6 electrical tests for Current Transformers explained

By testguy May 12, 2017

1 Comment

It is essential to inspect and test current transformers and their connected instruments at regular intervals. Photo Credit: ABB

Current transformers play an important role in the **monitoring** and **protection** of electrical power systems. CT's are instrument transformers used for converting primary current into a reduced secondary current for use with meters, relays, control equipment and other instruments.

The importance of **instrument transformer tests** is often underestimated. Current transformers for metering purposes must have a high degree of accuracy to ensure *precise billing* while those used for protection must *react quickly* and correctly in the event of a fault.

Risks such as **confusing instrument transformers** for metering and protection, or **mixing up connections** can be reduced significantly by testing before initial use. At the same time, **electrical changes** in a CT, caused for example by aging insulation, can be identified at an early stage.

For these reasons and more, it is essential to **inspect and calibrate** current transformers and their connected instruments at **regular intervals**. There are 6 electrical tests that should be performed on CT's to ensure accuracy and optimal service reliability:

Contents

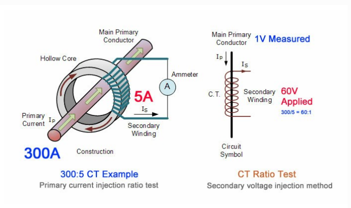
1. Ratio Test

CT ratio is described as the ratio of primary current input to secondary current output at full load. For example, a CT with a ratio of **300:5** will produce **5 amps** of secondary current when **300 amps** flow through the primary.

If the primary current changes, the secondary current output will change accordingly. For example, if **150 amps** flow through a **300 amp** rated primary the secondary current output will be **2.5 amps**.

(300:5 = 4:1) (150:300 = 2.5:5)

Unlike the voltage or power transformer, the current transformer consists of only *one or very few* turns as its **primary winding**. This primary winding can be of either a single flat turn, a coil of heavy duty wire wrapped around the core or just a conductor or bus bar placed through a central hole.



A CT ratio test can be performed by injecting a primary current and measuring the current output, or by injecting a secondary voltage and measuring the induced primary voltage. Photo: TestGuy.

The ratio test is conducted to *prove that the ratio of the CT is as specified*, and to verify the ratio is correct at different taps of a multi tap CT. The turn's ratio is equivalent to the voltage ratio of potential transformers and can be expressed as follows:

$$N2/N1=V2/V1$$

- **N2** and **N1** are **number of turns** of secondary and primary windings
- **V2** and **V1** are the secondary and primary side **voltage readings**

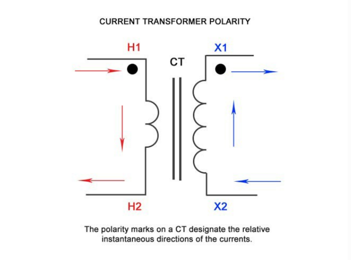
Ratio tests are performed by applying a **suitable voltage** (below saturation) to the *secondary* of the CT under test while the **primary side voltage is measured** to calculate the turns ratio from the expression above.

> **DANGER:** Use caution when conducting a CT ratio test and **do NOT** apply a voltage high enough that would cause the transformer to saturate. Applying a saturation voltage will result in readings that won't be accurate.

2. Polarity Test

The **polarity of a CT** is determined by the direction in which the coils are wound around the transformer core (clockwise or counterclockwise) and by how the leads are brought out of the CT case. All **current transformers are subtractive polarity** and should have the following designations to visually identify the direction of current flow:

- **H1** - primary current, **line** facing direction
- **H2** – primary current, **load** facing direction
- **X1** - **secondary** current



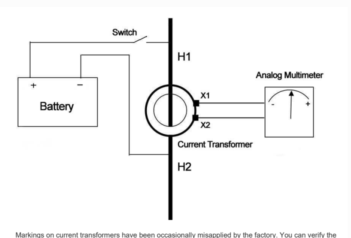
A CT under test is assumed to have correct polarity if instantaneous current direction for primary and secondary current is opposite to each other. Photo: TestGuy.

The **polarity marks** on a CT designate the relative *instantaneous directions* of the currents. The polarity test proves that the predicted direction of secondary CT current (leaving) is correct for a given direction of primary current (entering).

