Instrument Transformer Services (ITS)

Current Transformer Reclassification

CONTENTS

Purpose of this document

This document explains the technology and application of Schneider Electric's Instrument Transformer Services (ITS) offering for CT Reclassification. It includes an overview of the hardware and software used in the application, and an example of a typical field installation procedure.

Executive Summary

Schneider Electric has developed a system that performs live, dynamic characterization and accuracy improvement of medium- and high-voltage current transformers (CTs). The system relies on a highly accurate split-core reference current sensor that is live-line deployed at substations rated up to 765 kV.

By comparing the measurements from the reference current sensor with the existing relay-class CT, the system can produce error correction parameters for the reclassification of the existing CT. These error correction parameters are *programmed into an advanced revenue meter, which then dynamically corrects and effectively reclassifies the accuracy rating of the existing relay-class CT.

Experimental results from laboratory and field testing illustrate the effectiveness of the new system and its ability to increase the accuracy of the overall revenue metering system.

An Appendix includes a sample report, including the associated graphs and tables, generated after tests at National Grid's Porter Substation in 2005.

The ITS System

At the core of the CT reclassification system is a highly accurate reference current sensor, known as the Primary Sensor, which is deployed using live-line methods on voltages up to 765 kV. The Primary Sensor is based on a split core, active CT design capable of providing highly accurate measurement.

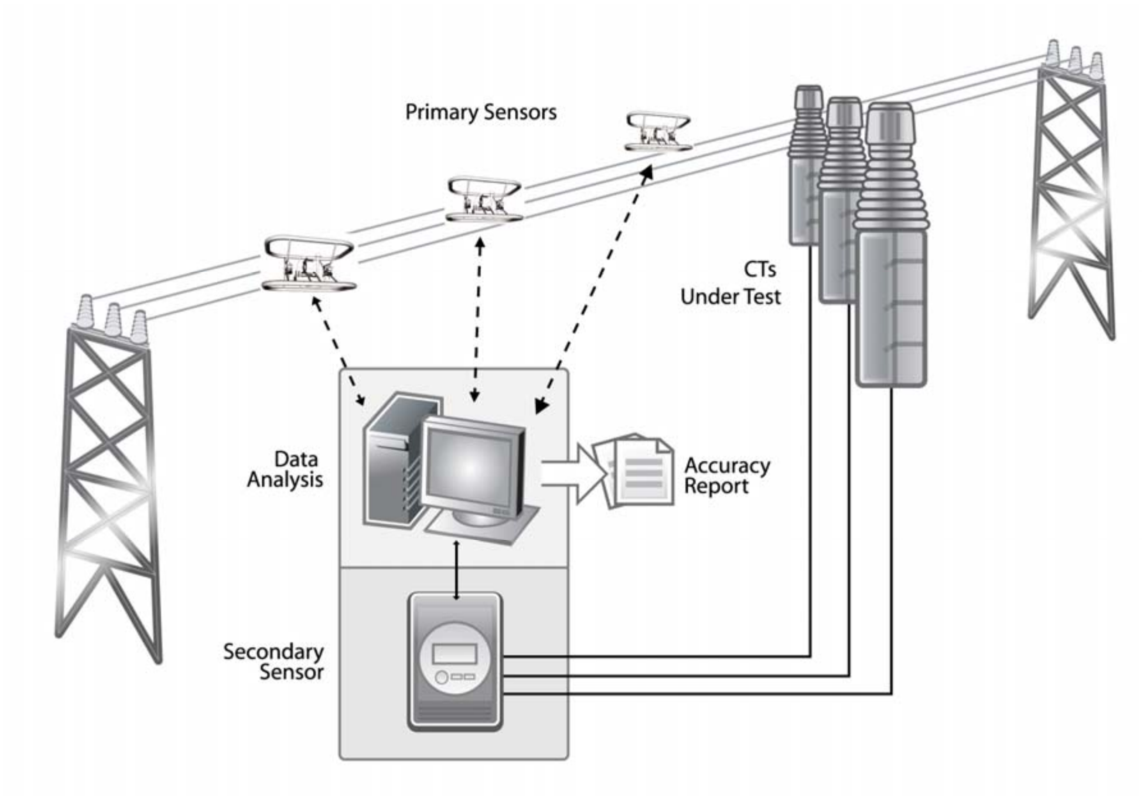


Figure 1 (above) illustrates a typical system installation in an high voltage substation. Traceable to NIST and NRC standards, three Primary Sensors are installed using live-line methods on the high-side bus in series with the circuit breaker containing the existing relay-class CTs under test. While mounted on the bus, the Primary Sensors each wirelessly stream data to a computer workstation in the nearby substation control building.

The software on the computer workstation communicates over the wireless link with each Primary Sensor. The software simultaneously communicates to an advanced 3-phase meter, known as the Secondary Sensor, which is connected to the secondary wiring of the existing relay-class CT under test. The software system collects global positioning system (GPS) time-synchronized data from each of the 3 Primary Sensors on the bus while also collecting corresponding GPS time-synchronized data from the meter connected to the secondary side of the CT under test.

The collected data is then analyzed. The software compares the time-synchronized data from the three Primary Sensors to the respective 3-phase data collected from the meter to calculate the appropriate ratio correction factors (RCF) and phase angle correction factors (PACF) for each test point over the dynamic operating range of the relay-class CT under test. These correction parameters are then programmed into the advanced revenue meter. This revenue meter dynamically corrects for the ratio and phase angle errors of the relay-class CT over its operational range. This effectively reclassifies the CT to be of revenue metering accuracy.

The Primary Sensors are then removed from the bus and the system is left with only the advanced revenue meter connected to the secondary wiring of the existing relay-class CTs. The revenue meter, using the correction parameters, measures highly accurate energy data and reports this back to the utility data collection and billing system.

