ANSI Instrument Transformers, Pinetops, NC

Kuhlman Field Engineering Services
Instrument transformer on-site testing

Field Engineering Services

Field Engineering Services (cont.'d)

- Turnkey installation
  - Install new units – all sizes, all manufacturers
- Contract services
  - Remove, relocate, reassemble existing units
  - Retro-fit units with new equipment
  - Oil processing, oil dryout

Field Engineering Services (cont.'d)

- Special services
  - On-site testing of Instrument transformers
  - Provide training for maintenance and/or operation
  - Installation of transformer coolers and pumps – GEA/R&G
  - Installation of transformer monitoring equipment – DR Monitoring and control
  - Installation of transformer protector equipment – TPC Corporation

On-site test capability
FES in-service and on-site accuracy testing

KUHLMAN ELECTRIC CORPORATION
101 KUHLMAN DRIVE
CRYSTAL SPRINGS, MS 39059

CERTIFIED INSTRUMENT TRANSFORMER TEST REPORT

Customer: KUHLMAN ELECTRIC

S.W.O. No: 431489
Order No.: XX
Cust. Order No.: XX
Catalog No.: XX
Type: -350
Spec. No.: XX

Accy. Rating: XX
Ratio: 1:1

BIL: 350 (KV)
N.S.V.: (KV)
Primary Voltage: 115 (V)
Secondary Voltage: 115 (V)
Tertiary Voltage: 57.5 (V)
Frequency: 60 (Hz)
Thermal Rating (VA): XX (VA)

SERIAL #: 4314890201 PAGE #: 1 OF 1

PRI. VOLT.: 115

SEC. CONN.		SEC. VOLT.		
X1 - X3		115		
X1 - X2		57.5		

POLARITY: OK

INDUCED POTENTIAL: 840 KV @ 400 Hz for 18 sec.

APPLIED POTENTIAL:
PRI-SEC & GND 10 KV @ 60 Hz for 60 sec.
SEC-PRI & GND 10 KV @ 60 Hz for 60 sec.

EACH UNIT RIV AND PCB FREE

Tests performed have been carried out in our test laboratory in accordance with latest revision of ANSI/IEEE C57.13 and customer specifications.

Certified: David Walker Tester: DW Date: 09/27/02

09/27/2002 FQP5-05-02-1 RE

Generation/Transmission needs for instrument transformers (ITs)

- Competitive electric utility market
  - More power wheeling/power needs
  - Control of supply chain resources
  - Requires reliable power delivery
  - Equipment availability

Generation/Transmission needs for ITs (cont.'d)

- Deregulation of electric power
  - GENCO to TRANSCO separation
  - ISO activity requires metering
  - Need to use existing ITs
- Bottom-line focused
  - Billing and current swings
  - Must verify performance of ITs

On-site accuracy testing of ITs

- In-service (Burden Injection) testing
  - Excitation characteristics verification
  - Done on-line/no outage
- Revenue metering (Voltage Injection) testing
  - Brief outage
  - Traceable to NIST (Revenue Billing)
  - Each CT given RCF and PA data
- Voltage and current comparator testing
  - Brief outage
  - Comparator testing as stated in IEEE standard
  - BCTs and also voltage transformers (VTs) up to 34.5 kV

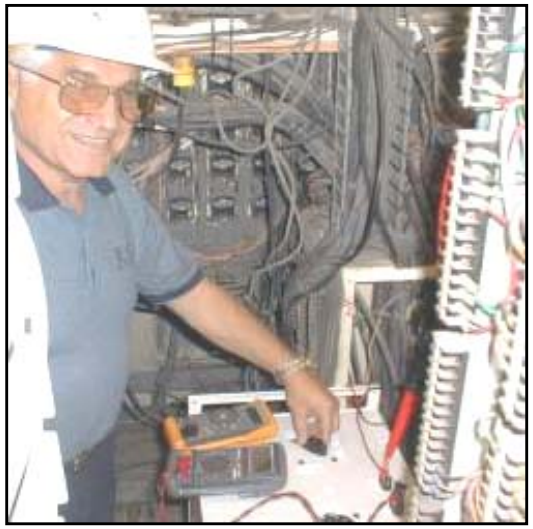
On-site accuracy testing of ITs (cont.'d)

