Application Guide

A Guide for Power Factor Testing Instrument Transformers: CCVTs, PTs, and CTs

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1 Introduction

The following information is intended to provide the reader with a basic introduction to performing Power Factor tests on Instrument Transformers. This is not an exhaustive resource, and does not include advanced troubleshooting or test analysis. This is simply intended to guide the user through the testing process.

The processes outlined in this guide are based on using the CP TD1 accessory with either a CPC 100 or a TESTRANO 600. However, these test procedures can be applied with any Power Factor test-instrument. For safety purposes, we recommend that the operator reads the user manual before using the equipment. Please exercise caution and observe all applicable safety standards when performing these tests.

The following guide has been divided into sections, each representing a different type of Instrument Transformer. When testing a CCVT, if you are not sure which category the test-specimen falls into, please refer to the “CCVT Introduction” section to better identify which category it belongs to. If you are testing a CCVT, in most cases, you will be testing a “CCVT with an Inaccessible Potential Terminal”.

2 CCVT Introduction

Note, if the CCVT under test only has one “housing unit”, then it will have a total of two Capacitors (C1 and C2). If the CCVT under test has two “housing units”, then it will have a total of three Capacitors (C1-2, C1-1, and C2).

C2: This is the bottom-most Capacitor of the CCVT. The C2 Capacitor is located below the C1-1 Capacitor, in the bottom-most housing unit of the CCVT (see Figure 1).

C1-1: The C1-1 Capacitor is located directly above the C2 Capacitor, in the bottom-most housing unit of the CCVT (see Figure 1). Note, if you are testing a two-unit CCVT, then the C1-1 Capacitance (pF) value may not be indicated on the nameplate.

C1-2: The C1-2 Capacitor is located directly above the C1-1 Capacitor. The C1-2 Capacitor is typically located in its own housing unit, directly above the bottom-most housing unit of the CCVT (see Figure 1). Note, if you are testing a two-unit CCVT, then the C1-2 Capacitance (pF) value may not be indicated on the nameplate.

C1: The C1 Capacitance is the series capacitance of C1-1, C1-2, C1-3, etc. If the CCVT under test only has one housing unit, then only one Capacitor will comprise the C1 Capacitance.

Note, if the CCVT under test has more than two housing units “in the stack”, then there may exist a C1-3 Capacitor, a C1-4 Capacitor, etc.

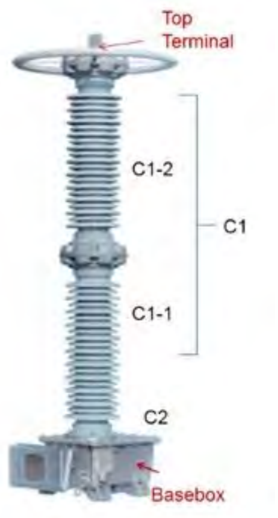


Figure 1: Two-Unit CCVT with an Inaccessible Potential Terminal

2.1 Typical CCVT Construction (for CCVT Models with an Inaccessible Potential Terminal)

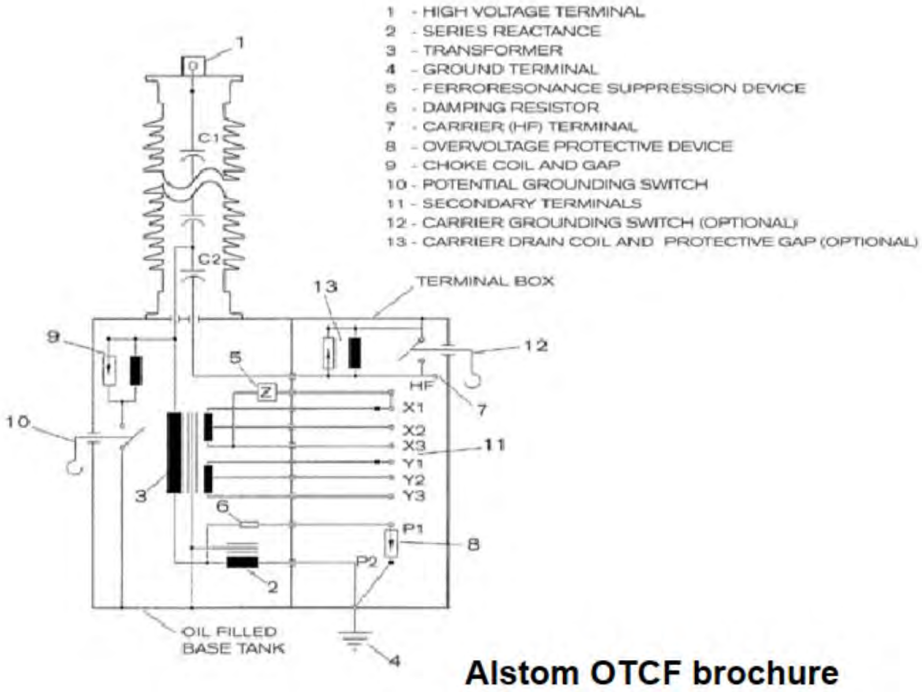
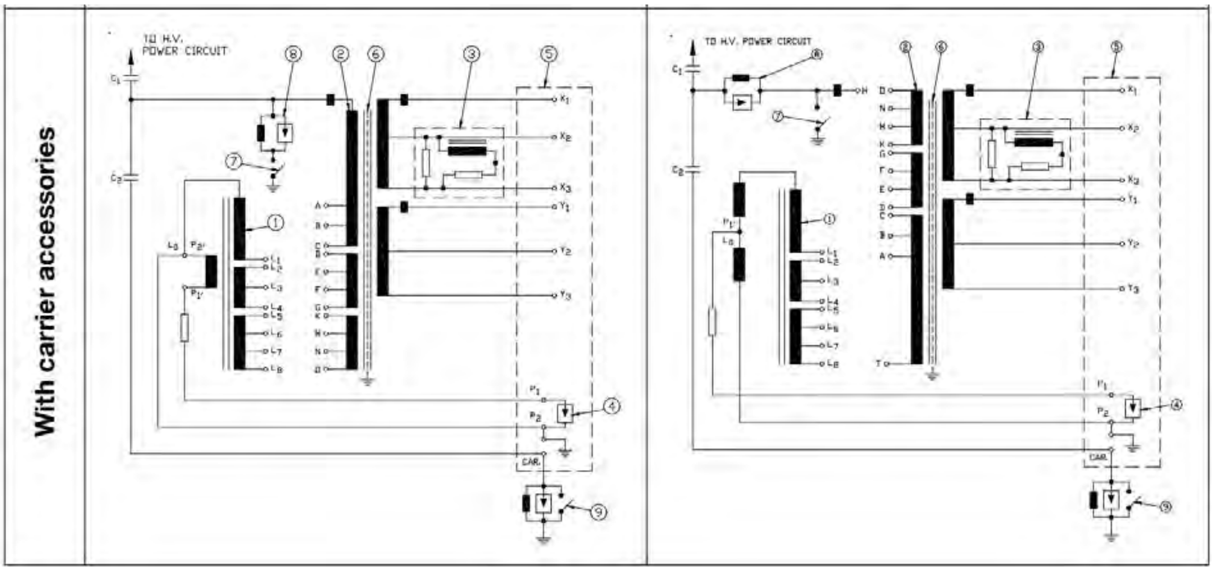


Figure 2: Typical Alstom OTCF CCVT Wiring Diagram



Legend:
① Series Reactors
② Intermediate Voltage Transformer
③ Harmonic Suppression Filter
④ Sealed Protective Gap
⑤ Secondary Terminal Board
⑥ Faraday Field
⑦ Potential Ground Switch
⑧ Choke Coil & Gap Assembly
⑨ Drain Coil, Gap & Carrier Ground Switch Assembly

Figure 3: Typical Trench CCVT Wiring Diagram (with carrier accessories)

2.2 The Carrier Terminal

The Carrier Terminal, which is typically located in the base box (aka junction box) of the CCVT, is critical for the CCVT Power Factor measurement.

- For the “older style” of CCVTs with accessible Potential Terminals (e.g. General Electric and Westinghouse CCVTs), the Carrier Terminal can typically be disconnected and isolated for testing.

- For modern CCVTs, the Carrier Terminal (often referred to as the “HF terminal”) is typically located in the base box of the CCVT, and may need to be disconnected from ground-potential, from the drain coil, and/or from accessory leads. The following two Figures demonstrate where to find the Carrier Terminals for a Trench TEIRF 115kV CCVT and an Alstom Type OTCF-300 CCVT, respectively.

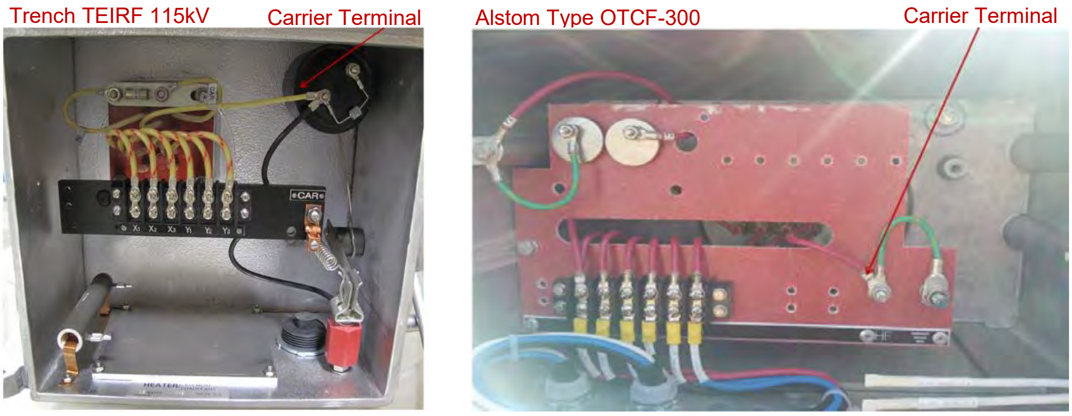


Figure 4: Trench and Alstom CCVT Baseboxes (showing Carrier/HF Terminal)

2.3 The Potential Terminal

The test procedure for performing a Power Factor measurement on a CCVT is largely dictated by if the CCVT has an accessible Potential Terminal.

- For the “older style” of CCVTs (e.g. General Electric and Westinghouse CCVTs), the Potential Terminal is typically accessible.

- For modern CCVTs, the Potential Terminal is typically NOT accessible, and CANNOT be accessed for Power Factor measurements. Typically, Trench and Alstom CCVTs fall under this category.

3 CCVT Power Factor Testing

3.1 CCVT with an Inaccessible Potential Terminal - Single-Unit Stack

The procedure for testing a single housing unit CCVT with an inaccessible Potential Terminal is provided in this section. The Trench TEIRF 115kV CCVT (shown in the following Figure) is an example of a single housing unit without an accessible Potential Terminal.

For a single housing unit CCVT, there are typically only two individual capacitors, C1 and C2, that can be tested. For this CCVT type, there are three recommended Power Factor measurements, which are summarized in the following Table. Please observe the following steps prior to executing Test #1:

- ✓ De-energize the CCVT unit
- ✓ Ground the metallic terminal(s) of the CCVT, to discharge any remaining energy within the capacitors
- ✓ Disconnect and isolate the CCVT line-terminal from any bus, cable, support insulators, etc.
- ✓ Close the Potential ground switch and the Carrier ground switch (if applicable)
- ✓ Ensure that both the CCVT housing and the test-equipment are solidly bonded to earth-ground potential
- ✓ Clean and dry the exterior surfaces of the CCVT's housing units
- ✓ *Note, for the C2 measurement, the test-voltage should not exceed the voltage-rating of the Carrier Terminal – If you are unsure, we recommend applying a test-voltage of 500V, for the C2 Test

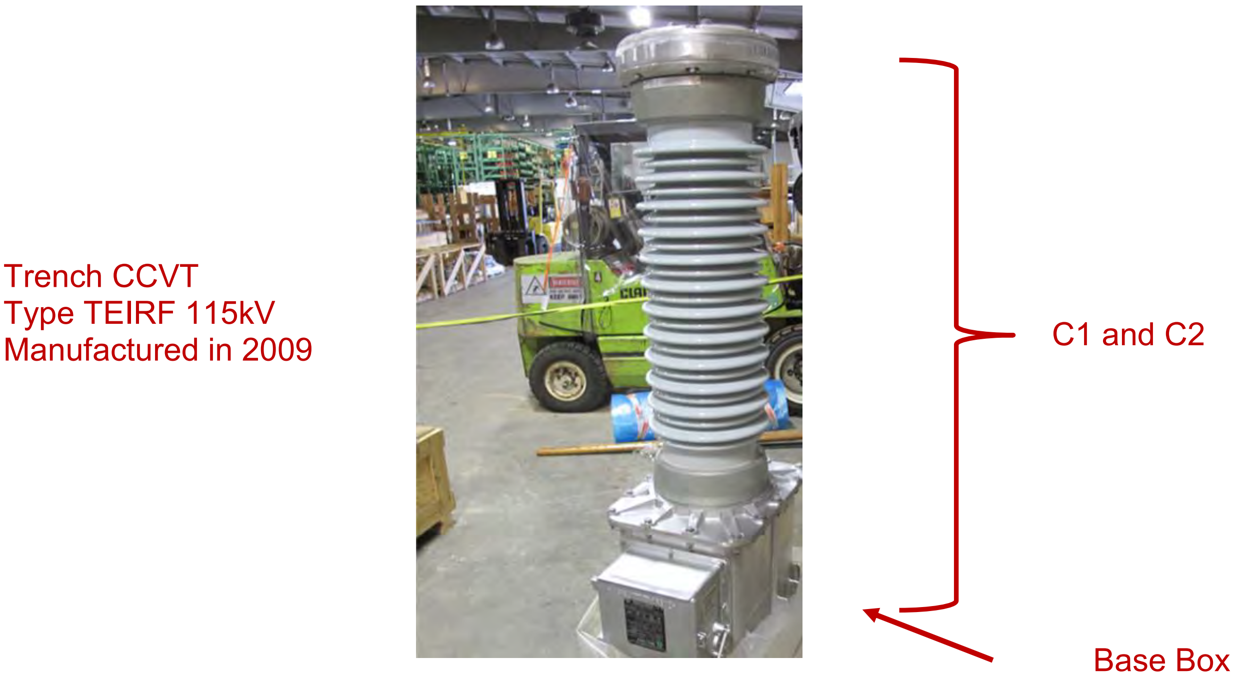


Figure 5: Trench TEIRF 115kV CCVT

Table 1: Single-Unit CCVT with an Inaccessible Potential Terminal - Power Factor Test Plan

Test	Measured Capacitance	Test Mode	Carrier Grounding Switch	Potential Grounding Switch	High Voltage Lead	Low Voltage Lead	Typical Test Voltage
1 (recommended)	C1 and C2 Series Test (Overall)	UST-A	Closed	Open	Line-Terminal (Top of C1 Capacitor)	Carrier Terminal	10kV
2 (recommended)	C2	GSTg-A	Closed	Closed	Carrier Terminal	Line-Terminal (Top of C1 Capacitor)	*500V
3 (recommended)	C1	GST	Closed	Closed	Line-Terminal (Top of C1 Capacitor)	-	10kV

