Application Guide

Brandon’s Notes on Different Transformer Types

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Introduction

This collection of notes is intended to bring awareness to the nuances of different transformer types and configurations. This guide discusses the nuances of voltage regulators, three winding transformers, dry type transformers, zigzag grounding transformers, and other transformer types. I hope that this information can be helpful to you in some way, when testing and managing the condition of your transformers.

-Brandon

Content

1 Voltage Regulators

1.1 Overview

The key tests for a voltage regulator are outlined below. I also included some useful tips for testing voltage regulators below.

> Overall Power Factor
> Bushing C1 Power Factor (if the bushings have test taps but they probably won't)
> Bushing C2 Power Factor (if the bushings have test taps but they probably won't)
> Exciting Current Test (only if time allows)
> TTR
> DC Winding Resistance

The Voltage Regulator Asset type is in PTM under Transformer. PTM provides guided testing for this asset. VRs are very similar to autotransformers, but the bushing terminal markings are S, L, and S0L0…NOT H, X, and H0X0).

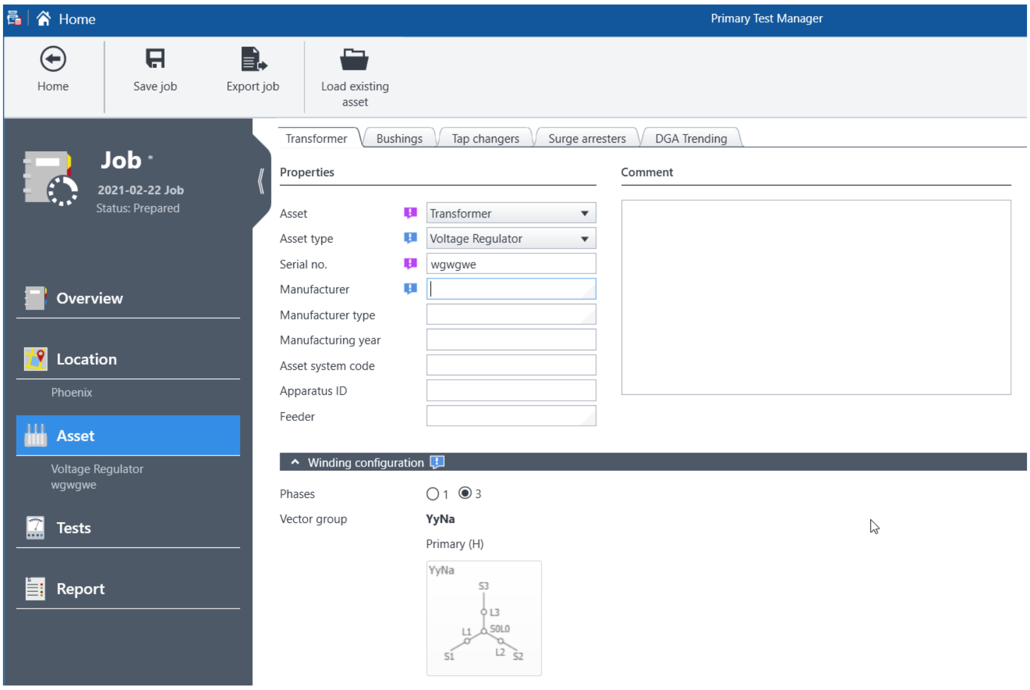

Figure 1: Asset Creation for Voltage Regulator

Voltage Regulators can be either Type A or Type B, where Type B is more popular in NA. You need to place the OLTC on the correct winding (i.e. L vs. S winding) to properly represent Type A or Type B. Also, the Tap Scheme should be set to match the nameplate order.

A Type A Voltage Regulator will typically be set up so that the OLTC is assigned to the L winding (see the figure below). A Type B Voltage Regulator will typically be set up so that the OLTC is assigned to the S winding (see the figure below).

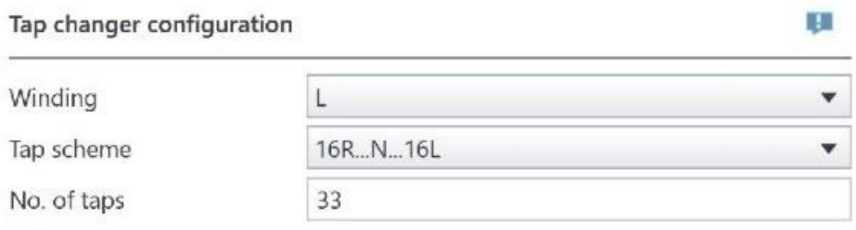

Figure 2: OLTC Creation for Type A

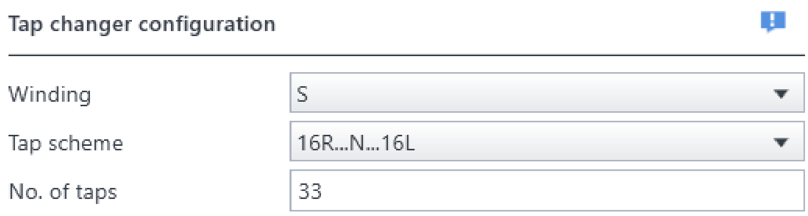

Figure 3: OLTC Creation for Type B

1.2 Overall Power Factor measurement tips for a voltage regulator

> Ensure that both the regulator and the test-equipment are solidly grounded to earth-ground
> Short-circuit all the bushing terminals of the regulator using non-insulated leads. Note, the shorting-jumpers should be connected as tightly as possible from bushing terminal-to-bushing terminal.
> Disconnect the “bus” from all the bushing terminals of the regulator
> Remove the in-service ground from any neutral bushing terminal (e.g. S0L0)
> Place the LTC in any off-neutral tap-position
> Ensure that the HV cable is “in the clear”, and that the last two feet of the HV cable is not touching any surface of the transformer (e.g. the transformer tank, the bushings, etc.)
> Perform a GST test
  - Energize the bushing terminals with the HV cable and measure the insulation to ground
  - The red current measurement lead is not used for this measurement – please disconnect it

1.3 TTR on voltage regulators

The following two scenarios are common when testing voltage regulators,

1. When performing the TTR test on a voltage regulator, the voltages for each tap-position may not be explicitly defined on the nameplate. In other words, on the nameplate, the user may only see the nominal voltage rating (e.g. 12.470kV) and the percent difference between each tap, or between the Neutral-tap and extreme tap-positions. In these cases, even if the user calculates the difference between each tap (or between the Neutral and extreme tap-positions) correctly, the measured TTR for each tap will probably be slightly different than the calculated TTR; in these cases, the measured TTR and the calculated TTR often differ by more than 0.5%.
2. When performing the TTR test on voltage regulators, it is common that the percent deviation exceeds 0.5% when comparing the measured TTR and the nominal TTR, especially when testing the tap-positions farthest from the neutral (e.g. the extreme raise and lower tap positions).