- Test applicable for many applications
  - Bushing current transformers (BCTs) in power transformers
  - BCTs in dead tank circuit breakers
  - Free standing current transformers (CTs)
  - Specialized testing for CT continuous current capability
  - VTs up to 34.5 kV

FES In-service CT testing

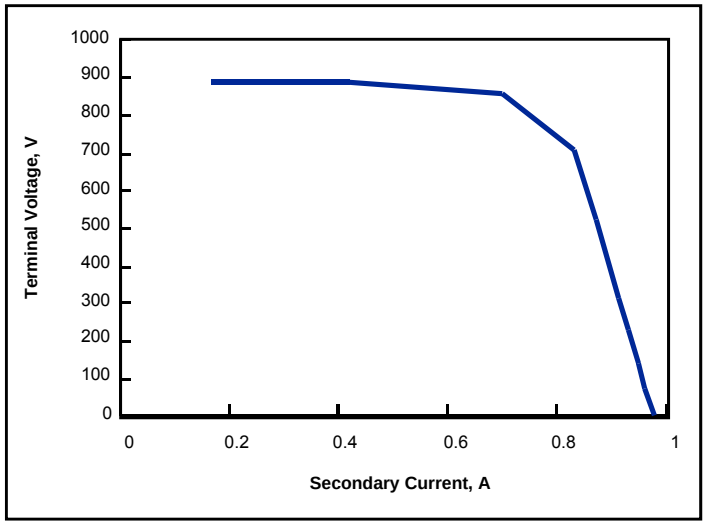
- In-service (Burden Injection) testing
  - On-line evaluation of BCT/Generator Current Transformers (GCTs)
    - CT excitation performance
    - General CT accuracy verification
    - CT and load problems identified
    - Testing of GCTs without outage
  - Results oriented testing
    - CT health and performance
    - Define mode of failure
    - Wiring verification

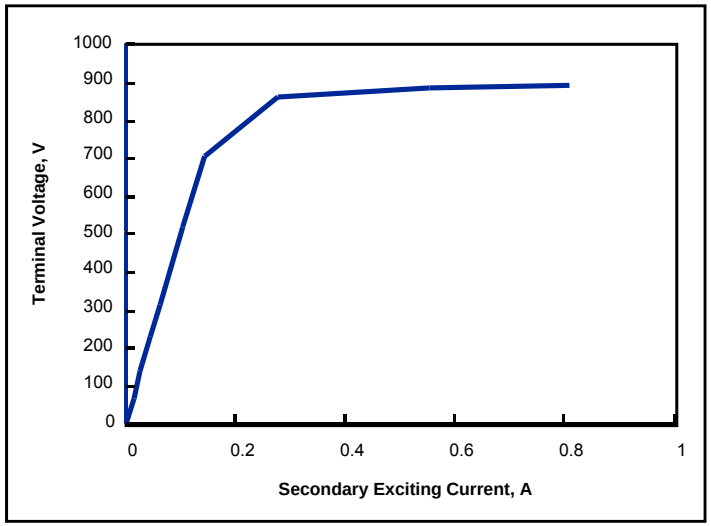
FES In-service CT testing (cont.'d)



- Secondary access only – energized primary
  - Variable resistance type of test
    - Access needed to shorting block to replace CT burden
    - Existing BCT burden disconnected (1-2 minutes)
    - CT secondary V and I readings at each burden