System Components

The Primary Sensors

The Primary Sensors are installed, one per phase, on the HV conductors, typically in the feeder bay in the HV yard. They are installed so that they will measure the same current that passes through the CT under test. Each Primary Sensor has onboard recording of current magnitude and phase angle data. The unit can be configured via the Bluetooth link or serial port. When the test is complete, the data is sent to a computer via a Bluetooth wireless link. Once the unit is removed form the conductor, the data can also be extracted via a serial connection. An onboard GPS receiver provides time synchronization.

Figure2. Self-power HV Primary Sensor (left) and Figure 3, the Battery Powered Primary Sensor (above)

Features:

- Split core, active CT
- Self-powered
- Live-line installation
- Onboard GPS time synchronization
- Bluetooth wireless communications
- Electronics module for measuring RMS current magnitude and phase angle
- High voltage rating up to 765 kV

The Secondary Sensor

The Secondary Sensor consists of a single unit for measuring three separate phases. The unit is powered from a 120VAC receptacle and communicates via wireless Bluetooth. The unit connects into the test CT secondary circuit either via split-plugs in the existing test switch (preferable) or by hard wiring. An onboard GPS receiver located on the C phase card provides time synchronization. As the unit is typically located indoors, an outdoor GPS antenna is required.

Supporting hardware

The CT Reclassification system also contains the following hardware:

- Communication antennae for Bluetooth wireless
- GPS antenna for Secondary Sensor
- GPS repeater for Secondary Sensor
- PC for data acquisition
- Serial communication converters

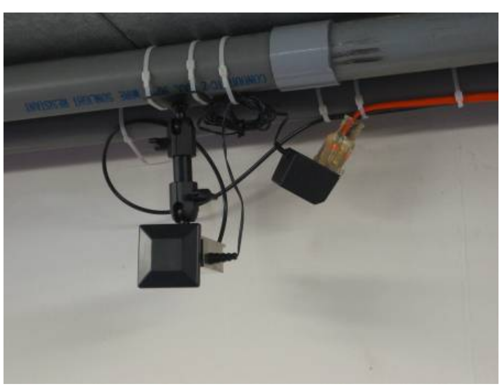


Figure 5. GPS repeater, if necessary, can be mounted inside the control building.

Field Procedure

Summary

1. Temporarily install high-accuracy, self-powered, clamp-on, wireless Primary Sensors on each phase of the bus at the desired high-voltage metering point.
2. Install a Secondary Sensor in the substation, connected to the secondaries of the CT under test.
3. Communicate wirelessly to the primary and Secondary Sensors.
4. Gather GPS time synchronized data on a PC from the Primary Sensors and the Secondary Sensor as the load varies on the system.
5. Analyze data and calculate the accuracy error of the CT under test.
6. Generate an accuracy report for each CT under test.
7. Remove the equipment.
8. Move on to the next metering point and repeat the procedure.

Figure 7. (above) Installing the HV Primary Sensor using hot sticks

Figure 8 (left) installing the Battery Powered Primary Sensor

List of Equipment Required

Part	Details	√
Laptop computer	Bluetooth capable with necessary software	
3x Primary Sensors	Sensors	
	16 Li cells for each sensor	
Secondary Sensor	Blue box	
	Power cord	
	6x Current test leads	
	3x split plugs	
GPS repeater with power supply	For repeating GPS signal to inside of building	
GPS antenna and mount	Fix / support outside of control room	
Coax cable and connectors (BNC for repeater, TNC for antenna end)	For connection between GPS repeater and outside GPS antenna.	
1x Power Bar	Supply power to laptop, Secondary Sensor, GPS repeater.	
1x Extension cable	25 foot for power to laptop, Secondary Sensor, GPS repeater..	
Standard tool kit	Screwdriver set, long nosed pliers, side cutters, small crescent wrench, wire strippers, multi-meter	
cable ties (12”)		
Spare parts for sensors	Boards, antennae, connectors etc TBD.	
Safety Equipment	Hardhats, safety shoes, eye protection, coveralls as required by customer site.	

Arrange for the Utility Company to provide:

Authorization to use split plugs in CT circuit (e.g. ABB FT Flexitest switch compatible test plug)	
Mounting for Secondary Sensor GPS antenna	
Hand Drill and assortment of bits (for antenna mounting if needed).	
Silicon sealer for hole to outside of relay house (if needed)	
2x Ladders (1 small, 1 tall): 1 to mount antenna on outside corner of control room; 1 to mount GPS repeater on inside of control room.	
Location for Secondary Sensor (probably on the floor next to metering panel)	
2x Shot gun hot sticks	
One set of drawings for station	
Hard Hats for those who need them	

CT Specifications

CT Manufacturer and Model:	
CT Ratio:	
CT Type (relay/Metering):	

VT Specifications

VT Manufacturer and Model:	
VT Ratio:	
System Voltage:	

Primary Sensor Serial Numbers	
	A-phase
	B-phase
	C-phase

Typical Workflow

Site walk:

- Hold discussions with utility contacts to go over the pre-commissioning checklist.
- Review the appropriate substation drawings.
- Perform a site walk to meet contacts, determine proposed location of equipment and distances between locations. Take photos.
- Make appropriate arrangements if there is protection equipment connected to the test CT secondary.

Before commissioning:

- Check and calibrate (if necessary) the Primary and Secondary Sensors
- Assemble and test the whole system in Victoria.
- Pack and ship equipment to site with enough lead time (allow 1 week to the USA).

