systems
- AMR
- Demand response
- Distribution automation

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## Energy Automation Systems
- Product development & design to be defined for O&G specific requirements. Remote monitoring, management & control.
Transformer Products
3Ø Transformer product scope

- Pad-mounted and Substation transformers
- kVA range:
  - 45-12,000
  - Envirotemp™ FR3™ Filled
- Primary Voltage
  - 2400 to 46,000 volts
  - Up to 250 kV BIL
- Secondary Voltage
  - 120 to 24,940 volts
  - 125 kV BIL
Liquid Power Transformers
Pad-mounted vs. Substation

- No Fencing
- Smaller Footprint
- Less Space Needed
- Underground Feed
- No Overhead Lines
Liquid-Filled Transformer Four Letter Cooling Classes

1. Medium Internal
2. Mechanism
3. Medium
4. Mechanism External
# Liquid-Filled Transformer Four Letter Cooling Classes

<table>
<thead>
<tr>
<th>Letter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>O</strong></td>
<td>Liquid with flash point less than or equal to 300°C</td>
</tr>
<tr>
<td><strong>K</strong></td>
<td>Liquid with flash point greater than 300°C</td>
</tr>
<tr>
<td><strong>L</strong></td>
<td>Liquid with no measurable flash point</td>
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</table>

**Second Letter**

<table>
<thead>
<tr>
<th>Letter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>N</strong></td>
<td>Natural convection through cooling equipment and windings</td>
</tr>
<tr>
<td><strong>F</strong></td>
<td>Forced circulation through cooling equipment, natural convection in windings</td>
</tr>
<tr>
<td><strong>D</strong></td>
<td>Forced circulation through cooling equipment, directed flow in man windings</td>
</tr>
</tbody>
</table>

**External**

<table>
<thead>
<tr>
<th>Letter</th>
<th>Description</th>
</tr>
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<td><strong>A</strong></td>
<td>Air</td>
</tr>
<tr>
<td><strong>W</strong></td>
<td>Water</td>
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**Fourth Letter**

<table>
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<th>Letter</th>
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<tbody>
<tr>
<td><strong>N</strong></td>
<td>Natural convection</td>
</tr>
<tr>
<td><strong>F</strong></td>
<td>Forced circulation</td>
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</table>
Forced Air
Forced Air
### Envirotran Plus kVA Ratings

<table>
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<tr>
<th>55°C Rise ONAN/KNAN</th>
<th>65°C Rise ONAN/KNAN</th>
<th>75°C Rise KNAN</th>
<th>55°C Rise ONAF/KNAN</th>
<th>65°C Rise ONAF/KNAN</th>
<th>75°C Rise KNAF</th>
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<tr>
<td>500</td>
<td>560</td>
<td>610</td>
<td>575</td>
<td>644</td>
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<td>12208</td>
<td>12500</td>
<td>14000</td>
<td>15260</td>
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</table>
High Voltage Connections

- Dead Front means no exposed connections
Live Front

- Live Front means exposed connections
Live Front vs. Dead Front
Transformer Bushing Layout Radial Feed vs. Loop Feed
System Configurations Radial Feed vs. Loop Feed
Transformer Construction

☐ Winding Material
  - Aluminum or Copper

☐ No-Load Taps
  - +/- 2-2 1/2% (Standard) on High Voltage
  - - 4 - 2 1/2% (optional)
  - Other Tap positions available

☐ Fluid
  - Envirotemp FR3 Fluid
  - Mineral Oil
  - Other (Luminol or Voltesso are possible)
Envirottemp FR3 the First Truly Green Dielectric Fluid

- May be Used Indoors and Outdoors
- 100% Food Grade Ingredients
- Rapid Biodegradation Rate
- Renewable Resource Based
- Non-Toxic (zero trout fingerling mortality)
- Does Not Contain Petroleum, Silicones, nor Halogens*

* PCB’s, SF6, CFC, PERC, etc.
Why Envirotemp™ FR3™ is better

- Higher moisture content in insulation during manufacturing process
- Natural ester based fluid - higher affinity for and tolerance of moisture
  - 25 C saturation levels
    - Mineral oil: 70 ppm
    - Envirotemp™ FR3™: 1000 ppm
- Insulation moisture migrates to Envirotemp™ FR3™ when transformer is loaded in the field
- Maintains dielectric strength similarly to mineral oil in terms of relative saturation meaning higher dielectric strength throughout the life of the transformer
Why Envirotelm™ FR3™ is better

- FR3™ fluid extends insulation life by a factor of as much as 5-8 times because it has the unique ability to draw out retained moisture and absorb water driven off by aging paper.