If the voltage regulator has a 3-Phase configuration, then what is most important for the TTR test analysis, is that the measured ratio is reasonably similar when comparing the three phases to each other. In nearly all cases, when testing a 3-Phase regulator or transformer, if the measured TTR is reasonably similar when comparing the three phases to each other, then the TTR “passes”. The phase-comparison analysis strategy supersedes the nameplate-comparison analysis strategy.

For single-phase voltage regulators, the TTR analysis is more challenging because you cannot directly compare the measured ratio for one phase to the other two phases on the same unit (like you can for a 3-Phase regulator). If you are testing a single-phase voltage regulator, then comparing the TTR measurement to TTR measurements performed on its sister units can be helpful. Comparing to a previous/historical TTR measurement on the same regulator can also be helpful.

I recommend using your best judgement when analyzing the TTR test on a voltage regulator. Keep in mind that, in most cases, the TTR test should “pass”. If there is reason to suspect that a given voltage regulator has a problem, then I would tend to be stricter with the analysis. If not, then I would tend to be more lenient with the analysis.

1.4 Voltage regulator without an accessible neutral terminal – workaround:

You can test this voltage regulator by treating it as a two-winding transformer with a Yy0 vector group configuration (see the screenshot below). The two-winding transformer with a Yy0 vector group configuration workaround is a nice solution for all the tests except for Overall Power Factor (see below). For the connection diagrams (for the tests other than Overall Power Factor), just swap the H terminals with S’s and the X terminals with L’s.

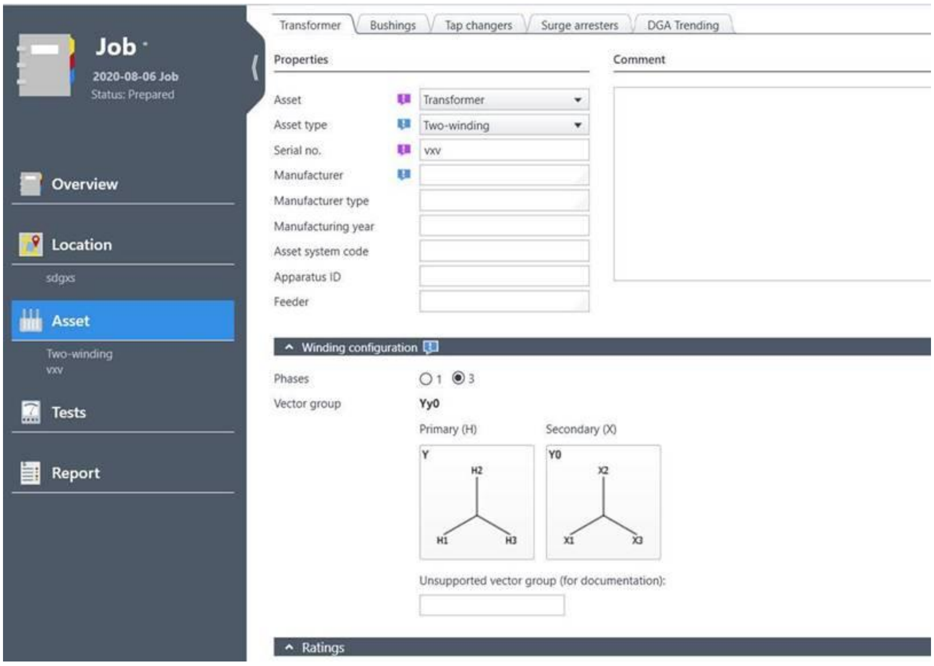

Figure 4: Asset Creation for Workaround

For the Overall Power Factor measurement on a regulator *without* an accessible neutral:

> Ensure that both the regulator and the test-equipment are solidly grounded to earth-ground

- Short-circuit all the bushing terminals of the regulator using non-insulated leads. Note, the shorting-jumpers should be connected as tightly as possible from bushing terminal-to-bushing terminal.
- Disconnect the “bus” from all the bushing terminals of the regulator
- Place the LTC in any off-neutral tap-position
- The high-voltage lead will be placed on either of the six bushing terminals
  - Ensure that the HV cable is “in the clear”, and that the last two feet of the HV cable is not touching any surface of the transformer (e.g. the transformer tank, the bushings, etc.)
- **Perform a GST test**
  - **Energize the bushing terminals with the HV cable and measure the insulation to ground**
  - **The red current measurement lead is not used for this measurement – please disconnect it**
  - **The test voltage will be dictated by the rating of the secondary winding and the secondary bushings**
  - **Execute line 4 only in the two-winding Overall PF test plan**

2 Wye Wye Two-Winding with Bonded Neutral and H0X0 Bushing

2.1 Recommended Winding Configuration/Vector Group

I recommend using the following Winding Configuration/Vector Group in PTM for this transformer type. For the connection diagrams in PTM (for the tests other than Overall Power Factor), you can use them without any issue.

