# An Overview of Dry, Liquid & Cast Coil Transformers.

## What is Best for My Application?

Ken Box, P.E. - Schneider Electric
John Levine, P.E. - Levine Lectronics & Lectric

# Low Voltage General Purpose Dry Type Transformers

## Selecting & Sizing Dry Type Transformers

From EC&M Magazine

- http://www.csemag.com/single-article/selecting-sizing-transformers-for-commercial-buildings/4efa064775c5e26f27bfce4f0a61378e.html
- 3 Phase: 15 – 1000kVA, 600V max primary
- 1 Phase: 15 – 333 kVA, 600V max primary
- Specialty transformers, custom ratings, exceptions

# Insulation System

- The insulation system is the maximum internal temperature a transformer can tolerate before it begins to deteriorate and eventually fail.
- Most ventilated transformers use a Class 220˚ C insulation system. This temperature rating is the sum of the winding rise temperature, normally 150˚ C, the maximum ambient temperature, 40˚ C, and the hot spot allowance inside the coils, 30˚ C.
- Insulation = Winding rise + Coil Hot Spot + Max Ambient
- For ventilated transformers, 80˚ C and 115˚ C are also common low temperature rise transformer ratings.
- The standard winding temperature is 150˚ C for a ventilated transformer.
- All three of these temperature rise ratings utilize the 220˚ C insulation system.

# Insulation

- Class 220 insulation

  40 C ambient
  + 150 C average rise
  + 30 C hotspot
  
  _______
  220 C hotspot temp.

- Class 180 insulation

  40 C ambient
  + 115 C average rise
  + 25 C hotspot
  
  _______
  180 C hotspot temp.

- Class 200 Insulation

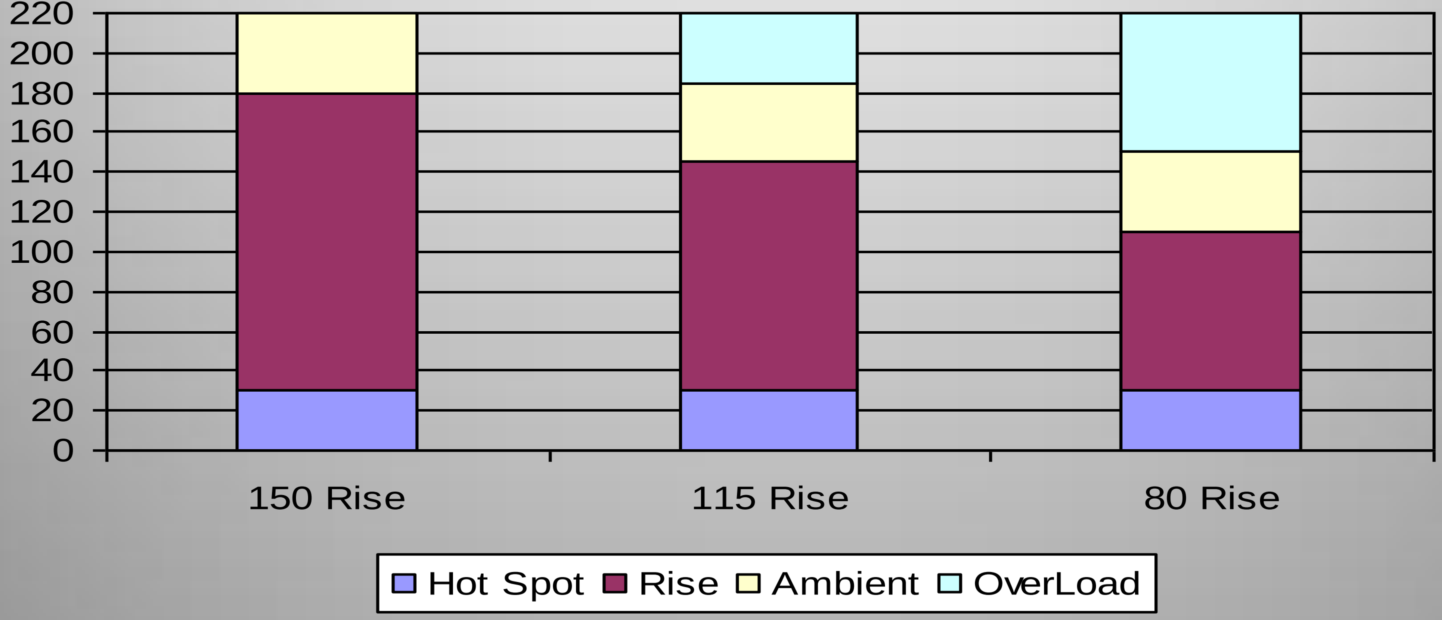
  40 C ambient
  + 130 C average rise
  + 30 C hotspot
  
  _______
  200 C hotspot temp.

- Class 150 Insulation

  40 C ambient
  + 80 C average rise
  + 30 C hotspot
  
  _______
  150 C hotspot temp.

# Low Temperature Rise

- Overload Capacity
- Longer transformer life



# Transformer losses.

- Transformers aren’t perfect devices; they don’t convert 100% of the energy input to useable energy output.
- The difference between the energy input and that which is available on their output is quantified in losses.
- Transformer losses fall into two categories: no-load losses and load losses. No-load losses—commonly referred to as core losses or iron losses—are the amount of power required to magnetize, or energize, the core of the transformer.
- Since most distribution transformers are energized 24/7, no-load losses are present at all times, whether a load is connected to the transformer or not.
- When lightly loaded, no-load losses represent the greatest portion of the total losses.

# Load Losses

- Load losses, on the other hand, are those losses incident to carrying a load, and include winding losses ($I^2R$ losses), stray losses due to stray fluxes in the windings and core, and circulating currents in parallel windings.
- Because load losses are a function of the square of the load current, they increase quickly as the transformer is loaded. ($I^2R$)
- Load losses represent the greatest portion of the total losses when a transformer is heavily loaded..

# Low temperature rise energy-efficient transformers

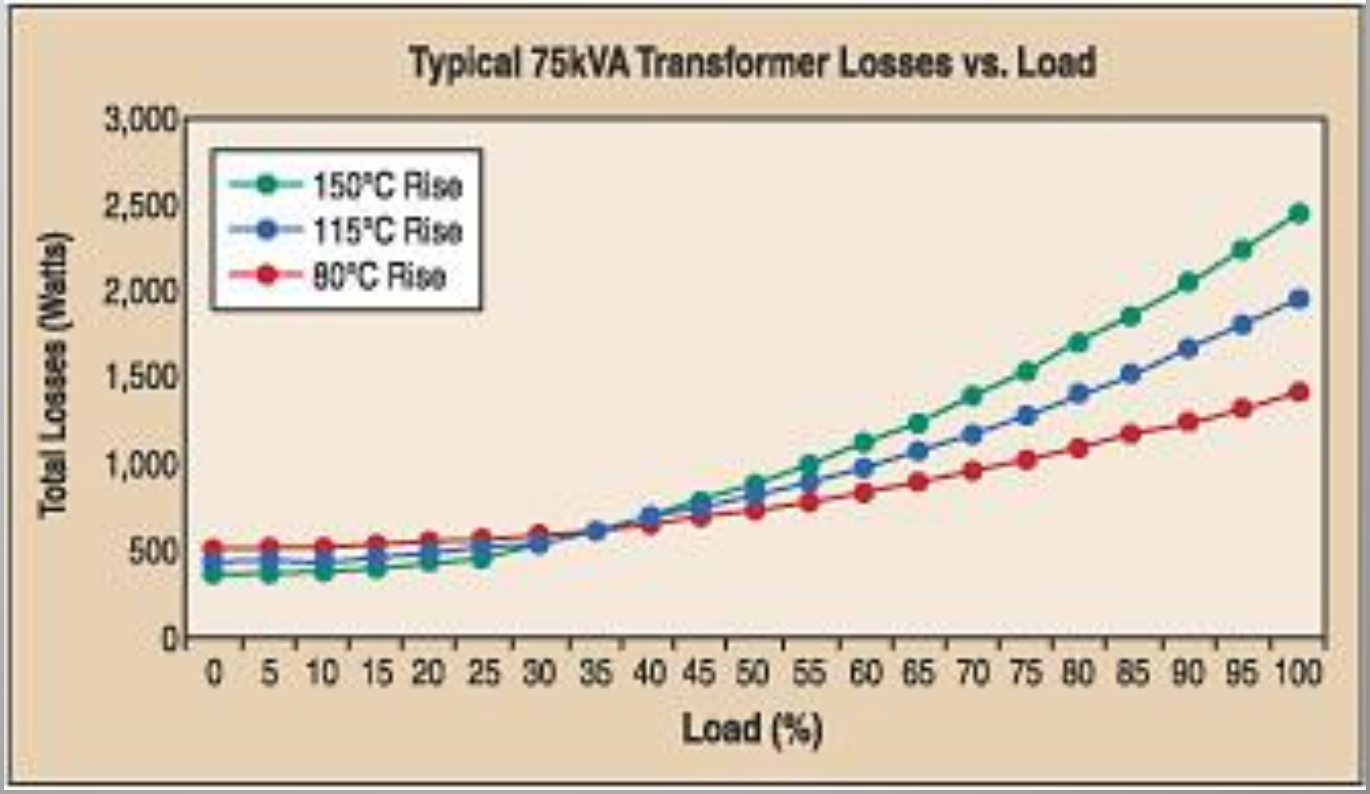
- Low temperature rise—80° C and 115° C transformers have been available for more than 40 years.
- Until recently, the term "energy-efficient transformer" referred exclusively to these transformers.
- Low temperature rise transformers also use the 220° C insulation system and are designed to have lower load losses than equivalent rated 150° C rise transformers.
- As previously mentioned, load losses are most critical at high load levels.
- This means that when a transformer is loaded in excess of half its full load capacity, low temperature rise transformers provide better energy efficiency than standard 150° C rise transformers.