- It also helps prevent paper molecules from severing when exposed to heat. These properties can result in an increase of overload ability and/or longer transformer insulation life, resulting in both lower life cycle costs and delayed asset replacement.”
FIRE SAFETY – Flash & Fire Point of Dielectric Fluids

![Bar chart showing the flash and fire points of different dielectric fluids.](chart.png)
ENVIRONMENTAL IMPACT Biodegradation Rate of Dielectric Fluids

FR3 spill degrades in 21 days
ENVIRONMENTAL IMPACT - Biodegradation Rate of Dielectric Fluids

- Biodegradation - "Transformation of a substance into new compounds through biochemical reactions or the actions of microorganisms such as bacteria." - U.S. Geological Survey, 2007

- "A process by which microbial organisms transform or alter (through metabolic or enzymatic action) the structure of chemicals introduced into the environment." - U.S. Environmental Protection Agency, 2009

This may be characterized for purpose of hazard assessment as:

1. Primary. Alteration of the chemical structure of a substance resulting in loss of a specific property of that substance.

2. Environmentally acceptable. Biodegradation to such an extent as to remove undesirable properties of the compound. This often corresponds to primary biodegradation but it depends on the circumstances under which the products are discharged into the environment.

3. Ultimate. Complete breakdown of a compound to either fully oxidized or reduced simple molecules (such as carbon dioxide/methane, nitrate/ammonium, and water).

FR3 biodegradation rate and completeness meets the U.S. Environmental Protection Agency (EPA) criteria for “Ultimate Biodegradability” classification.”
FR3 Relative Accelerated Aging Study

Transformer Aging Study

- 500 hours = 10 yrs
- 1000 hours = 20 yrs
- 2000 hours = 40 yrs
- 4000 hours = 80 yrs
Liquid Indoors

- Liquid-filled can be Listed and Labeled as meeting the NEC by a Nationally Recognized Testing Laboratory (NRTL).
- FM Approved; or UL Classified with FR-3 Fluid; Less Flammable Fluids
- Complies with Indoor Installation requirements
- No Fire Suppression Systems Req’d
- Pad-mounted and Substation transformers
Indoor installations

- NEC® allows for indoor installation of liquid-filled transformers with few constraints:
- Less-Flammable Liquid-Filled Transformers - NEC 450-23
- May be installed in Type I or Type II non-combustible buildings with these restrictions:
  - No combustible materials stored around transformer
  - Fluid confinement (Cooper can provide with transformer as an option)
  - Installation to comply with all fluid listing restrictions.

Examples of fluid containment
Dual Voltage Switch

- Allows for Two Primary Voltages
  - Facilities with two voltages on system
  - Future system upgrade

- Maximum Voltage Ratio - 3.3:1

- Coils are placed in series or parallel depending on voltage requirements

- Example: 4160V x 13,200V
Overcurrent protection

- Expulsion & Back-up Current-Limiting Fusing
  Fusing – Expulsion (Bay-O-Net Mounted) & Partial Range Current-Limiting
Overcurrent Protection

- Expulsion Fuse in Series With Partial Range Back-up Current-Limiting Fuse
  - Internal cartridge mounted
  - For higher ratings than Bay-O-Net mounting is rated
Overcurrent protection

- What if ....
- Transformer rating exceeds what may be internally fused
- Resettable device preferred
- No single phasing
- More sophistication needed/wanted
VFI Transformer

- Vacuum Fault Interrupter (VFI) Installed Integral to the Transformer
- Switchgear-type over-current protection for large pad-mounted or substation transformers
- Control box in HV Termination compartment (pad-mounted)
VFI transformer

- 3Ø Primary over-current protection and switching (Vacuum Fault Interrupter) installed integral to transformer.
- Resettable medium voltage breaker with electronic control
- Over 100 minimum trip settings
VFI transformer