3.1.1 C1 and C2 Series Measurement (recommended)

The test procedure for the C1 and C2 series Power Factor measurement (aka the Overall Test) is provided in the following Table. Before executing the C1 and C2 series Power Factor measurement, please perform the following steps,

- ✓ Disconnect and isolate the Carrier from ground-potential, from the drain coil, and from any accessory leads (if applicable)
- ✓ The test voltage (typically 10kV) should not exceed the line-to-ground rating of the CCVT insulation
- ✓ Open the Potential ground switch

Table 2: Single-Unit CCVT with an Inaccessible Potential Terminal – C1 and C2 Series Test

Test	Measured Capacitance	Test Mode	Carrier Grounding Switch	Potential Grounding Switch	High Voltage Lead	Low Voltage Lead	Typical Test Voltage
1 (recommended)	C1 and C2 Series Test (aka the Overall Test)	UST-A	Closed	Open	Line-Terminal (Top of C1 Capacitor)	Carrier Terminal	10kV

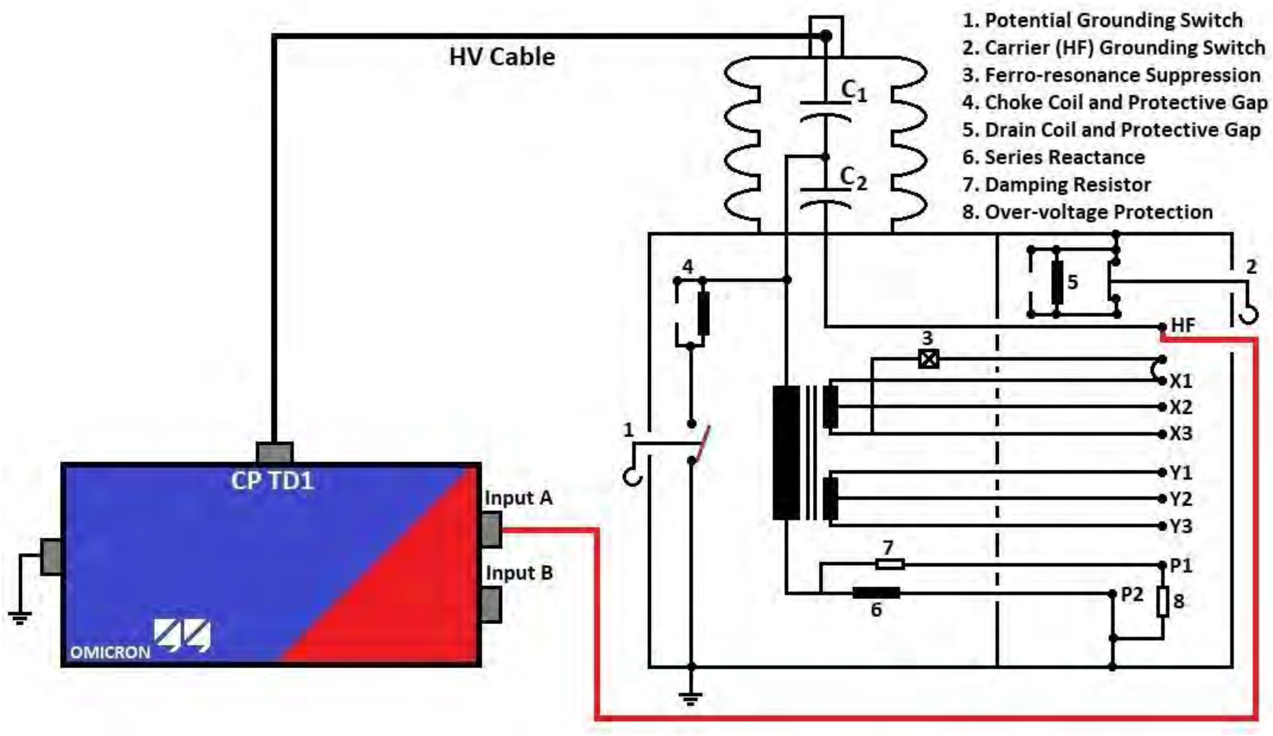


Figure 6: Single-Unit CCVT with an Inaccessible Potential – C1 and C2 Series Test Wiring Diagram

3.1.2 C2 Measurement (recommended)

The test procedure for the C2 Power Factor measurement is provided in the following Table. Before executing the C2 Power Factor measurement, please perform the following steps,

- ✓ Leave the Carrier ground switch closed
- ✓ Disconnect and isolate the Carrier from ground-potential, from the drain coil, and from any accessory leads (if applicable)
- ✓ Close Potential ground switch
- ✓ *Note, for the C2 measurement, the test-voltage should not exceed the voltage-rating of the Carrier Terminal – If you are unsure, we recommend applying a test-voltage of 500V, for the C2 Test

Table 3: Single-Unit CCVT with an Inaccessible Potential Terminal – C2 Power Factor Test

Test	Measured Capacitance	Test Mode	Carrier Grounding Switch	Potential Grounding Switch	High Voltage Lead	Low Voltage Lead	Typical Test Voltage
2 (recommended)	C2	GSTg-A	Closed	Closed	Carrier Terminal	Line-Terminal (Top of C1 Capacitor)	*500V

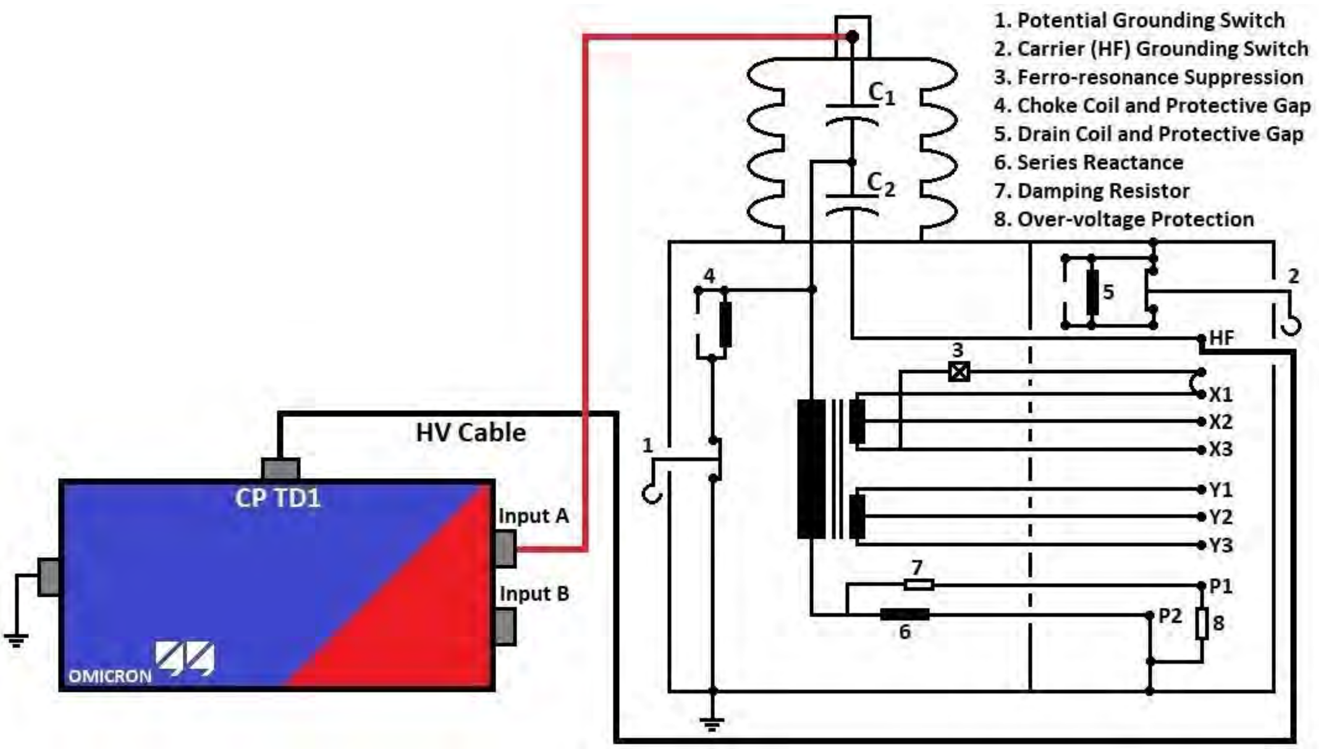


Figure 7: Single-Unit CCVT with an Inaccessible Potential – C2 Power Factor Test Wiring Diagram

3.1.3 C1 Measurement (recommended)

The test procedure for the C1 Power Factor measurement is provided in the following Table. Before executing the C1 Power Factor measurement, please perform the following steps,

- ✓ Reconnect the Carrier to ground-potential, to the drain coil, and to any accessory leads (if applicable)
- ✓ Both the Potential and Carrier ground switches should be closed
- ✓ The test voltage (typically 10kV) should not exceed the line-to-ground rating of the CCVT

Table 4: Single-Unit CCVT with an Inaccessible Potential Terminal – C1 Power Factor Test

Test	Measured Capacitance	Test Mode	Carrier Grounding Switch	Potential Grounding Switch	High Voltage Lead	Low Voltage Lead	Typical Test Voltage
3 (recommended)	C1	GST	Closed	Closed	Line-Terminal (Top of C1 Capacitor)	-	10kV

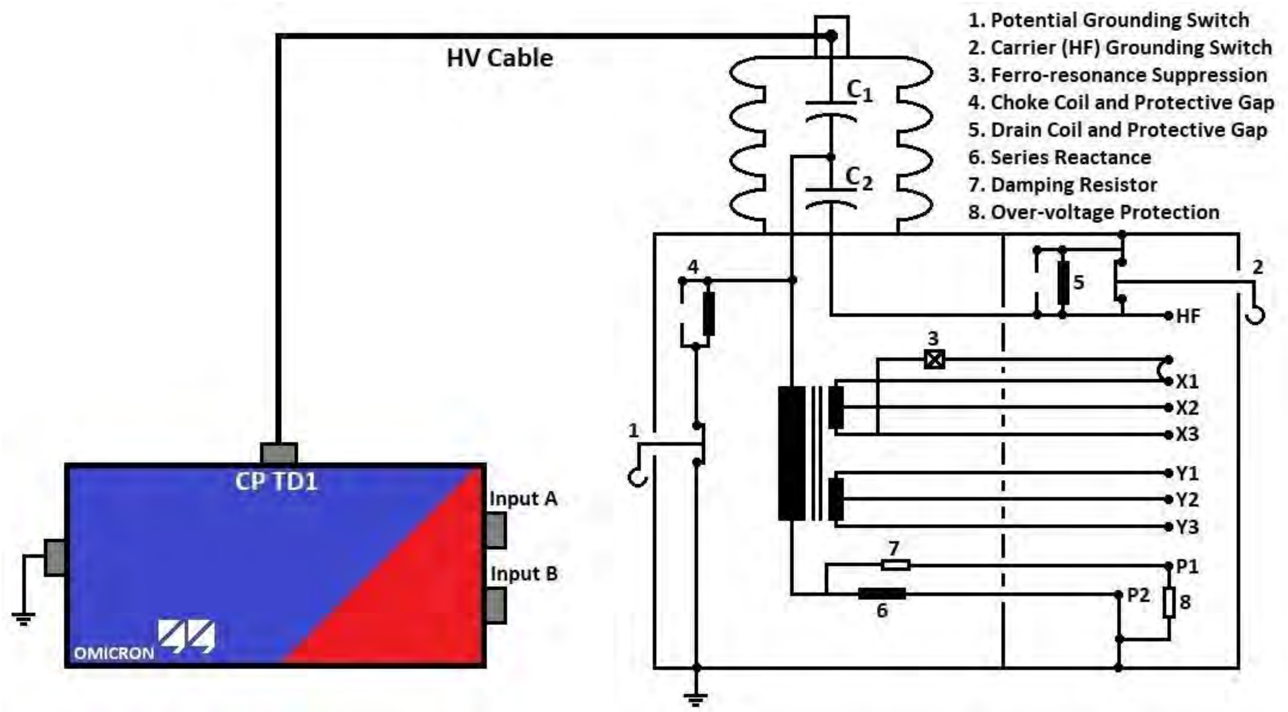


Figure 8: Single-Unit CCVT with an Inaccessible Potential Terminal – C1 Power Factor Wiring Diagram

3.2 CCVT with an Inaccessible Potential Terminal - Two-Unit Stack

The procedure for testing a CCVT with an inaccessible Potential Terminal, and with a two-unit housing stack, is provided in the following section. The Alstom OTCF 300 CCVT (shown in the following Figure) is an example of a CCVT with a two-unit housing stack.

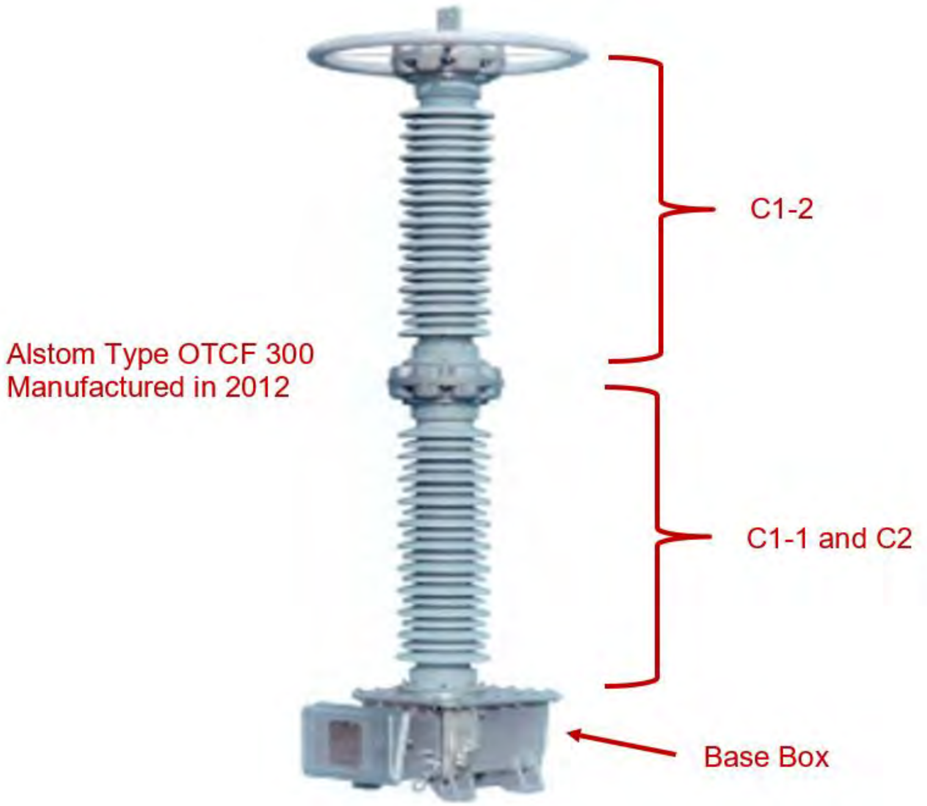


Figure 9: Alstom Type OTCF 300 CCVT

For this type of CCVT, there are typically three individual Capacitances (C2, C1-1, and C1-2). There are six possible Power Factor measurements (summarized in the following Table) that could be performed. Please observe the following steps prior to executing Test #1:

- ✓ De-energize the CCVT unit
- ✓ Ground the metallic terminal(s) of the CCVT, to discharge any remaining energy within the capacitors
- ✓ Disconnect and isolate the CCVT line-terminal from any bus, cable, support insulators, etc.
- ✓ Close the Potential ground switch and the Carrier ground switch (if applicable)
- ✓ Ensure that both the CCVT housing and the test-equipment are solidly bonded to earth-ground potential
- ✓ Clean and dry the exterior surfaces of the CCVT's housing units
- ✓ *Note, for the C2 measurement, the test-voltage should not exceed the voltage-rating of the Carrier Terminal – If you are unsure, we recommend applying a test-voltage of 500V, for the C2 Test

Table 5: Two-Unit CCVT with an Inaccessible Potential Terminal - Power Factor Test Plan

Test	Measured Capacitance	Test Mode	Carrier Grounding Switch	Potential Grounding Switch	High Voltage Lead	Low Voltage Lead	Typical Test Voltage
1 (recommended)	C1 and C2 Series (Overall Test)	UST-A	Closed	Open	Line-Terminal (Top of C1-2 Capacitor)	Carrier Terminal	10kV
2 (recommended)	C2	GSTg-A	Closed	Closed	Carrier Terminal	Line-Terminal (Top of C1-2 Capacitor)	*500V
3 (recommended)	C1-1	GSTg-A	Closed	Closed	Top of C1-1 Capacitor	Line-Terminal (Top of C1-2 Capacitor)	10kV
4 (recommended)	C1-2	UST-A	Closed	Closed	Top of C1-1 Capacitor	Line-Terminal (Top of C1-2 Capacitor)	10kV
5 (optional)	C1 (C1-1 and C1-2 Series)	GST	Closed	Closed	Line-Terminal (Top of C1-2 Capacitor)	-	10kV
6 (optional)	*C1-1 and C2 Series	GSTg-A	Closed	Open	Top of C1-1 Capacitor	Line-Terminal (Top of C1-2 Capacitor)	10kV

*Note, for measurement #6, the measured Power Factor % value may be abnormally high, abnormally low, or negative. This behavior is typical for measurement #6; therefore, for measurement #6, we recommend to not analyze the Power Factor % value. Instead, please only analyze the measured Current (mA) and Watt Losses (W).