Installing the system:

- Complete the form part of this document with details for this deployment.
- Place Secondary Sensor at the Test Switch panel in the Control Room.
- Install GPS repeater if necessary. Otherwise, deploy GPS antenna with direct connection to Secondary Sensor.
- Connect the Secondary Sensor to the test CT circuit using a split plug in the CT test switch.
- Apply power to the Secondary Sensor from a 120VAC wall receptacle
- Using the laptop, verify communication to Secondary Sensors. Check GPS levels (only available on Phase C). Set CT ratio. In general verify readings/operation are as expected.
- Install batteries in the Primary Sensors if necessary.
- Check communications to Primary Sensors before installation.
- Witness and advise on installation of Primary Sensors on HV conductors. If work is done dead, then System Control makes the system live. Monitor state of line using the installed power meter.
- Install Primary Sensors on HV conductors and liven up.
- Configure the Primary Sensors using the laptop. Verify communication to Primary Sensors. Check GPS levels. Set CT ratio. Generally verify that readings/operation are as expected.
- Check that each sensor pair is in-phase.
- Configure logging intervals on all sensors to desired rate (1 minute)
- Take photos of (try to capture panel/equipment labels for records):
    - Primary Sensors in location
    - CT / breaker name plates
    - Secondary Sensor with split plugs installed

Load variance

To fully test the CT, the load must vary to exercise the CT through its dynamic range. There are two ways to perform this load variance:

1: Operator assisted load variance:

- This method of load variance on the CT requires the assistance of an operator to switch loads in the substation, thus varying the current through the CT under test.
- This method allows a complete test of a CT in less than one day.
- This is the desired method of load variance, but due to system constraints, substation design and operating procedures, it may not always be feasible.

2: Natural Load Variance:

- This method relies on the natural loading of the system to exercise the CT through a dynamic range.
- This method is used if the CT is on a circuit that is critical and cannot be varied manually by operator intervention.
- With natural load variance, a full sweep of current values is not always achievable.
- This method can capture more than 90% of the CT's operating range over a 14-day period.
- Statistically, CTs show good linearity from 20%-100% of load, and values can be extrapolated to determine the accuracy at points not measured by the system.

Uninstalling the system

- If there is protection equipment in CT secondary circuit, make appropriate arrangements to block tripping before removing split plugs.
- Switch off power to the Secondary Sensor.
- Pull Split plugs, return to normal and replace covers on test switches.
- Unblock protection tripping if it was blocked.
- Arrange for removal of sensors from HV conductors.
- If used, remove batteries and dispose of properly.

Downloading data

- Apply power to all sensors.
- Using the laptop and the SuperMon software application, start download of data. (approx 2 hours)

Data collection and analysis

The system software is designed to perform three main functions

- Data collection
- Data analysis
- Report generation

The following procedures are performed by a certified Schneider Electric service engineer:

Steps:

1. Initiate the software to automatically and continuously collect data from all phases of the Primary Sensor (e.g. Phase A, Phase B, Phase C) over the Bluetooth link
2. Initiate the software to automatically and continuously collect data from all phases of the Secondary Sensor (e.g. Phase A, Phase B, Phase C) over the serial link.
3. System collects data over the necessary range of current, as the system varies its load.
4. Analyse the collected data, performing statistical analysis to calculate Ratio Correction Factor (RCF) and Phase Angle Correction Factor (PACF) for each CT under test.
5. Generate a certified and traceable accuracy report for each CT, based on the system calculated RCF and PACF error parameters.

Data Analysis

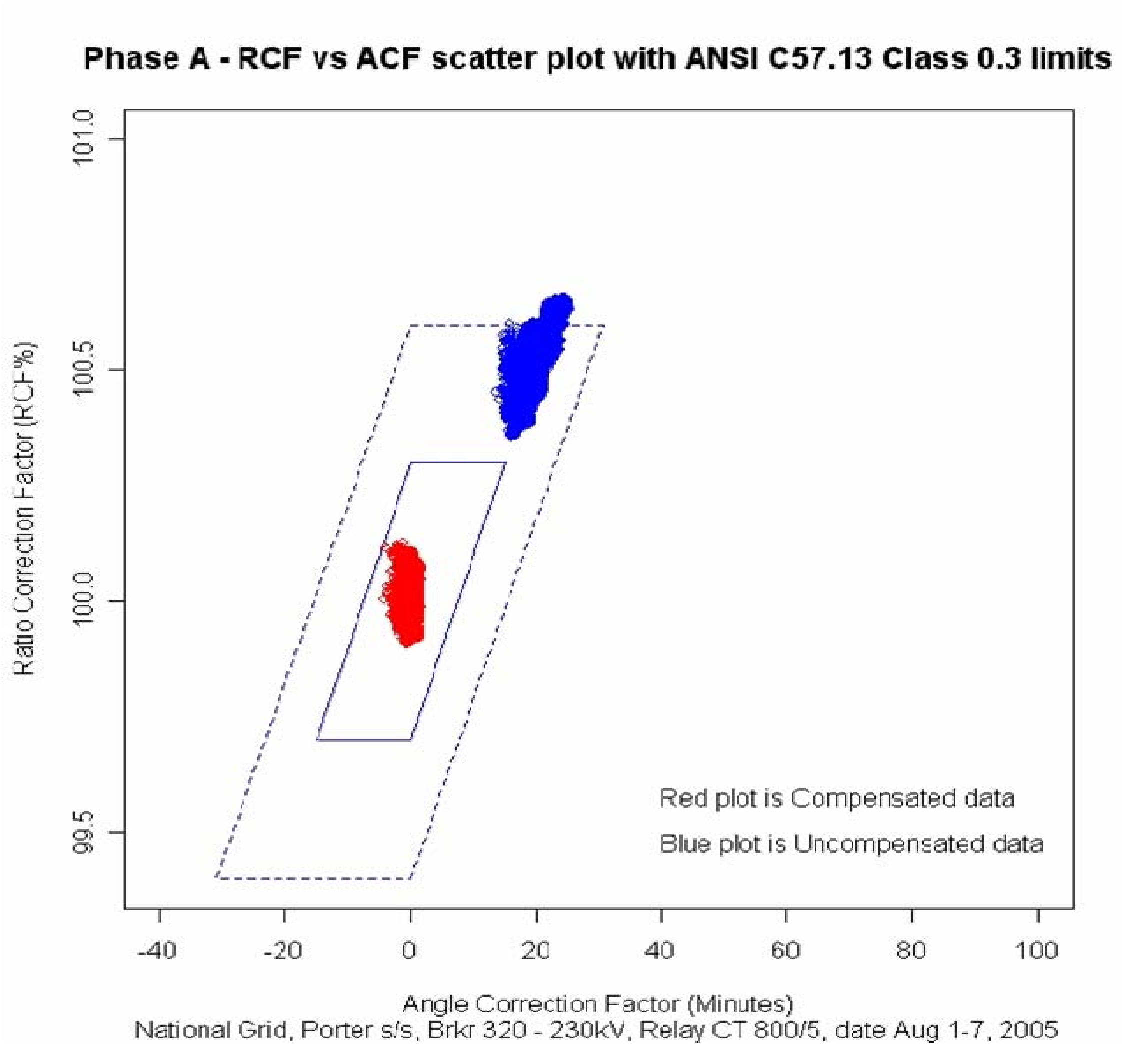
- Process the data using a custom Excel macro to provide ITC constants. The Excel macro application checks the sampled data and discards bad samples along with the synchronous sample form the other sensor.
- Examples of bad samples could include GPS not locked, once-off extreme RMS current values, etc.
- The macro then assigns the data into bins of like sample points.
- Linear regression is applied to the binned data to obtain 8 points on the CT characteristic for each of Ratio Correction Factor (RCF) and Angle Error.