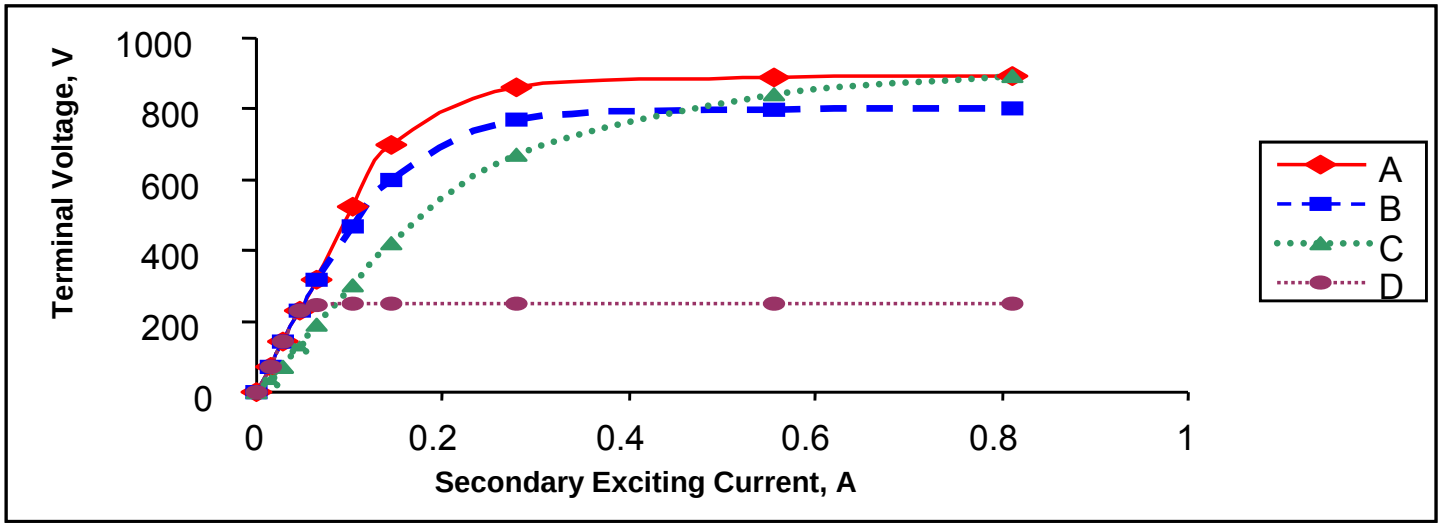
FES In-service CT testing (cont.'d)





- Excitation curve generated for each unit tested
  - Excitation current defined as reduction in secondary current
  - Done during stable primary current operation

Current transformer modes of failure



- Design model of correct current transformer curve performance
- Current transformer with turn to turn fault
- CT core lamination insulation failure/cores with mechanical deformation.
  - (If return points match Curve A – the core was magnetized).
- Current transformer with winding or secondary wiring insulation failure

FES In-service CT testing (cont.'d)

- Passive in nature
- Burden injection
- Done while CT is in service under normal operation
- Secondary current and voltage from the CT is recorded with burden changes up to saturation
- Excitation current (derived from the current decline at each burden) and plotted versus voltage
- Individual excitation curve developed for each CT tested
- Curve data identifies CT performance

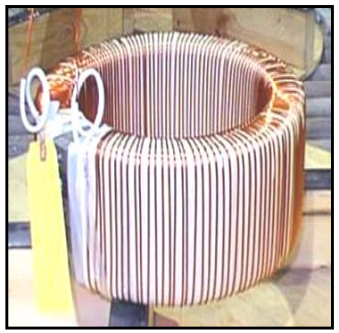
Revenue metering (voltage injection) testing

- Revenue metering verification voltage injection testing
  - Off-line test
    - Short outage for testing
    - CT remains installed
  - RCF and PA metering certification
    - CT fundamental design parameters
    - On site measurements
  - NIST traceability
    - Instrumentation traceable to NIST
    - Metering data extracted from actual readings

Metering opportunities





- Any relaying CT located inside major electrical equipment can potentially provide metering accuracy capability.

Standard IEEE C57.13 (1993)
Metering accuracy requirements

- ITs must meet standard specifications
  - Current transformers 0.3% @ rated burden
  - Voltage transformers 0.3% @ rated burden
- Current transformers (CT)
  - Error of +/-0.3% at 100% current
    - (Error of +/-0.6% at 10% current)
  - CT rated burden to meet site needs
- Voltage transformers (VT)
  - Error of +/-0.3% at 90-110% volts
  - VT rated burden to meet site needs

Revenue metering (voltage injection) testing

- Only secondary connections needed - open primary
  - CTs remain installed inside of equipment
    - Primary circuit opened somewhere
    - Very clearly defined CTs tested
    - Test equipment used very portable
  - Use voltage injection
    - Energizes CT secondary
    - On site measurements of VA, watts, ex. Current
  - Results are traceable for accuracy use
    - RCF and PA readings provided for tested CTs
    - Quick testing timing (one minute per CT)
    - Test report issued on each CT

Injection vs. comparator method

- Equipment traceable to NIST standards
  - Field readings have NIST traceability
- RCF and PA based on empirical CT design formulas
  - Ratio error (RE)= Io x sin (θ + ϕ) / Isec (RE is proportional to core loss current)
  - Phase angle (PA)= Io x cos (θ + ϕ) / Isec (PA is proportional to the magnetizing current)
- Test for accuracy using knopp tester vs. injection method
  - Equivalent results

