Testing Potential Transformers

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Potential transformers (PTs) are necessary to a power system for metering and protective relaying to convert higher system voltages to lower control voltages that are more practical from an equipment, operation, and safety perspective.

There are three basic styles used to transformer system voltages to control voltages:

1. **Potential Transformers (PTs) or Voltage Transformers (VTs)**
   PTs or VTs are the most common device used. These devices use standard transformer theory with 2-3 windings (one primary with one or two secondary windings) with a magnetic connection via an iron core. The high side winding is constructed with more copper turns than the secondary(ies) and any voltage impressed on the primary winding is reflected on the secondary windings in direct proportion to the turns ratio or PT ratio. The secondary windings often have 2 taps with a nominal voltage of 115/67V, 120/69V, or 120/208V. This style of PT is the most accurate style in use. A typical PT is shown in Figure 1.

Figure 1

2. **Control Potential Transformers (CPTs)**
   CPTs are standard PTs or VTs with a higher VA rating and are used to supply control power for a circuit breaker or motor starter. These transformers are not designed for accuracy and should not be used in revenue metering or primary protection systems.

   Special attention should be paid to following items:
   - The equipment ratings connected to the secondary should be verified to ensure the combination of devices does not exceed the VA rating of the transformer.
   - The primary connection is also important as a CPT connected to the load side of the circuit breaker or motor starter may prevent the device from operating until after the device has been closed.
   - All CPTs that supply trip power should be supplemented with an external device such as a capacitive trip unit to provide at least one trip signal after a power system loss of voltage. Some typical CPTs are shown in Figure 2. A typical application is shown in Figure 3.