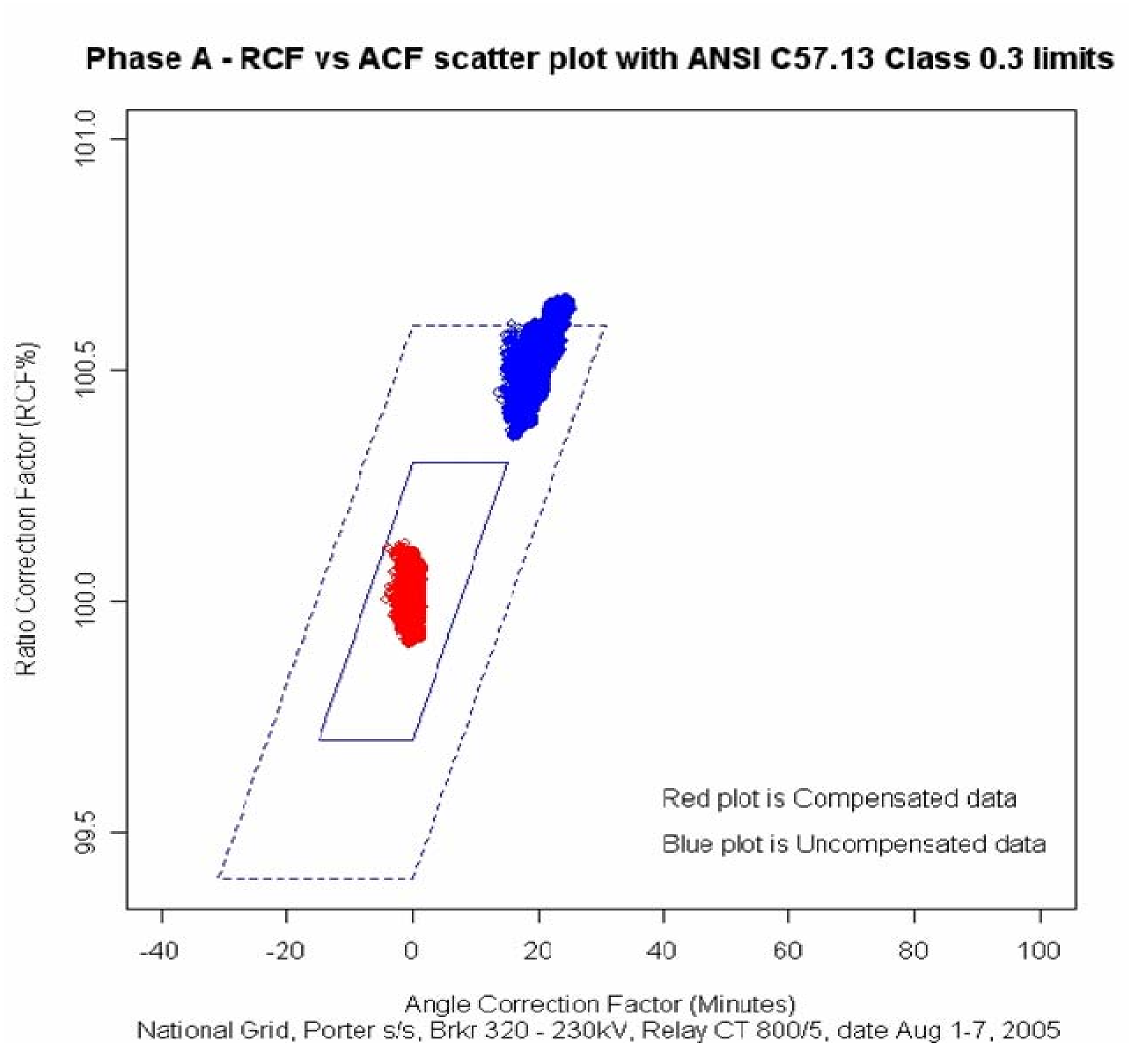
Program meter with ITC constants

- Apply Instrument Transformer Correction data to the PowerLogic ION8000 series meter.
- PT/CT Correction can be configured in the ION8600 via ION software using ION Setup
- The PT/CT Correction Setup Assistant allows you to configure the *Instr Xformer* modules on the ION meters
- Open ION Setup and connect, in Basic Mode, to the desired meter
- Open the Revenue folder in the Setup Assistant and click PT/CT Correction
- For each desired tab, select the Correction Type, and simply input the Ratio Correction Test Data and the Phase Correction Test Data points

The Instrument Transformer Correction module is a core module; there is an ITC module for each current input (I1, I2, I3, I4) and for each voltage input to the meter (V1, V2, V3). Note that the correction affects only the 1 second values in the Power Meter module. No highspeed, harmonics, or waveform values are affected by the correction.

Please see the *Sample Report* in Appendix A for graphs and tables.


