Current Transformers
CT Saturation Curve Testing

CT Saturation Curve Tester Sheet 1 of 2
Designed by Vail Gilliland

Purpose

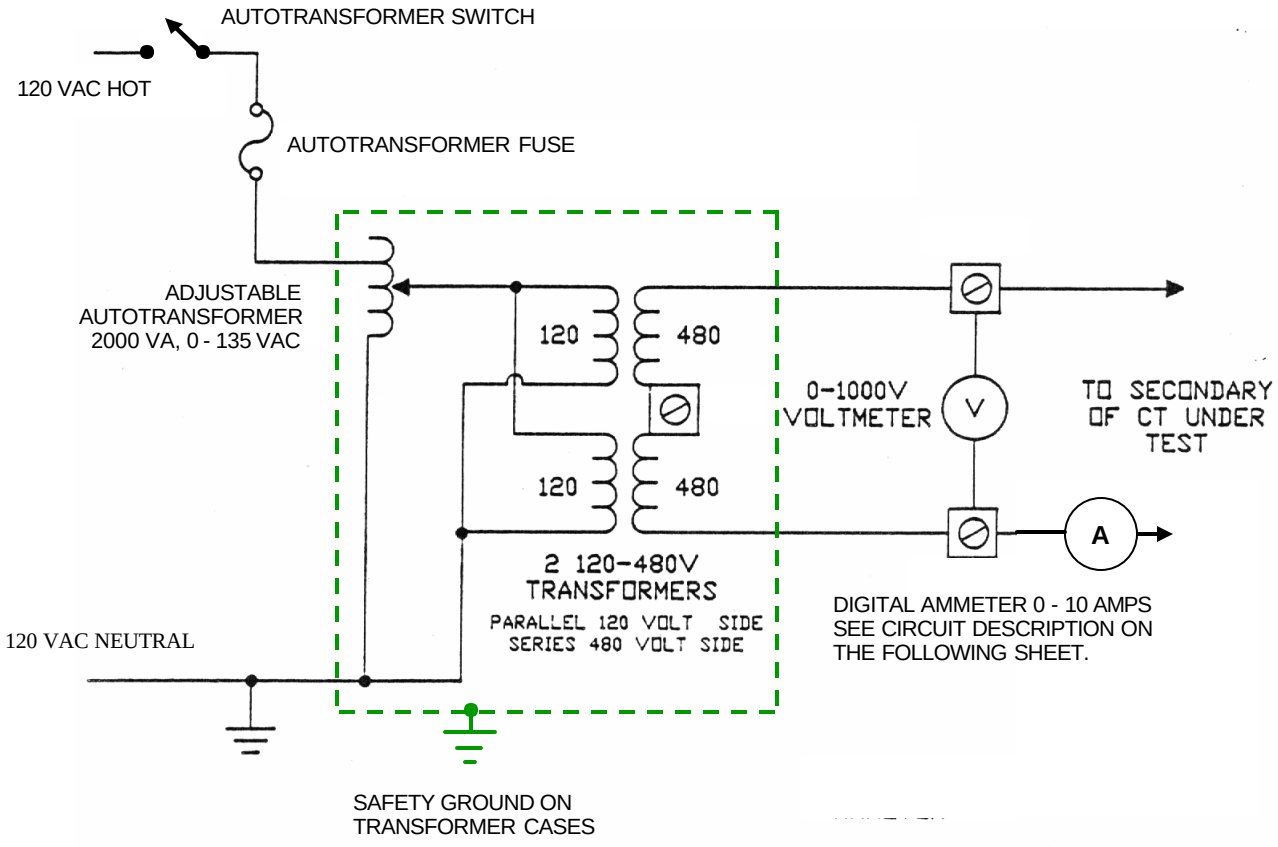
This circuit is used to plot the Saturation Curve of an Instrument Current Transformer. The test results are compared with the manufacturer's published data (see sample curves on Sheet 6 of the Current Transformer article published last month). A transformer with shorted secondary turns or a one-turn primary short due to improper mounting will result in a test plot which varies from the published curve. This test is performed only on de-energized, out-of-service equipment. The CT under test need not be removed from the equipment provided the primary is first de-energized and isolated and the secondary is then disconnected. See Circuit Description and Test Procedure on Sheet 10.

WARNING !

This test set-up develops high voltage.

The test procedure is intended for use by experienced electrical personnel only and requires the use of established safety procedures and proper Personal Protective Equipment (PPE).