Site test data

- On site CT accuracy testing
  - Measured components:
    - Secondary winding resistance
    - Voltage representing operating levels
    - Exciting current into CT
    - Watts into CT
    - VA reading

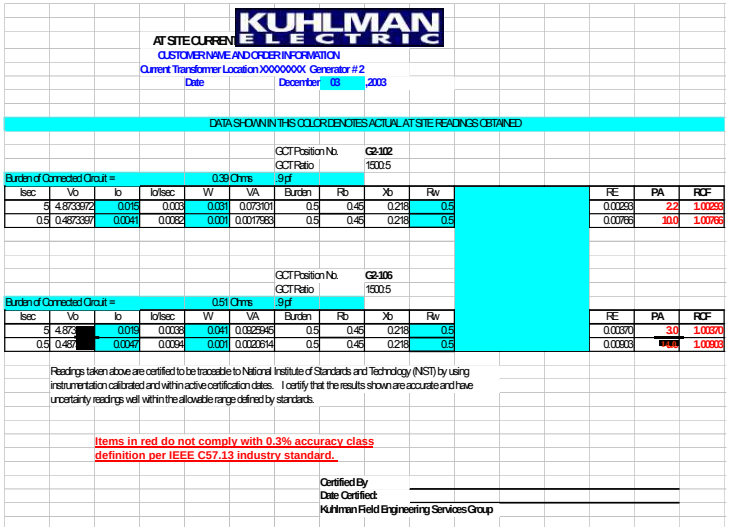
Site test data (cont.'d)

Isec	Vo	Io	Io/Isec	W	VA	Burden	Rb	Xb	Rw	RE	PA
5	9.45	0.0068	0.00136	0.04100	0.0643	1.8	1.62	0.785	0.1	0.00131	1.2
0.5	0.95	0.001	0.0019	0.00065	0.0009	1.8	1.62	0.785	0.1	0.00180	2.1
5	4.95	0.0055	0.0011	0.01700	0.0273	0.9	0.81	0.392	0.1	0.00106	1.0
0.5	0.50	0.0008	0.0016	0.00028	0.0004	0.9	0.81	0.392	0.1	0.00149	2.0
5	2.96	0.005	0.001	0.00900	0.0148	0.5	0.45	0.218	0.1	0.00096	0.9
0.5	0.30	0.0006	0.0012	0.00013	0.0002	0.5	0.45	0.218	0.1	0.00108	1.8

Ratio Error and Phase Angle values are derived from actual site readings

- Calculated values:
  - Voltage at operating levels
  - Angles between VA and watts
  - Angle between Z and X of burden
  - Ratio error
  - Phase angle

Transformer test information certified reports



KUHLMAN ELECTRIC

AT SITE CURRENT

CUSTOMER NAME AND ORDER INFORMATION

Current Transformer Location XXXXXXXX Generator # 2

Date December 03 ,2003

DATA SHOWN IN THIS COLOR DENOTES ACTUAL AT SITE READINGS OBTAINED

GCT Position No. G2-1U2

GCT Ratio 1500:5

Burden of Connected Circuit = 0.39 Ohms .9 pf

Isec	Vo	Io	Io/Isec	W	VA	Burden	Rb	Xb	Rw		RE	PA	RCF
5	4.8733972	0.015	0.003	0.031	0.073101	0.5	0.45	0.218	0.5		0.00293	2.2	1.00293
0.5	0.4873397	0.0041	0.0082	0.001	0.0017983	0.5	0.45	0.218	0.5		0.00766	10.0	1.00766

GCT Position No. G2-1U5

GCT Ratio 1500:5

Burden of Connected Circuit = 0.51 Ohms .9 pf

Isec	Vo	Io	Io/Isec	W	VA	Burden	Rb	Xb	Rw		RE	PA	RCF
5	4.873	0.019	0.0038	0.041	0.0925945	0.5	0.45	0.218	0.5		0.00370	3.0	1.00370
0.5	0.487	0.0047	0.0094	0.001	0.0020814	0.5	0.45	0.218	0.5		0.00903	[illegible]	1.00903

Readings taken above are certified to be traceable to National Institute of Standards and Technology (NIST) by using instrumentation calibrated and within active certification dates. I certify that the results shown are accurate and have uncertainty readings well within the allowable range defined by standards.