Phase A - RCF vs ACF scatter plot with ANSI C57.13 Class 0.3 limits
Ratio Correction Factor (RCF%)
101.0
100.5
100.0
99.5
Red plot is Compensated data
Blue plot is Uncompensated data
-40
-20
0
20
40
60
80
100
Angle Correction Factor (Minutes)
National Grid, Porter s/s, Brkr 320 - 230kV, Relay CT 800/5, date Aug 1-7, 2005



Manufacturing Standards

Schneider Electric's patented ION® technology is developed in world-class production and test facilities, along with an ISO-certified quality system, to ensure a wide range of the best products the market has to offer. We are the world's leading designer and manufacturer of advanced power monitoring devices and software certified to ISO 9000 Quality Assurance standards.

Schneider Electric certifies that our manufactured Power Monitoring and Control products meet published specifications and are calibrated and tested using equipment and standards traceable to the National Institute of Standards and Technology (**NIST**) in the US or the National Research Council of Canada (**NRC**).

As pioneers in the field of energy information and control we continue to define the leading edge. Our innovations include:

- First micro-processor based power meter

- First meter with remote communications capability
- First PC-based software for remote power monitoring
- First meter with on-board data, event, and fault recording
- First meter with programmable set-point capabilities
- First meter with object-oriented modularity and flexibility
- First revenue-approved meter with Ethernet support
- First meters with full Internet connectivity

Appendix A: Sample Report

Current Transformer Reclassification Data Analysis

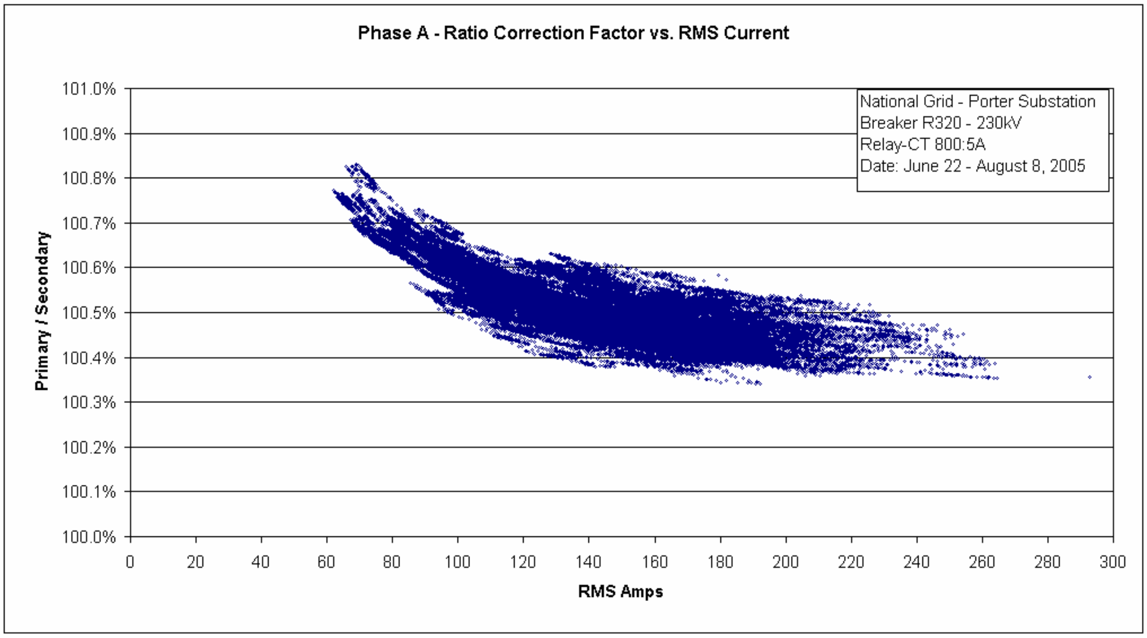
National Grid - Porter Substation
230kV Circuit Breaker R320
Relay-class bushing CT 800:5A
Phase A

