July, 2012

This goal for this month's paper is to provide a basic understanding of tests performed on each liquid filled transformer. The following standards detail the general construction requirements as well as the specific tests which the transformer must be subjected to.

IEEE C57.12.00—IEEE Standard General Requirements for Liquid-Immersed Distribution, Power, and Regulating Transformers

IEEE C57.12.90—IEEE Standard Test Code for Liquid-Immersed Distribution, Power, and Regulating Transformers

These standards define "routine" tests that are performed on all transformers as well as "type" tests which are performed on each unique design.

Routine tests:

1. Winding Resistance
2. Ratio, Polarity and Phase Relation
3. Core Loss and Exciting Current
4. Load Loss and Impedance
5. Induced Potential
6. Applied Potential (Hi-Pot)
7. Production Line Impulse Test
8. Insulation Resistance
9. Insulation Power Factor
10. Leak (pressure) Test

Type Tests:

1. Full ANSI impulse Voltage Test
2. Temperature rise test
3. Short Circuit Test

Type tests are performed on new designs and are required to insure that the general design parameters are sufficient to insure reliable service. Pacific Crest

Transformers performs ANSI impulse and temperature rise tests in house while short circuit tests are performed by an independent test laboratory.

The capability to perform the required tests requires an extensive array of specialized equipment including multi-voltage test transformers, a high frequency generator, and an impulse generator.

The first 6 routine tests listed above are those typically performed as customer "Factory witness tests". Following is a brief description of each as well as the PCT pass criteria.

1. Winding Resistance Measurement
(Resistance)

PURPOSE: To measure resistance of all windings in the transformer under test in order that the I^2R losses can be calculated. Also, to verify, through acceptable resistance readings, that all bolted connections are tight, and that crimped connections and conductor splices are adequate.

SETUP: A digital Wheatstone or Kelvin bridge is used to apply a very low DC current to each of the HV and LV windings which returns the result in ohms. The low current is necessary to insure against heating of the windings which would lead to false readings due to an increase in resistance.

PASS CRITERIA:
The variation in resistance measurements between phases of the same winding shall not exceed the limits specified by the transformer manufacturer.

2. Ratio Measurement and Vector Relationship Check
(Ratio, Polarity and Phase Relation)

PURPOSE: To verify the voltage ratio of each coil in the transformer under test by checking the turns ratio of the HV and LV windings and (2) to verify that the windings are connected correctly to provide the specified primary to secondary vector relationship.

SETUP: A ratiometer is used to perform this test. This equipment connects to each phase of the HV and LV winding and via the application of a very low voltage determines the ratio of the high voltage windings to the low voltage windings. These values are compared to those supplied from Engineering.

PASS CRITERIA:

- Ratio: Compute ratio tolerances from nominal transformer rated voltages. Maximum tolerances from calculated ratio = ±0.5%.
- Vector Relationship: A correct ratio will verify the desired vector relationship, or polarity. A test that yields no ratio at all or one that is far different than the calculated ratio may indicate a connection problem in the transformer under test.
- Note: A large difference between exciting current readings while ratioing different coils of a transformer may indicate a problem such as a turn-to-turn short.

3. No Load Loss and Excitation Current Measurement

(Core Loss and Exciting Current)

PURPOSE: To measure no load loss (core loss) and excitation current, and verify that these values are within acceptable tolerance of the calculated values. This will confirm that the core design (i.e. cross-sectional area and lamination thickness) is adequate to handle the required flux density, and that the cores were properly assembled.

SETUP: The secondary terminals of the transformer under test is connected to a variable AC voltage source with no connections to the primary bushings. The voltage is gradually increased until full rated voltage is obtained. The core loss in watts as well as the current is recorded and compared to design data supplied by Engineering.

PASS CRITERIA:

Core loss shall not exceed design value by more than 10%.

Maximum excitation current:

- wound core 2%
- stacked core 5%

5 legged distributed gap ***wound*** core/coil

3 legged ***stacked*** core/coil

If tested core loss exceeds maximum allowance, another test shall be made at 110% of rated secondary voltage, and the resulting data shall be submitted to a design engineer for review.