- Up to 35 kV rating
- 600 or 900 A continuous rating
- 12 kA & 16 kA interrupting rating*
- Optional secondary relay
- Used to trip VFI on secondary fault
- Helps mitigate secondary arc flash hazards
On/Off Load-Break Switch(s)
On/Off Load-Break Switch(s) (two)
On/Off Load-Break Switch(s) (three)
On/Off Load-Break Switch(s) (three)
Load-break Switching

(a) Loop feed

(b) Radial feed
4-Position sectionalizing switches

- V-Blade Switch

- Description of Positions
  - Feed from A & B
  - Feed from A only
  - Feed from B only
  - Open — the loop is open and the transformer is de-energized
4-Position sectionalizing switches

T-Blade Switch

- Description of Positions
  - Feed from A & B
  - Feed from A only
  - Feed from B only Open — the loop is closed and the transformer is de-energized
Features and accessories - 3-Position Selector Switch

- Applications with Two Separate Sources Which May Not Be Tied Together
- Allows selection of “A” source or “B” source or Open
- Open means transformer is off or de-energized
- Both Sources Cannot Simultaneously Feed the Transformer
- No Interlocks Required
Other optional accessories

- Gauges
  - Liquid level
  - Temperature
  - Pressure vacuum
  - Alarm contacts
- LV breaker provisions
- Watt-hour Meter
- 304L stainless steel
  - Full
  - Partial
- Others
  - Winding temperature indicator
  - Rapid rise relay
Addressing arc flash
Addressing arc flash
Addressing arc flash

- Essential monitoring equipment accessible outside termination compartments
- Drain Valve & Sampler
- Gauges
- Load-break switches
Addressing arc flash

- Externally operable visible break switching
- Reduce unnecessary arc flash exposure
- Improved visibility and safety compared to standard load-break switch mounting
- Ability to ground transformer windings with on/off/ground option
- Reduce maintenance costs
- Maintains tamper resistance
Externally operated visible load-break switch

Visible break window

Gages

Load-break switch handle
Taps

- Change the quantity of high-voltage windings to match incoming primary voltage
- Goal is obtain correct secondary voltage
- ± 2 - 2.5 % (split taps) are most common
Taps

- Tap Voltage Values Appear on the Transformer Nameplate
Over-Voltage Protection

- Surge arresters
- Classes defined by:
  - Voltage rating
  - Protective characteristics
  - Pressure Relief
Dry vs. Liquid

- Fire Safety
- Losses & Efficiency
- First Cost
- Overload Capacity
- Sound Levels
- Temperature Rise
- Contamination
- Diagnostics (DGA)
- Extended Life
- Protection
- Floor Space Required
Each line-up performs the same function
Double-ended unit substation

FR3 Filled Transformer

MV Circuit Breaker
Canadian Electrical Code

- 26-242 – Outdoor transformer installations
- Pad-mounted transformers
- Min. 3m to combustible surface or material on a building
- Min. 6m to windows, doors, or ventilation inlets or outlets
- Except if:
  - Internal current-limiting fuses & pressure relief
  - 3m on access side(s) and 1m on other sides
Standard Substation Accessories

- De-energized tap changer
- One inch combination drain and filtering valve/sampling device
- Pressure test connect
- One inch upper filling and filter press connection
- Pressure relief valve
- Provision for lifting and jacking
- Ground pads
- Non-corrosive nameplate
- Liquid level gauge
- Temperature gauge
- Pressure/vacuum gauge
Optional Accessories

- Pressure relief device (std above 2500 kVA)
- Rapid Rise relay (seal-in panel optional)
- Winding temperature indicator and relay
- Contacts for temperature, liquid level, and pressure/vacuum gauges
- Pressure/vacuum bleeder (std above 2500 kVA)
- Surge arresters
- Throats/flanges/ ATC (primary and/or secondary connections)
  - Can accommodate equipment by others i.e. LV switchgear
Optional Accessories (continued)

- Air terminal chambers (primary and/or secondary connections with sidewall mounted bushings)
- Detachable bolt-on radiators with valves
- Fan control package
- Nitrogen blanket, 2 - 3 p.s.i., including purge valves
- Nitrogen preservation system includes: bottle, regulator, and appropriate high and low pressure contacts
Questions