This test is performed only on de-energized, out-of-service equipment, and requires that the CT primary be de-energized and isolated, and then the CT secondary must be disconnected from its burden (load). Be certain to properly reconnect the current transformer at the conclusion of the test - *an open-circuited CT can develop a dangerously-high voltage; an incorrectly connected CT may not trip the protective relay!*



Test Set Schematic

CT Saturation Curve Tester Sheet 2 of 2

Test Method Overview

The circuit on the preceding page (Sheet 9) is used to provide an adjustable 0 - 1000 VAC which is injected on the secondary winding of the current transformer being tested. Using the adjustable autotransformer, the secondary excitation voltage and current applied to the CT are *gradually* increased from zero while incremental voltage and current readings are taken. A plot of the CT secondary voltage and current is made on log - log (logarithmic) scale engineering graph paper at each step of the test. The constructed plot is then compared with the manufacturers published curves (see Sheet 6); a deviation from these curves indicates either a primary one-turn short circuit due to improper mounting or shorted secondary turns.

Circuit Description

Two 480 - 120 volt control transformers are back-fed with the 120 volt windings connected in parallel and the 480 volt windings connected in series. (The kVA rating of these transformers must be large enough to supply 5 amps of current on a momentary basis to get above the "knee" of the saturation curve.) An adjustable 0 - 135 VAC is supplied by the autotransformer which feeds the parallel connected 120 volt transformer windings.

To achieve accurate test results, both the CT secondary excitation voltage and excitation current need to be *accurately* measured.

The voltmeter must have a 1000 VAC range.

One method of measuring the excitation current is to series a Digital Multi-Meter (DMM) with the test circuit output and measure the current directly using the AC amps function. Care needs to be taken not to exceed the internal current rating of the instrument (10 amps on most DMM's).

An alternate approach, for making the current measurement, is to use a low-current clamp-on adapter such as the TPI A254 (see picture on Sheet 8) which has the ability to read AC currents as low as 10 milliamps. Several wraps of the conductor through this current probe will extend the low-end accuracy; the meter reading is then divided by the number of turns used.

Test Procedure

WARNING! This test set-up develops high voltage - see precautions on previous sheet.

- Verify that the adjustable autotransformer is un-plugged, turned off, and set at zero.
- Connect the test equipment as shown in the diagram on the preceding page and connect the output leads to the secondary leads of the current-transformer-under-test.
- Apply the 120 VAC power to the autotransformer input.
- Gradually increase the autotransformer setting until a small output current is measured. Ten milliamps (0.010 amps) is a good first step. Read the voltage at this step and plot the voltage and current readings on the log-log graph paper.
- Continue to increase the autotransformer setting in a series of small steps, taking voltage and current readings at each step and plotting the results on the graph paper. Watch for the development of the "knee" of the curve and make very careful adjustments in this voltage and current range. The current will increase in much larger increments at this point for a given amount of voltage increase, so use care to prevent blowing a meter fuse or autotransformer fuse.
- At the conclusion of the test, reduce the autotransformer output voltage to zero and remove power from the system.

Current Injection Testing

Purpose

Electrical equipment such as circuit breakers, protective relays, and meters are routinely tested to verify proper operation of current sensing elements. This testing is performed using high-current, low-voltage test equipment that provides a means of adjusting the value of current and also of measuring the operating time of the device under test. The output waveform of the test current is critical and must be sinusoidal; testing with equipment that produces a non-sinusoidal waveform - such as SCR's - will not produce accurate results.

CAUTION! Current injection testing is performed on de-energized, out-of-service equipment only!

Types of High-Current Testing

- **Primary Injection Testing** is used to test the overall operation of a current circuit. In this type of test, a high current is injected in the Current Transformer (CT) primary winding and the resulting secondary current is measured in each of the CT secondary devices such as meters and relays. This test is primarily conducted during commissioning of new equipment or after a major circuit modification to insure that the equipment is correctly connected. The polarity of the current may also be critical and other equipment, such as a Phase Angle Meter, may be used in conjunction with the high-current test source.

- **Secondary Injection Testing** is periodically performed on the individual devices such as relays and meters to verify the accuracy and proper operation of the equipment. These devices receive their input current from the CT secondary winding so these tests will be at a much lower level of current than that used for primary injection. Proper operation of the current-sensing protective equipment can be verified by comparing the device operating characteristics with the manufacturers published time-current characteristic curves.