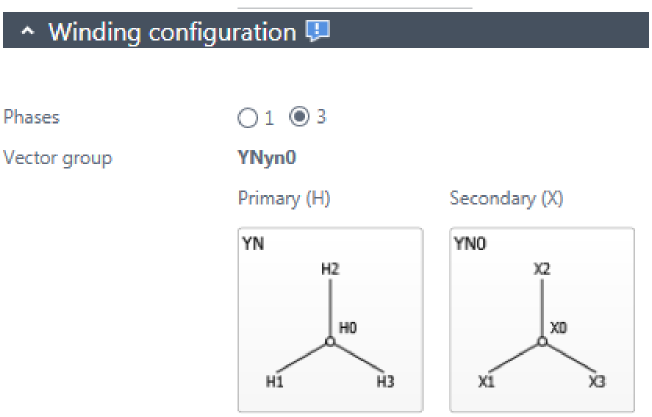

Figure 5: Recommended Vector Group

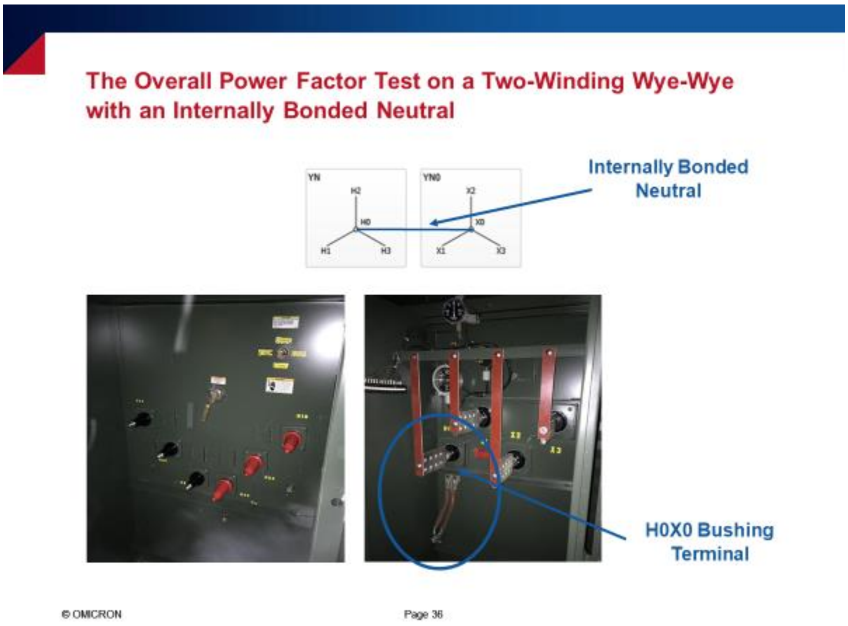

Figure 6: Example of this Transformer Type

2.2 Overall Power Factor Test

To perform a Power Factor measurement on this type of transformer, first confirm that the neutrals are internally short-circuited together and that only one neutral bushing is accessible (most likely labeled H0X0). Then,

- Ensure that both the transformer and the test-equipment are solidly grounded to earth-ground
- Short-circuit all the bushing terminals of the transformer using non-insulated leads. Note, the shorting-jumpers should be connected as tightly as possible from bushing terminal-to-bushing terminal.
- Disconnect the “bus” from all the bushing terminals of the autotransformer
- The high-voltage lead will be placed on either of the seven bushing terminals
- Ensure that the HV cable is “in the clear”, and that the last two feet of the HV cable is not touching any surface of the transformer (e.g. the transformer tank, the bushings, etc.)
- **Perform a GST test**
  - **Energize the bushing terminals with the HV cable and measure the insulation to ground**
  - **The red current measurement lead is not used for this measurement – please disconnect it**
  - **The test voltage will be dictated by the rating of the secondary winding and the secondary bushings**
  - **Execute line 4 only in the two-winding Overall PF test plan**

2.3 Exciting Current Test

- Remove the in-service ground from the bonded neutral H0X0
- Perform the measurement for each phase as expected for a Wye primary with a neutral
  - Connect the high voltage injection lead to H1 bushing terminal & the measurement lead to the bonded neutral H0X0
  - Perform a UST-A measurement
  - Repeat for each phase (H2-H0X0 & H3-H0X0)

3 Transformers with an Electrostatic Shield Ground – Overall Power Factor

An electrostatic shield ground typically only influences the Overall Power Factor measurement, so the other measurements should produce normal/typical results. If the power factor measurement is performed on a transformer that has an electrostatic ground shield between two (or more) windings, the measured current and capacitance is typically abnormally low for the inter-winding insulation (UST) measurements, due to the presence of the electrostatic shield ground. The shield acts as a guard and blocks the current flowing from the injection winding to the measurement winding.

When a transformer has an electrostatic shield ground located between two (or more) windings, typically, we recommend only analyzing the percent power factor for the Grounded Specimen Test (GST – e.g. CH and CL) measurements. The UST measurement(s) with an unusually low capacitance/current (approximately below 100pF) should be disregarded and not considered when analyzing the results.

When the test specimen has an unusually low capacitance/current (approximately below 100pF), the power factor percent can be unreliable and misleading. When the measured current is low, a small change with the measured current may result in a disproportionally large change in power factor.

Note, although the measured percent power factor for the UST measurement(s) are typically disregarded, the measured current and capacitance could be documented for future reference. A defect involving the electrostatic shield ground (e.g. a loss of a ground connection) may be detected if the current and capacitance of the UST measurement(s) changes over time.