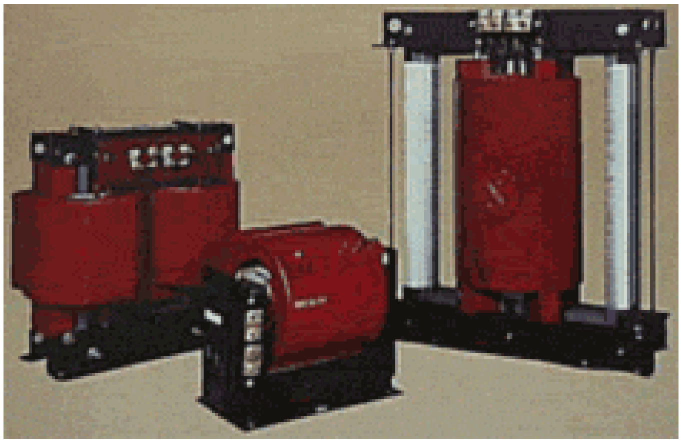

Figure 2

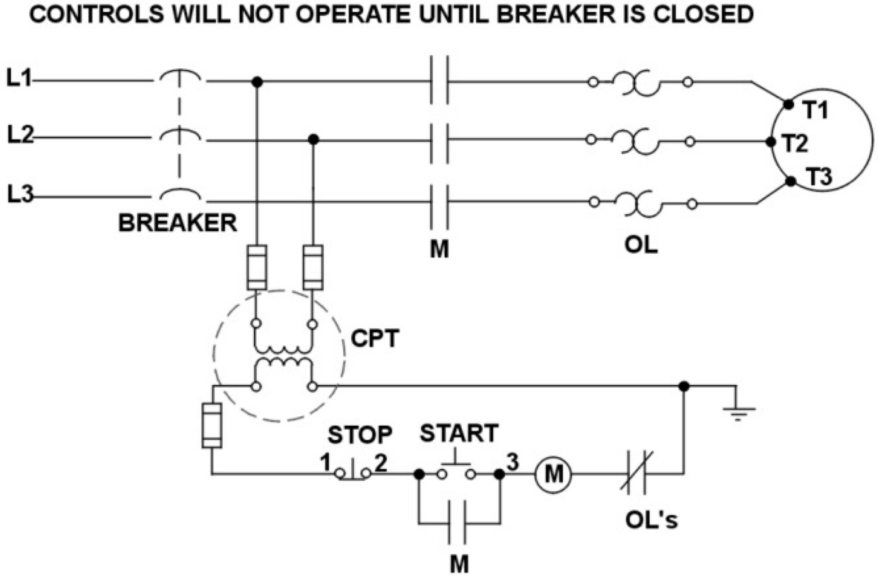

Figure 3

3. **Capacitive Voltage Transformers (CVTs)**
CVTs are often used in high voltage (115kV and higher) applications and use a series of capacitors as a voltage divider. The capacitors are connected between the system voltage and the polarity of a PT. As the PT secondary is normally grounded through an internal jumper, an external switch is often used to isolate the PT from ground during testing. The correct switch position must be determined before energizing the CVT to ensure correct operation. An internal schematic diagram of a CVT is shown in Figure 4. CVTs are less expensive and are often used in place of high voltage PTs to reduce capital costs.

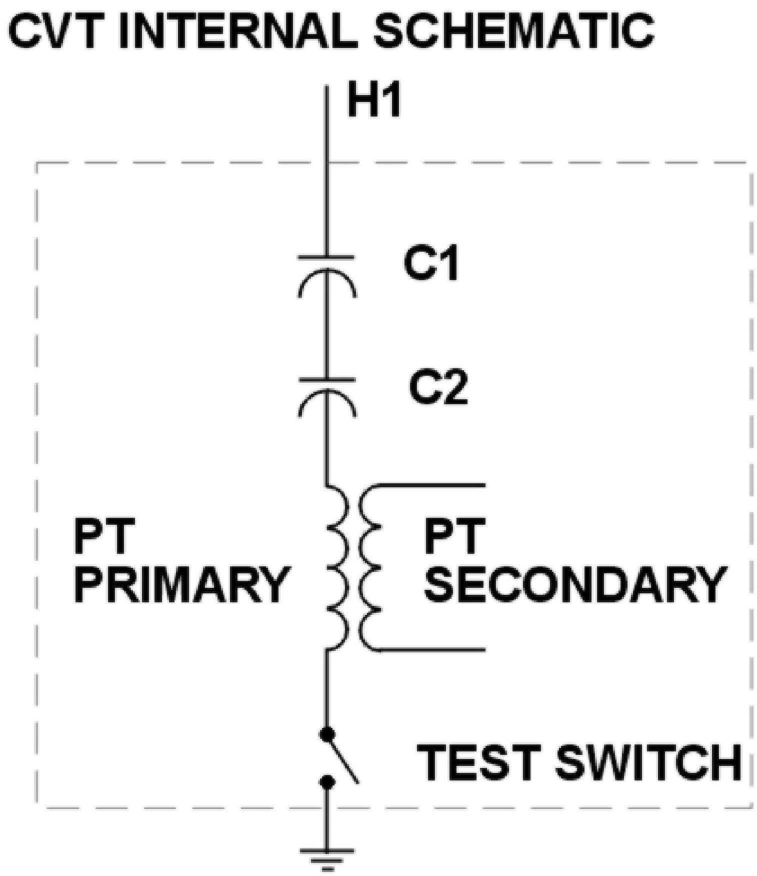

Figure 4

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This article is a basic guideline for PT testing using the most basic of equipment and is arranged in accordance with the NETA standards for easy reference.

1. *Visual and Mechanical Inspections*

I. *Compare equipment nameplate data with drawings and specifications.*

Every PT test form should include the serial number, model number, ratios and accuracy class.

- The serial number is important for PT identification and comparisons between your results and the manufacturer's.
- The model number is important for comparison of test results to manufacturer's specifications and for ordering replacement or spare PT's or parts.
- The PT ratio is the most important piece of information and must be recorded from the nameplate or the design criteria. The ratio determines the PT operating characteristics. If the PT has multiple taps (different possible ratio combinations), all taps should be recorded for future reference in case a new PT ratio is required for the application.
- The accuracy class indicates the PT's performance characteristics. A PT's accuracy is dependent on the number of devices connected to the secondary terminals. PT load is also called the burden that is usually defined in Volt-Amps and Power Factor at 120 secondary volts. Standard burden designations are shown in Table 1. Classifications for accuracy have also been designated as shown in Table 2. It is possible that one PT can be rated for different accuracies at different burdens. For example a PT can be rated 0.3W, 0.6Y and 1.2ZZ. However, if the actual burden or power factor falls outside the guidelines in Tables 1 and 2, the PT's accuracy is not guaranteed.