Taking care to observe proper **polarity is important** when installing and connecting current transformer to power metering and protective relays. At the same instant of time, that the primary current is **entering** the **primary** terminal the corresponding secondary current should be **leaving** the similarly **marked secondary** terminal.

A CT under test is assumed to have **correct polarity** if instantaneous current direction for primary and secondary current is **opposite to each other**. CT Polarity is *critical* when CT's are being used together in single-phase or three-phase applications.

Most modern day CT test equipment is capable of performing the **ratio test** automatically using a simplified test lead setup and will display polarity as correct or incorrect. **CT polarity** is verified manually by utilizing a **9V battery** and **analog voltmeter** with the following test procedure:



Markings on current transformers have been occasionally misapplied by the factory. You can verify the polarity of a CT in the field with a 9V battery. Photo: TestGuy.

CT Polarity Test Procedure

1. **Disconnect all power** prior to testing and connect the analog voltmeter to the secondary terminal of the CT to be tested. The **positive terminal** of the meter is connected to terminal **X1** of the CT while the **negative terminal** is connected to **X2**.
2. Run a piece of wire **through the high side** of the CT window and shortly make contact with the **positive end** of the 9-volt battery to the **H1** side (sometimes marked with a dot) and the **negative end** to the **H2** side. It is important to *avoid continuous contact*, which will short circuit the battery.
3. If polarity is correct, the momentary contact causes a **small deflection** in the analog meter in the **positive direction**. If the deflection is negative, the polarity of the current transformer is reversed. The terminals **X1** and **X2** need to be reversed and the test can be carried out.

> **Note:** Polarity is not important when connecting to ammeters and voltmeters. Polarity is important only when connecting to wattmeters, watt-hour meters, varmeters, and induction-type relays. To maintain polarity, the **H1** side of the CT must be **toward the source** of power; then the **X1** secondary terminal is the polarity connection.

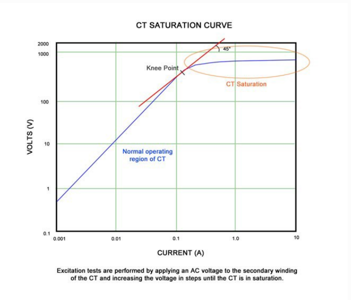
3. Excitation (Saturation) Test

When a **CT is "saturated"**, the magnetic path inside the CT operates like a short circuit on the transmission line. Almost all of the energy supplied by the primary winding is shunted away from the secondary winding and is used create a magnetic field inside the CT.

Saturation testing for a current transformer identifies the rated knee point against IEEE or IEC standards, the point at which the transformer is no longer able to output current in proportion to its specified ratio.

Excitation tests are performed by applying an AC voltage to the **secondary winding** of the CT and increasing the **voltage in steps** until the CT is in saturation. The **"Knee" point** is determined by observing a small voltage increase causing a large increase in current.

The test voltage is *slowly decreased* to zero to **de-magnetize the CT**. The test results are plotted on a logarithmic (log-log) graph and evaluated based on the transition period between normal operation and saturation.



Excitation tests are performed by applying an AC voltage to the secondary winding of the CT and increasing the voltage in steps until the CT is in saturation. Photo: TestGuy.

The **excitation curve** around the points where current jumps up for a small increase of voltage; is very important for comparison of curves with published curves or similar CT curves. The excitation test **results should be compared** with published manufacturer's data or previous recordings to determine any deviations from previously obtained curves.

IEEE defines the **saturation** as "*the point where the tangent is at 45 degrees to the secondary exciting amperes*". Also known as **"knee" point**. This test verifies that the CT is of correct accuracy rating, has no shorted turns in the CT and no short circuits are present in the primary or secondary windings of the CT under test.

4. Insulation Resistance Test

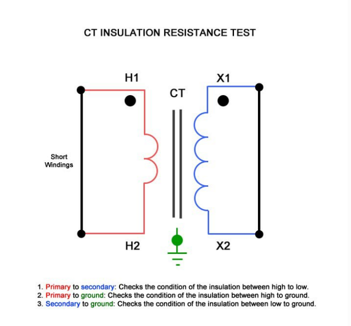
The insulation between the current transformer windings and windings to ground should be checked for dielectric strength while performing a comprehensive CT test. **Three tests** are performed to determine the condition of the insulation of the CT under test:

1. **Primary to secondary**: Checks the condition of the insulation between high to low.
2. **Primary to ground**: Checks the condition of the insulation between high to ground.
3. **Secondary to ground**: Checks the condition of the insulation between low to ground.