3.2.1 C1 and C2 Series Measurement (recommended)

The test procedure for the C1 and C2 series Power Factor measurement is provided in the following Table. Before executing the C1 and C2 series Power Factor measurement, please perform the following steps,

- ✓ Leave the Carrier ground switch closed
- ✓ Disconnect and isolate the Carrier Terminal from ground, from the drain coil, and from any accessory leads (if applicable)
- ✓ Open the Potential grounding switch, for the C1 and C2 series measurement
- ✓ The test voltage (typically 10kV) should not exceed the line-to-ground voltage rating of the CCVT

Table 6: Two-Unit CCVT with an Inaccessible Potential Terminal - C1 and C2 Series Power Factor Test

Test	Measured Capacitance	Test Mode	Carrier Grounding Switch	Potential Grounding Switch	High Voltage Lead	Low Voltage Lead	Typical Test Voltage
1 (recommended)	C1 and C2 Series (Overall Test)	UST-A	Closed	Open	Line-Terminal (Top of C1-2 Capacitor)	Carrier Terminal	10kV

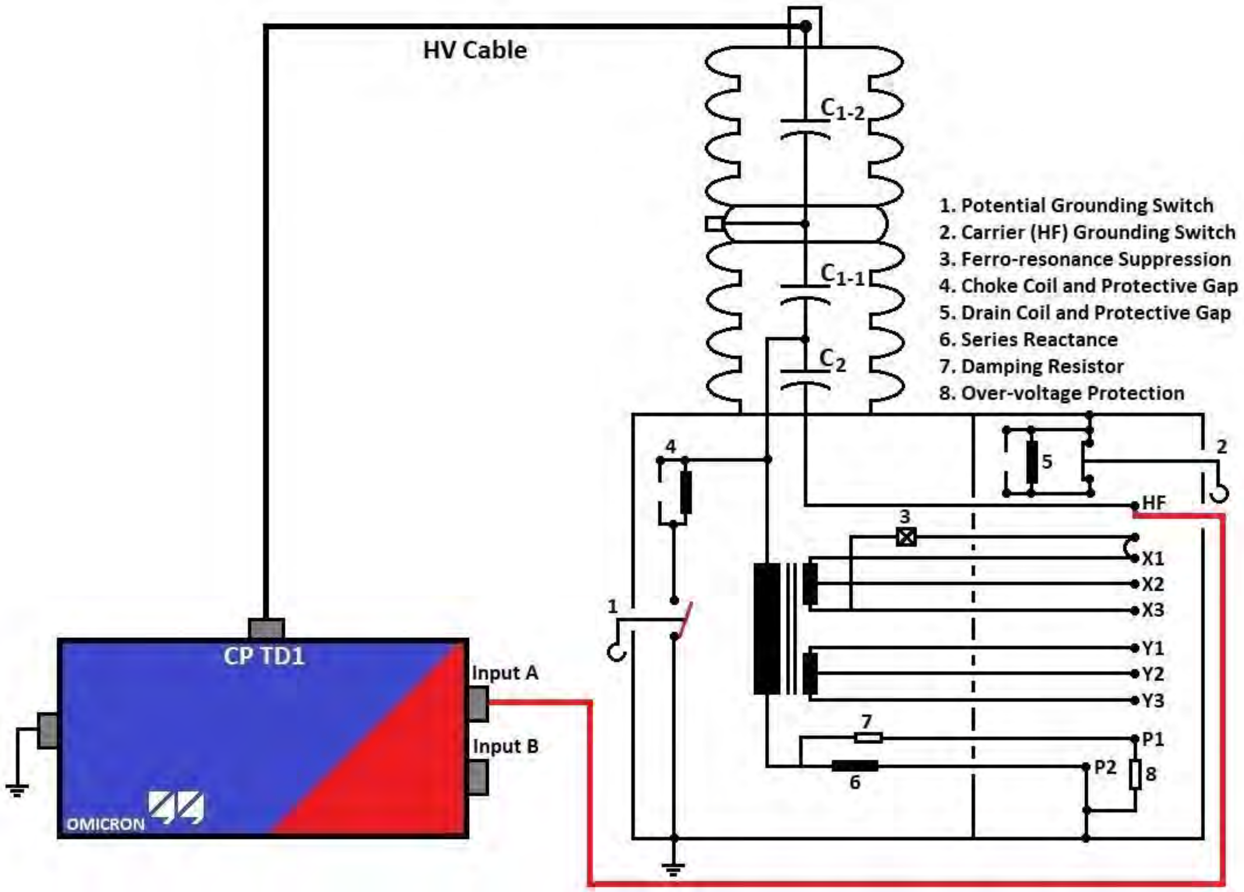


Figure 10: Two-Unit CCVT with an Inaccessible Potential Terminal - C1 and C2 Series Power Factor Test Wiring Diagram

3.2.2 C2 Measurement (recommended)

The test procedure for the C2 Power Factor measurement is provided in the following Table. Before executing the C2 Power Factor measurement, please perform the following steps,

- ✓ Close the Potential grounding switch for the C2 measurement
- ✓ Leave the Carrier ground switch closed
- ✓ Disconnect and isolate the Carrier Terminal from the ground, from the drain coil, and from any accessory leads (if applicable)
- ✓ *Note, for the C2 measurement, the test-voltage should not exceed the voltage-rating of the Carrier Terminal – If you are unsure, we recommend applying a test-voltage of 500V, for the C2 Test

Table 7: Two-Unit CCVT with an Inaccessible Potential Terminal - C2 Power Factor Test

Test	Measured Capacitance	Test Mode	Carrier Grounding Switch	Potential Grounding Switch	High Voltage Lead	Low Voltage Lead	Typical Test Voltage
2 (recommended)	C2	GSTg-A	Closed	Closed	Carrier Terminal	Line-Terminal (Top of C1-2 Capacitor)	*500V

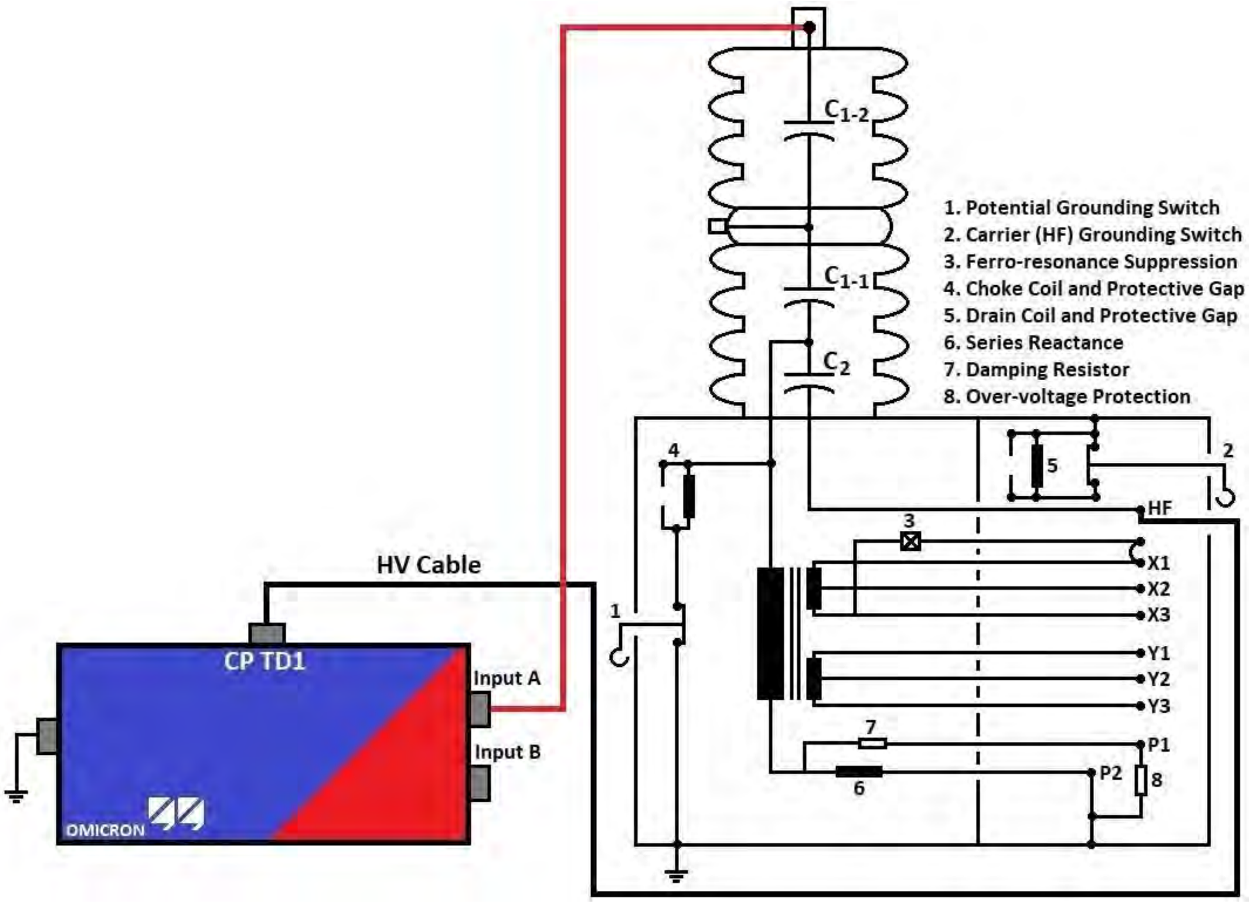


Figure 11: Two-Unit CCVT with an Inaccessible Potential Terminal - C2 Power Factor Test Wiring Diagram

3.2.3 C1-1 Measurement (recommended)

The test procedure for the C1-1 Power Factor measurement is provided in the following Table. Before executing the C1-1 Power Factor measurement, please perform the following steps,

- ✓ Reconnect the Carrier Terminal to ground-potential, to the drain coil, and/or to any accessory leads (if applicable)
- ✓ Both the Potential and Carrier ground switches should be closed
- ✓ The test voltage (typically 10kV) should not exceed the line-to-ground rating of the CCVT

Table 8: Two-Unit CCVT with an Inaccessible Potential Terminal - C1-1 Power Factor Test

Test	Measured Capacitance	Test Mode	Carrier Grounding Switch	Potential Grounding Switch	High Voltage Lead	Low Voltage Lead	Typical Test Voltage
3 (recommended)	C1-1	GSTg-A	Closed	Closed	Top of C1-1 Capacitor	Line-Terminal (Top of C1-2 Capacitor)	10kV

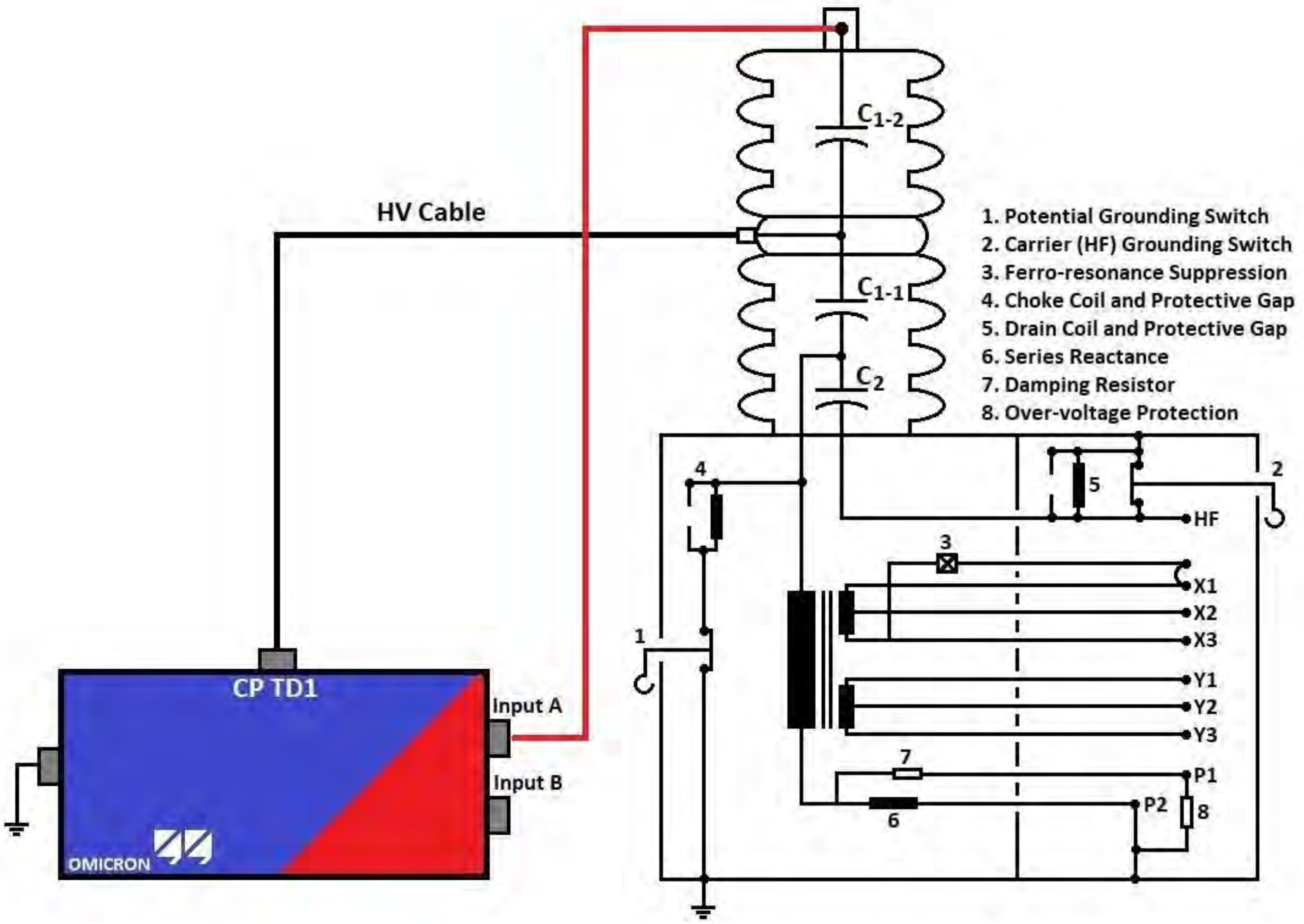


Figure 12: Two-Unit CCVT with an Inaccessible Potential Terminal – C1-1 Wiring Diagram