Table 1 - Standard Burdens for Potential Transformers

Burden	Volt-Amps at 120V	Burden Power Factor
W	12.5	0.7
X	25.0	0.7
Y	75.0	0.85
Z	200.0	0.85
ZZ	400.0	0.85

Table 2 - Accuracy Classes for Potential Transformers

Accuracy Class	Limits of Transformer Ratio Correction Factor	Limits of Power Factor Load
1.2	1.012 – 0.988	0.6 – 1.0
0.6	1.006 – 0.994	0.6 – 1.0
0.3	1.003 – 0.997	0.6 – 1.0

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Based on Tables 1 and 2, this means our example PT (0.3W, 0.6Y and 1.2ZZ) will have the following operating characteristics:

- 0.3W indicates the PT will operate with an accuracy between 99.7-100.3% if:
  - The operating system power factor is greater than 0.6
  - The secondary connected devices do not exceed 12.5VA and operate at a power factor greater than 0.7.
- 0.6Y indicates the PT will operate with an accuracy between 99.4-100.6% if:
  - The operating power factor is greater than 0.6
  - The connected devices do not exceed 25VA and operate at a power factor greater than 0.85.
- 1.2ZZ means the PT will operate with an accuracy between 99.8-101.2% if:
  - The operating power factor is greater than 0.6
  - The connected devices do not exceed 25VA and operate at a power factor greater than 0.85.

II. *Inspect physical and mechanical condition.*

The PT should be checked for any cracks or any other obvious damage that may have occurred during shipping or installation.

III. *Verify that all grounding connections provide contact.*

- Use an ohmmeter or contact resistance test set to measure the resistance between the PT primary grounding connection and a known ground to ensure an electrical connection exists. Visually inspect the connection to ensure it is tight and protected from obvious physical damage.
- Use an ohmmeter or contact resistance test set to measure the resistance between the PT secondary grounding connection and ground to ensure an electrical connection is installed. Special attention is required to ensure that the PT secondaries of any connected group are grounded at one point only and that the ground connection cannot be easily removed while the PT is in service. (E.g. Grounding point made on the line side of test switches)
- Ensure (if possible) that multiple grounds do not occur when synchronizing systems are enabled.

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IV. Verify correct operation of transformer withdrawal mechanism and grounding operation.

- When the PT is withdrawn ensure that there is no longer any connection with the primary electrical system. It is a good idea to remove all as a safety precaution to prevent back-feeding dangerous voltages into the system during testing. The fuses should not be replaced until all PT and control system testing is completed and the PT energization is imminent.
- Use an ohmmeter or contact resistance test set to measure the resistance between the PT primary and ground when in the fully withdrawn position to ensure the PT grounding device is operational.

V. Verify correct primary and secondary fuse sizes.

- Inspect the fuses and ensure they are the sized correctly for the particular application and meet the design requirements. Typically "E" rated current limiting fuses are used to protect PT's.

2.0 Electrical Tests

I. Perform insulation resistance tests winding to winding and each winding to ground.

To test the insulation integrity you will need a megohmmeter or hipot rated to produce the specified maximum test voltage. The test voltage should NEVER exceed 1.6 times the PT rating unless authorized by the PT manufacturer. Use the following test procedure for PT insulation tests.

a. Isolate all windings from ground.
b. Install a jumper across each full winding.
c. Connect the megohmmeter to one terminal of the H side of the PT and the negative to one side of the X side and to ground.
d. Increase the voltage slowly to the test voltage and let stand for one minute. Monitor the insulation resistance during the test to ensure that reading is not linear and does not increase exponentially as the test voltage increases. Either condition could indicate insulation failure, poor insulation, and/or improper test connections.
e. Record the insulation resistance, temperature, humidity, and equipment designation.
f. Use the insulation resistance compensation Table 3 to determine the equivalent insulation resistance at 20°C.
g. Check NETA ATS-99 Table 10.9 to ensure the 20°C equivalent resistance is not lower than the specified value or compare results to previous test results. Ensure previous results have been converted to equivalent 20°C resistances.