Frequency of Tests

The frequency of these preventive maintenance current tests depend up the importance of the protection: high voltage equipment will often be tested annually; medium-voltage equipment is often tested and calibrated every-other year, and a three- or four-year interval for 480 volt equipment may be considered adequate.

Testing Thermal Devices

- Thermal overload relays for 480 volt and lower voltage equipment - either bimetallic or melting alloy type - are not usually tested as the test current can damage the element. (Critical applications should be protected by a more reliable device such as an electromechanical or electronic relay.)

- Large thermal circuit breakers are sometimes periodically tested for proper operation by current injection. If successive tests are made the device must have time to cool-down between tests for accurate results to be obtained.

- Electromechanical thermal relays must be tested within the instrument case for proper results. As with thermal breakers, the device must have time to cool down between successive tests.

Testing Instantaneous Elements

- Because of the high current involved when testing magnetic trip elements in circuit breakers or relays, the current should be adjusted as quickly as possible using the test set MOMENTARY FUNCTION to prevent damage to the equipment-under-test.

- The maximum trip point setting of the instantaneous magnetic trip element of a thermal/magnetic circuit breaker is usually 10 times the thermal element value. Testing the magnetic element may result in damage to the thermal element (which is in series with the magnetic trip coil) if the test current is prolonged. Motor Circuit Protectors (MCP's) have a magnetic trip element only and can be safely tested.

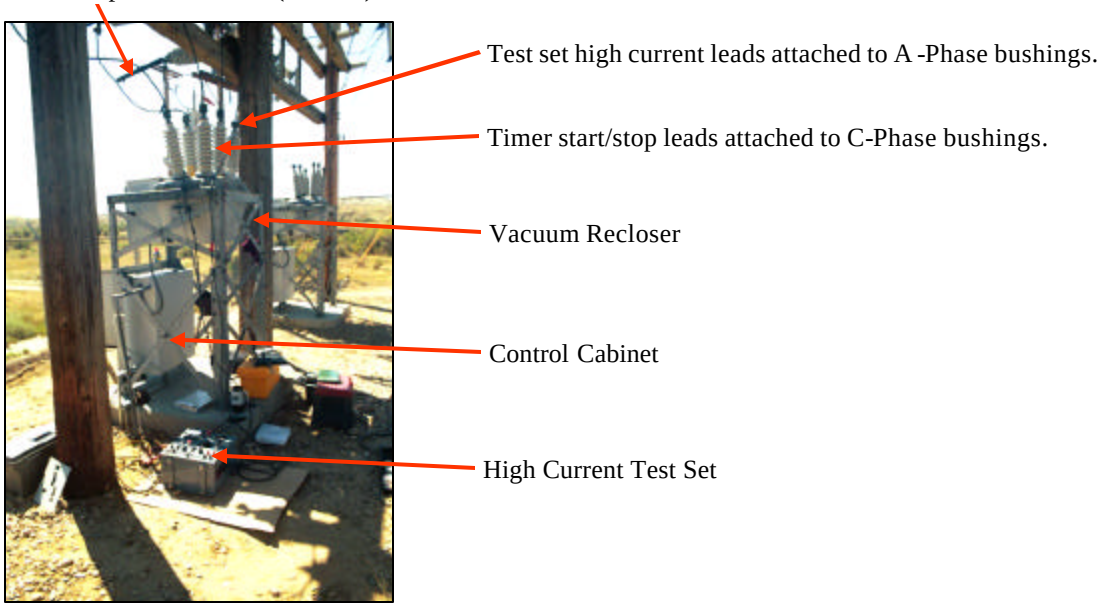
- Protective relay instantaneous elements are tested at either the engineered setting or the "as-found" setting.

High Current Testing
CT Primary Injection

Test Set-Up

In the photo below a high current test set is used to check the trip and reclose timing on a three-phase 35.4 kV substation vacuum recloser. The relaying scheme is tested one-phase-at-a-time. The high current leads are attached to the phase being tested. The test set timer start/stop leads are attached to a different phase using this pole as a "dry" set of contacts. See Sheet 7 for a photo of the recloser internal bushing current transformers. This recloser uses 130 VDC station battery for trip and close power.

CAUTION ! This procedure cannot be used on electronic controlled reclosers that have a high-voltage closing coil or on hydraulic reclosers that have a high-voltage series trip coil and a high-voltage closing coil.



Field Test on 34.5 kV Recloser

Kilowatt Classroom Photo

Test Set-Up Schematic
Recloser shown top view.