# Longer Life

- DoE – use 33 years for Life of Low Voltage Distribution Transformers
- IEEE Standard C57.96 – 1999
  Guide for Loading Dry-Type Distribution and Power Transformers
  - Fully Loaded Low Voltage Transformers Standard
    - 150° C Rise – ~8 years
    - 115° C Rise – ~60 years
    - 80° C Rise - ~ >200 years
  - @ 35% Loading Point – 75° C Temperature instead of 170° C
    - 150° C Rise - ~>100 years
    - 115° C Rise - ~>100 years
    - 80° C Rise - ~ >100 years
- Actual Real World Loading for Commercial Applications – 15-20%
- Optimum efficiency is 70-80% loading.

# Energy Losses vs. Load %

- NEMA TP-1 Standard
- Assumes the transformers are feeding linear loads



# Overload Capacity

- Typical Loading Commercial Applications – 15-20%

- Overload Capacity – marketed by all manufactures as "emergency"
  - To obtain the capacity – Device needs to carry dual nameplate
  - 115° C – 15% and 80° C – 30%

    75kVA / 115° C Rise 86.25kVA / 150° C Rise
    75kVA / 80° C Rise 97.5kVA / 150° C Rise

  - Once dual name plated – NEC requires compliance with the highest kVA rating on Nameplate

## SECTION 26 20 00.17 ENERGY EFFICIENT DISTRIBUTION TRANSFORMERS – Industry References

- NFPA 70 - National Electrical Code
- NEMA ST20
- UL 1561
- NEMA TP1, TP2, TP3
- 10 CFR 429 & 430

# NEMA ST-20

- NEMA Publishes Reinstated NEMA ST 20-2014 Dry Type Transformers for General Applications – June 2014
  - The reinstated and revised edition of NEMA ST 20 applies to single-phase and polyphase dry-type transformers (including autotransformers and non-current-limiting reactors) for supplying energy to power, heating, and lighting circuits, and designed to be installed and used in accordance with the National Electrical Code®. It also covers transformers with or without accessories having ratings of 1.2 kV class, 0.25 kVA through 4000 kVA
  - NEMA ST 20 is one of the few standards in the marketplace that specifically addresses sound levels for this particular type of transformer.
- C57-12.01 IEEE Standard General Requirements for Dry-Type Distribution and Power Transformers Including Those with Solid- Cast and/or Resin-Encapsulated Windings
  - This standard is intended as a basis for the establishment of performance, interchangeability, and safety requirements of equipment described, and for assistance in the proper selection of such equipment. Electrical, mechanical, and safety requirements of ventilated, non-ventilated, and sealed dry-type distribution and power transformers or autotransformers (single and polyphase, with a voltage of 601 V or higher in the highest voltage winding) are described. The information in this standard applies to all dry-type transformers

# NEMA TP1, TP2, TP3

## NEMA TP1

**Provides the basis for determining the energy efficiency of certain single- and three-phase dry-type and liquid-filled distribution transformers and assists with the proper selection of such equipment.**

## NEMA TP2

**Standard Test Method for Measuring the Energy Consumption of Distribution Transformers. The document provides a standardized method for measurement of distribution transformer loss to achieve energy efficiency levels outlined in NEMA publication TP 1, Guide for Determining Energy Efficiency for Distribution Transformers**

## NEMA TP3

**Defines the labeling of distribution transformers tested to the efficiency levels specified in TP1**

## DOE Final Rules 10 CFR 429 and 431

- 10 CFR 429
  - Provisions for Statistical Sampling Plans for Certification Testing
    - 10 CFR 429.47
      - 10 CFR 429.70
  - APPENDIX C TO SUBPART C OF PART 429: SAMPLING PLAN FOR ENFORCEMENT TESTING OF DISTRIBUTION TRANSFORMERS
- 10 CFR 431
  - Subpart K—Distribution Transformers
  - Appendix A to Subpart K of Part 431—Uniform Test Method for Measuring the Energy Consumption of Distribution Transformers

# Distribution Transformer Definition 10 CFR 431.192

- As defined in the Code of Federal Regulations (CFR), “distribution transformer” means a transformer that (1) has an input voltage of 34.5 kV or less; (2) has an output voltage of 600 V or less; (3) is rated for operation at a frequency of 60 Hz; and (4) has a capacity of 10 kVA to 2500 kVA for liquid-immersed units and 15 kVA to 2500 kVA for dry-type units.
- The term “distribution transformer” does not include: autotransformer; drive (isolation) transformer; grounding transformer; machine-tool (control) transformer; non-ventilated transformer; rectifier transformer; regulating transformer; sealed transformer; special-impedance transformer; testing transformer; transformer with tap range of 20 percent or more; uninterruptible power supply transformer; or welding transformer.
- Manufacturers have complied with the U.S. Department of Energy (DOE) energy conservation standards for distribution transformers since 2007.

# Department of Energy 10 CFR 431.192 – April 2013

- Low Voltage Distribution Transformers
    - Three Phase set at CSL-3+ levels from the DoE engineering analysis
    - Single Phase set at CSL-0 levels (no change) from the DoE engineering analysis
    - Minimum Levels of Efficiency at 4 significant digits instead of 3.

**Prior to January 1, 2016**
**Energy Conservation Standards for Low-Voltage Dry-Type Distribution Transformers**

| Single phase | | Three phase | |
|---|---|---|---|
| kVA | Efficiency (%) | kVA | Efficiency (%) |
| 15 | 97.7 | 15 | 97.0 |
| 25 | 98.0 | 30 | 97.5 |
| 37.5 | 98.2 | 45 | 97.7 |
| 50 | 98.3 | 75 | 98.0 |
| 75 | 98.5 | 112.5 | 98.2 |
| 100 | 98.6 | 150 | 98.3 |
| 167 | 98.7 | 225 | 98.5 |
| 250 | 98.8 | 300 | 98.6 |
| 333 | 98.9 | 500 | 98.7 |
| | | 750 | 98.8 |
| | | 1000 | 98.9 |

**After January 1, 2016**
**Energy Conservation Standards for Low-Voltage Dry-Type Distribution Transformers**

| Single phase | | Three phase | |
|---|---|---|---|
| kVA | Efficiency (%)[1] | kVA | Efficiency (%)[1] |
| 15 | 97.70 | 15 | 97.89 |
| 25 | 98.00 | 30 | 98.23 |
| 37.5 | 98.20 | 45 | 98.40 |
| 50 | 98.30 | 75 | 98.60 |
| 75 | 98.50 | 112.5 | 98.74 |
| 100 | 98.6 | 150 | 98.83 |
| 167 | 98.70 | 225 | 98.94 |
| 250 | 98.80 | 300 | 99.02 |
| 333 | 98.90 | 500 | 99.14 |
| | | 750 | 99.23 |
| | | 1000 | 99.28 |

Note: All efficiency values are at 35 percent of nameplate-rated load, determined according to the DOE Test Method for Measuring the Energy Consumption of Distribution Transformers under Appendix A to Subpart K of 10 CFR part 431.

- Date of Manufacturing – January 1, 2016

DOE Home Page

Note CSL=Candidate Standard Level

# What is the Effect of the DoE Law?

- Transformers cost more $$$.
- Transformers are physically larger in size.
- Transformers weigh more.
- Impedances are lower.
- Isc  values are different.
- Inrush values are different.
- Model numbers changed or discontinued.

# “I’m from the Federal Gov’t & I’m here to help!”

*The DoE has concluded that the standards in their final ruling represent the maximum improvement in energy efficiency that is technologically feasible and economically justified, and will result in significant conservation of energy*.

- Over 10,000 Designs evaluated at multiple efficiency levels
- Actual installed base loading conditions-Low Voltage 15 to 20%
- The DoE Law still sets standard load testing at 35%.

# K-Rated & Harmonic Mitigating Dry Type Transformers

# Harmonic mitigating transformers

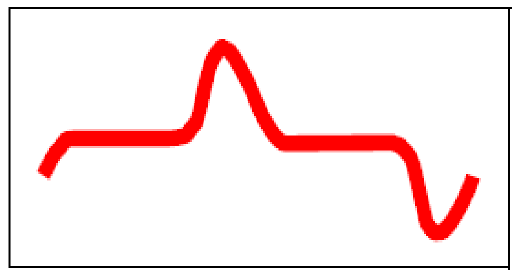
- It's a fact of life in today's world that many loads are nonlinear in nature.
- Nonlinear loads reduce the efficiency of distribution transformers, including K-factor rated transformers. The higher the content of nonlinear loads, the lower the efficiency of the transformer.
- Most harmonic mitigating transformers are at least 98% efficient, even when the load is 100% nonlinear in nature.
- Under normal loading conditions, the life expectancy of a transformer is at least 20 years. Over the lifetime of the transformer, even a minor improvement in efficiency can result in significant energy savings.
- HMT transformers actually do something to mitigate the harmonics not just deal with the increased heating resulting from non-linear loads.

