ABB Field Engineering Services
Instrument transformer on-site testing
Field Engineering Services

Leave it to the TRANSFORMER EXPERTS

Unloading

Oil-Filling

Testing

Assembly
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
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 bushing current transformers (BCTs) & 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 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
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) = $I_0 \times \sin (\theta + \phi) / I_{sec}$ (RE is proportional to core loss current)
  - Phase angle (PA) = $I_0 \times \cos (\theta + \phi) / I_{sec}$ (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)

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Calculated values:

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

Ratio Error and Phase Angle values are derived from actual site readings.
Transformer test information certified reports

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
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

- 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
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

0.15% Accuracy

0%1% Current Range 400%
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

0.15% Accuracy

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 (microprocessor meters with IT correction)

As installed readings

- Results on accuracy can be at meter point (circuit tested at the point of meter connection)