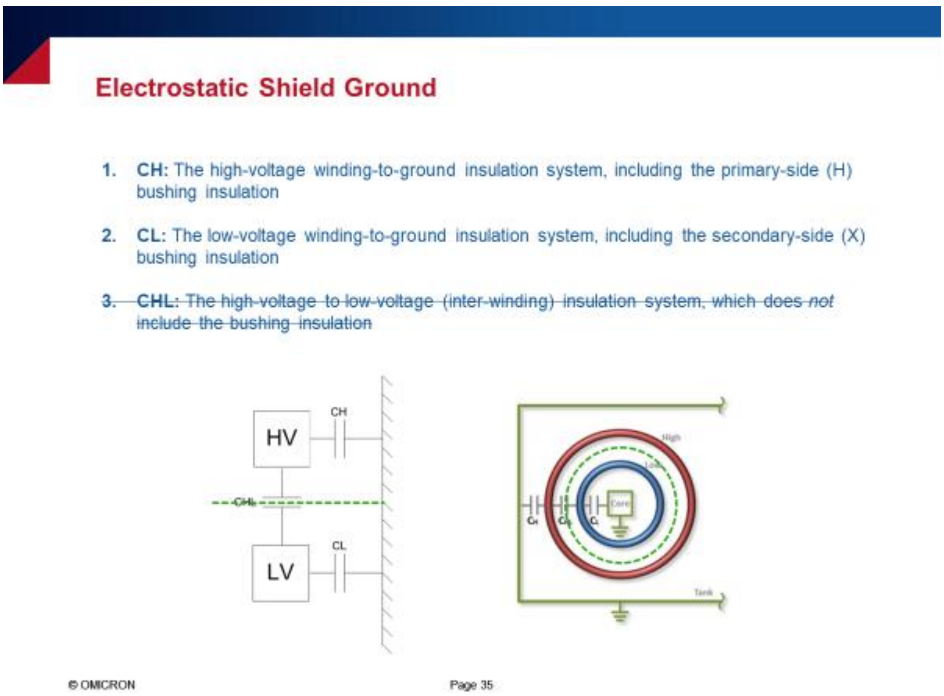

Figure 7: Diagrams Showing Presence of Electrostatic Shield Ground

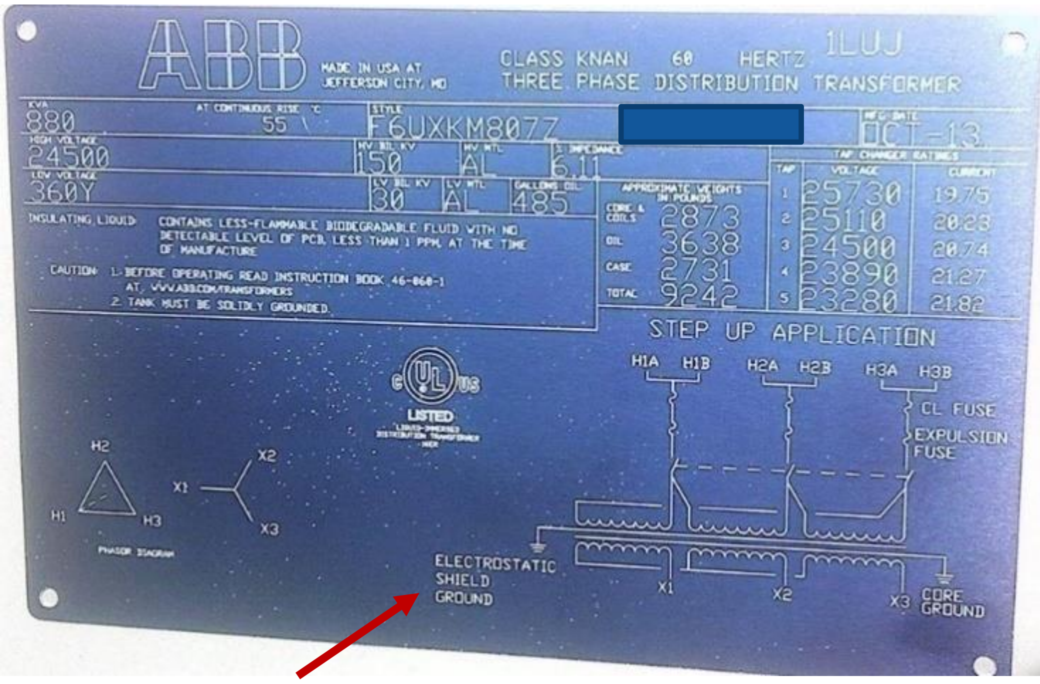

Figure 8: Nameplate Example Showing Presence of Electrostatic Shield Ground

4 Low Power Rated Transformers (approximately < 3-5MVA) – Overall Power Factor

Due to the relatively low power/voltage rating of these units, there could be some unique challenges when assessing the Overall PF measurement. Transformers with relatively low power ratings (e.g. approximately < 3-5MVA) tend to test with "higher than normal" Power Factor values (sometimes up to and exceeding 1%). For an oil-filled transformer of this size, I would expect that the range of Overall PF values could be wider than we typically see (i.e. relative to a larger "power transformer"); therefore, Overall PF values exceeding 0.5% can be expected and allowed on a case by case basis. A common industry rule-of-thumb is that if the transformer is rated at 500kVA or below, then Power Factor values up to 1% (assuming it's filled with mineral oil) are possible and are allowed on a case by case basis.

In general, the higher the voltage/power rating of the transformer, the stricter we tend to be with the Power Factor assessment. The lower the voltage/power rating of the transformer, the more lenient we tend to be with the Power Factor assessment.

Note, for distribution transformers, sometimes the bushings require a metal rod (i.e. a pin) to be inserted into a female end of the bushing terminal. It has been observed that the measured overall power factor is typically "higher than normal" for transformers that utilize these pins for the bushing terminals.

5 Natural Ester/FR3/“Less-Biodegradable Fluid” Transformers – Overall Power Factor

It is not uncommon that a power factor measurement on a transformer filled with a "Less-Flammable Biodegradable Fluid" (e.g. natural ester) has higher power factor value relative to a transformer filled with mineral oil. Therefore, higher power factor values are expected and are allowed within reason. Typically, for a transformer filled with natural ester, we recommend that the measured power factor is below 1%.

For a transformer filled with natural ester, a measured power factor value higher than 1% is unusual and may warrant further investigation, unless it’s a relatively low power/voltage rated unit (e.g. approximately < 3MVA). Transformers rated for approximately < 3MVA that are filled with a "Less-Flammable Biodegradable Fluid" have been known to test in the 1-2% range.

The best method for performing the analysis on transformers filled with a "Less-Flammable Biodegradable Fluid" would be to document and trend the measured power factor over time, in order to look for any increases in power factor. Another analysis strategy is to compare the results to a sister unit transformer(s).