# How Harmonic Mitigating Transformers Address Harmonics

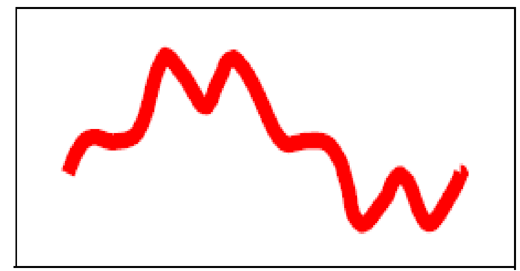
- Add Source Impedance (3-5%)
  - Limits Crest Factor
- Phase Shifting
  - 30° Shift (Delta to Wye or Wye to ZigZag)

    Cancel – Triplen Harmonics ($3^{rd}$, $9^{th}$, $15^{th}$, …)

**Secondary Current**



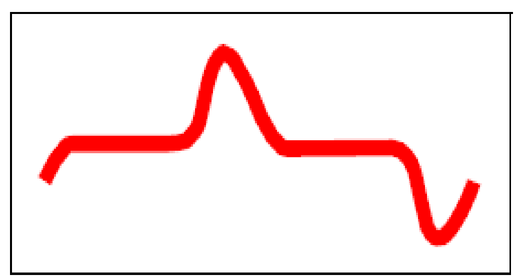
**Primary Current**



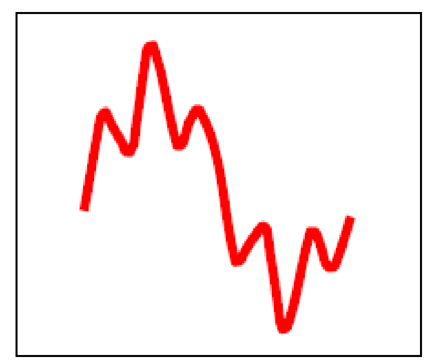
  - 0° Shift (Delta to ZigZag)

    Cancel – Triplen Harmonics ($3^{rd}$, $9^{th}$, $15^{th}$, …)

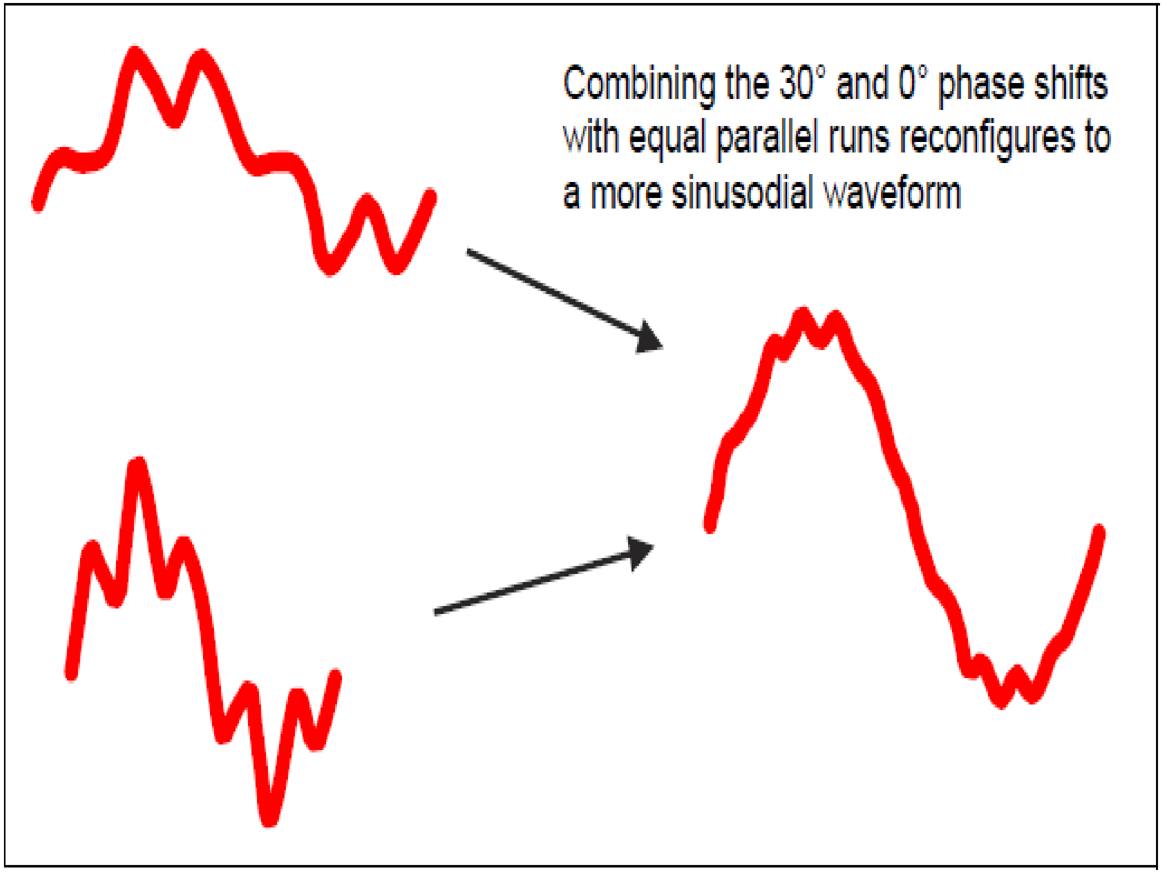
**Secondary Current**



**Primary Current**



## Combination of 30° and 0° with Equal Parallel Runs




For maximum benefits from harmonic mitigating transformers, both 30° and 0° phase-shift-equivalent products should be incorporated into the system. When this is not possible due to floor space, load requirements, or economic conditions, either product can be incorporated into the system. To combine even more harmonics, the customer can add the +15° or -15°(45°) products to their application.

# K-Rated Transformers

- The "K-Factor" conveys a transformer's ability to serve varying degrees of nonlinear loads without exceeding its rated temperature rise limits.
- If the harmonic current components are known, the K-Factor can be calculated and compared to the transformer's nameplate K-Factor.
- As long as the load K-Factor is equal to or less than the transformer's rated K-Factor, the transformer does not need to be derated.
- The higher the K-Factor, the more non-linear loads the transformer can handle.

# *“Testing Reveals Surprising K-Factor Diversity” by Bob Arthur*

EC&M April, 1993 pages 51-55

- *The total K-factor of office load systems does not correlate with the relatively high values of harmonics seen on individual branch circuit loads.*
- *Higher K-factor calculations were the result of drastically under loaded feeders where the K-factor has little or no consequence to the supply transformer.*
- *Higher order harmonics from multiple electronic loads occur at random phase angles and are constantly changing…which results in a dramatic reduction and/or cancellation of higher frequency harmonics.*
- *In fact, the higher the number of single phase non-linear loads on a given distribution panel, the lower the K-factor.*
- *Example: 26 – single $\Phi$, non-linear devices on line, the K-factor was reduced from 13.9 to 4.6.*
- *Oversizing transformers or selecting unnecessarily high K-factor rated transformers has the effect of increasing the neutral conductor currents.*
- *Only at near or full load on the transformer is it necessary to utilize a K-rated transformer.*
- *Misunderstandings about transformer K-ratings come from the failure to recognize the difference between individual branch circuit load K-factors and the total load harmonics that appear at the transformer feeder terminals.*

# *Plant Engineering* – August, 1994 – Bill Perkins

- *Comprehensive tests conducted on nonlinear office loads at several commercial and industrial facilities have shown that a higher population mix of electronic office equipment actually reduces the total load K-factor.*
- *The tests revealed that no office location in the study required a transformer K-rating greater than K-9.*

# *Pure Power Magazine – December 1999 pages 30-32*

Written by Bob Arthur

- *Survey taken indicate average loading levels for dry type transformers of 35% for commercial facilities and 50% for industrial plants.*
- *Despite current distortion at individual loads, K-factor levels were significantly lower at the transformer supply terminals.*
- *The study conclusions show a clear influence of source impedance on lowering office computer load k-factor. Current distortion decreased as more computers were added to the line.*
- *Regardless of current distortion change, the maximum loss point in transformer coils is always at full load. Consequently, the true K-factor rating of a transformer must be based only on full load harmonics.*

# Application Best Fit – Fix This Mess!

- Transformers cost more $$$.
- *Reduce the size of your transformer – 70-80% is optimum $\eta$ point. 80℃ Rise (30% overload)*
- Transformers are physically larger in size.
- *Not if I can use a 45kVA instead of a 75kVA*
- Transformers weigh more.
- *Not if I can use a 45kVA instead of a 75kVA*
- Impedances are lower.
- *Check with the mfrs. – minimum concern*
- Isc values are different.
- *Check with the mfrs. – minimum concern*
- Inrush values are different.
- *Surprise – some were less!*
- Model numbers changed or discontinued.
- *Memorizing stuff increases brain folds!*

# Medium Voltage Dry Type Power Transformers

# References


- **A.** IEEE C57.12.01™ - Standard General Requirements for Dry-Type Distribution and Power Transformers Including Those with Solid Cast and/or Resin-Encapsulated Windings
- **B.** ANSI C57.12.28 - Switchgear and Transformers, Pad-Mounted Equipment - Enclosure Integrity
- **C.** ANSI C57.12.50 - Requirements for Ventilated Dry-Type Distribution Transformers, 1-500 kVA Single-Phase and 15-500 kVA Three-Phase, with High Voltage 601-34,500 Volts, Low Voltage 120-600 Volts
- **D.** ANSI C57.12.51 - Requirements for Ventilated Dry-Type Power Transformers, 501 kVA and Larger Three-Phase, with High Voltage 601-34,500 Volts, Low Voltage 208Y/120-4160 Volts.
- **E.** ANSI C57.12.55 - Conformance Standard for Transformers - Dry-Type Transformers Used in Unit Installations, Including Unit Substations
- **F.** IEEE C57.12.56™ - Standard Test Procedure for Thermal Evaluation of Insulation Systems for Ventilated Dry-Type Power and Distribution Transformers
- **G.** IEEE C57.12.58™ - Guide for Conducting a Transient Voltage Analysis of a Dry-Type Transformer Coil
- **H.** IEEE C57.12.59™ Guide for Dry-Type Transformer Through-Fault Current Duration
- **I.** IEEEI C57.12.70™ - Terminal Markings and Connections for Distribution and Power Transformers
- **J.** IEEE C57.12.80™ - Standard Terminology for Power and Distribution Transformers
- **K.** IEEE C57.12.91™ - Test Code for Dry-Type Distribution and Power Transformers
- **L.** IEEE C57.94™ - Recommended Practice for Installation, Application, Operation, and Maintenance of Dry-Type General Purpose Distribution and Power Transformers
- **M.** IEEE C57.96™ - Guide for Loading Dry-Type Distribution and Power Transformers
- **N.** IEEE C57.105™ - Guide for Application of Transformer Connections in Three-Phase Distribution Systems