Items in red do not comply with 0.3% accuracy class definition per IEEE C57.13 industry standard.

Certified By

Date Certified:

Kuhlman Field Engineering Services Group

- Traceable to industry standards
  - Actual ratio tap used for metering being tested
    - At important current levels (10% and 100%) or user defined levels
    - At applicable burden to support – actual burden measured on site
  - Certified report issued
    - Within two weeks of test
    - Can be used for revenue capture
    - Any unit not meeting 0.3% highlighted in red

Injection metering accuracy testing summary

- Field testing (over a 12 month period)
  - 100 generator CTs
  - 233 station service CTs
  - 39 oil circuit breaker CTs
- Ratios/CTs tested
  - 200:5 to 35000:5
  - GCTs, BCTs, and wound CTs

Injection metering accuracy testing summary (cont.'d)

- Accuracy results
  - Generator CTs = 87 of 100 CTs (87% in 0.3% class)
    - 9000:5 ratio CTs 0.6% (9 cores not annealed)
    - 1200:5 ratio CTs 0.6%
  - Station service CTs = 176 of 233 CTs (75.6% in 0.3% classes)
    - 200-800:5 ratio CTs 0.6%
  - OCB CTs = 18 of 39 CTs (46% in 0.3% classes)
    - 800:5 tap ratio CTs 0.6%

CT design information

- Metering CTs
  - Revenue 0.3% demands
    - 0.3% maximum error at 100% rated current
    - 0.6% maximum error at 10% rated current
  - Can be turns compensated (biased to achieve best accuracy at rated burdens)
- Relaying CTs
  - Core sized to develop a specified voltage at fault level operation
  - Generally good metering accuracy at high ampere-turns/large core cross-section
  - Non-compensated design (actual turns count equal nameplate ratio information)

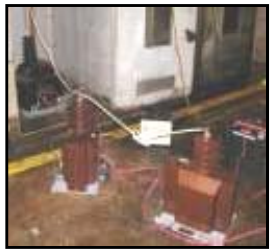
CT design information (cont.'d)

- Majority of relay CTs are metering accurate
  - C400/C800 rated – 600:5 ratios and higher
  - Large core cross-section = low operating flux densities
  - No supporting test certifications
- Not all relay CTs with ratios above 1000:5 are accurate
  - Non-annealed relay cores
  - Cores that have experienced mechanical tension (higher Iex)
  - Turn-to-turn problems with CTs windings

True comparator CT accuracy test

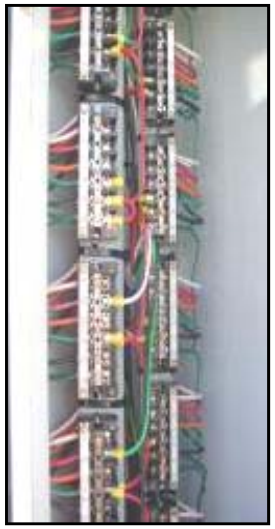
- CT secondary and primary access
  - Off-line test for BCTs in OCBs
    - Outage for testing
    - Isolated from primary circuit
  - RCF/PA certification - comparator method
    - Highly accuracy comparator & standard transformer
    - Driver transformer
    - Accurate burdens
  - NIST trace-ability
    - Standard and comparator traceable to NIST
    - RCF and PA readings recorded

On site VT accuracy testing



- True comparator accuracy testing through 34.5 kV
  - Primary and secondary access needed
    - Off-line test
      - Outage for testing
      - Isolated from primary circuit
    - RCF/PA certification - voltage comparator method
      - Highly accurate comparator and standard VT
      - Driver transformer
      - Accurate burdens
    - NIST trace-ability
      - Comparator and standard VT traceable to NIST
      - Actual readings on RCF and PA taken

Current transformer test
Continuous thermal current rating factor



- Determine CT current capability
  (so as to not limit main apparatus use at higher currents)
  - Off-line test-secondary access only
    - Outage for testing
    - Primary circuit opened
  - Define application
    - Bushing size/voltage rating
    - Distance from terminal block to CT
    - Wire size of secondary leads
    - Ratio of CT tested
  - Define exact winding resistance
    - Accurate measure of winding DC resistance
  - Perform excitation test
    - Develops the core size
    - CT loss characteristics