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h. Repeat steps a. through g. exchanging primary and secondary connections to include all the following tests for 2 and 3 winding PTs. Use Figure 5 diagrams to help you visualize the connections.
   - 2 winding
     - H-X&G
     - X-H&G
   - 3 Winding
     - H-X&G (Guard Y)
     - H-Y&G (Guard X)
     - X-H&G (Guard Y)
     - Y-H&G (Guard X)
     - X-Y&G (Guard H)
     -

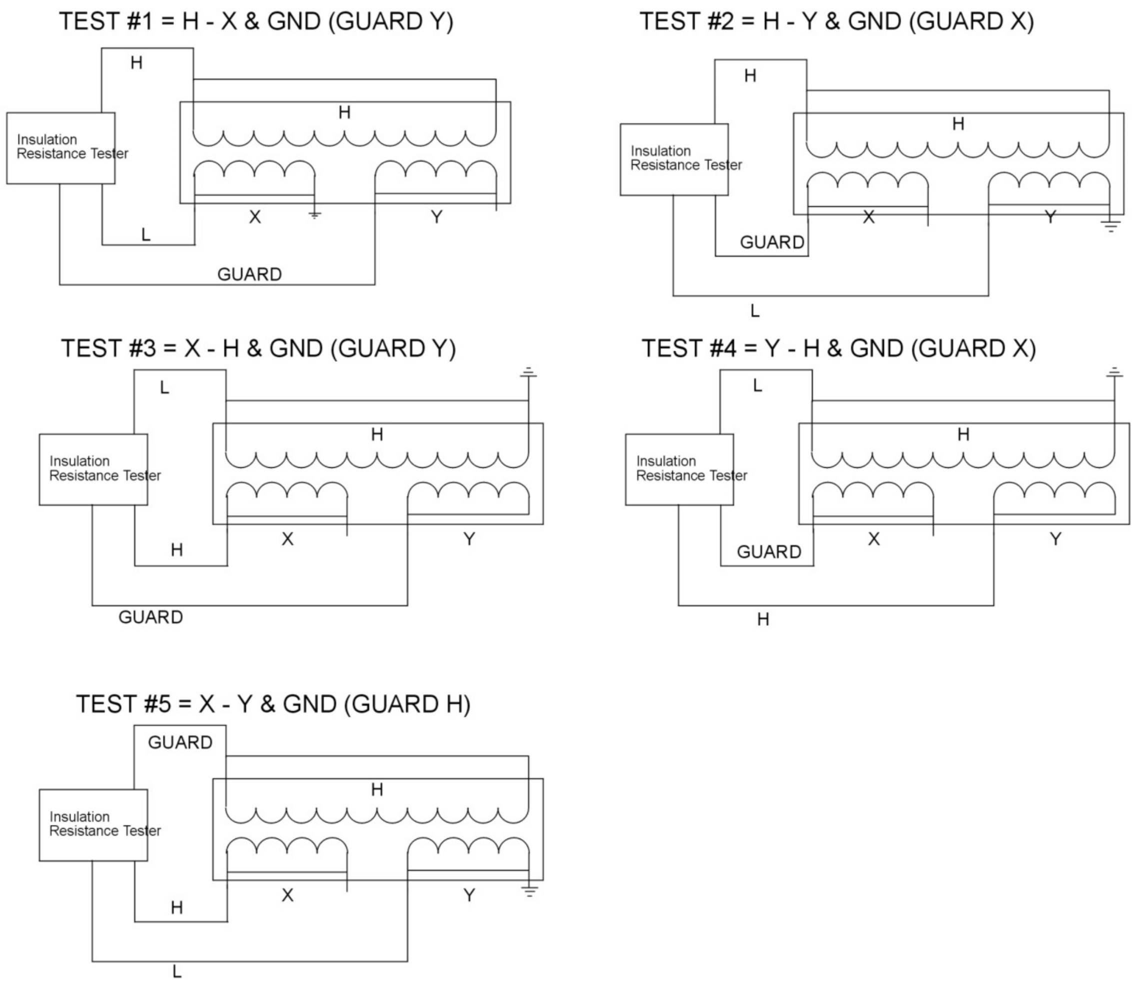

Figure 5

TABLE 3

Insulation Resistance Conversion Factors

for Conversion of Test Temperature to 20ºC

Temperature		Multiplier	
ºC	ºF	Apparatus Containing Immersed Oil Insulations	Apparatus Containing Solid Insulations
0	32	0.25	0.40
5	41	0.36	0.45
10	50	0.50	0.50
15	59	0.75	0.75
20	68	1.00	1.00
25	77	1.40	1.30
30	86	1.98	1.60
35	95	2.80	2.05
40	104	3.95	2.50
45	113	5.60	3.25
50	122	7.85	4.00
55	131	11.20	5.20
60	140	15.85	6.40
65	149	22.40	8.70
70	158	31.75	10.00
75	167	44.70	13.00
80	176	63.50	16.00

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II. Perform a polarity test on each transformer to verify the polarity marks or H1-X1 relationship as applicable. We describe the two polarity test methods available using the most basic equipment.

a. To test polarity using DC voltage, a lantern battery and a voltmeter with an analog scale is required. Use the following steps for DC polarity testing as shown in Figure 6:

i. Connect the positive of the voltmeter to the marked terminal of the high voltage side of the PT and the negative lead to the non-marked.

ii. Calculated the expected voltage using the battery voltage and the PT ratio. (Battery voltage * PT ratio) if the expected voltage exceeds the battery rating; switch the battery to the primary side of the PT and voltmeter to the secondary side. Re-calculate the expected voltage and set the voltmeter scale accordingly. (Battery Voltage / PT ratio)

iii. Connect the negative terminal of the battery to the non-polarity of the PT winding under test. Momentarily touch or connect the battery positive terminal to the polarity terminal of the PT winding under test.

iv. Closely watch the needle or analog scale of the voltmeter. It should jump in the positive direction. This happens in a fraction of a second and the meter must be monitored very closely. If the voltmeter kicks in the positive direction the polarity marks are correct and if it kicks in the negative direction then the polarity marks are incorrect.

v.