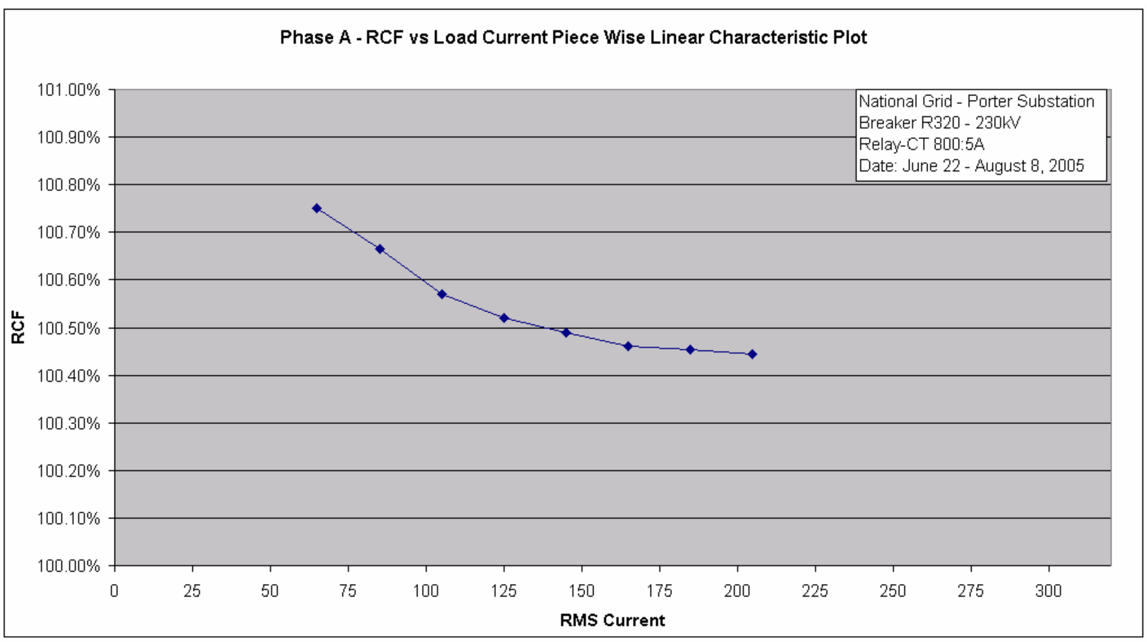
Date: June 22 – August 8, 2005

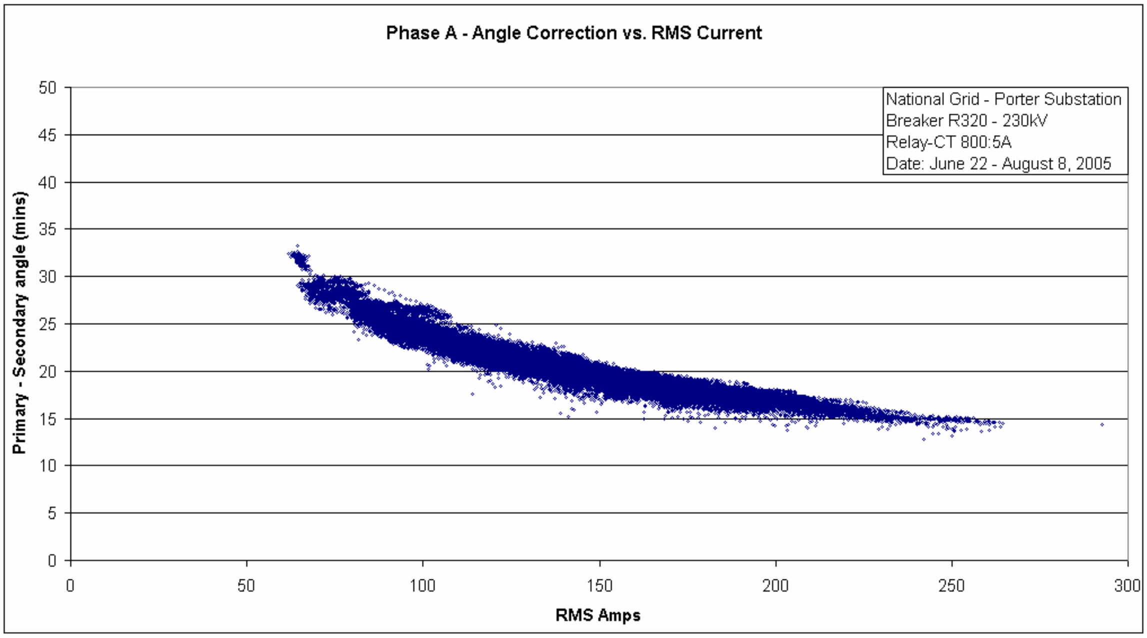
Schneider Electric

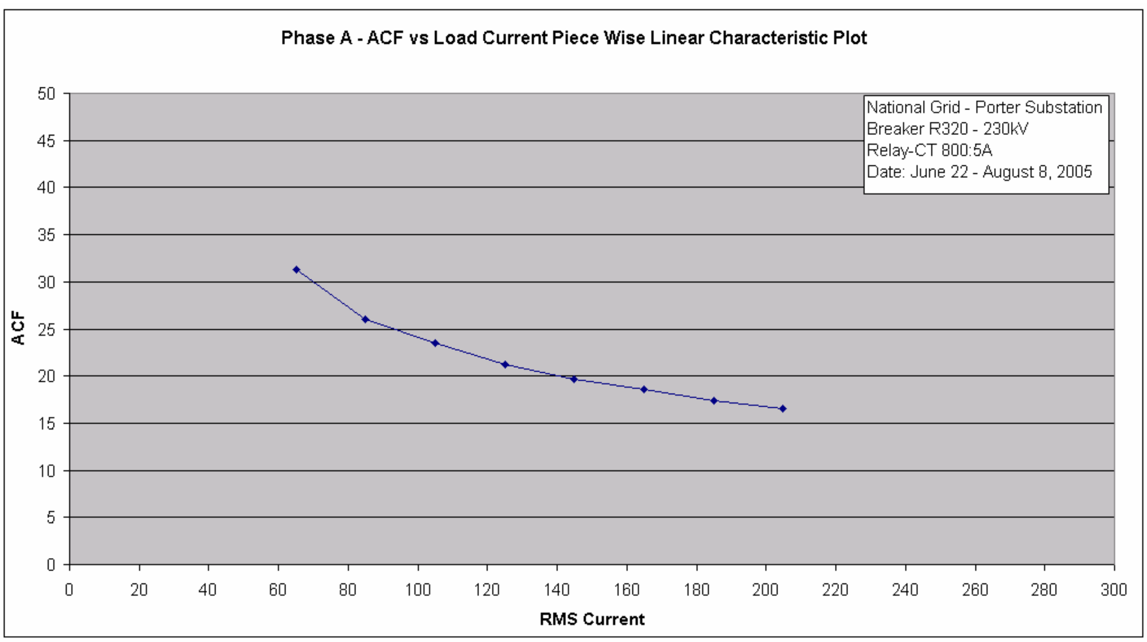
Version History

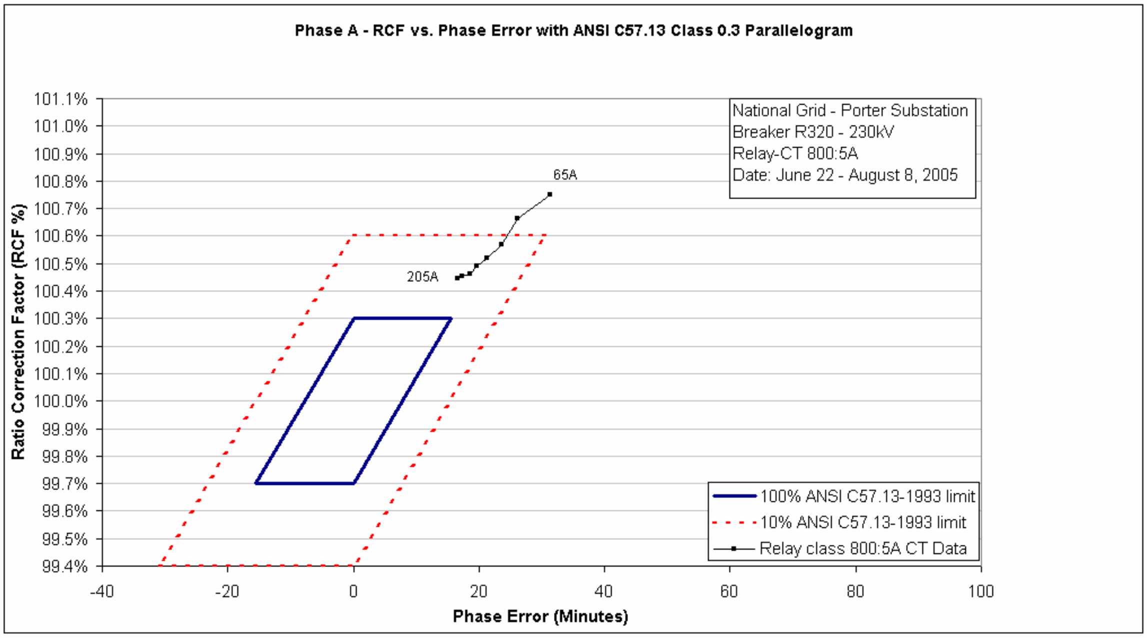
Version	Date	Author	Comments
V1	August 9, 2005	Eric Haight	RCF & ACF Scatter Plots and Piece Wise Linear Plots, Parallelogram Plot, Load Profile Plot and Histogram