# Power Dry Product Range

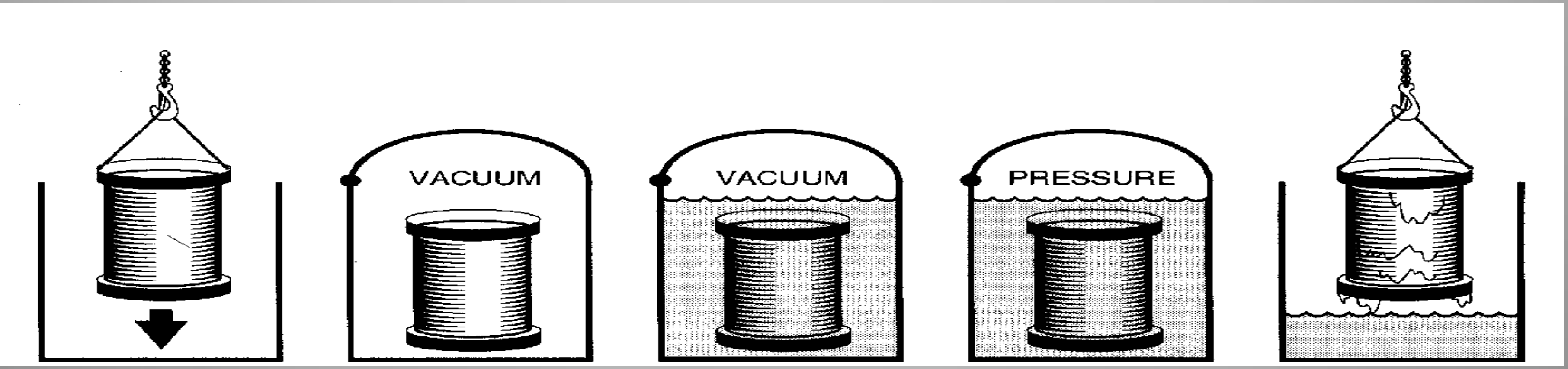
- 112.5 – 5000 kVA
- Up to 35 KV primary, 150 KV BIL
- Up to 6600V secondary, 30 KV BIL
- Fan overload capabilities, FA increases kVA by 1/3
- Self cooled overload capabilities
  - @115°C and 80°C Rise
- Aluminum and Copper windings
- Indoor or outdoor
- Higher kVA available – check your mfr.

# Power Dry Product Range

- VPI - Vacuum Pressure Impregnated - $
- VPE - Vacuum Pressure Encapsulated - $$
- Cast Coil - $$$
- Buzz Words – “Whatever-Cast”

VPI Process
(Vacuum Pressure Impregnated)

- **Dry vacuum cycle** → pulls vacuum which dries out the coil
- **Vacuum immersion** → introduces polyester resin into the dielectric
- **Vacuum hold cycle** → time period to allow further saturation
- **Pressure cycle** → pressure applied at 75psi for 45 minutes
- **Curing** → baking in oven at 350F solidifies the dielectric




Core/Coil is put into tank | Dry vacuum cycle | Vacuum immersion & vacuum hold cycles | Pressure cycle | Tank is depressurized, coil is removed

# Best Applications for Power Dry Transformers (VPI)

- Lowest first cost type of Power Dry Type Transformer
- Lighter weight compared to liquid filled & cast coil
- Indoor Clean Environment
- Can be installed outdoors with proper weather enclosures

# VPI Power-Dry Transformers

## Advantages

- Excellent for Indoor Use
  - Schools, Hospitals, Office Buildings
  - Locations  where a liquid spill can not be tolerated
  - No containment pit required, providing for lower installation and maintenance costs

- Non-Flammable
  - 220°C Insulation Class
  - Will not support combustion

- Comparable price to a Seed Oil, liquid filled transformer
  - Very economical when compared to Cast Coil

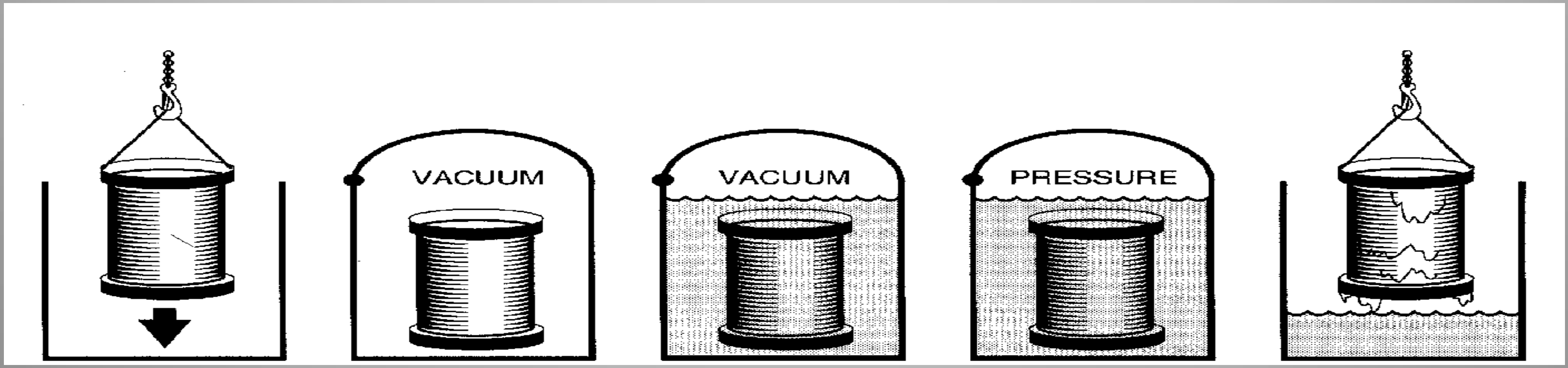
# VPI Power-Dry Transformers

## Disadvantages

- Lower BIL Levels than Liquid Filled
  - Standard for 15kV Class is 60kV BIL, Liquid Filled is 95kV BIL
  - Standard for 600V Class is 10kV BIL, Liquid Filled is 30kV BIL
- Moisture Absorption
  - Must pre-dry unit before energizing to eliminate moisture from coils
- More Susceptible to Airborne Contaminants
  - Ventilated enclosure, contaminants may accumulate on coils

# VPE Process
# (Vacuum Pressure Encapsulated)

- Similar to VPI Process
- **VPI** uses **Polyester Resin**
- **VPE** uses **Silicone Varnish**
- Thinner coating requires 4 cycles
- Developed for Air Craft Carrier Applications
- Less susceptible to moisture absorption than VPI




**Core/Coil is put into tank** | **Dry vacuum cycle** | **Vacuum immersion & vacuum hold cycles** | **Pressure cycle** | **Tank is depressurized, coil is removed**

# Cast Coil Transformers

# Cast Coil Applications

- 3-phase, cast-epoxy units are particularly suited for applications requiring a dry-type transformer with superior performance characteristics.
- The windings are completely impregnated with epoxy resin forming the solid dielectric system. This protects the windings from moisture and environmental airborne contaminants and provides exceptional strength to withstand extreme thermal shock and the mechanical forces of short circuits
- These transformers meet the more stringent ANSI/IEEE standards for liquid-filled transformers, but have the added advantages of a dry-type.
- Cast Coil transformers are an ideal replacement for the PCB-filled or PCB-contaminated units.
- Available in both indoor and outdoor enclosures. Combustion byproducts of cast coil transformers have been tested and documented to be environmentally safe and nonflammable.
- Windings are partial-discharge tested to provide a reliable high voltage dielectric system.
- Production tests as prescribed by IEEE C57.12.91™ as well as 100% impulse testing.