Insulation resistance readings should remain fairly constant over a period of time. A **sharp dip** in trending of insulation resistance values point towards **insulation degradation** and further investigation is required to diagnose the problem.

Insulation tests on current transformers are usually performed at 1000VDC. Prior to testing, **short the primary winding** of the CT under test by connecting H1 and H2, then **short the secondary winding** of the CT under test by connecting X1 and X2-X5.

Remove the neutral ground and isolate the CT from any associated burden. After the **windings are shorted**, the CT will be a three terminal specimen.



Three insulation resistance tests are performed to determine the condition of the insulation of the CT under test. Photo: TestGuy.

Insulation resistance test values for CT's should be **compared with similar readings** obtained with previous tests. Any large deviation in historical readings should call for further investigation.

The **minimum insulation resistance** that is accepted is **1 Megohm**. Any reading in Megohms is considered to be a good insulation, however, it's the *trending* of insulation test results that gives the true condition of CT insulation.

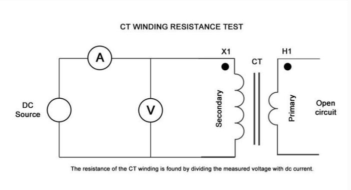
> **Note:** Insulation readings are greatly affected by the specimen temperature. Should a reading be compared to previously taken readings, proper **correction factors** need to be applied, if taken under different temperature conditions before drawing any conclusion.

5. Winding Resistance Test

The **DC winding resistance** measurement is an important measurement in accessing the true condition, state and accuracy of a CT. Winding resistance in a CT **will change** over a period of time depending on the specimen age, use, external conditions and loading effect.

It is recommended to **measure DC winding resistance periodically** on a single tap or multi tap CT and trend the values. A high precision *low resistance measurement circuit* is required to obtain this small winding resistance.

The **winding resistance** of a current transformer is found by dividing the **voltage drop** across the winding (measured from dc milli voltmeter) with the applied **dc current** through the winding. The CT should be *demagnetized* after the completion of winding resistance test.



Measure CT winding resistance by passing a DC current through the winding and measure the voltage drop. Divide the measured voltage by the measured current. Photo: TestGuy.

> **Tip:** Run a *saturation test* to demagnetize the CT at the completion of all *winding resistance* tests.

6. Burden Test

The **burden** of a current transformer can be defined as the **total impedance** in ohms on the *secondary output* terminals. The **total burden** is a combination of impedance offered by watt-hour meter coils, relay current coils, contact resistance, terminal blocks, wire resistance and test switches used in the **secondary loop**.

Each CT has a **secondary burden** when connected in a relay or metering circuit. CT's are expected to provide the secondary **output current** based upon their accuracy class.

If a current transformer is not properly sized based upon **secondary loop burden**, it may result in a *decrease* in CT secondary current. Burden testing is important to verify that CT is supplying current to a circuit that does not exceed its burden rating.

The **burden test** is also useful in ensuring that the CTs are:

- Not energized with **shorting devices** installed (if used for metering or protection)
- Not left with an **open circuit** when not used
- Connected with a **single ground** point
- All **connections** are tight

Measure burden by injecting the **rated secondary current** of the CT from its terminals towards load side by isolating the CT secondary with all connected load, and observe the **voltage drop** across the injection points - and at every point of the **circuit to ground**.

This method is time consuming, but only requires a voltage source, a resistance, and a voltmeter. Measuring the voltage drop at the source combined with ohms law will give us the **burden impedance**. Analyzing the voltage drop patterns throughout the circuit **confirms the wiring** is correct.

Current transformer burdens are typically expressed in VA. The burden test is performed to verify that the CT is capable of supplying a known current into a known burden while maintaining its stated accuracy. A burden test is typically performed at **full rated secondary current** value (ex. 5A or 1A).

How to calculate CT Burden

Depending on their accuracy class, CTs are divided into two groups: Metering and Protection (Relay). A CT can have burden ratings for both groups.