V2	August 10, 2005	Eric Haight	Added RCF & ACF Data Points

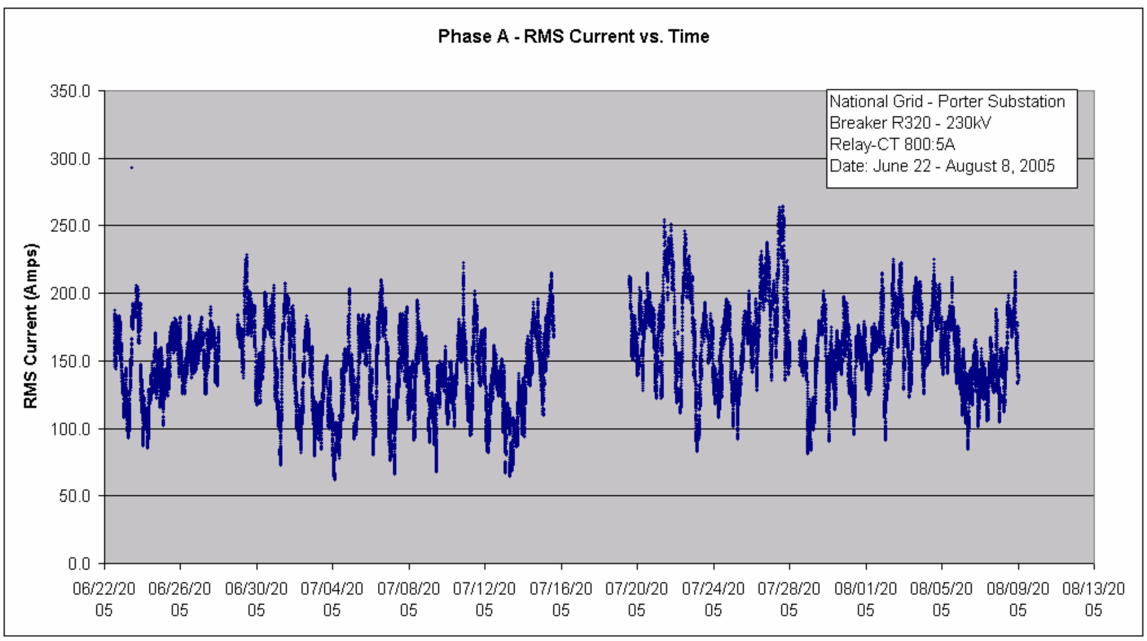

Phase A - Ratio Correction Factor vs. RMS Current
National Grid - Porter Substation
Breaker R320 - 230kV
Relay-CT 800:5A
Date: June 22 - August 8, 2005
Primary / Secondary
101.0%
100.9%
100.8%
100.7%
100.6%
100.5%
100.4%
100.3%
100.2%
100.1%
100.0%
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
RMS Amps