# Typical Cast Coil Ratings

- 150-10000 kVA
- Up to 35 KV primary, 200 KV BIL
- Up to 6,600V secondary, 75 KV BIL
- Self Cooled (AA) and Fan (FA) overload capabilities
- Indoor or Outdoor
- Primary and secondary coils are fully cast under a vacuum
- Standard Copper conductor, Aluminum optional
- Higher kVA, special voltages available

# Best Application for Cast Coil

- Where maximum reliability is important
- Damp, dusty, dirty heavy industrial environments
- Long periods of no-loads and or cold, damp environments
- Outdoor, high humidity
- Data Centers
- Healthcare
- Heavy Industrial

# Benefits of Cast Coil vs Liquid Filled

- No Fluids to Leak, Contaminate, or Burn
- Far Less Maintenance, No Yearly Fluid Testing
- Higher Short Circuit Strength
- Non - Flammable
- Longer Design Life when compared to VPI
- Greater Fan Overload Capability
- Lower Installation Costs

# Liquid Filled Transformer

Outline:

- Ratings and Terms
- Transformer Types
- Types of Liquids
- Features
- Phase Shift
- Protection
- Tools
- Future

# How Transformers are Rated

- Liquid Filled Transformers have triple rating. Example is 6/8/10 MVA has a base rating of 6 MVA, 8 MVA with the fans on and a 55 degrees C rise, and 10 MVA with the fans on and a 65 degrees C rise. Some manufactures are now rating transformers to 75 degrees C rise.
- Designs allow for a 30 degree C ambient and a 10 degree C hot spot.  Based on 65 degrees the transformer can get to 105 degrees C.
- Design life is 40 years.  The average Liquid Filled Transformer in the US Today is 44 years old

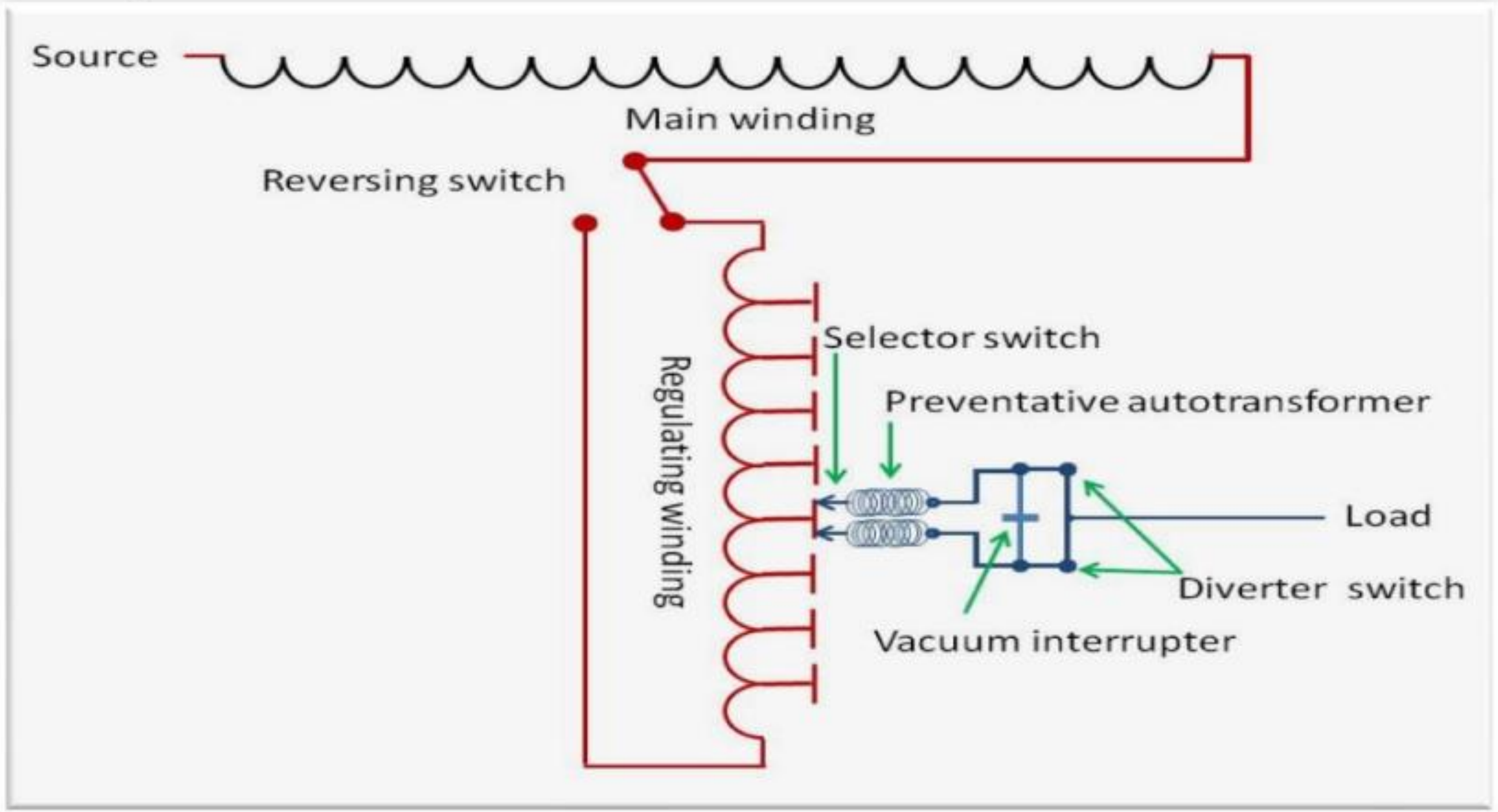
# Terms

- **ONAN (oil natural, air natural)** is an oil filled transformer that is cooled by natural convection.
- **ONAF (Fan)** is an oil filled transformer that is cooled by natural convection and has additional capacity when cooling fans are turned on.
- **OFAF** is an oil filled transformer that uses forced (pumped) oil and additional cooling fans.

# Terms

- **Live Front** – has exposed electrical connections (typical in a substation)
- **Dead Front** - electrical connections are protected (typical in a pad mount with doors)
- **Radial Feed** - only one primary source
- **Loop Feed** – has 2 primary sources. (loops to next transformer)
- **BIL Level** – Basic Impulse Level - This is the lightning impulse withstand voltage the transformer can handle

# Load Tap Changer




Schematic detailing key components of LTC transformer

# Transformer Types

- Pole
- Pad
- Unit Substation
- Substation
- Network

# Pole Mount Transformer
# Typically 5 KVA to 225 KVA


- Low cost
- Typically single phase with 120/240 Volt secondary
- May have one or two primary bushings

# Pad Mount
# 225 KVA to 10 MVA

- **Compartmental**
- **Tamper-proof**
- **Cubic in shape**
- **Dead front or Live front**
- **Usually underground entry**
- **Loop feed or Radial Feed**