3.2.4 C1-2 Measurement (recommended)

The test procedure for the C1-2 Power Factor measurement is provided in the following Table. Before executing the C1-2 Power Factor measurement, please perform the following steps,

- ✓ Leave the Carrier Terminal connected to ground-potential, to the drain coil, and/or to any accessory leads (if applicable)
- ✓ Both the Potential and Carrier ground switches should be closed
- ✓ The test voltage (typically 10kV) should not exceed the line-to-ground rating of the CCVT

Table 9: Two-Unit CCVT with an Inaccessible Potential Terminal - C1-2 Power Factor Test

Test	Measured Capacitance	Test Mode	Carrier Grounding Switch	Potential Grounding Switch	High Voltage Lead	Low Voltage Lead	Typical Test Voltage
4 (recommended)	C1-2	UST-A	Closed	Closed	Top of C1-1 Capacitor	Line-Terminal (Top of C1-2 Capacitor)	10kV

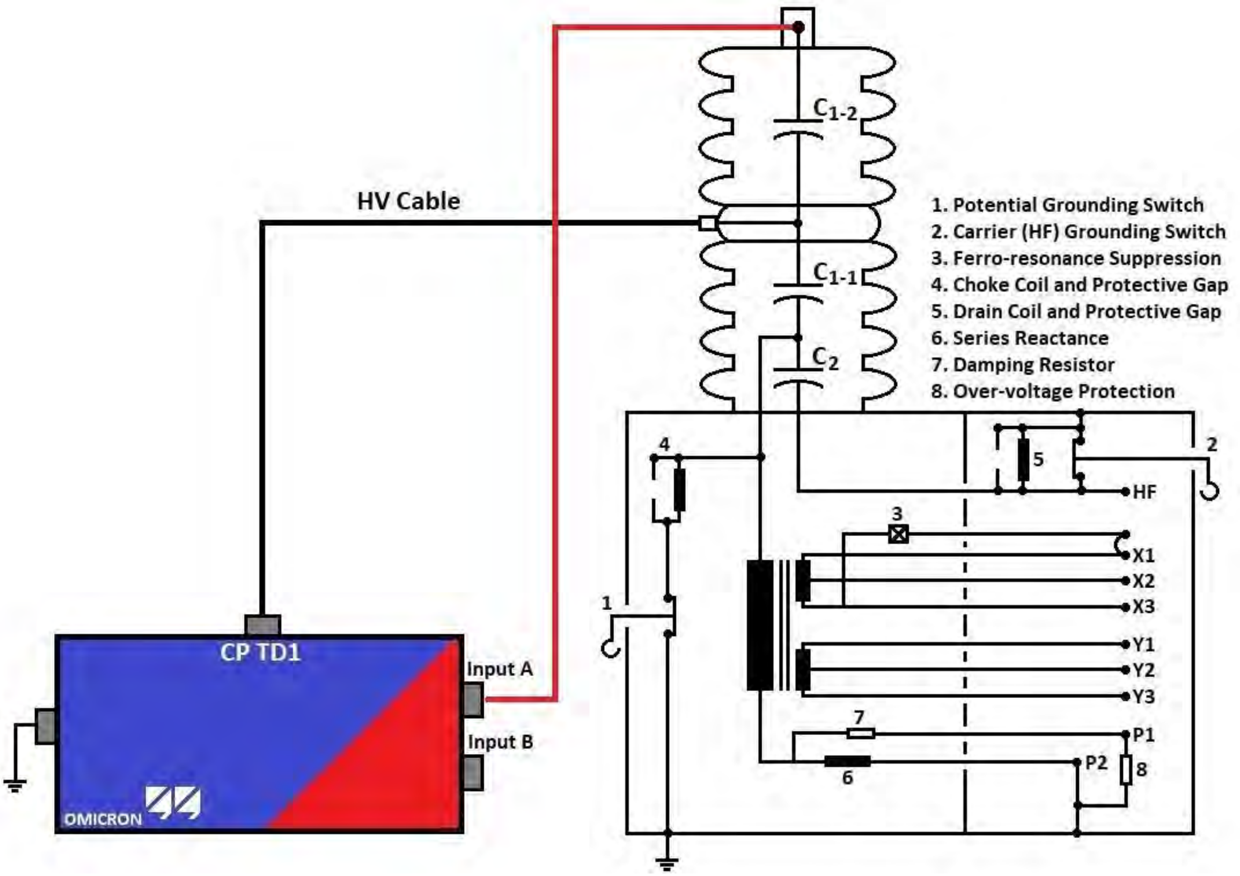


Figure 13: Two-Unit CCVT with an Inaccessible Potential Terminal – C1-2 Wiring Diagram

3.2.5 C1-1 and C1-2 Series Measurement (optional)

The test procedure for the C1-1 and C1-2 series Power Factor measurement is provided in the following Table. Before executing the C1-1 and C1-2 series Power Factor measurement, please perform the following steps,

- ✓ Both the Potential and Carrier ground switches should be closed
- ✓ Leave the Carrier Terminal connected to ground-potential, to the drain coil, and/or to any accessory leads (if applicable)
- ✓ The test voltage (typically 10kV) should not exceed the line-to-ground rating of the CCVT

Table 10: Two-Unit CCVT with an Inaccessible Potential Terminal - C1-1 and C1-2 Series Power Factor Test

Test	Measured Capacitance	Test Mode	Carrier Grounding Switch	Potential Grounding Switch	High Voltage Lead	Low Voltage Lead	Typical Test Voltage
5 (optional)	C1 (C1-1 and C1-2 Series)	GST	Closed	Closed	Line-Terminal (Top of C1-2 Capacitor)	-	10kV

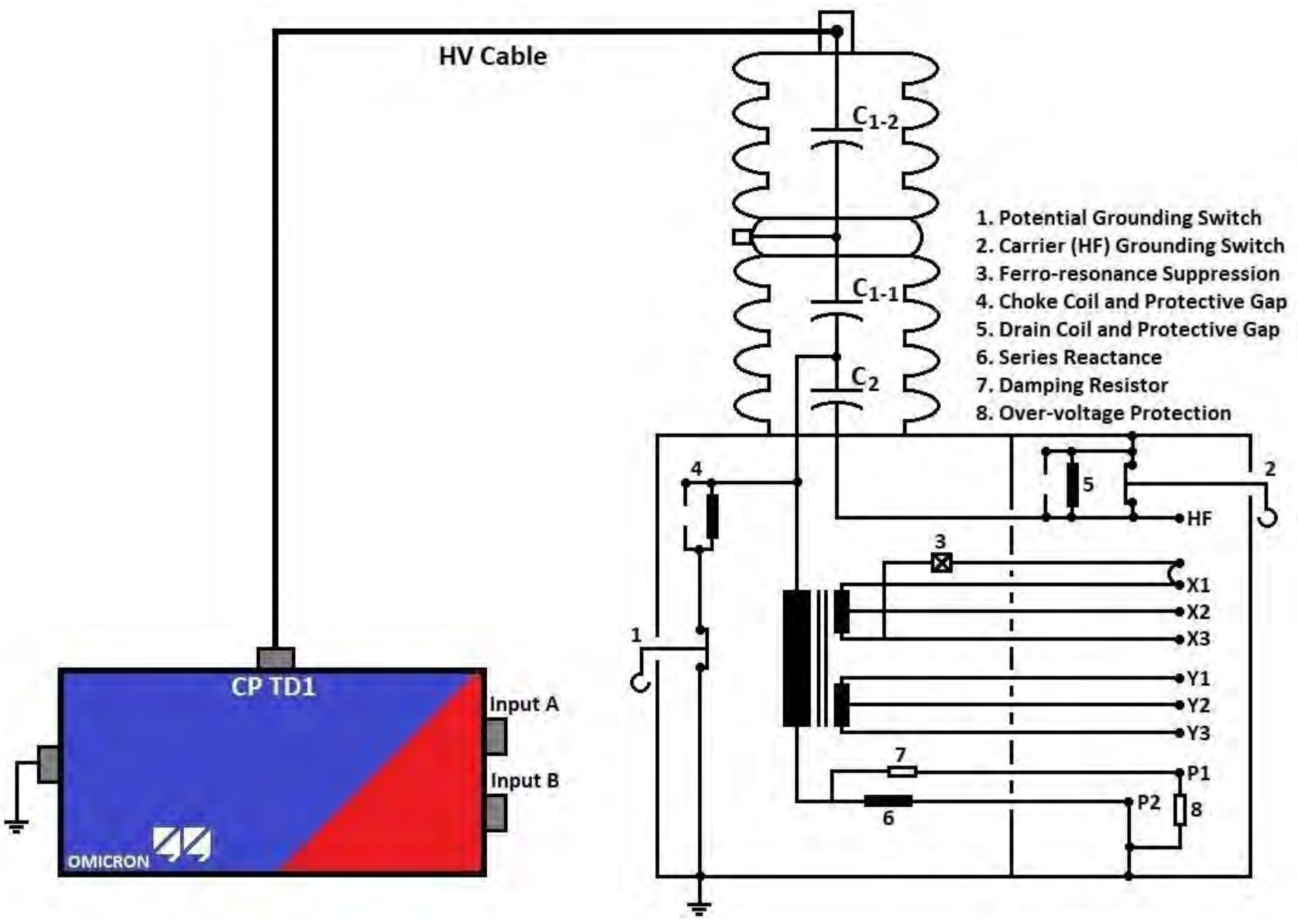


Figure 14: Two-Unit CCVT with an Inaccessible Potential Terminal - C1-1 and C1-2 Series Test Wiring Diagram

3.2.6 C1-1 and C2 Series Measurement (optional)

The test procedure for the C1-1 and C2 series Power Factor measurement is provided in the following Table. Before executing the C1-1 and C2 series Power Factor measurement, please perform the following steps,

- ✓ Leave the Carrier ground switch closed
- ✓ Leave the Carrier Terminal connected to ground-potential, to the drain coil, and/or to any accessory leads (if applicable)
- ✓ Open the potential grounding switch for the C1-1 and C2 series measurement
- ✓ The test voltage (typically 10kV) should not exceed the line-to-ground rating of the CCVT

Table 11: Two-Unit CCVT with an Inaccessible Potential Terminal - C1-1 and C2 Series Test

Test	Measured Capacitance	Test Mode	Carrier Grounding Switch	Potential Grounding Switch	High Voltage Lead	Low Voltage Lead	Typical Test Voltage
6 (optional)	*C1-1 and C2 Series	GSTg-A	Closed	Open	Top of C1-1 Capacitor	Line-Terminal (Top of C1-2 Capacitor)	10kV

*Note, for measurement #6, the measured Power Factor % value may be abnormally high, abnormally low, or negative. This behavior is typical for measurement #6; therefore, for measurement #6, we recommend to not analyze the Power Factor % value. Instead, please only analyze the measured Current (mA) and Watt Losses (W).

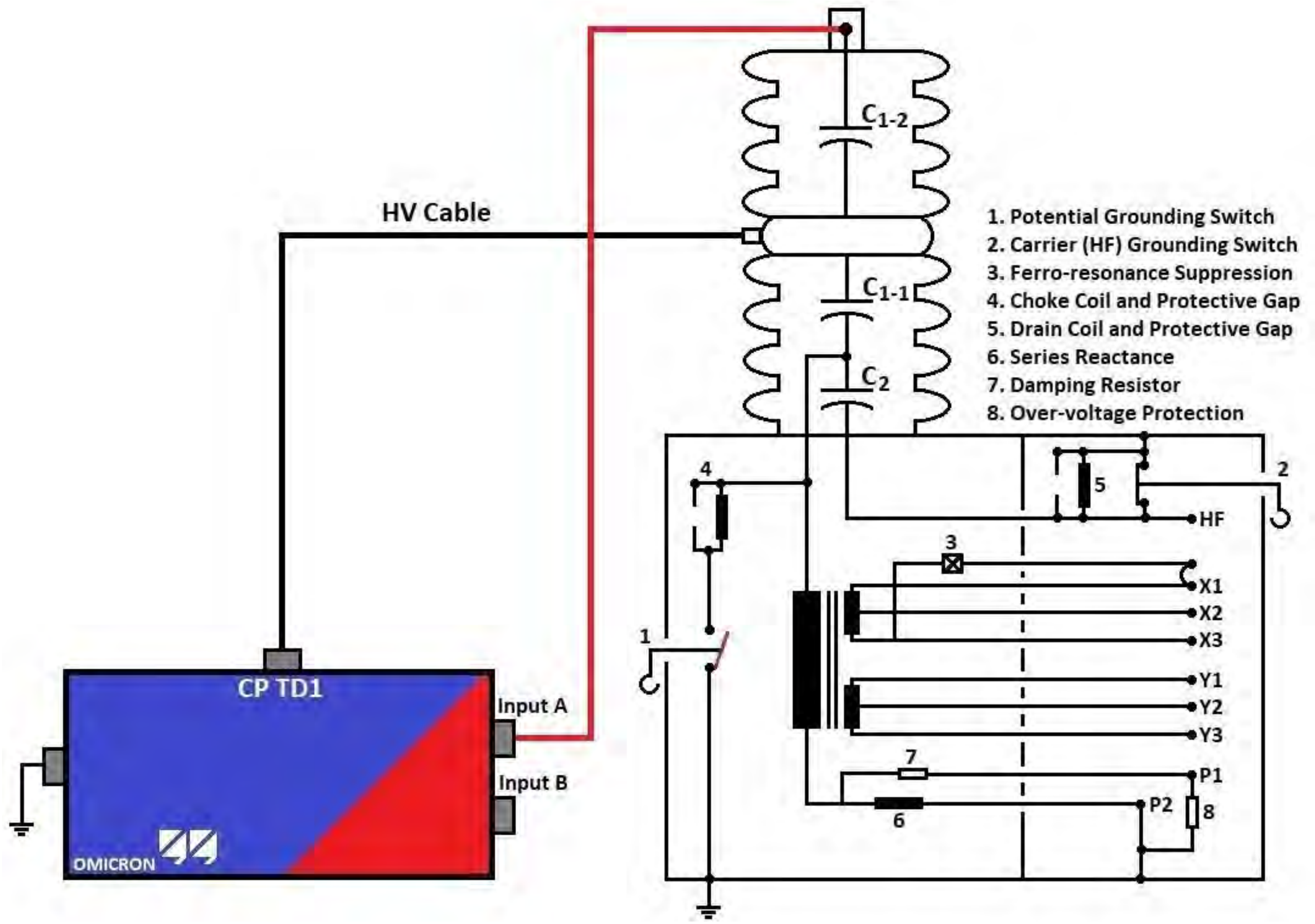


Figure 15: Two-Unit CCVT with an Inaccessible Potential Terminal - C1-1 and C2 Series Test Wiring Diagram

3.3 CCVT with an Accessible Potential Terminal - Single-Unit Stack

The procedure for testing a single housing unit CCVT with an accessible Potential Terminal is provided in this section.