4. Load Loss and Impedance

PURPOSE: To determine, by test and calculation, load losses and total losses of a transformer under test. Also, to determine the impedance voltage of the transformer, expressed as a percentage of the rated primary voltage, from which may be calculated the winding currents under short circuit conditions. The losses obtained from this test combined with the core loss data validates if the transformer tank and radiators are sufficient to allow for proper cooling.

SETUP: The LV terminals are shorted together. The HV terminals are connected to a variable AC voltage source. Voltage is than applied to the HV and increased until such time that rated current is reached. The voltage and wattage is recorded and compared to data supplied by Engineering.

PASS CRITERIA:

Tested total losses shall not exceed design losses by more than 6%. The limits of tested impedance are ±7.5% of specified impedance. Losses or impedance values that exceed limits should be submitted to engineering for review.

5. Induced Voltage Test

(Induced Potential)

PURPOSE: To verify coil and lead insulation levels by inducing the transformer under test to *twice* its rated voltage at high frequency for 7200 cycles. This test verifies turn to turn and layer to layer insulation, as well as lead to lead insulation within the high voltage and low voltage lead assemblies.

SETUP: This test is performed using a high frequency generator (180 HZ). Since frequency and inductive reactance are inversely proportional, the double voltage required for this test is made possible because the core does not saturate.

PASS CRITERIA:

There should be no collapse or pull down of the test voltage. Smoke and bubbles from coils or lead assemblies may also indicate an insulation failure.

6. Applied Potential Test

(Hi-Pot)

PURPOSE: To verify the adequacy of winding to winding, and winding to ground insulation in each coil of the transformer under test. This test also verifies the adequacy of all live-to-ground clearances in the transformer.

SETUP: During this test, each winding is shorted out by connecting its bushings together. The ANSI specified voltage is then applied to the winding under test with the other windings connected to ground. No voltage is induced in the winding under test or magnetic flux induced in the core; hence the insulation between turns or between layers in the winding under test is not stressed.

PASS CRITERIA:
Failure of a winding is indicated by loss of test voltage and/or test set circuit breaker tripping. Failure can also be indicated by smoke and bubbles from coils or lead assemblies, or by an audible thump from inside the tank.

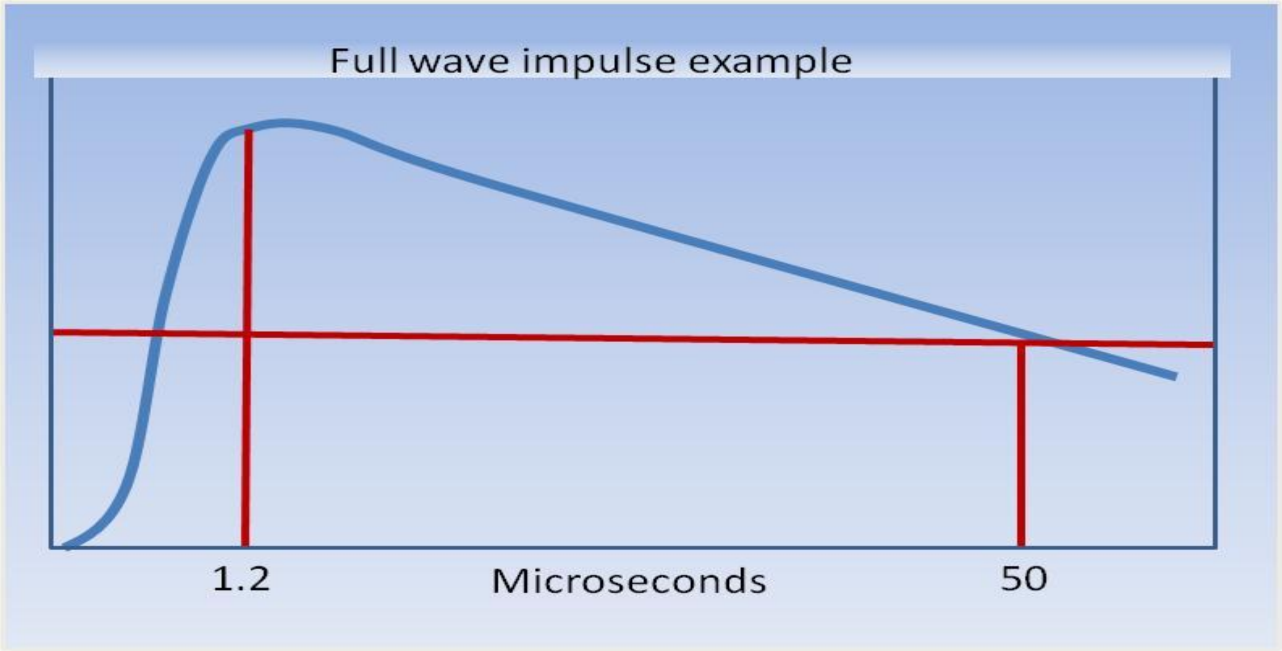
Tests 7 through 10 as listed above are not normally witnessed (for various reasons), but test data is available upon request at the time of the Factory Witness Test.