Current transformer test (cont.'d)
Continuous thermal current rating factor

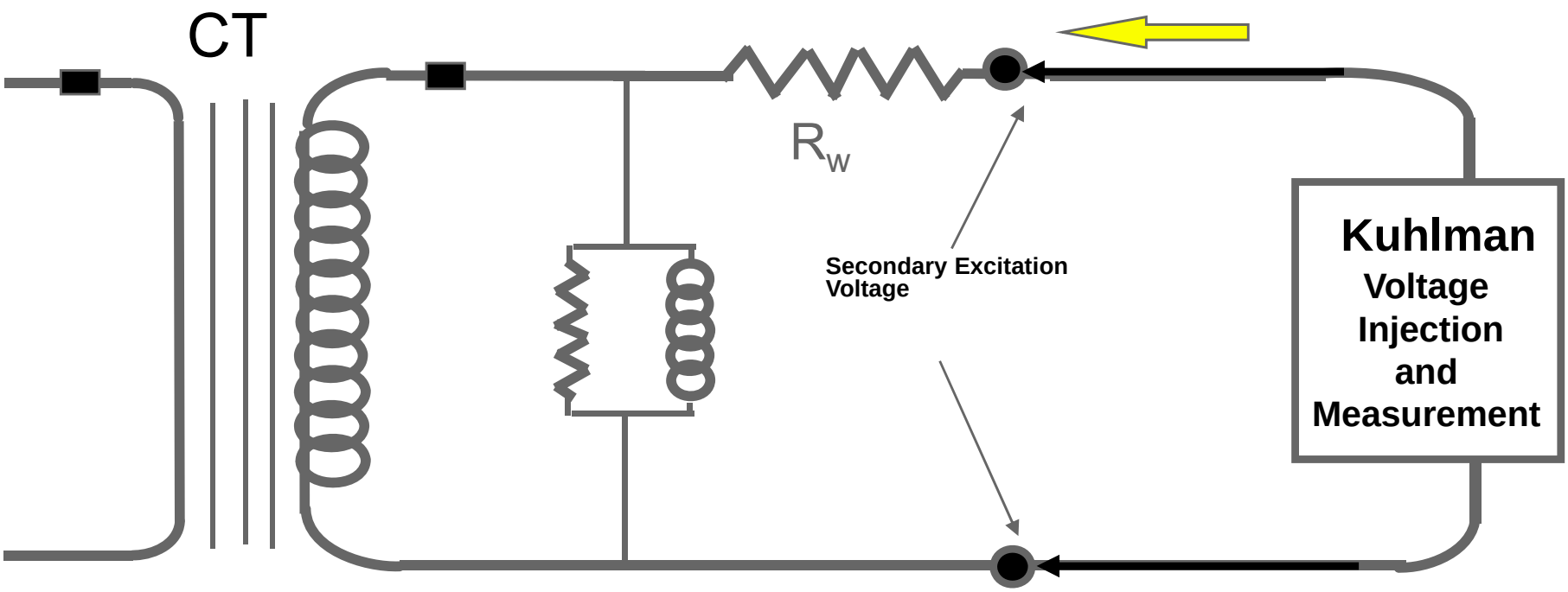
- On site unit RF testing (BCTs and GCTs)
  - CT rating factor defined by
    - Secondary copper cross-section
    - Core cross-section – saturation point
  - Limited by
    - 55°C rise over 30° ambient (85°C)
    - Accuracy performance (metering accuracy)
  - Must have access to shorting terminal block
    - DC resistance of winding
    - Excitation characteristics

Current transformer test (cont.'d)
Continuous thermal current rating factor

- Testing procedure (BCTs and GCTs)
  - Record
    - CT ratio
    - CT accuracy (if known)
    - Bushing kV application/type bushing
    - CT to terminal block dimension and wire size
  - Site conditions
    - Primary opened and de-energized
    - Demagnetize CTs
  - Measurements
    - DC resistance (on each tap)
    - Excitation test