H1-H2-H3-H0 Primary
X1-X2-X3-X0 Secondary

# Unit Substation

**Bushings on Sidewalls**

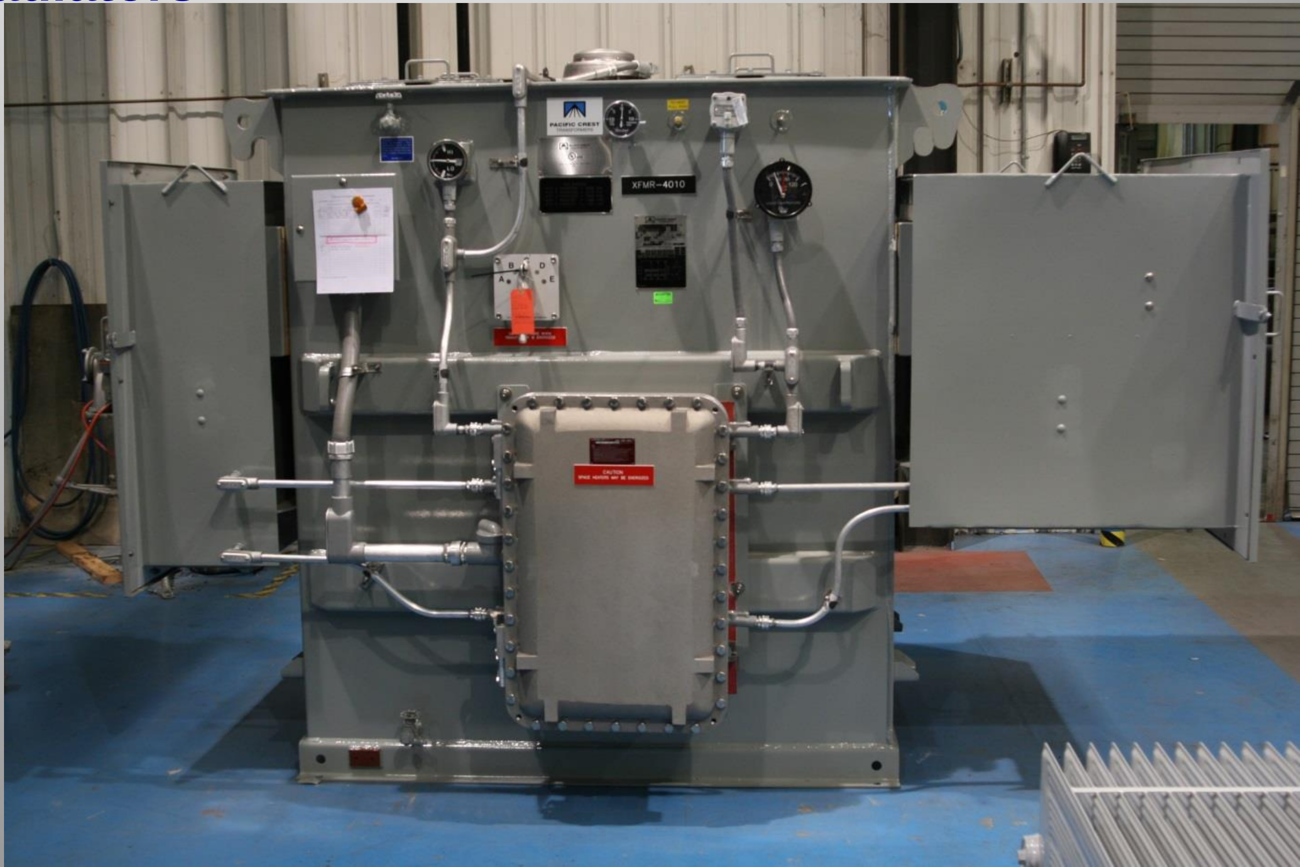
**Multiple configurations:**

**Close-Couple to Gear Underground Cable with Air Terminal Chambers (ATCs)**

**May have removable Radiators**

**Bus Duct Flange**

**Could be a “hybrid”**

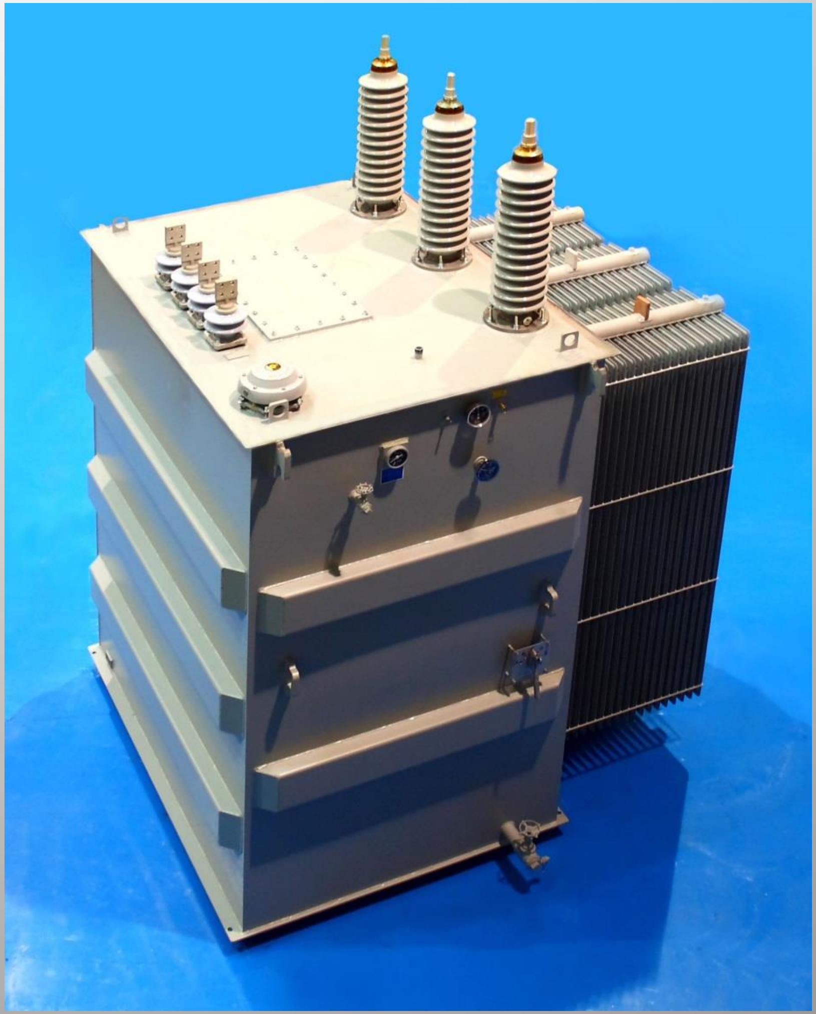


# Typical Unit Substation Installation

# Double Ended Sub would mirror this with a Tie Breaker in the middle (M-T-M)

# Station Type

- **Cover-mounted bushings**
- **Medium Voltage and Small Power**
- **Bushings shipped uninstalled**



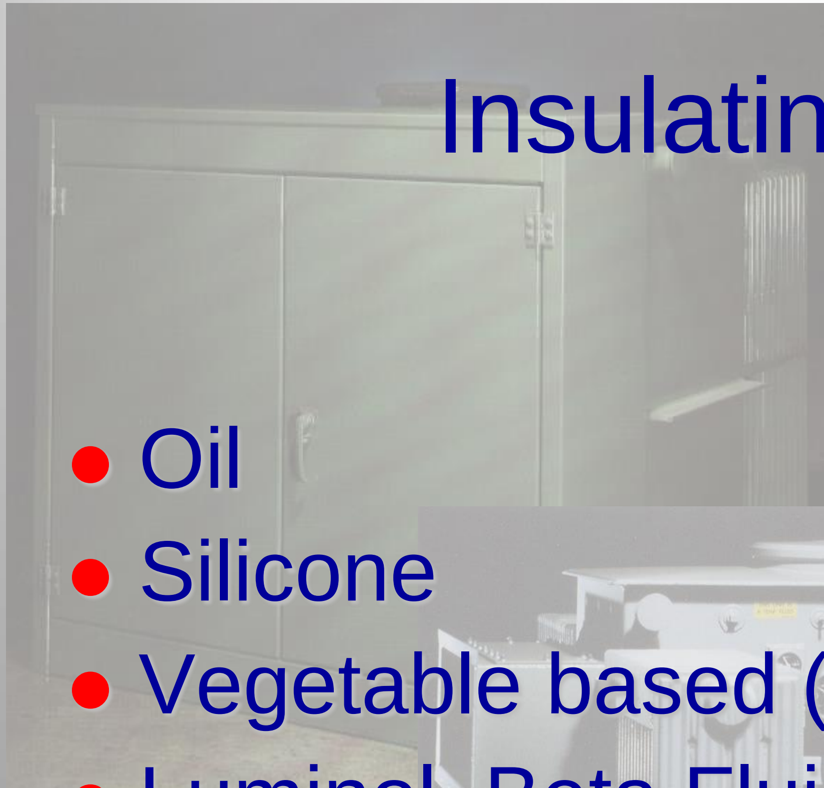
# Network Transformer

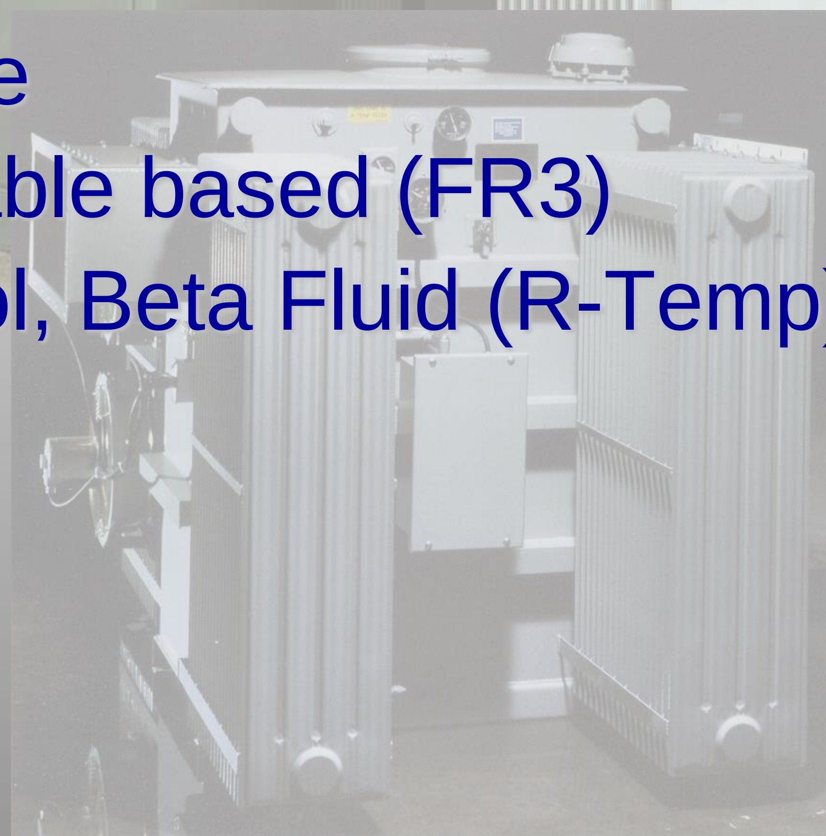
May be located under a street and subject to some submersion

# Transformer Special Duty Applications

- Rectifier
- Grounding
- Step-up duty
- Motor Duty
- Small Power / Transmission
- Mine duty
- Load tap changers
- Solar Transformer

# Insulating Fluids





- Oil
- Silicone
- Vegetable based (FR3)
- Luminol, Beta Fluid (R-Temp)