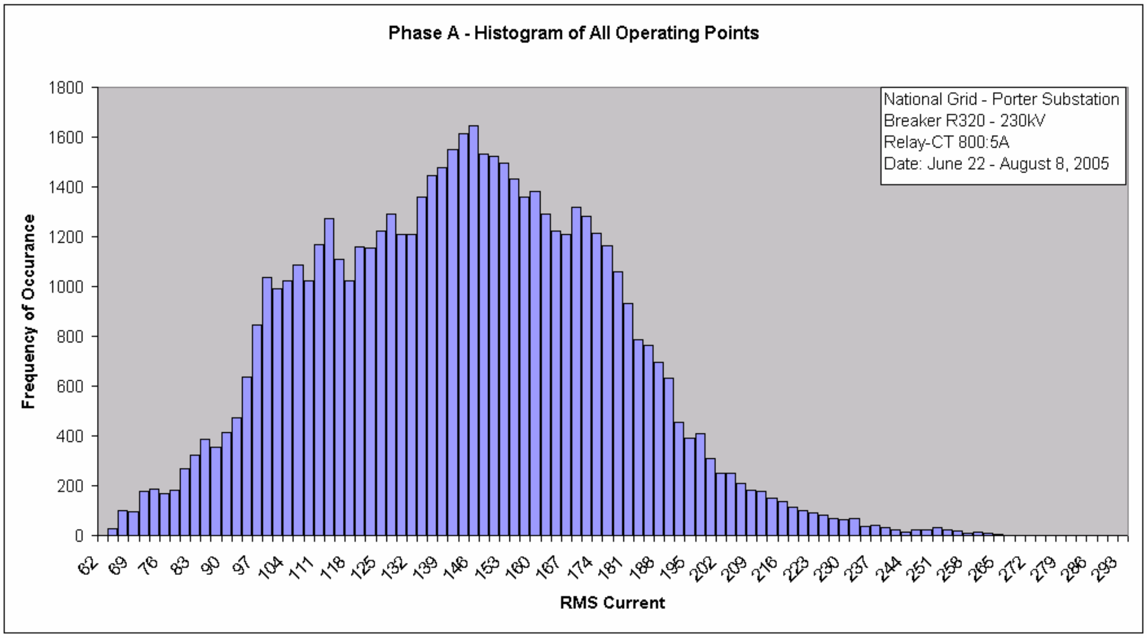

Phase A - RCF vs Load Current Piece Wise Linear Characteristic Plot
National Grid - Porter Substation
Breaker R320 - 230kV
Relay-CT 800:5A
Date: June 22 - August 8, 2005
RCF
101.00%
100.90%
100.80%
100.70%
100.60%
100.50%
100.40%
100.30%
100.20%
100.10%
100.00%
0
25
50
75
100
125
150
175
200
225
250
275
300
RMS Current


Phase A - Angle Correction vs. RMS Current
National Grid - Porter Substation
Breaker R320 - 230kV
Relay-CT 800:5A
Date: June 22 - August 8, 2005
Primary - Secondary angle (mins)
RMS Amps
0
5
10
15
20
25
30
35
40
45
50
0
50
100
150
200
250
300


Phase A - ACF vs Load Current Piece Wise Linear Characteristic Plot
National Grid - Porter Substation
Breaker R320 - 230kV
Relay-CT 800:5A
Date: June 22 - August 8, 2005
ACF
RMS Current
0
5
10
15
20
25
30
35
40
45
50
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300


Phase A - RCF vs. Phase Error with ANSI C57.13 Class 0.3 Parallelogram
National Grid - Porter Substation
Breaker R320 - 230kV
Relay-CT 800:5A
Date: June 22 - August 8, 2005
65A
205A
Ratio Correction Factor (RCF %)
Phase Error (Minutes)
100% ANSI C57.13-1993 limit
10% ANSI C57.13-1993 limit
Relay class 800:5A CT Data


Phase A - RMS Current vs. Time
National Grid - Porter Substation
Breaker R320 - 230kV
Relay-CT 800:5A
Date: June 22 - August 8, 2005
RMS Current (Amps)


Phase A - Histogram of All Operating Points
National Grid - Porter Substation
Breaker R320 - 230kV
Relay-CT 800:5A
Date: June 22 - August 8, 2005
Frequency of Occurance
RMS Current
1800
1600
1400
1200
1000
800
600
400
200
0
62
69
76
83
90
97
104
111
118
125
132
139
146
153
160
167
174
181
188
195
202
209
216
223
230
237
244
251
258
265
272
279
286
293

RCF ITC Data Points								
Point#	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
RMS center	65	85	105.0	125.0	145.0	165.0	185.0	205.0
Bin Width	1%	1%	1%	1%	1%	1%	1%	1%
Bin Width (Amps)	0.65	0.85	1.05	1.25	1.45	1.65	1.85	2.05
Count	56	259	979	1345	1998	1702	1191	395
Mean RMS	65.0	85.0	105.0	125.0	145.0	165.0	185.0	204.9
Mean RCF	100.75%	100.66%	100.57%	100.52%	100.49%	100.46%	100.45%	100.45%
RCF Std Deviation	0.0001	0.0003	0.0003	0.0004	0.0004	0.0004	0.0004	0.0004
Confidence Interval	0.00%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.01%
Min	100.74%	100.57%	100.48%	100.40%	100.38%	100.36%	100.34%	100.36%
Max	100.77%	100.71%	100.65%	100.62%	100.61%	100.59%	100.55%	100.54%
diff	0.03%	0.14%	0.17%	0.21%	0.23%	0.23%	0.20%	0.18%

ACF ITC Data Points								
Point#	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
RMS	65	85	105.0	125.0	145.0	165.0	185.0	205.0
Width	1%	1%	1%	1%	1%	1%	1%	1%
Width (Amps)	0.65	0.85	1.05	1.25	1.45	1.65	1.85	2.05
Count	56	259	979	1345	1998	1702	1191	395
Mean RMS	65.0	85.0	105.0	125.0	145.0	165.0	185.0	204.9
Mean ACF	31.3	26.1	23.5	21.3	19.7	18.6	17.4	16.6
ACF Std Deviation	1.18	0.77	0.84	0.65	0.66	0.54	0.57	0.62
Confidence Interval	0.70	0.21	0.12	0.08	0.07	0.06	0.07	0.14
Min	28.56	23.82	21.28	19.14	16.64	16.26	14.58	13.78
Max	33.24	29.25	26.43	23.92	21.78	19.92	19.06	17.90
diff	4.68	5.43	5.16	4.78	5.14	3.66	4.48	4.12

I rated:	800		
Current	***Test Point (% rated I)***	***RCF***	***ACF***
65	8.13	1.0075	31.28
85	10.63	1.0066	26.07
105	13.13	1.0057	23.54
125	15.63	1.0052	21.26
145	18.13	1.0049	19.72
165	20.63	1.0046	18.55
185	23.13	1.0045	17.40
205	25.63	1.0045	16.57

ITC Constants

Magnitude Correction text string:
{8.13,1.0075},{10.63,1.0066},{13.13,1.0057},{15.63,1.0052},{18.13,1.0049},{20.63,1.0046},{23.13,1.0045},{25.63,1.0045}

Phase Angle Correction text string:
{8.13,31.28},{10.63,26.07},{13.13,23.54},{15.63,21.26},{18.13,19.72},{20.63,18.55},{23.13,17.4},{25.63,16.57}

These text strings are entered into the appropriate fields in the Instrument Transformer Correction Module in the ION Power Meter. A detailed description of the ITC Module can be found in the ION Reference Online Help file (as installed with ION Enterprise)