		Power factor		
Assessment against	Limit	Silicone	Mineral oil	Natural ester
Absolute limits for measurements	Low limit (fail)	0.000 %	0.000 %	0.000 %
	Low limit (warn.)	0.100 %	0.100 %	0.100 %
	High limit (warn.)@ <230kV	0.500 %	0.500 %	1.000 %
	High limit (warn.)@ >=230kV	0.500 %	0.400 %	1.000 %
	High limit (fail)	1.000 %	1.000 %	2.000 %
Absolute limits for cross check	Multiplier (high warn. limit)	1.10	1.10	1.10
	Multiplier (high fail limit)/Divider (low fail limit)	1.20	1.20	1.20

Figure 9: PTM Overall PF Limits for Different Insulating Fluids

6 Dry Type Transformers – Overall Power Factor

In general, performing and analyzing Power Factor measurements on dry-type transformers is often challenging, due to,

> The Power Factor measurements performed on dry-type transformers are often significantly higher relative to transformers filled with oil - in other words, the range of Power Factor values obtained from testing dry-type transformers is very wide. Often the Overall Power Factor measurement can yield values in the 0.25%-10% range, which may be normal/typical for a given dry-type transformer.

> Often, one or more of the Overall Power Factor/Capacitance measurements on a dry-type transformer yields a relatively small Capacitance (pF) value (e.g. < 500pF), which indicates that there is a minimal amount of insulation being tested for that measurement.

- In general, measurements with relatively small Capacitances (pF) values are more sensitive (and thus, are more prone to measurement error), than measurements with relatively sizeable Capacitances (pF)
- In general, the measurements with low Capacitances (pF) values usually produce the highest power factor values (i.e. sometimes in the 4-10% range).
- Measurements with relatively small Capacitances (pF) values (e.g. the CH measurement on a dry-type transformer) typically test the integrity of,
  - The bushings associated with the winding being energized
  - The support insulators that are supporting the winding structure

> The test-environment - The test-environment can heavily impact any Power Factor measurement, but even more so for Power Factor measurements performed on a dry-type transformer. For example, moisture/contamination on the surfaces of the bushings and/or the windings can significantly influence the Overall Power Factor test results.

The best method for analyzing the Overall Power Factor on a dry-type transformer is to document and trend the measured power factor over time, to look for any increases in Power Factor. Another analysis strategy is to compare the results to a sister unit transformer(s). The frequency sweep test on dry type transformers has to be taken with a grain of salt, as the rules we typically use for this test only apply to fluid filled insulation systems. I would focus more on the 60Hz Power Factor for dry type transformers.

7 Federal Pacific Electric/Federal Pioneer Electric/FPE Transformers – Overall Power Factor

Some transformer Load-Tap-Changers (LTCs) utilize a “tie-in resistor”, which has been known to influence the Overall Power Factor measurement when the transformer is tested in the Neutral tap-position. Specifically, Federal Pioneer Electric and Federal Pacific Electric transformers with LTCs have been known to exhibit this behavior. If these transformers are tested in the Neutral tap-position, then it can compromise the Power Factor measurement; therefore, always ensure that the LTC is NOT in the Neutral tap-position when the Overall Power Factor measurement is performed (for any transformer).

Note, all the Federal Pioneer Electric and Federal Pacific Electric transformers I’ve ever seen have a tie-in resistor. The tie-in resistor seems to create an abnormally large amount of leakage current flowing to ground, which usually results in an abnormally high or negative Power Factor value.

An example of a tie-in resistor is shown in the screenshot below. From my understanding, when the LTC is placed in the Neutral position, the tie-in resistor is connected to the regulating winding, so that when the reversing switch changes position, the regulating winding does not float to an undesired potential.

Figure 10: Nameplate Example Showing Presence of Tie-In Resistor

8 Autotransformers

8.1 Overall Power Factor measurement tips for an Autotransformer without a tertiary

- Ensure that both the autotransformer and the test-equipment are solidly grounded to earth-ground
- Short-circuit all the bushing terminals of the autotransformer using non-insulated leads. Note, the shorting-jumpers should be connected as tightly as possible from bushing terminal-to-bushing terminal.
- Disconnect the “bus” from all the bushing terminals of the autotransformer
- Remove the in-service ground from any neutral bushing terminal (e.g. H0X0)
- Place the LTC in any off-neutral tap-position
- Ensure that the HV cable is “in the clear”, and that the last two feet of the HV cable is not touching any surface of the transformer (e.g. the transformer tank, the bushings, etc.)
- Perform a GST test
    - Energize the bushing terminals with the HV cable and measure the insulation to ground
    - The red current measurement lead is not used for this measurement – please disconnect it

8.2 Autotransformer without an accessible neutral H0X0 terminal – workaround:

You can test this autotransformer by treating it as a two-winding transformer with a Yy0 vector group configuration (see the screenshot below). The two-winding transformer with a Yy0 vector group configuration workaround is a nice solution for all the tests except for Overall Power Factor (see below). For the connection diagrams in PTM (for the tests other than Overall Power Factor), you can use them without any issue.