For a single housing unit CCVT, there are typically only two individual capacitors, C1 and C2, that can be tested. For this CCVT type, there are three recommended Power Factor measurements, which are summarized in the following Table. Please observe the following steps prior to executing Test #1:

- ✓ De-energize the CCVT unit
- ✓ Ground the metallic terminal(s) of the CCVT, to discharge any remaining energy within the capacitors
- ✓ Disconnect and isolate the CCVT line-terminal from any bus, cable, support insulators, etc.
- ✓ Close the Potential ground switch and the Carrier ground switch (if applicable)
- ✓ Ensure that both the CCVT housing and the test-equipment are solidly bonded to earth-ground potential
- ✓ Clean and dry the exterior surfaces of the CCVT's housing units
- ✓ For all three Power Factor measurements, both the Carrier and the Potential Terminals must be disconnected and isolated from any drain coils, gaps, and/or accessory leads.

Table 12: Single-Unit CCVT with an Accessible Potential Terminal - Power Factor Test Plan

Test #	Measured Capacitance	Test Mode	Carrier Grounding Switch	Potential Grounding Switch	High Voltage Lead	Low Voltage Lead	Potential Terminal	Typical Test Voltage
1 (recommended)	C1 and C2 Series (Overall Test)	UST-A	Closed	Closed	Line-Terminal (Top of C1 Capacitor)	Carrier Terminal	Floating	10kV
2 (recommended)	C1	UST-A	Closed	Closed	Line-Terminal (Top of C1 Capacitor)	Potential Terminal	Low Voltage Lead	10kV
3 (recommended)	C2	UST-A	Closed	Closed	Potential Terminal	Carrier Terminal	High Voltage Lead	2kV

3.4 CCVT with an Accessible Potential - Two-Unit Stack

For this type of CCVT, there are typically three individual Capacitances (C2, C1-1, and C1-2). There are six possible Power Factor measurements (summarized in the following Table) that could be performed. Please observe the following steps prior to executing Test #1:

- ✓ De-energize the CCVT unit
- ✓ Ground the metallic terminal(s) of the CCVT, to discharge any remaining energy within the capacitors
- ✓ Disconnect and isolate the CCVT line-terminal from any bus, cable, support insulators, etc.
- ✓ Close the Potential ground switch and the Carrier ground switch (if applicable)
- ✓ Ensure that both the CCVT housing and the test-equipment are solidly bonded to earth-ground potential
- ✓ Clean and dry the exterior surfaces of the CCVT's housing units
- ✓ For all six Power Factor measurements, both the Carrier and the Potential Terminals must be disconnected and isolated from any drain coils, gaps, and/or accessory leads.

Table 13: Two-Unit CCVT with an Accessible Potential Terminal - Power Factor Test Plan

Test #	Measured Capacitance	Test Mode	Carrier Grounding Switch	Potential Grounding Switch	High Voltage Lead	Low Voltage Lead	Ground	Potential Terminal	Carrier Terminal	Typical Test Voltage
1 Recommended	C1 and C2 Series (Overall Test)	UST-A	Closed	Closed	Line-Terminal (Top of C1-2 Capacitor)	Carrier Terminal	-	Float	Low Voltage Lead	10kV
2 Recommended	C1-2	GSTg-A	Closed	Closed	Top of C1-1 Capacitor	Potential Terminal	Top of C1-2 Capacitor	Low Voltage Lead	Float	10kV
3 Recommended	C1-1	UST-A	Closed	Closed	Top of C1-1 Capacitor	Potential Terminal	Top of C1-2 Capacitor	Low Voltage Lead	Float	10kV
4 Recommended	C2	UST-A	Closed	Closed	Potential Terminal	Carrier Terminal	Top of C1-2 Capacitor	High Voltage Lead	Low Voltage Lead	2kV
5 optional	C1-1 and C2 Series	UST-A	Closed	Closed	Top of C1-1 Capacitor	Carrier Terminal	Top of C1-2 Capacitor	Float	Low Voltage Lead	10kV
6 optional	C1 (C1-1 and C1-2 Series)	GSTg-A	Closed	Closed	Potential Terminal	Carrier Terminal	Top of C1-2 Capacitor	High Voltage Lead	Low Voltage Lead	2kV

4 CCVT Ratio Test

This section provides the test procedure for performing a Ratio Test (aka the Turns-Ratio Test) on a CCVT. Although the test-plan outlined in this section focuses on applying the OMICRON CPC 100, the test-plan can be adapted for other test-instruments.

Before the Ratio Test is performed, please observe the following steps,

- ✓ Open the Potential grounding switch for the duration of the Ratio measurement. If the CCVT has an accessible Potential Terminal, please note that the Potential Terminal must remain connected to any “in-service” leads when the Ratio measurement is performed.
- ✓ Close the Carrier grounding switch for the duration of the Ratio measurement. If the CCVT has an accessible Carrier Terminal, please note that the Carrier Terminal must remain connected to any “in-service” leads (e.g. the drain coil, any protective gaps, etc…) when the Ratio measurement is performed.
- ✓ The test-voltage for the Ratio Test should not exceed the line-to-ground rating of the CCVT. Typically, a test-voltage of 2kV is applied for the CCVT Ratio Test.

Table 14: CCVT Ratio Test Test-Plan

Test #	Measurement	Carrier Grounding Switch	Potential Grounding Switch	2kV Red Lead	2kV Black Lead	V1 AC Red Lead	V1 AC Black Lead	All Other Secondary Terminals	Typical Test Voltage
1	X1-X3 Ratio	Closed	Open	Line-Terminal (Top of C1 Capacitor)	Basebox Case of CCVT	X1	X3 (and ground X3)	Float	2kV
2	X1-X2 Ratio	Closed	Open	Line-Terminal (Top of C1 Capacitor)	Basebox Case of CCVT	X1	X2 (and ground X2)	Float	2kV
3	Y1-Y3 Ratio	Closed	Open	Line-Terminal (Top of C1 Capacitor)	Basebox Case of CCVT	Y1	Y3 (and ground Y3)	Float	2kV
4	Y1-Y2 Ratio	Closed	Open	Line-Terminal (Top of C1 Capacitor)	Basebox Case of CCVT	Y1	Y2 (and ground Y2)	Float	2kV

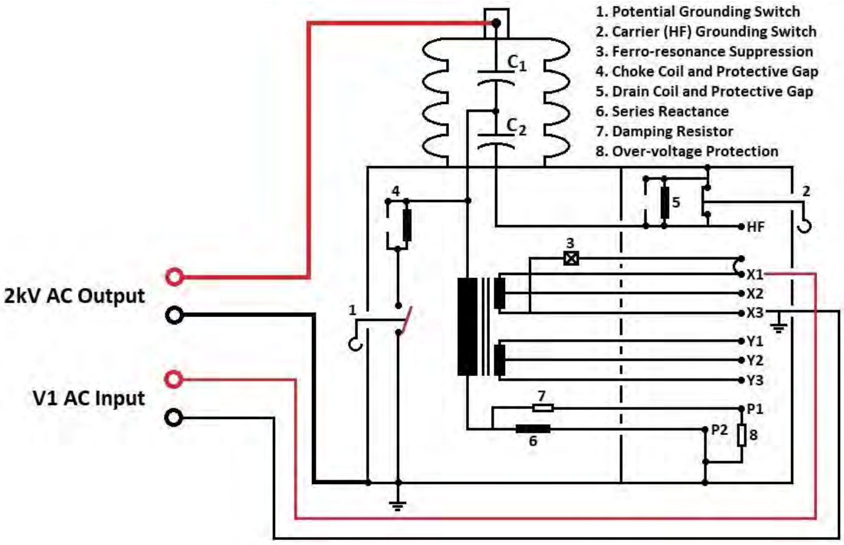


Figure 16: Single-Unit CCVT Ratio Test - Connection Diagram for Measurement #1

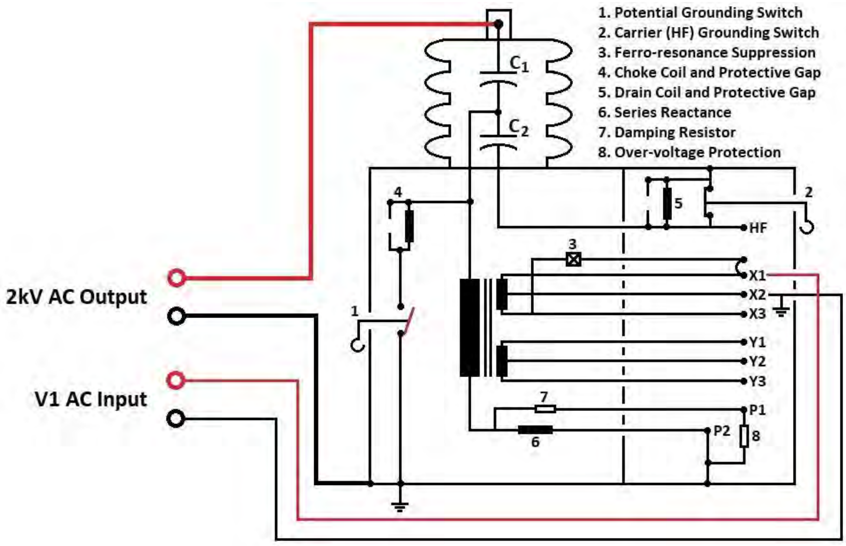


Figure 17: Single-Unit CCVT Ratio Test - Connection Diagram for Measurement #2

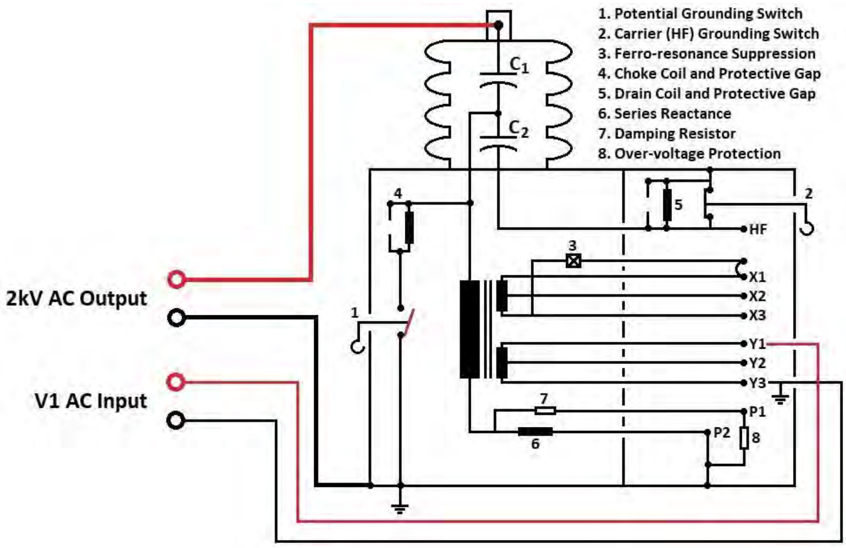


Figure 18: Single-Unit CCVT Ratio Test - Connection Diagram for Measurement #3

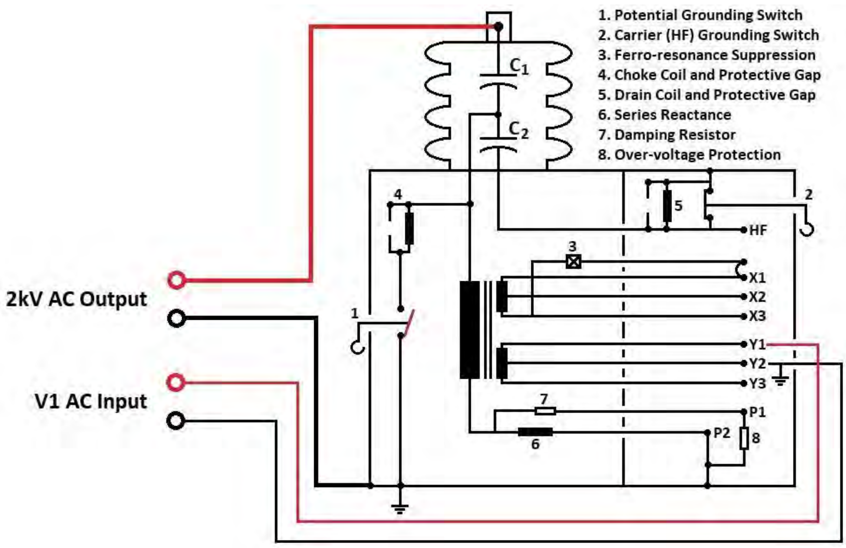


Figure 19: Single-Unit CCVT Ratio Test - Connection Diagram for Measurement #4

5 CCVT Testing Examples

Note, all the examples provided in this section are of CCVTs with inaccessible Potential Terminals.