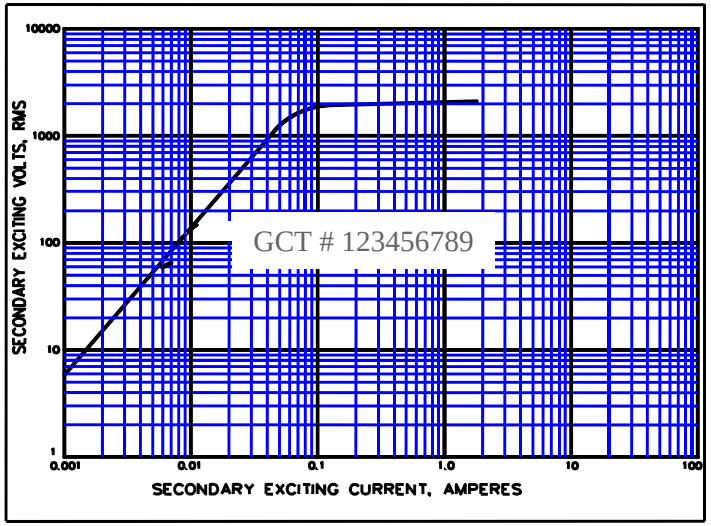
Current transformer test (cont.'d)
Continuous thermal current rating factor

Measure DC Resistance and I_{EX} Current



Secondary Voltage Injected - Measure Excitation Current

Current transformer test (cont.'d)
Continuous thermal current rating factor



Bushing Size= 115kV & Make

CT Approximate Size*(optional)* **= 10-14" ID**

CT to Terminal Block Distance= 20' of #10AWG

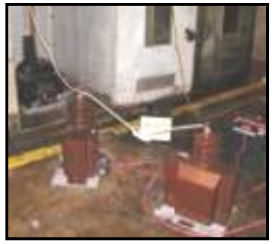
- Dynamic secondary excitation curve for each CT
- Installation details- bushing kV, lead run
- DC resistance of winding

DC resistance = 0.565 ohms @ 20°C

Current transformer test (cont.'d)
Continuous thermal current rating factor

- Analyze site data (BCTs and GCTs)
  - Calculate RF on each CT tested
    - Winding resistance
    - Calculated core size
    - Wire cross-section calculated
  - Result tolerance
    - +/- 15% of true value on RF
  - Rating factor categorized
    - RF=1.0, 1.5, 2.0, 3.0, 4.0

On site Kuhlman FES testing
Summary

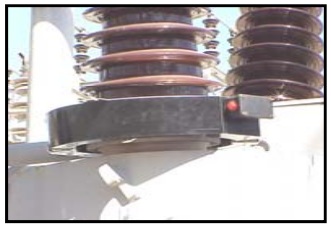


- Current transformers
  - In-service energized testing: in place and energized-excitation performance (patented)
  - Injection accuracy method: in place and de-energized-metering (RCF & PA) error (patented)
  - True comparator method: in place only on OCB-uses standard CT/ comparator (IEEE test)
  - Rating factor definition: in place and de-energized-verifies CT current limit (Kuhlman proprietary)
- Voltage transformers
  - True comparator method: in place and de-energized-standard VT with comparator (IEEE test)

Benefit to user
What's in it for me?

- Better utilize existing equipment
  - In place – provides needed data
  - Existing broad-based applications throughout system
  - Saves real estate
- Eliminates the need to buy additional CTs
  - No purchase costs
  - No installation costs
  - Already wired out for connections
- Eliminates need for high voltage oil-filled/gas-filled CTs
  - No maintenance – reduces overall maintenance
  - Safer – inherently safe LV CTs on HV circuit

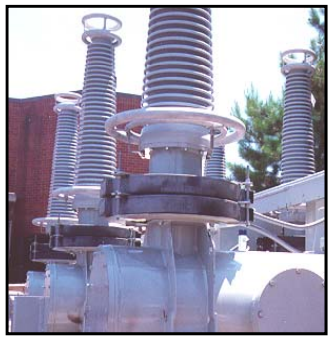
On site accuracy test failures – what next?
High accuracy ACCUSlip revenue metering CTs



- Outdoor-rated slipover CTs
  - 0.3% and 0.15% high accuracy rating
  - Rating factors of 4.0
  - Window sizes 6” to 42”