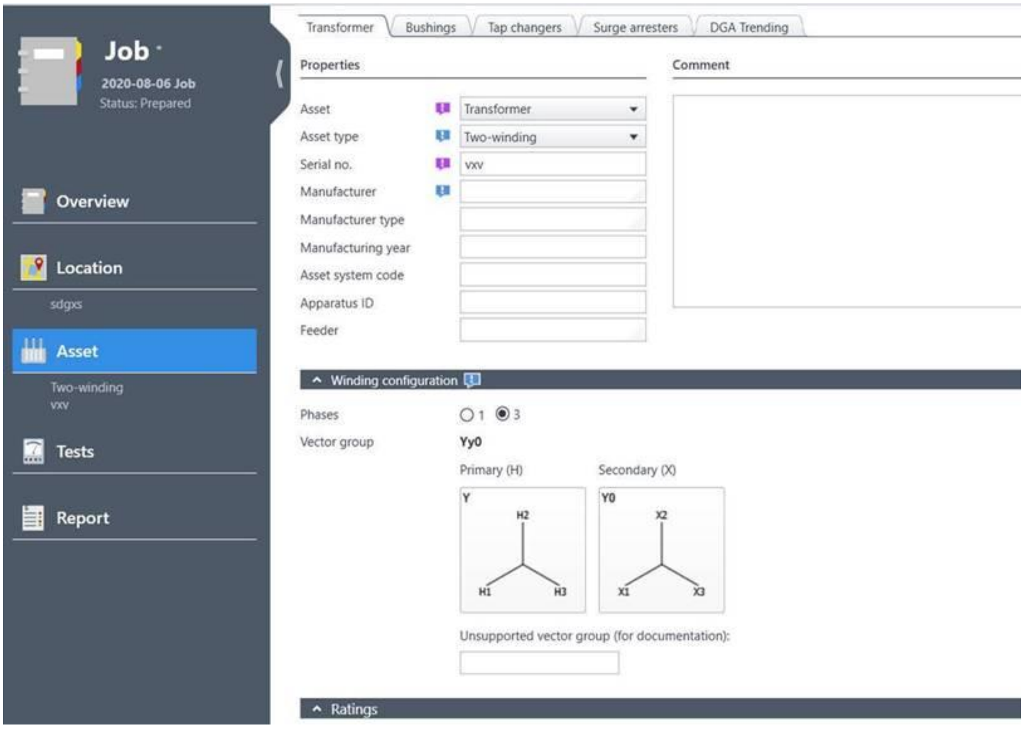

Figure 11: Asset Creation for Workaround

For the Overall Power Factor measurement on an autotransformer *without* an accessible neutral:

> Ensure that both the autotransformer and the test-equipment are solidly grounded to earth-ground

> Short-circuit all the bushing terminals of the autotransformer using non-insulated leads. Note, the shorting-jumpers should be connected as tightly as possible from bushing terminal-to-bushing terminal.

> Disconnect the "bus" from all the bushing terminals of the autotransformer

> Place the LTC in any off-neutral tap-position

> The high-voltage lead will be placed on either of the six bushing terminals
  - Ensure that the HV cable is "in the clear", and that the last two feet of the HV cable is not touching any surface of the transformer (e.g. the transformer tank, the bushings, etc.)

> **Perform a GST test**
  - **Energize the bushing terminals with the HV cable and measure the insulation to ground**
  - **The red current measurement lead is not used for this measurement – please disconnect it**
  - **The test voltage will be dictated by the rating of the secondary winding and the secondary bushings**
  - **Execute line 4 only in the two-winding Overall PF test plan**

9 Three winding transformers

9.1 Unusual UST Power Factor (CHT or CLT or CHL) and Low Capacitance issue when testing a three-winding transformer

An unusually low capacitance value (pF) is often measured when testing a three-winding transformer. It's usually the CHT measurement that has the unusually low capacitance value (pF), but it can be either (or any combination) of the three UST measurements. Often the center winding (typically the secondary X winding) guards the current flowing from the primary to the tertiary winding during the CHT measurement. However, any of the windings can act as a guard and block the current flowing from the injection winding to the measurement winding.

When the test specimen has an unusually low capacitance/current (approximately below 100pF), the power factor percent can be unreliable and misleading. When the measured current is low, a small change with the measured current may result in a disproportionally large change in power factor.

The UST measurement(s) with an unusually low capacitance/current (approximately below 100pF) should be disregarded and not considered when analyzing the results.

Block 1: injection at H

Start all ☑ Use global corr. factor (K) 1.2

		No.	Measurement	Test mode	Sweep	V test	Freq.	V out	I out	Watt losses	PF meas	PF corr	Cap. meas	Assessment
Start	+	1	ICH+ICHL+ICHT	GST	None	10.00 kV	60.00 Hz	10.00 kV	38.49 mA	777.17 mW	0.2019 %	0.2423 %	10207.0 pF	Pass
Start	+	2a	ICH (V)	GSTg-A+B	Voltage	10.00 kV	60.00 Hz	10.00 kV	14.70 mA	353.75 mW	0.2407 %	0.2888 %	3894.3 pF	Pass
Start	+	2b	ICH (f)	GSTg-A+B	Frequency	2.00 kV	60.00 Hz	2.00 kV	2.94 mA	12.78 mW	0.2174 %	0.2609 %	3895.3 pF	Pass
Start	+	3a	ICHL (V)	UST-A	Voltage	10.00 kV	60.00 Hz	10.00 kV	23.55 mA	415.31 mW	0.1764 %	0.2116 %	6248.4 pF	Pass
Start	+	3b	ICHL (f)	UST-A	Frequency	2.00 kV	60.00 Hz	2.00 kV	4.71 mA	16.42 mW	0.1742 %	0.2091 %	6250.0 pF	Pass
Start	+	4a	ICHT (V)	UST-B	Voltage	10.00 kV	60.00 Hz	10.00 kV	0.24 mA	3.30 mW	0.1381 %	0.1657 %	63.3 pF	Investigate
Start	+	4b	ICHT (f)	UST-B	Frequency	2.00 kV	60.00 Hz	2.00 kV	0.05 mA	0.13 mW	0.1333 %	0.1599 %	63.4 pF	Investigate

Block 2: injection at X

Start all ☑ Use global corr. factor (K) 1.2

		No.	Measurement	Test mode	Sweep	V test	Freq.	V out	I out	Watt losses	PF meas	PF corr	Cap. meas	Assessment
Start	+	5	ICL+ICLT+ICLH	GST	None	10.00 kV	60.00 Hz	10.00 kV	49.27 mA	1055.30 mW	0.2141 %	0.2570 %	13064.5 pF	Pass
Start	+	6a	ICL (V)	GSTg-A+B	Voltage	10.00 kV	60.00 Hz	10.00 kV	8.52 mA	276.46 mW	0.3245 %	0.3894 %	2258.1 pF	Pass
Start	+	6b	ICL (f)	GSTg-A+B	Frequency	2.00 kV	60.00 Hz	2.00 kV	1.70 mA	10.81 mW	0.3171 %	0.3805 %	2258.1 pF	Pass
Start	+	7a	ICLT (V)	UST-B	Voltage	10.00 kV	60.00 Hz	10.01 kV	17.19 mA	367.87 mW	0.2138 %	0.2566 %	4556.9 pF	Pass
Start	+	7b	ICLT (f)	UST-B	Frequency	2.00 kV	60.00 Hz	2.00 kV	3.44 mA	14.58 mW	0.2124 %	0.2548 %	4557.7 pF	Pass
Start	+	8a	ICLH (V)	UST-A	Voltage	10.00 kV	60.00 Hz	10.00 kV	23.55 mA	414.15 mW	0.1759 %	0.2110 %	6249.0 pF	Pass
Start	+	8b	ICLH (f)	UST-A	Frequency	2.00 kV	60.00 Hz	2.00 kV	4.71 mA	16.40 mW	0.1740 %	0.2088 %	6249.8 pF	Pass