5.1.1 Example 1: Trench TEIRF 115kV (2009)

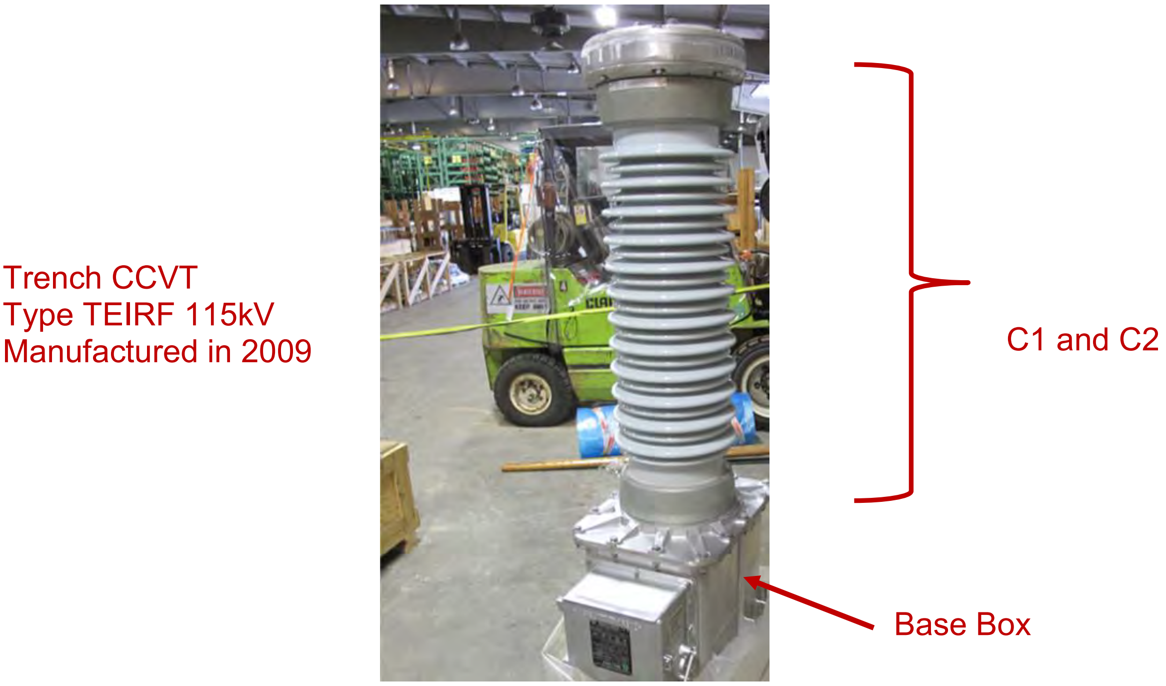


Figure 20: Trench TEIRF 115kV CCVT

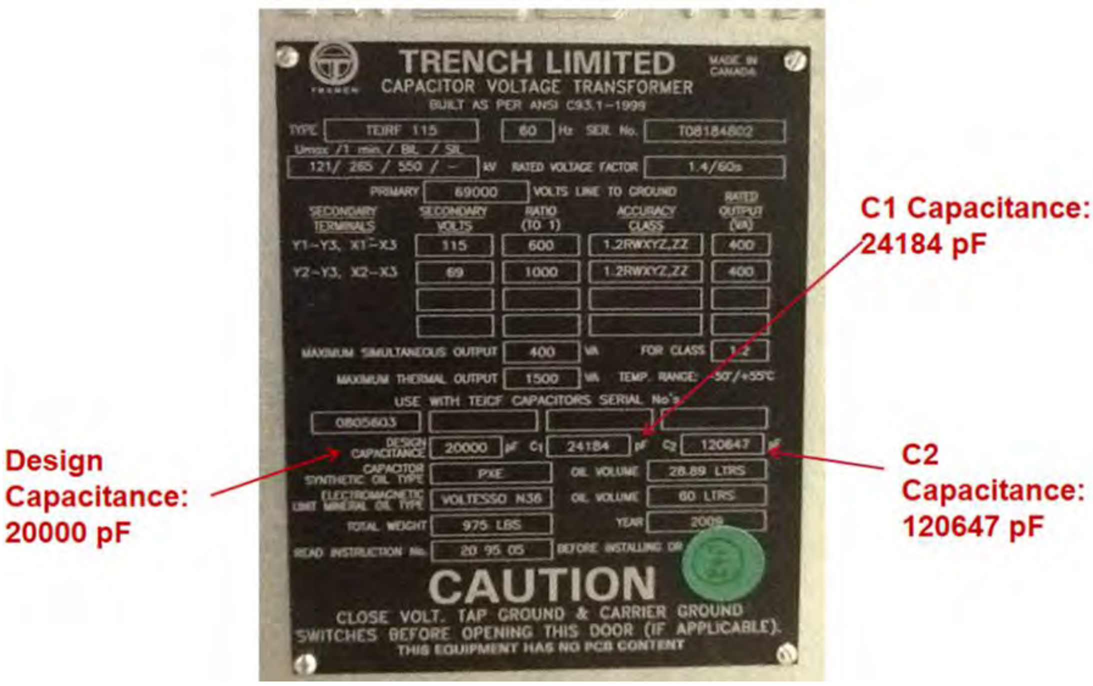


Figure 21: Nameplate Capacitance of Trench TEIRF 115kV CCVT

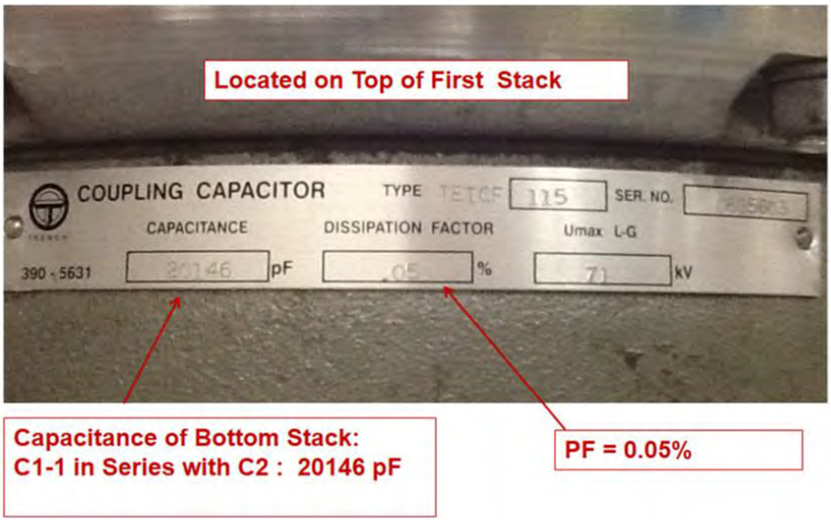


Figure 22: Nameplate Stack Capacitance of Trench TEIRF 115kV CCVT

Table 15: Power Factor Results for Example 1

Test #	Measurement	Measured Power Factor	Measured Capacitance	Nameplate Capacitance
1	C2	0.08%	120,788pF	120,647pF
2	C1	0.07%	24,193pF	24,184pF
3	C1 and C2 Series Test		20,155pF (Calculated)	20,146pF

= C1*C2/C1+C2 = 24193*120788/ 24193 + 120788 pF

Table 16: Ratio Results for Example 1

Test	Measurement	Nameplate Ratio	Measured Ratio	Ratio Deviation
1	X1-X3 Ratio	3.332	3.341	-0.27%
2	X1-X2 Ratio	-	-	-
3	Y1-Y3 Ratio	3.332	3.344	-0.36%
4	Y1-Y2 Ratio	-	-	-

5.1.2 Example 2: Alstom Type OTCF-300 (2012)

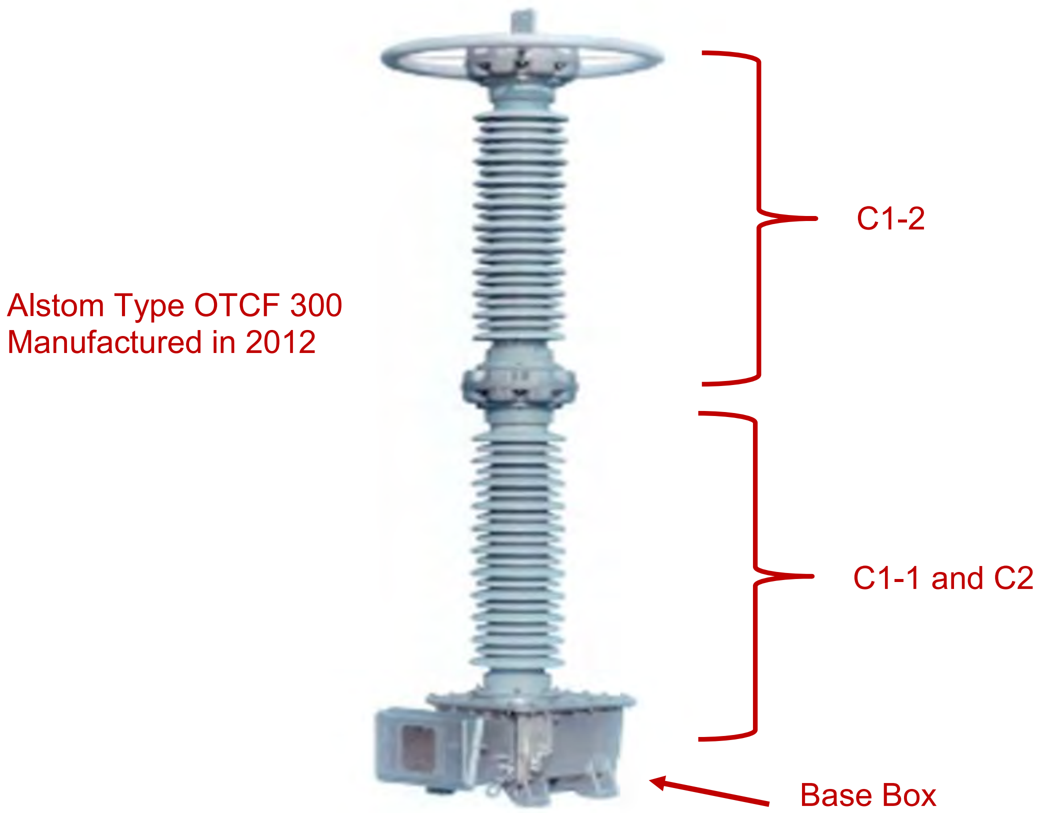


Figure 23: Alstom Type OTCF 300 CCVT

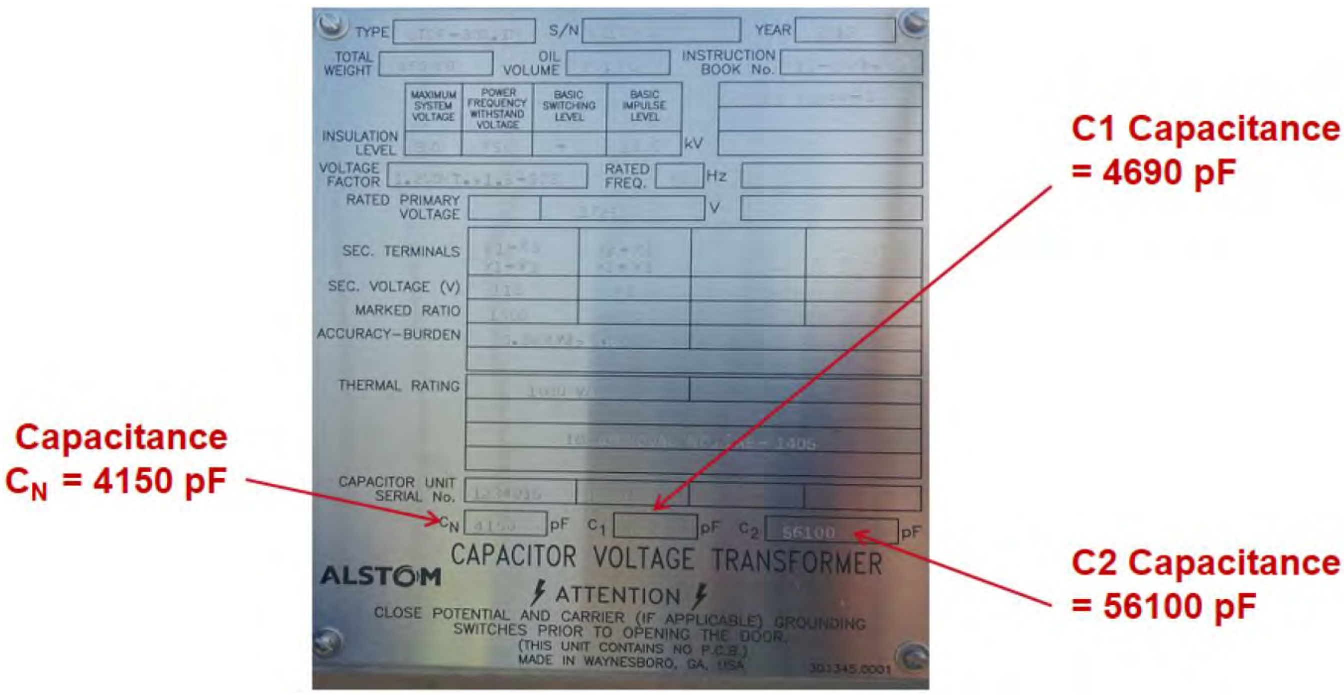


Figure 24: Nameplate of Alstom Type OTCF 300 CCVT

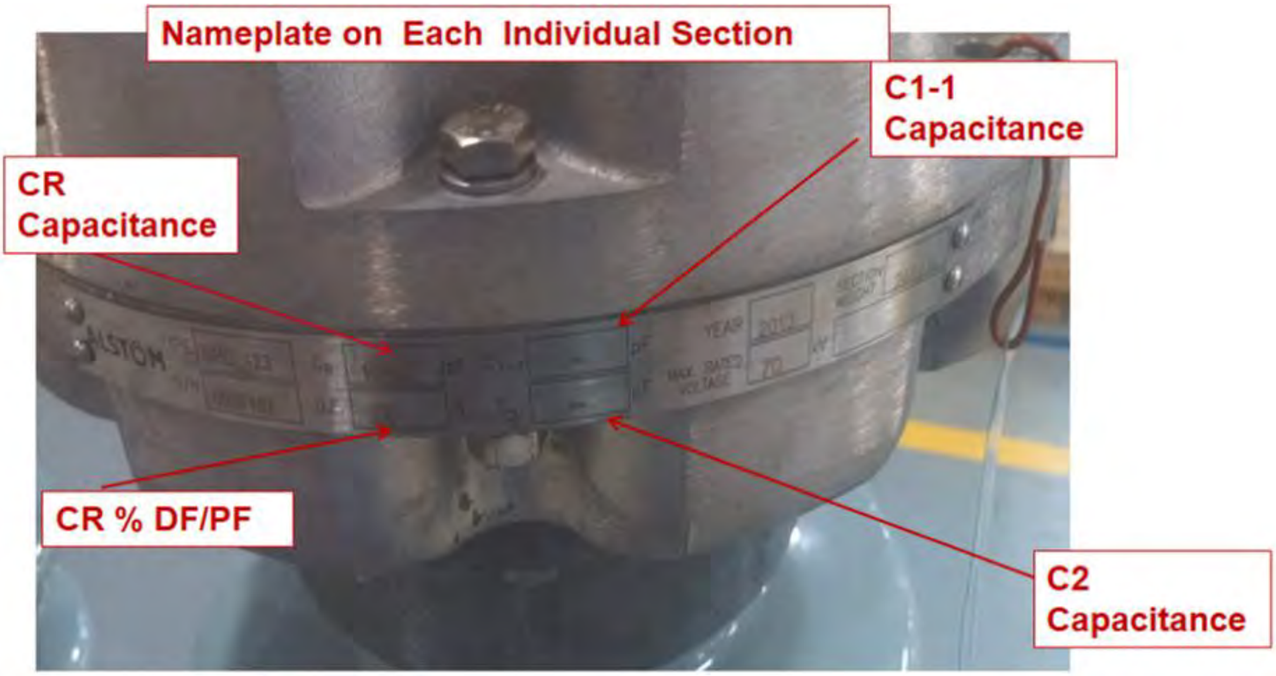


Figure 25: Capacitor Stack Nameplate of Alstom Type OTCF 300 CCVT

Table 17: Power Factor Results for Example 2

Test	Measured Capacitance	Measured Power Factor	Nameplate Power Factor	Measured Capacitance	Nameplate Capacitance
1	C2	0.12%	-	56,469pF	56,100pF
2	C1-1	0.14%	-	10,209pF	-
3	C1-2	0.17%	0.09%	8,723pF	8,711pF (Not Shown in Pictures)
4 (optional)	C1 (C1-1 and C1-2 Series)	-	-	4,703pF (Calculated)	4,690pF
5 (optional)	C1-1 and C2 Series	-	-	-	-
6 (optional)	C1 and C2 Series	-	-	4,341pF (Calculated)	4,150pF

Table 18: Ratio Results for Example 2

Test	Measurement	Nameplate Ratio	Measured Ratio	Ratio Deviation
1	X1-X3 Ratio	1.333	1.337	-0.11%
2	X1-X2 Ratio	-	-	-
3	Y1-Y3 Ratio	1.333	1.337	-0.11%
4	Y1-Y2 Ratio	-	-	-

6 HVCT Power Factor Testing

6.1 HVCT Power Factor for HVCTs without Test Taps

The following section provides the test procedure for performing a Power Factor measurement on a high-voltage current transformer that does not have a test tap. Before executing the Power Factor measurement, please perform the following,

- ✓ De-energize the HVCT unit
- ✓ Ground all the accessible primary terminal(s) of the HVCT, to discharge any remaining stored energy
- ✓ Disconnect and isolate the HVCT's primary terminal(s) from any bus, cable, support insulators, etc.
- ✓ Short-circuit the primary terminals of the HVCT (e.g. short-circuit H1 and H2, or H1 and H0)
- ✓ Completely isolate all secondary terminals of the HVCT from any external connections
- ✓ Ground one terminal on each secondary winding of the HVCT before executing the Power Factor measurement
- ✓ Note, all other terminals on the secondary winding(s) (that are not grounded) should be open-circuited (i.e. floating) for the duration of the Power Factor measurement

The test procedure for performing a Power Factor measurement on an HVCT that does not have a test tap is provided in the following Table.