# Rectangular Layer Coils

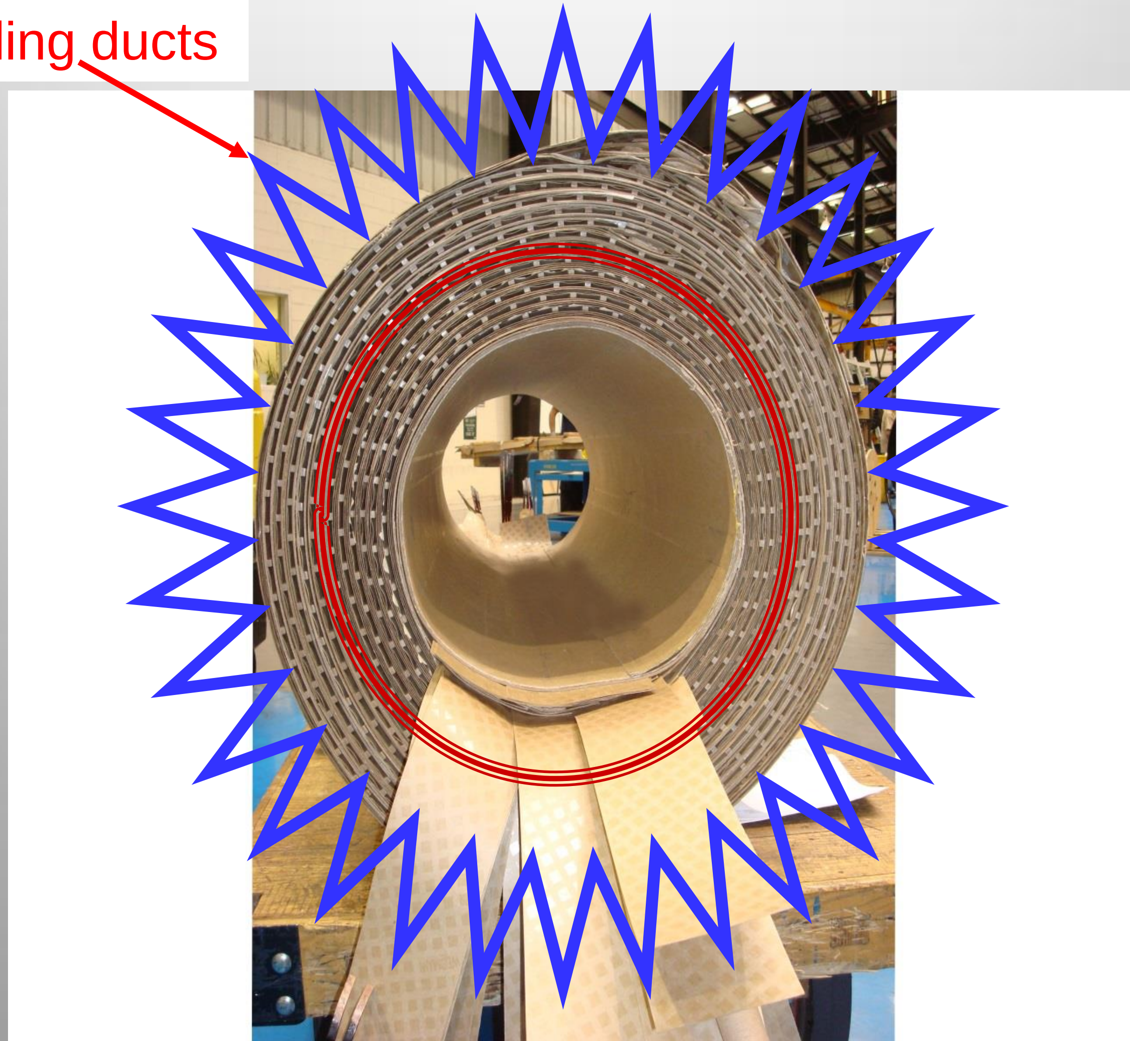
Coils made first then Steel rapped around Coils

# Rectangular Coils

- Good for simple, stable distribution loads
- Low voltage sheet winding adds structural strength
- Smaller footprint

# Circular Layer Coils

360 degree cooling ducts

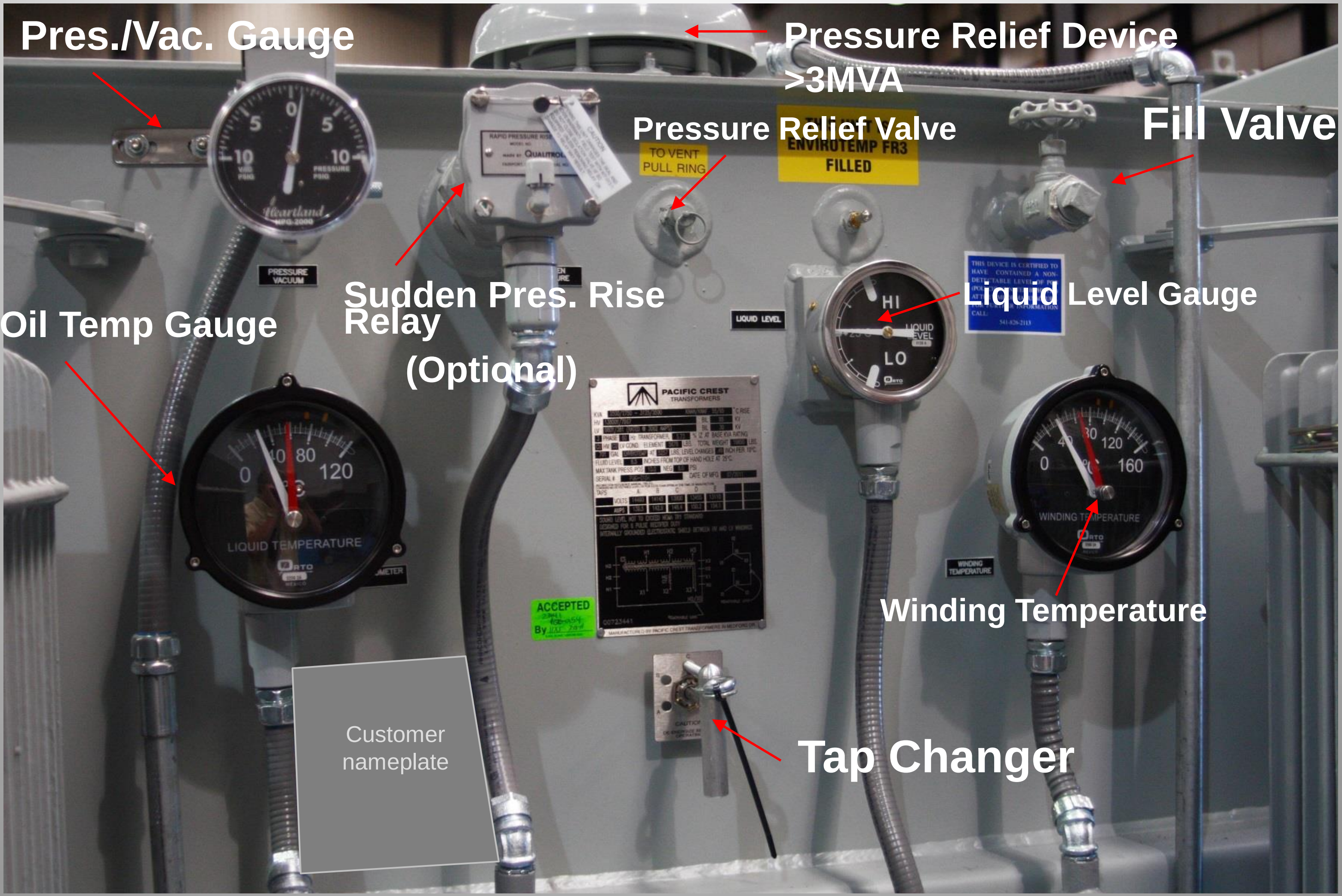


Radial forces are equalized during short circuits & overloads

# Circular Layer Windings

- Round shape spreads radial forces in 360˚ (start round, stay round)
- Designed for demanding and varying duty cycle
- More efficient, better cooling design

# Features


Pres./Vac. Gauge
Pressure Relief Device
>3MVA
Fill Valve
Pressure Relief Valve
Sudden Pres. Rise
Relay
(Optional)
Oil Temp Gauge
Liquid Level Gauge
Winding Temperature
Customer
nameplate
Tap Changer

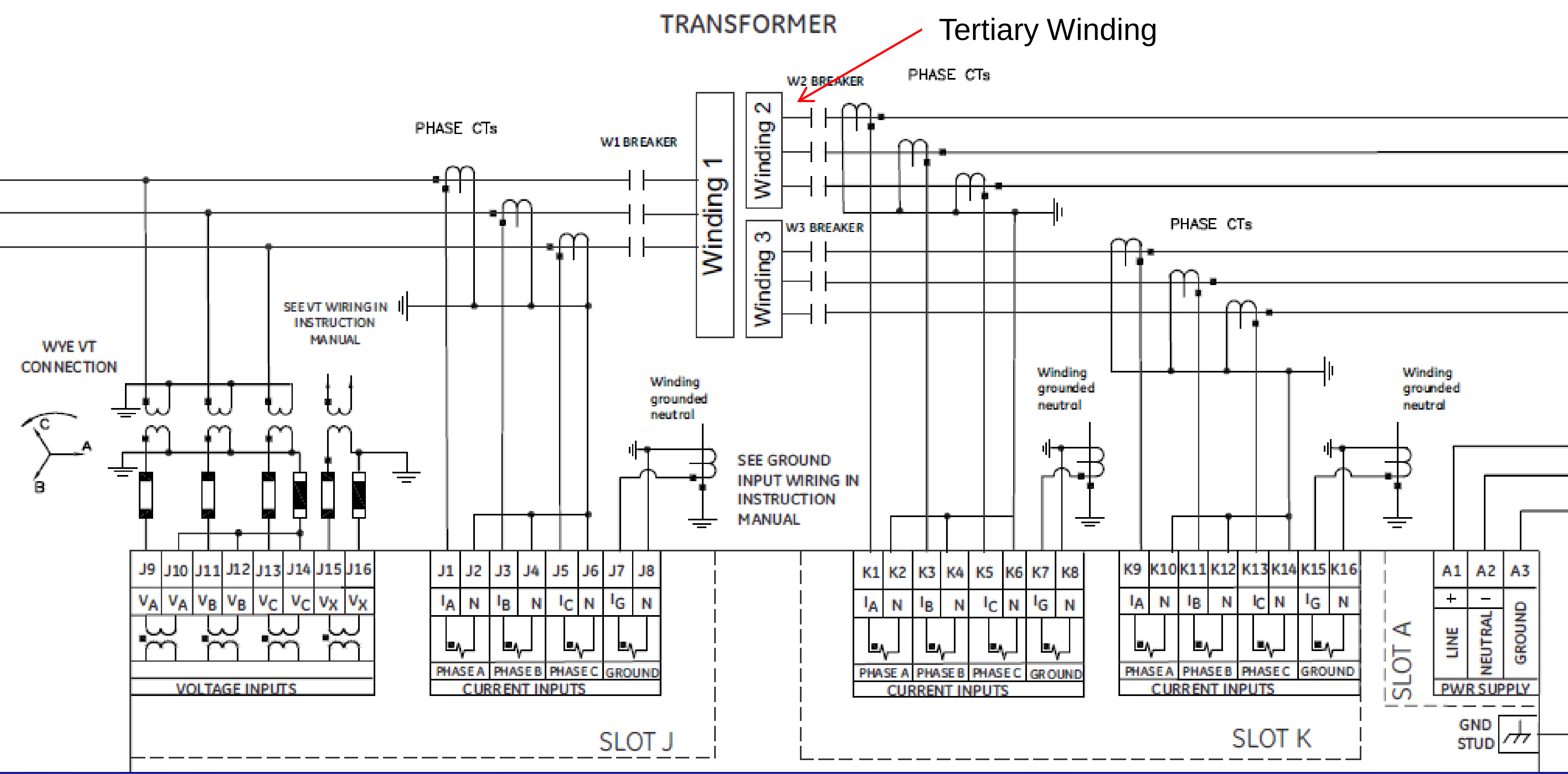
Why do Utilities like to use Wye – Wye Transformers while Industrial like to use Delta - Wye?