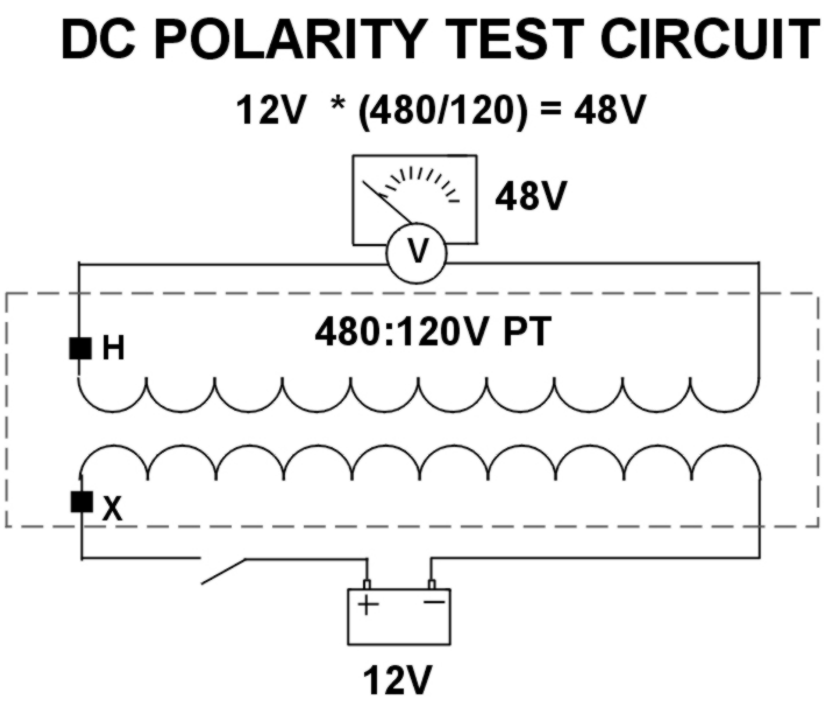

Figure 6

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b. To test polarity using ac voltage; a variac and voltmeter are required. Use the following steps to test for PT polarity using the AC method as shown in Figure 7.
   i. Connect a variac across the primary winding of the PT.
   ii. Connect a voltmeter (VM1) across the primary PT winding and variac.
   iii. Connect a voltmeter (VM2) from the polarity mark of the H side to the non-polarity mark of the X side.
   iv. Connect the non-polarity mark of the H side winding to the polarity mark of the X side winding.
   v. Increase the voltage to a known value. Calculate the expected value. ([VM1/PT ratio]+[VM1]) if VM2 displays the expected result, the PT polarity markings are correct. If VM2 is less than the expected result, the test connection or the PT polarity markings are incorrect. (Note: VM1 and VM2 can be 1 voltmeter switching between positions if the test voltage remains stable.)
   vi.