Block 3: injection at Y

Start all ☑ Use global corr. factor (K) 1.2

		No.	Measurement	Test mode	Sweep	V test	Freq.	V out	I out	Watt losses	PF meas	PF corr	Cap. meas	Assessment
Start	+	9	ICT+ICTH+ICTL	GST	None	7.00 kV	60.00 Hz	7.00 kV	56.33 mA	1238.24 mW	0.3140 %	0.3768 %	21338.4 pF	Pass
Start	+	10a	ICT (V)	GSTg-A+B	Voltage	7.00 kV	60.00 Hz	7.00 kV	44.12 mA	1057.51 mW	0.3424 %	0.4109 %	16717.9 pF	Pass
Start	+	10b	ICT (f)	GSTg-A+B	Frequency	2.00 kV	60.00 Hz	2.00 kV	12.61 mA	85.81 mW	0.3403 %	0.4084 %	16717.0 pF	Pass
Start	+	11a	ICTH (V)	UST-B	Voltage	7.00 kV	60.00 Hz	7.00 kV	0.17 mA	1.73 mW	0.1478 %	0.1774 %	63.4 pF	Investigate
Start	+	11b	ICTH (f)	UST-B	Frequency	2.00 kV	60.00 Hz	2.00 kV	0.05 mA	0.14 mW	0.1469 %	0.1763 %	63.4 pF	Investigate
Start	+	12a	ICTL (V)	UST-A	Voltage	7.00 kV	60.00 Hz	7.00 kV	12.02 mA	179.72 mW	0.2136 %	0.2563 %	4556.8 pF	Pass
Start	+	12b	ICTL (f)	UST-A	Frequency	2.00 kV	60.00 Hz	2.00 kV	3.44 mA	14.56 mW	0.2119 %	0.2543 %	4557.4 pF	Pass

Figure 12: Example Showing the Guarding Effect of the Center Winding for CHT

10 Zig zag grounding transformers

10.1 Recommended Asset and Winding Configuration in PTM

We don't have this specific Transformer Asset Type in PTM, but my recommended workaround is to use the following Asset Type in PTM; however, you'll need to ignore all the X terminals, X test leads, and X windings in the connection diagrams.

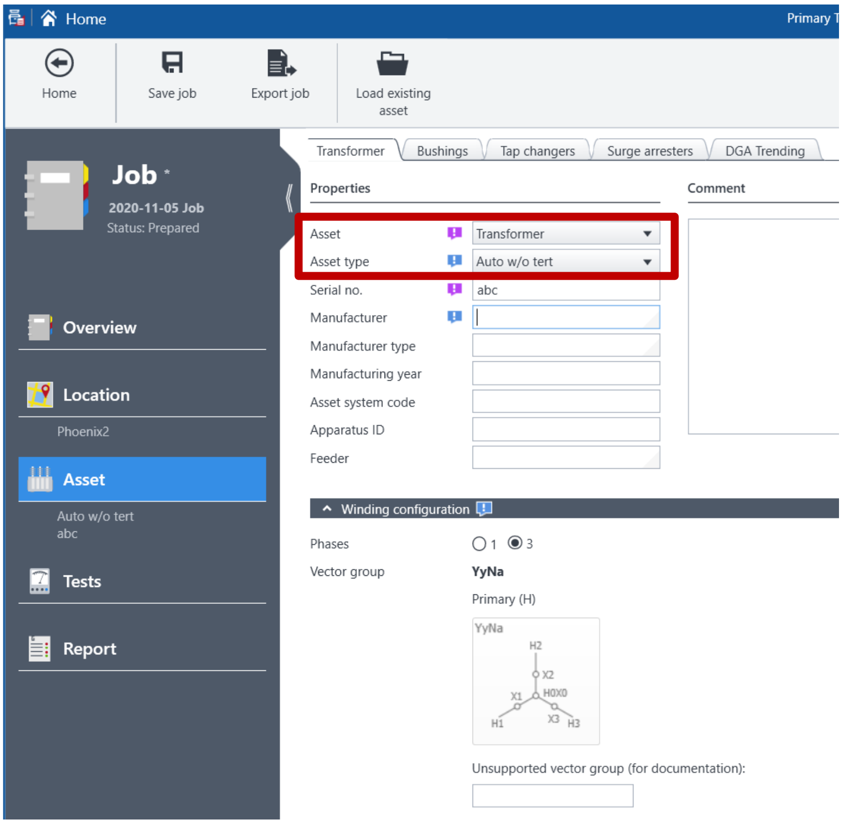

Figure 13: Asset Creation for Workaround

10.2 Recommended test list

If it's an oil filled one-winding zig-zag grounding transformer, you can perform,

> Overall PF
  - Ensure that both the transformer and the test-equipment are solidly grounded to earth-ground
  - Short-circuit all the bushing terminals of the transformer using non-insulated leads. Note, the shorting-jumpers should be connected as tightly as possible from bushing terminal-to-bushing terminal.
  - Disconnect the "bus" from all the bushing terminals of the autotransformer
  - The high-voltage lead will be placed on either of the bushing terminals
  - Ensure that the HV cable is "in the clear", and that the last two feet of the HV cable is not touching any surface of the transformer (e.g. the transformer tank, the bushings, etc.)
  - Perform a GST test
    - Energize the bushing terminals with the HV cable and measure the insulation to ground

  - The red current measurement lead is not used for this measurement – please disconnect it

- Exciting Current
  - Test H1-H0, H2-H0, and H3-H0
  - A “one high and two lows” phase pattern is typically expected - the measurement involving Phase A and C in series should be the “high” measurement
- DC Winding Resistance H
  - Test H1-H0, H2-H0, and H3-H0
  - With the TESTRANO 600 use the Single-Phase mode only
- SFRA (optional) – Test H1-H0, H2-H0, and H3-H0 (open circuit tests only)