7. Production line impulse test

PURPOSE: To verify, by application of two 1.2 x 50 μs negative impulse waves to each high voltage phase bushing, insulation levels and electrical clearances within the transformer under test. This test verifies the integrity of turn to turn, layer to layer, winding to winding, and lead to lead insulation, as well as live to live, and live to ground clearance distance. Impulse tests simulate switching and lightning surges that may be impressed on the transformer.

SETUP: The transformer under test is connected to the impulse generator. Each phase of each winding (HV and LV) is subjected to a voltage level dependent on the BIL (basic insulation level) of the winding under test. The impulse generator is made up of a number of capacitors that are charged in parallel to a level that when discharged in series will combine to achieve the required test voltage. The image of the voltage surge through each winding is captured on an oscilloscope.

PASS CRITERIA:
There should be no significant differences between voltage traces, displayed on the oscilloscope, from any HV bushing. Particular attention should be paid to the wave shape and voltage decay rate after the peak voltage of each voltage trace. Failure may also be indicated by an audible thump from the transformer tank, or by smoke and bubbles from coils or lead assemblies.



8. Insulation resistance
("Megger")

PURPOSE: Insulation resistance tests are made to determine the insulation resistance from individual windings to ground or between individual windings. This test will determine the condition of the insulation and that proper internal clearances have been met and maintained. This test is performed as a routine test on 501kVA and larger transformers.

SETUP: A digital megger with a maximum rating of 5 kV

PASS CRITERIA:
Insulation resistance measurements shall not be less than the minimum limits specified by the transformer manufacturer.

9. Insulation power factor

The ratio of power dissipated in the insulation in watts to the product of the effective voltage and current in volt-amperes when tested with a sinusoidal voltage. This test is used to give an indication of the condition (dryness) of the transformer insulation. There are no established limits for acceptable power factor readings in the transformer standards. A power factor value of 1.0% or less for distribution transformers is generally used as an acceptable value.

SETUP: The measurement is made with a capacitance bridge, measuring the capacitance between windings and between windings and ground, together with the power factor or loss angle of this capacitance.

10. Leak (pressure) test

PURPOSE:To apply pressure and check for leaks on the transformer.

SETUP: The completed transformer (cover welded) is pressurized at 7 PSI.

PASS CRITERIA:
UNIT HAS PASSED if no leaks are found and pressure remains constant (or does not drop more than expected with consideration of temperature differences) after a minimum of twelve (12) continuous hours under pressure.

UNIT HAS FAILED if a leak is found or if the pressure drops more than expected.
If leaks are detected, repair the transformer as needed. If the pressure drops more than expected, investigate tank seams, handholes, cover mounted bushings, etc., to determine where the leak is located and repair the transformer as needed.