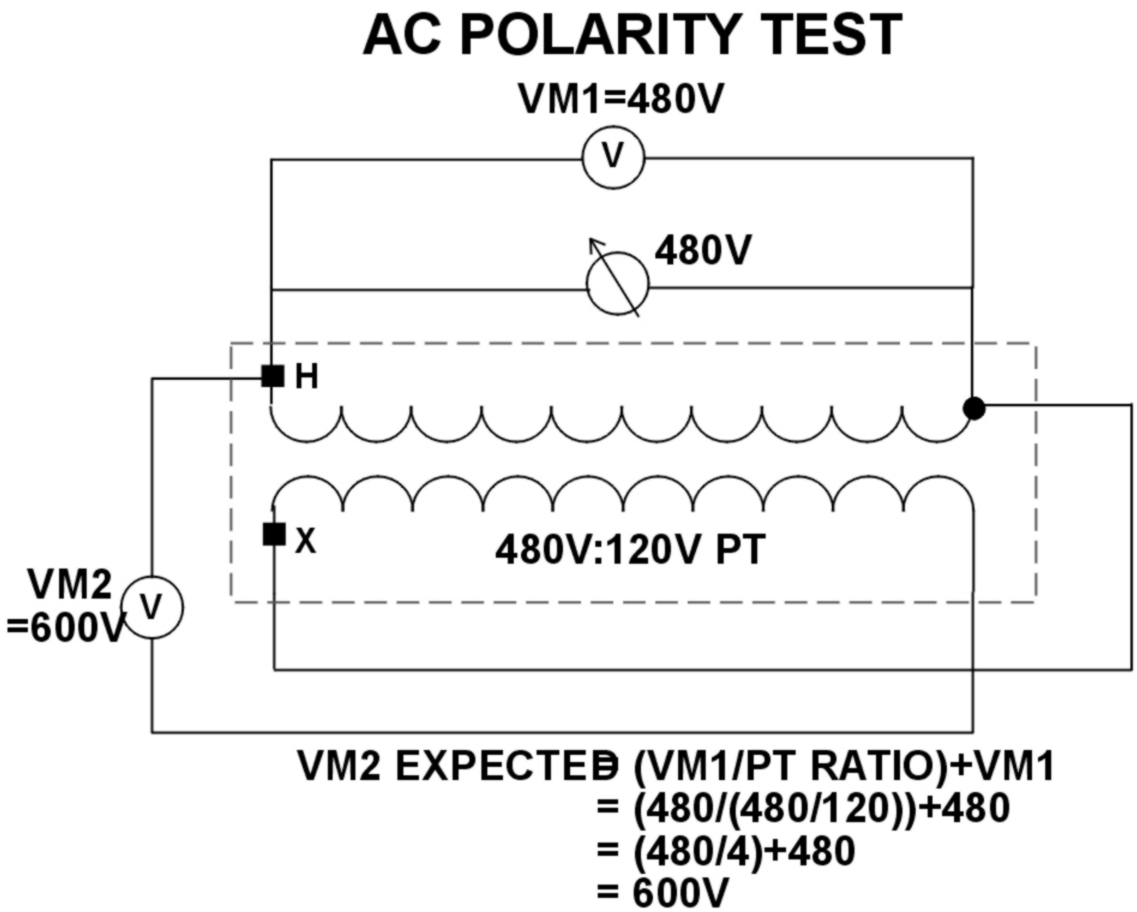

Figure 7

III. ***Perform a turn's ratio test on all tap positions if possible.***

Testing the ratio of a PT is a simple test and only requires a variac and a voltmeter. Use the following procedure for PT ratio Testing:

a. Connect the variac across the primary winding.
b. Increase the voltage to the test voltage. (Typically an easy multiple of the PT ratio e.g. 35:1V PT ratio = 35V) Calculate the expected secondary voltage. (Test voltage / PT Ratio)
c. Measure the secondary voltage and compare to the expected result.
d. After the ratio tests have been completed, ensure that the connection is left as specified.

Note: Never energize the secondary winding and measure the primary winding as dangerous voltages could be created.

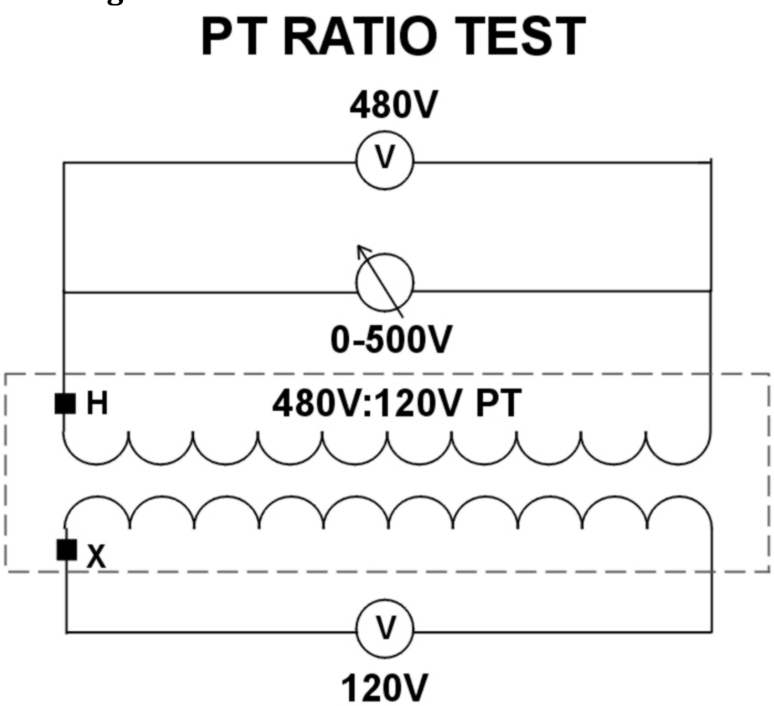

Figure 8

All of the above-mentioned tests use the same principles as the fancy test equipment available today and should they ever fail (Because that NEVER happens) you can get your trusty voltmeter and variac and keep on testing.

Credits:
Figure 1: http://www.geindustrial.com/cwc/products?pnlid=5&id=kvvolt
Figure 2: http://www.geindustrial.com/cwc/products?pnlid=5&id=sp-pwr
Westinghouse Technical Data Sheet 45-910; "Instrument Transformers Technical Data, Accuracy standards Index"; December 1945
Northern Alberta Institute of Technology; Electrical Engineering Technology Program; "Principle of Operation of Potential Transformers."