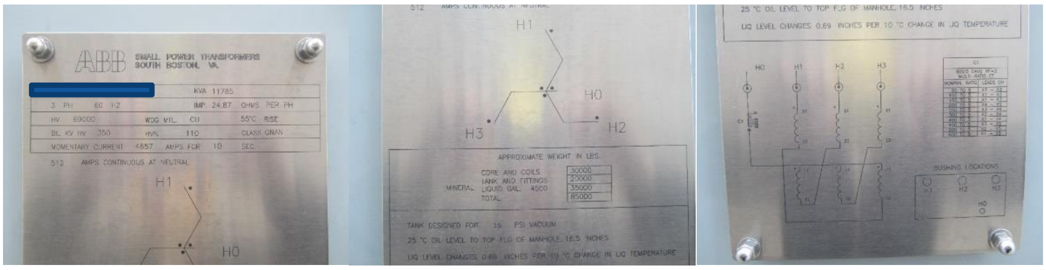

Figure 14: Nameplate Example

11 Phase shift transformers

Can we test phase shift transformers with the TESTRANO 600? Does the unit show the phase angle, or does it give a phase deviation from another phase?

Yes, phase shift transformers are a good application for the TESTRANO 600. The TESTRANO 600 shows the phase angle for all three phases. This is all due to its true 3-phase injection.

12 Transformer with a Broken Delta Tertiary (where there are only two accessible tertiary bushing terminals)

For the TESTRANO 600:

The winding resistance Y test is missing for this transformer configuration in PTM. What I recommend is to add a 2nd winding resistance X test to your test queue, and re-label it winding resistance Y using the left side panel (see the screenshot below). Please use the single-phase injection and start with maybe 5 or 10A. The test connections could be as follows - note, the “X” designations refer to the TESTRANO 600’s Secondary X cable test leads and NOT the X terminals on the transformer.

- Option one (X1-X0) - connect the X1 lead to the first tertiary bushing terminal and the X0 lead to the second tertiary bushing terminal. When you execute the test, you will only have reasonable results for Phase A and you'd have to disregard Phase B and C. Leave the X2 and X3 leads of the test set open circuited.
- Option 2 (X1 and X2 and X3-X0) connect the X1, X2, and X3 leads to the first tertiary bushing terminal of the transformer. Connect the X0 lead to the second tertiary bushing terminal of the

transformer. When you execute the test, the unit will perform three successive measurements, and all should have the same value. You're just testing the Y resistance three times.

The turns ratio test and the leakage reactance test involving the tertiary are not possible. Power factor and exciting current as shown in the software should work fine.

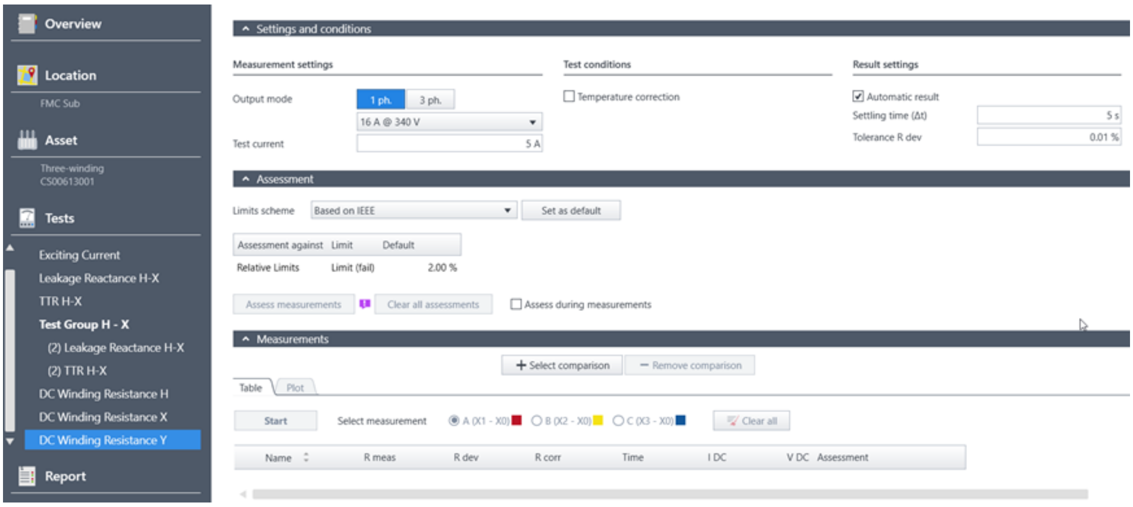

Figure 15: Test Plan Example for the Winding Resistance Y Test

For the CPC 100:
The winding resistance Y test is available in PTM, but the user only has to execute one of the three "phases" in the winding resistance Y test plan (executing the one measurement on any of the three "phases" is fine). One current injection and one voltage lead will be placed on each of the tertiary Y's two accessible terminals.

The turns ratio test and the leakage reactance test involving the tertiary are not possible. Power factor and exciting current as shown in the software should work fine.

13 Pole mounted transformers

The following measurements can be performed on pole-mount transformers using the CPC 100+TD12 or the TESTRANO 600+CP TD12,

- Overall Power Factor (up to 12kV)
  - Simple insulation check
  - Treat somewhat as a go/no-go test
  - Could compare results across sister-units
- Exciting Current Test (up to 12kV)
  - Simple insulation check
  - Treat somewhat as a go/no-go test
  - Could compare results across sister-units
- TTR
  - Functional check of the transformer
  - Simple insulation check
  - Could compare results across sister-units
- DC Winding Resistance H/X
  - Check the continuity of the winding and any associated connection points

- Could compare results across sister-units

OMICRON is an international company serving the electrical power industry with innovative testing and diagnostic solutions. The application of OMICRON products allows users to assess the condition of the primary and secondary equipment on their systems with complete confidence. Services offered in the area of consulting, commissioning, testing, diagnosis and training make the product range complete.

Customers in more than 140 countries rely on the company's ability to supply leading edge technology of excellent quality. Service centers on all continents provide a broad case of knowledge and extraordinary customer support. All of this together with our strong network of sales partners is what has made our company a market leader in the electrical power industry.

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