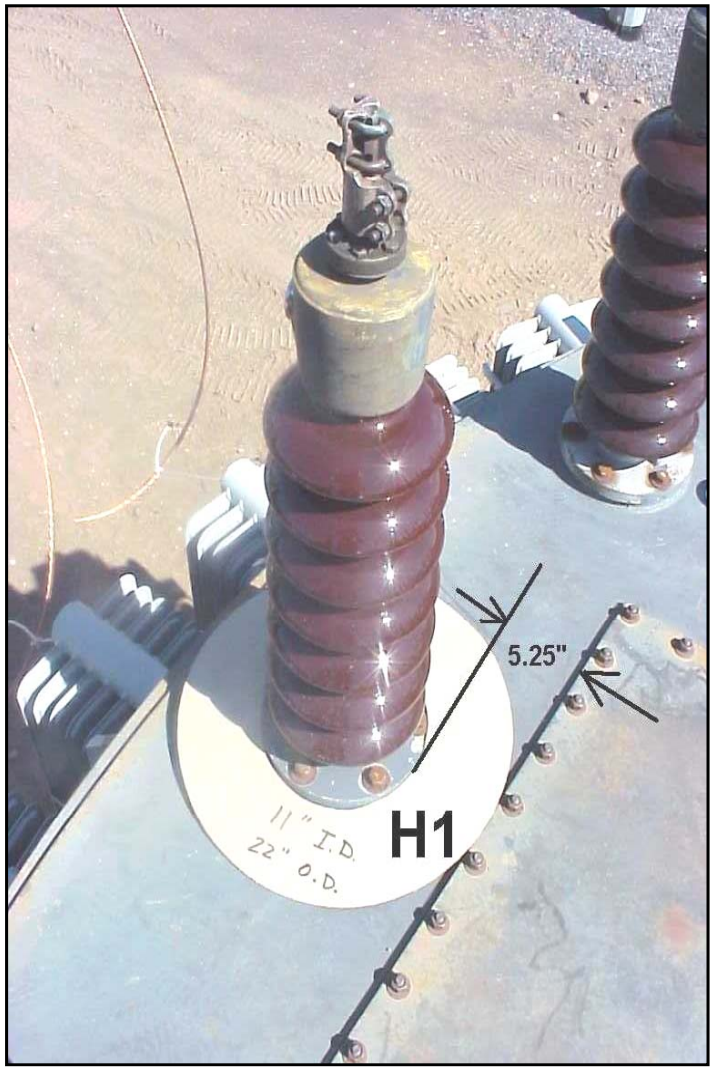
Help in sizing applications

PS-981



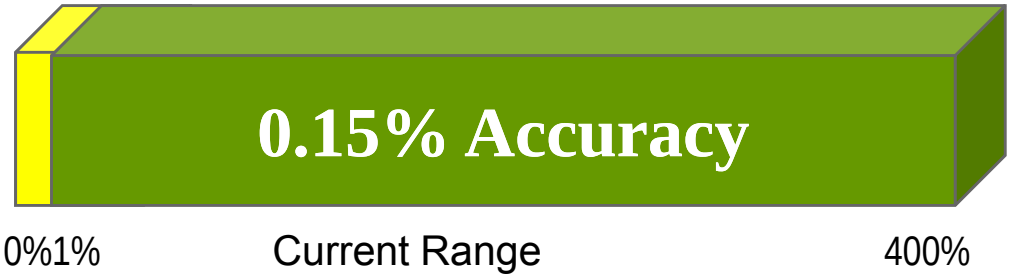
- Need good dimensions to ensure fit

Help in sizing applications (cont.'d)



On site accuracy test failures – what next?
Low side (5-34.5kV) revenue metering CTs

- LGX wide range performance
  - 0.15% B0.5 (0.3%B0.9)
  - 1% to 400% accuracy range
    (e.g. 400:5 – 4A to 1600A)
  - 400:5 to 1200:5 ratios



On site accuracy test failures – what next?
High side (25-500kV) revenue metering CTs

- Type CXM GSU metering with auxiliary power extended range
  - 0.15% from 0.5% to 400% current with RF=4.0
  - Designed for IPP use
  - High short-circuit strength CT
  - No burden restriction – B1.8

0 0.5% Current Range 400%

On site accuracy test failures – what next?
Accurate test points – IT error correction

- Actual CT error correction
  - RCF and PA from multiple points (obtained by field testing)
- Microprocessor-based meters
  - CT can be outside class 0.3 but corrected (micro-processor meters with IT correction)
- As installed readings
  - Results on accuracy can be at meter point (circuit tested at the point of meter connection)

Power and productivity
for a better world™