# Delta – Wye Phase Shift

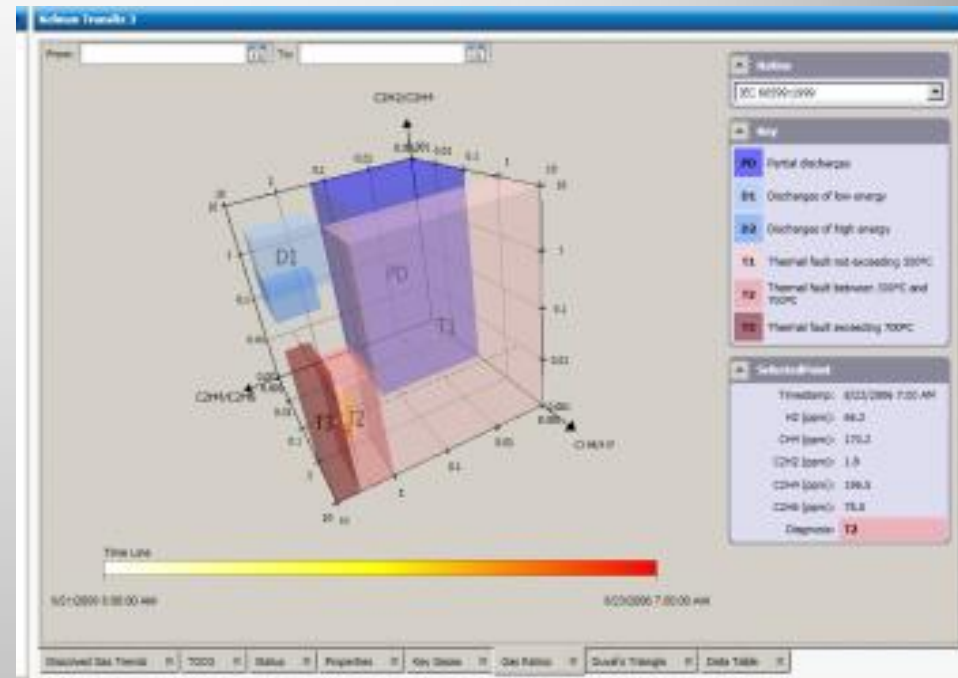
- Utilities may drop the voltage from 500KV to 480V through multiple transformers or a few transformers. You could easily have two sources at the same voltage with different phase shifts. Not as big a concern for Industrials for they want to isolate their loads
- Yy0 - Wye primary – Wye Secondary no shift
- Dy1 – Delta primary - Wye Secondary $30^0$ shift
- Dy5 - Delta primary - Wye Secondary $150^0$ shift

- See Transformer white papers at www.L-3.com

# Transformer Protection Relays use Current Differential Protection



# Transformer Gas Analyzers



# Levine Lectronics and Lectric

**Electrical Manufacturers Representative**

Search



## IEEE

Here are links to presentations and information that has been given by Levine Lectronics and Lectric at IEEE Meetings.

### ANSI

*ANSI Symbols*
*ANSI-GT-C37-2 Paper*

### Communication

*IEEE Communications-2015*
*Advanced Bus Transfer and Load Shedding Applications with IEC61850*
*Practical Applications of Ethernet in Substations and Industrial Facilities*
*Practical Applications of IEC61850 Protocol in Industrial Facilities*

### Transformers, Power, Current, and Potential

*IEEE CTs and PTs 2015*
*IEEE Dry, Liquid and Cast Coil Transformer – By Ken Box and John Levine*
*Power Transformer – White Papers*
*PSRC CT Saturation Calculator*
*PSRC CT Saturation Theory*

### Digital Relays

*Art-and-Science-of-Protective-Relaying*
*Conversion of Electromechanical settings to Digital settings*
*GE Digital Relays 2010*
*IEEE Memphis Protective Relays and Tools*
*Protection Relay Basics*
*Time Over Current Operating Times*


### Manufacturers

- Airotronics
- Electronic Power Design (EPD)
- GE Automation
- GE ITI
- GE Monitoring and Diagnostics
- GE Multilin
- Integra Enclosures
- Meg-Alert
- Micron Industries Corporation
- Northstar-Dynapar-Lakeshore
- Pacific Crest Transformers
- Post Glover Resistors
- Sky-Young Electronics
- Sprecher + Schuh – Auer Signal
- Weidmuller

### Visual and Listed Line Card

- Line Card
- Visual Line Card

## Generators

*IEEE Generator Protection*

*Low Zero-Sequence Impedances on Generators*

## Meters

*GE Power Quality*

*GE Meter Family*

## Motors

*EASA Root Cause Failures*

*Motor Protective Settings*

## Neutral Grounding

*Georgia Tech Zig-Zag Grounding Transformers*

*IEEE Grounding Transformers*

*IEEE Hybrid Grounding*

*Post Glover Resistance Grounding 2015*

*Post Glover Resistance Grounding 2015 (YouTube Video)*

## *Other*

*Faradays Law*

*Electrical Equipment Modernization Project – A Case Study*

*GE Multilin Resources ( YouTube Training Videos)*

*IEEE IAS Atlanta Archives*

*Levine Driving Requirements*

## Transformer White Papers

IEEE Dry, Liquid and Cast Coil Transformer – By Ken Box and John Levine

2016 DOE efficiency requirements

Class 1 Division 2

Dissolved Gas Analysis

Dissolved Gas Analysis syringe sampling procedure

Dual Voltage Transformers

Electric Arc Furnaces

Fundamental_Principles_Of_Transformer_Thermal_Loading_And_Protection_ERLPhase_TexasAM2010

FM & UL -Less Flammable Transformer Installation

IEEE Grounding Transformers

Induction Furnace Introduction

K-Factor and Transformers

Load Tap Changers

Managing Transient Voltage Surges

Mobile Substations

Multi-Voltage Testing Transformers

Oil Sampling


## Manufacturers

- Airotronics
- Electronic Power Design (EPD)
- GE Automation
- GE ITI
- GE Monitoring and Diagnostics
- GE Multilin
- Integra Enclosures
- Meg-Alert
- Micron Industries Corporation
- Northstar-Dynapar-Lakeshore
- Pacific Crest Transformers
- Post Glover Resistors
- Sky-Young Electronics
- Sprecher + Schuh – Auer Signal
- Weidmuller

## Visual and Listed Line Card

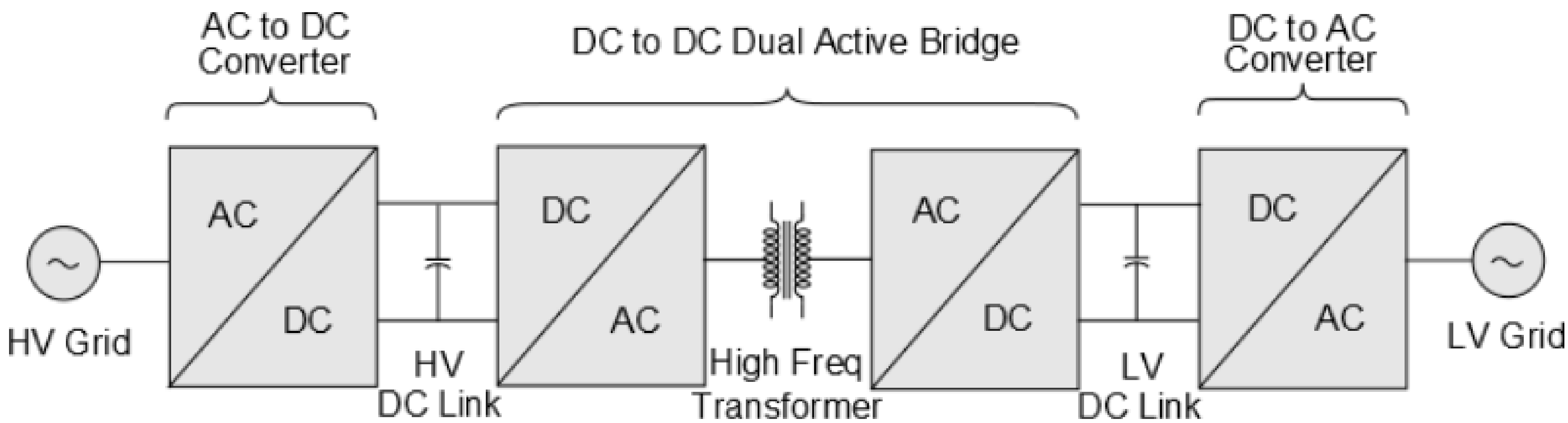
- Line Card
- Visual Line Card

Transformers Design has not changed much since the transformer was introduced in 1885.  Could anything change in the next 5 to 10 years?

What does the future look like?

# The Solid State Transformer (SST)

## Three stage SST



Thank you

Questions?