Metering CT's are typically specified as *0.2 B 0.5*

The *last number* specifies the **Burden in ohms**. For a CT with secondary current of **5 A** the VA burden rating can be calculated as:

$$VA = Voltage * Current = (Current)^2 * Burden = (5)^2 * 0.5 = 12.5\ VA$$

Relaying CT's are typically specified as *10 C 400*

The *last number* specifies the **max. Secondary voltage** at 20 times the rated secondary current without exceeding the 10 % ratio error. For a CT with secondary current rated at **5 A**, 20 times rated current secondary current would give a burden of **4 ohms**.

$$Burden = 400 / (20*5) = 4\ ohms$$

Burden in VA can be specified as:

$$VA = Voltage * Current = (Current)^2 * Burden = (5)^2 * 4 = 100\ VA$$

References

- Megger CTER MCT1605 User Manual
- Basics of Current Transformers – NK Technologies
- Testing and Commissioning of Current Transformer
- Back to the Basics – Current Transformer (CT) Testing
- Instrument Transformer Testing

Tags

acceptance testing, current transformers, maintenance, protective relays, reference guides, relay testing, test procedures, ttr, winding resistance

Comments

1 total comments

ryanebb • 1 Week Ago

Thanks for the excellent explanation of burden.

Reply

Leave A Comment

Login or Register to comment.

Follow TestGuy

Popular topics right now
Neta II Exam
Correct procedure for de-magnetizing transformer cores
CT saturation test
XFMR test question - wye-delta TTR
Limited - Prohibited - Restricted Boundaries
Limited Approach Boundary for 35kV switchgear

Related Content
Transformer Polarity Test Procedures
Introduction to Transformer Turns Ratio Testing
ETT Level 3: Transformers
Transformer Turns Ratio (TTR) Explained
Transformer Terms and Definitions
Transformer Diagnostics and Condition...
10 Critical Tests for New Power Circuit Breakers
ETT Level 2: Metering
Primary vs. Secondary Injection Testing for Circuit...
Switchgear and Switchboard Inspection and...
Insulation Resistance Testing Beginners Guide
Types and Construction of Power and...
Current Transformer Basics: Understanding...

Test Your Knowledge
Sharpen your skills with our collection of quizzes on electrical safety, maintenance & testing of electrical equipment and industry standards.
Tech Quiz Study Guide

Electrical Testing References
Protective Relay Protection Element Tests
Capacitive Reactance - How to Solve Series and Parallel Capacitors
Circuit Breaker Accessories
Switchboard Ratings
Transformer Insulation Classes
Three-Phase Transformer Winding Connections
Peak vs. Average vs. RMS Voltage
Circuit Breaker Contact Arrangements: Straight-through vs. Blow-apart
SF6 Circuit Breakers
Ohm's Law & Watt's Law Cheat Sheet
Protective Relaying Terms and Definitions
Basic Electrical Theory: The Fundamental Laws of Electricity
More...

Also on TestGuy
Infrared Thermography for Electrical Distribution Systems
Protective Relay Testing and Maintenance Overview
Surge Arresters: Selection, Application and Testing Overview
Ground Fault Protection Systems: Performance Testing Basics
Power Cable Testing and Diagnostics Overview
Zone Selective Interlocking (ZSI) Basic Principles
Transformer Winding Resistance Testing Explained
Electrical Shock and Arc Flash PPE Overview
10 Electrical Distribution System Arrangements Explained
Transformer Diagnostics and Condition Assessment
6 electrical tests for Current Transformers explained
Primary vs. Secondary Injection Testing for Circuit Breakers
More...

Follow us

Explore TestGuy
Sign Up Now
Log in
Tag Cloud
Electrical Testing Forum
P&C / Relay Testing Forum
Safety & Arc-Flash Forum
Tech Quiz
Technical Articles
Electrical Testing References
Electrical Videos
Industry Links
Back to Top

NETA Certification Training
NETA Study Guide (Start Here)
Level 2 Study Guide
Level 3 Study Guide
Level 4 Study Guide
Practice Exams
Level 2 Forum
Level 3 Forum
Level 4 Forum
Start Your Career

NICET Electrical Power Testing
NICET Level 1-4 Forum

Help and Support
Terms of Service
Privacy Statement
Advertise with Us
Contact Us