Table 19: Power Factor Test Plan for an HVCT that does not have a Test Tap

Test	Mode	Primary Terminals	X1 Y1 Z1	X2, X3, Xn Y2, Y3, Yn Z2, Z3, Zn
#1 (Overall Test)	GST	Energize	Ground	Float

The recommended test-voltage for a Power Factor measurement on an HVCT that does not have a test tap is provided in the following Table.

Table 20: Recommended Test-Voltage for a Power Factor Measurement Performed on an HVCT that does not have a Test Tap

Test	Oil-Filled < 15kV	Oil-Filled > 15kV	Dry-Type < 15kV	Dry-Type > 15kV
#1 (Overall Test)	HVCT Line-to-Ground Voltage Rating	10kV	2kV, HVCT Line-to-Ground Voltage Rating, and 125% of the HVCT Line-to-Ground Voltage Rating	2kV and 10kV

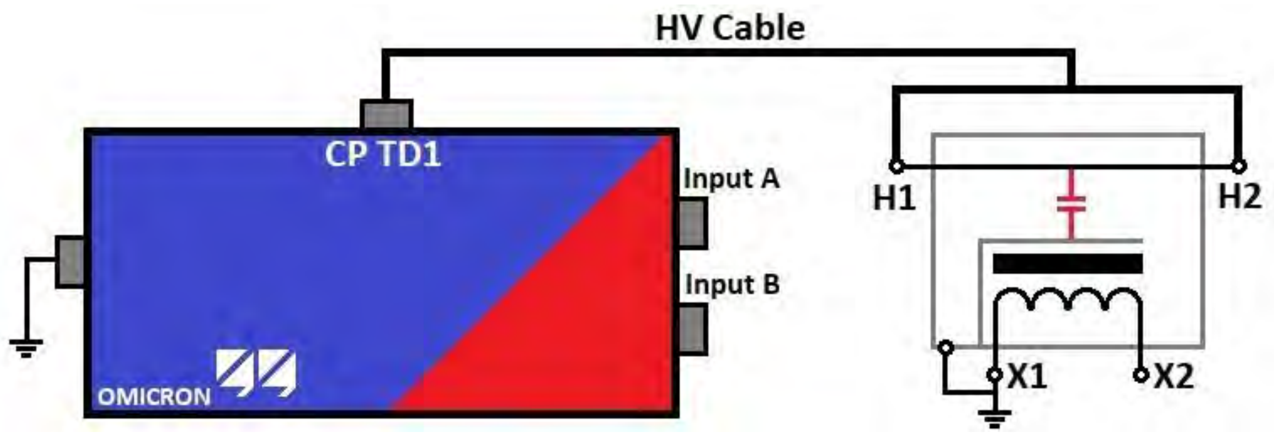


Figure 26: Wiring Diagram for a Power Factor Measurement Performed on an HVCT that does not have a Test Tap

6.2 HVCT Power Factor for HVCTs with Test Taps

The following section provides the test procedure for performing a Power Factor measurement on a high-voltage current transformer that has a test tap. Before the Power Factor measurement is performed, please perform the following,

- ✓ De-energize the HVCT unit
- ✓ Ground all the accessible primary terminal(s) of the HVCT, to discharge any remaining stored energy
- ✓ Disconnect and isolate the HVCT's primary terminal(s) from any bus, cable, support insulators, etc.
- ✓ Short-circuit the primary terminals of the HVCT (e.g. short-circuit H1 and H2, or H1 and H0)
- ✓ Completely isolate all secondary terminals of the HVCT from any external connections
- ✓ Ground one terminal on each secondary winding of the HVCT before executing the Power Factor measurement
- ✓ Note, all other terminals on the secondary winding(s) (that are not grounded) should be open-circuited (i.e. floating) for the duration of the Power Factor measurement

The test procedure for performing a Power Factor measurement on an HVCT that has a test tap, is provided in the following Table.

Table 21: Power Factor Test Plan for an HVCT that has a Test Tap

Test	Type	Mode	Primary Terminals	Tap Terminal	X1 Y1 Z1	X2, X3, Xn Y2, Y3, Yn Z2, Z3, Zn
#1	Overall	GST	Energize	Tap-Cap On (i.e. Connected)	Ground	Float
#2	CHL	GSTg-A	Energize	Red-A Lead	Ground	Float
#3	C1	UST-A	Energize	Red-A Lead	Ground	Float
#4	C2	GSTg-A	Red-A Lead	Energize	Ground	Float

The recommended test-voltages for Power Factor measurements performed on an HVCT that has a test tap, are provided in the following Table.

Table 22: Recommended Test-Voltages for Power Factor Measurements Performed on an HVCT that has a Test Tap

Test	Oil-Filled < 15kV	Oil-Filled > 15kV	Dry-Type < 15kV	Dry-Type > 15kV
#1, #2, and #3	HVCT Line-to-Ground Voltage Rating	10kV	2kV, HVCT Line-to-Ground Voltage Rating, and 125% of the HVCT Line-to-Ground Voltage Rating	2kV and 10kV
#4	500V			

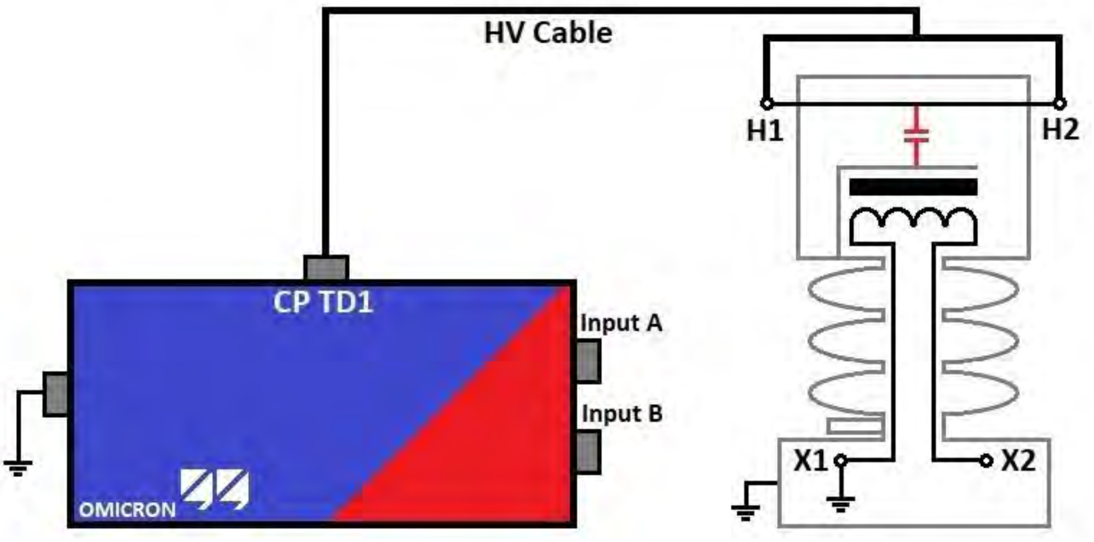


Figure 27: Wiring Diagram for Measurement #1 - For an HVCT that has a Test Tap

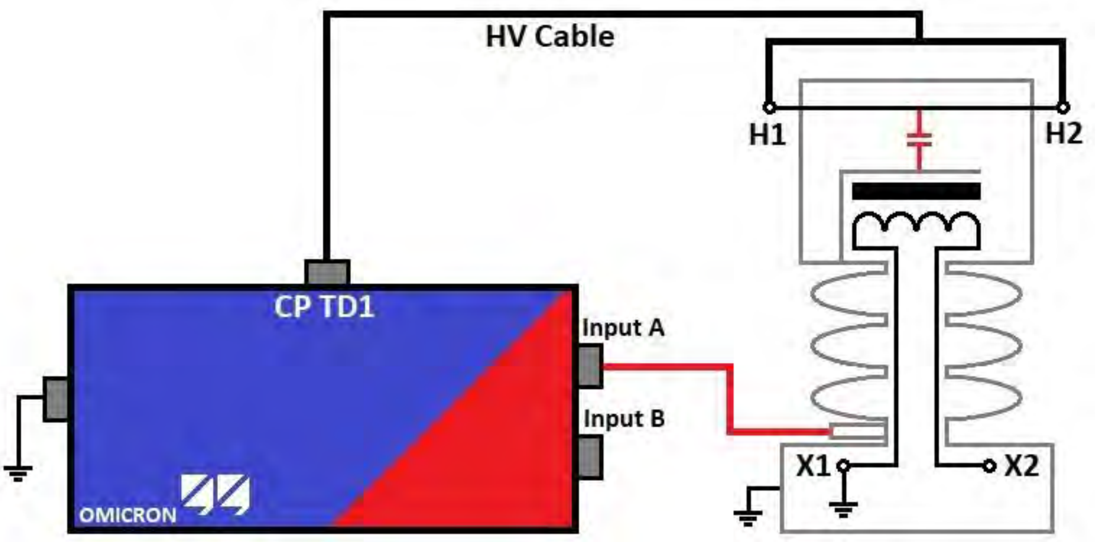


Figure 28: Wiring Diagram for Measurements #2 and #3 - For an HVCT that has a Test Tap

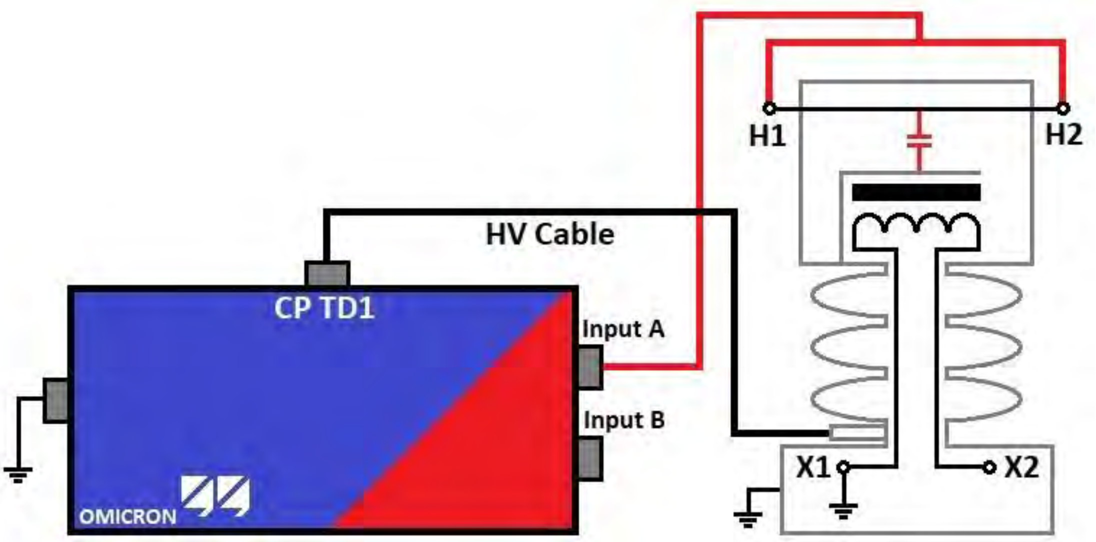


Figure 29: Wiring Diagram for Measurement #4 - For an HVCT that has a Test Tap

7 Potential Transformer Power Factor Testing

7.1 Potential Transformers where both primary terminals are accessible, and can be isolated from ground

The following section provides the test procedure for performing a Power Factor measurement on a potential transformer where both primary terminals are accessible and can be isolated from ground. If the potential transformer under test has a primary terminal that is NOT accessible, or CANNOT be isolated from ground, then please refer to Section 7.2.

Before the Power Factor measurement is performed, please perform the following steps,

- ✓ De-energize the PT unit
- ✓ Ground all the accessible primary terminal(s) of the PT, to discharge any remaining stored energy
- ✓ Disconnect and isolate the PT's primary terminal(s) from any bus, cable, support insulators, etc.
- ✓ Short-circuit the primary terminals of the PT (e.g. short-circuit H1 and H2, or H1 and H0)
- ✓ Remove all ground connections from the primary terminals
- ✓ Completely isolate all secondary terminals of the PT from any external connections
- ✓ Ground one terminal on each secondary winding of the PT before executing the Power Factor measurement
- ✓ Note, all other terminals on the secondary winding(s) (that are not grounded) should be open-circuited (i.e. floating) for the duration of the Power Factor measurement

The test procedure for performing a Power Factor measurement on a PT where both primary terminals are accessible and can be isolated from ground, is provided in the following Table.

Table 23: Power Factor test plan for a PT where both primary terminals are accessible and can be isolated from ground

Test	Type	Mode	H1	H2 (or H0)	X1 Y1 Z1	X2, X3, Xn Y2, Y3, Yn Z2, Z3, Zn
#1	Overall Test	GST	Energize (while H1-H2 or H1-H0 is Short-Circuited)		Ground	Float
#2	H1 Winding-to-Ground Insulation Test	GSTg-A	Energize	Red-A Lead	Ground	Float
#3	*Excitation Test	UST-A	Energize	Red-A Lead	Ground	Float
#4	H2 Winding-to-Ground Insulation Test	GSTg-A	Red-A Lead	Energize	Ground	Float
#5	*Excitation Test	UST-A	Red-A Lead	Energize	Ground	Float

*Note, for the Excitation Tests (i.e. measurements #3 and #5), the measured Power Factor % value may be abnormally high, abnormally low, or negative. This behavior is typical for the PT Excitation Tests; therefore, for the Excitation Tests (i.e. measurements #3 and #5), we recommend to not analyze the Power Factor % value. Instead, please only analyze the measured Current (mA) and Watt Losses (W).

Table 24: Recommended test-voltages for Power Factor measurements performed on a PT where both primary terminals are accessible, and can be isolated from ground

Test	Line-to-Line Oil-Filled PT > 15kV: Test Voltages	Line-to-Line Oil-Filled PT < 15kV: Test Voltages	Line-to-Ground Oil-Filled PT: Test Voltages	Line-to-Line Dry-Type PT: Test Voltages	Line-to-Ground Dry-Type PT: Test Voltages
#1 (Overall)	10kV	Do not Exceed the PT Line-to-Ground Voltage Rating	Do not Exceed the Neutral (H0) Terminal's Voltage Rating	2kV, PT Line-to-Ground Voltage Rating, and 125% of the PT Line-to-Ground Voltage Rating	Do not Exceed the Neutral (H0) Terminal's Voltage Rating
#2 and #3	10kV	Do not Exceed the PT Line-to-Ground Voltage Rating	Do not Exceed the PT Line-to-Ground Voltage Rating	2kV, And PT Line-to-Ground Voltage Rating	Do not Exceed the PT Line-to-Ground Voltage Rating
#4 and #5	10kV	Do not Exceed the PT Line-to-Ground Voltage Rating	Do not Exceed the Neutral (H0) Terminal's Voltage Rating	2kV, and PT Line-to-Ground Voltage Rating	Do not Exceed the Neutral (H0) Terminal's Voltage Rating

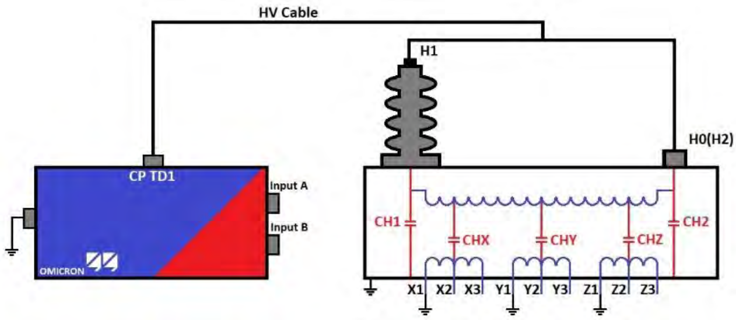


Figure 30: Wiring Diagram for Measurement #1 - For a PT where both primary terminals are accessible, and can be isolated from ground

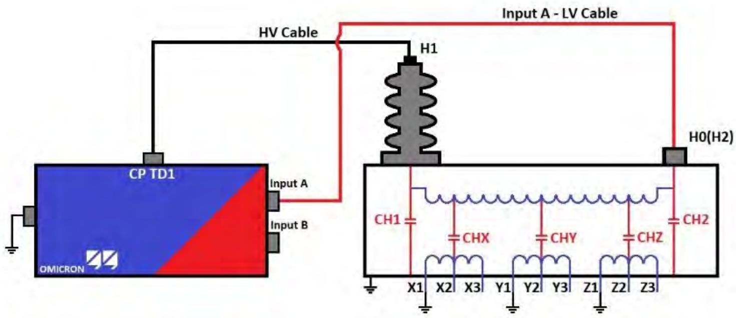


Figure 31: Wiring Diagram for Measurements #2 and #3 - For a PT where both primary terminals are accessible, and can be isolated from ground

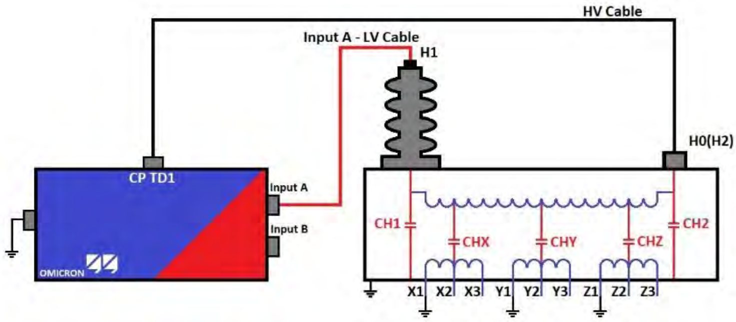


Figure 32: Wiring Diagram for Measurements #4 and #5 - For a PT where both primary terminals are accessible, and can be isolated from ground

7.2 Potential Transformers where one of the two primary terminals CANNOT be isolated from ground

The following section provides the test procedure for performing a Power Factor measurement on a potential transformer where one of the two primary terminals CANNOT be isolated from ground.

Before the Power Factor measurement is performed, please perform the following steps,

- ✓ De-energize the PT unit
- ✓ Ground all the accessible primary terminal(s) of the PT, to discharge any remaining stored energy
- ✓ Disconnect and isolate the PT's primary terminal(s) from any bus, cable, support insulators, etc.
- ✓ Remove the applied ground connection from the H1 primary terminal
- ✓ Completely isolate all secondary terminals of the PT from any external connections
- ✓ Ground one terminal on each secondary winding of the PT before executing the Power Factor measurement
- ✓ Note, all other terminals on the secondary winding(s) (that are not grounded) should be open-circuited (i.e. floating) for the duration of the Power Factor measurement

The test procedure for performing a Power Factor measurement on a potential transformer where one of the two primary terminals CANNOT be isolated from ground is provided in the following Table.

- ✓ If the PT has two secondary windings (e.g. X and Y), then perform Tests #1, #2, and #4
- ✓ If the PT has three secondary windings (e.g. X, Y, and Z), then perform Tests #1-#4

Table 25: Power Factor test plan for a PT where one of the two primary terminals CANNOT be isolated from ground

Test	Type	Mode	H1	H0	X1	Y1	Z1	X2, X3, Xn Y2, Y3, Yn Z2, Z3, Zn
#1	Inter-Winding Insulation Test (CHX)	UST-A	Energize H1	Grounded	Red-A Lead	Grounded	Grounded	Float
#2	Inter-Winding Insulation Test (CHY)	UST-A	Energize H1	Grounded	Grounded	Red-A Lead	Grounded	Float
#3	Inter-Winding Insulation Test (CHZ)	UST-A	Energize H1	Grounded	Grounded	Grounded	Red-A Lead	Float
#4	*Winding-to-Ground Insulation + Excitation Test	GSTg-A	Energize H1	Grounded	Red-A Lead (short-circuit X1, Y1, and Z1)			Float

*Note, for the Winding-to-Ground Insulation + Excitation Test (i.e. measurement #4), the measured Power Factor % value may be abnormally high, abnormally low, or negative. This behavior is typical for a PT Excitation Test; therefore, for the Winding-to-Ground Insulation + Excitation Test (i.e. measurement #4), we recommend to not analyze the Power Factor % value. Instead, please only analyze the measured Current (mA) and Watt Losses (W).

Table 26: Recommended test-voltages for Power Factor measurements performed on a PT where one of the two primary terminals CANNOT be isolated from ground

Test	Line-to-Line Oil-Filled PT > 15kV: Test Voltages	Line-to-Line Oil-Filled PT < 15kV: Test Voltages	Line-to-Ground Oil-Filled PT: Test Voltages	Line-to-Line Dry-Type PT: Test Voltages	Line-to-Ground Dry-Type PT: Test Voltages
#1-#4	10kV	Do not Exceed the Line-to-Ground Voltage Rating of the PT	Do not Exceed the Line-to-Ground Voltage Rating of the PT	Do not Exceed the Line-to-Ground Voltage Rating of the PT	Do not Exceed the Line-to-Ground Voltage Rating of the PT

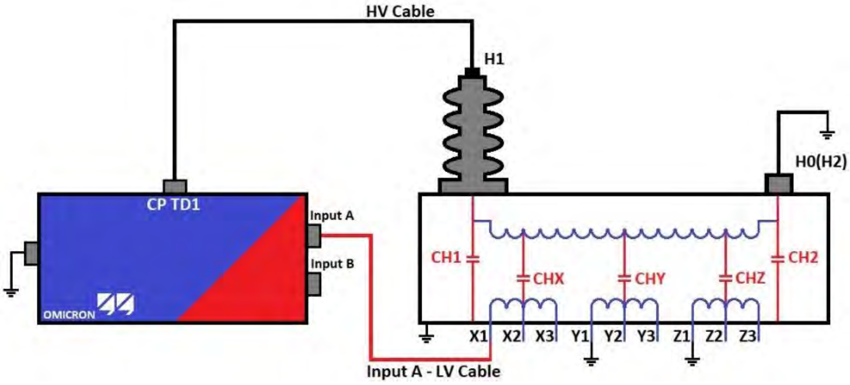


Figure 33: Wiring Diagram for Measurement #1 - For a PT where one of the two primary terminals CANNOT be isolated from ground

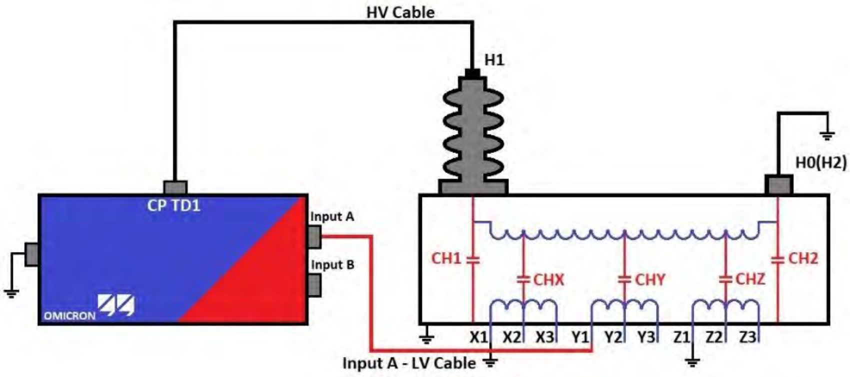


Figure 34: Wiring Diagram for Measurement #2 - For a PT where one of the two primary terminals CANNOT be isolated from ground

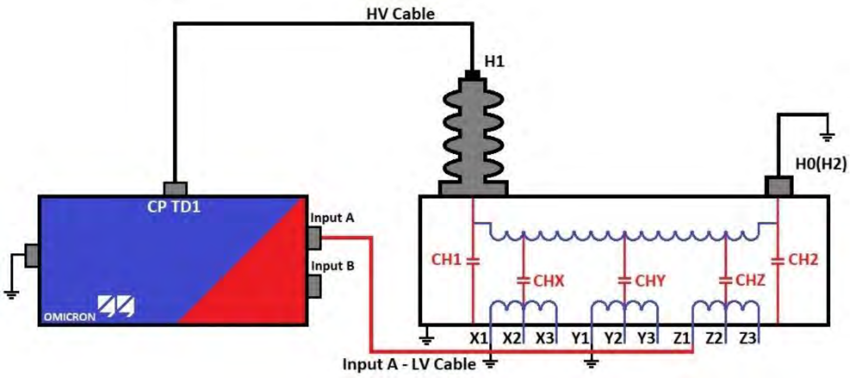


Figure 35: Wiring Diagram for Measurement #3 - For a PT where one of the two primary terminals CANNOT be isolated from ground

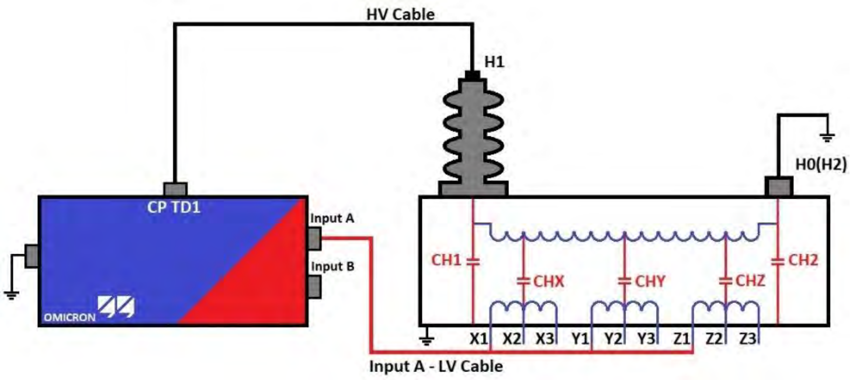


Figure 36: Wiring Diagram for Measurement #4 - For a PT where one of the two primary terminals CANNOT be isolated from ground

7.3 3-Phase Potential Transformers where the neutral bushing terminal is accessible, and can be isolated from ground

The following section provides the test procedure for performing a Power Factor measurement on a 3-Phase potential transformer where the neutral bushing terminal is accessible and can be isolated from ground.

Before the Power Factor measurement is performed, please perform the following steps,

- ✓ De-energize the PT unit
- ✓ Ground all the accessible primary terminal(s) of the PT, to discharge any remaining stored energy
- ✓ Disconnect and isolate the PT’s primary terminal(s) from any bus, cable, support insulators, etc.
- ✓ Remove the ground connections from all the primary bushing terminals
- ✓ Completely isolate all secondary terminals of the PT from any external connections
- ✓ Ground one terminal on each secondary winding of the PT before executing the Power Factor measurement
- ✓ Note, all other terminals on the secondary winding(s) (that are not grounded) should be open-circuited (i.e. floating) for the duration of the Power Factor measurement

Table 27: Power Factor test plan for a 3-Phase PT where the neutral bushing terminal is accessible, and can be isolated from ground

Test	Type	Mode	H1	H2	H3	H0	X1 Y1 Z1	X2, X3, Xn Y2, Y3, Yn Z2, Z3, Zn	Test Voltage
#1	Overall Test	GST	Energize (Short H1-H2-H3-H0)				Ground	Float	Do not Exceed the Neutral (H0) Terminal’s Voltage Rating
#2	H1 Test	GSTg-A	Energize	Red-A Lead (Short H2-H3-H0)			Ground	Float	Do not Exceed the PT Line-to-Ground Voltage Rating
#3	H2 Test	GSTg-A	Red-A Lead (Short H1-H3-H0)	Energize	Red-A Lead (Short H1-H3-H0)		Ground	Float	Do not Exceed the Line-to-Ground Voltage Rating of the PT
#4	H3 Test	GSTg-A	Red-A Lead (Short H1-H2-H0)		Energize	Red-A Lead (Short H1-H2-H0)	Ground	Float	Do not Exceed the PT Line-to-Ground Voltage Rating
#5	H0 Test	GSTg-A	Red-A Lead (Short H1-H2-H3)			Energize	Ground	Float	Do not Exceed the Neutral (H0) Terminal’s Voltage Rating
#6	*H1 Excitation Test	UST-A	Energize	Float	Float	Red-A Lead	Ground	Float	Do not Exceed the PT Line-to-Ground Voltage Rating
#7	*H2 Excitation Test	UST-A	Float	Energize	Float	Red-A Lead	Ground	Float	Do not Exceed the PT Line-to-Ground Voltage Rating
#8	*H3 Excitation Test	UST-A	Float	Float	Energize	Red-A Lead	Ground	Float	Do not Exceed the Line-to-Ground

*Note, for the Excitation Tests (i.e. measurements #6-#8), the measured Power Factor % value may be abnormally high, abnormally low, or negative. This behavior is typical for the PT Excitation Tests; therefore, for the Excitation Tests (i.e. measurements #6-#8), we recommend to not analyze the Power Factor % value. Instead, please only analyze the measured Current (mA) and Watt Losses (W).

8 References

[1] IEEE C57.152-2013 "IEEE Guide for Diagnostic Field Testing of Fluid-Filled Power Transformers, Regulators, and Reactors"

9 Support Resources

If you need immediate assistance, please contact one of the following Technical Support numbers:

Phone1: +1-713-830-4660
Phone2: +1-781-672-6200
support.usa@omicronenergy.com

If you need application support, please feel free to reach out to the following resources:

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