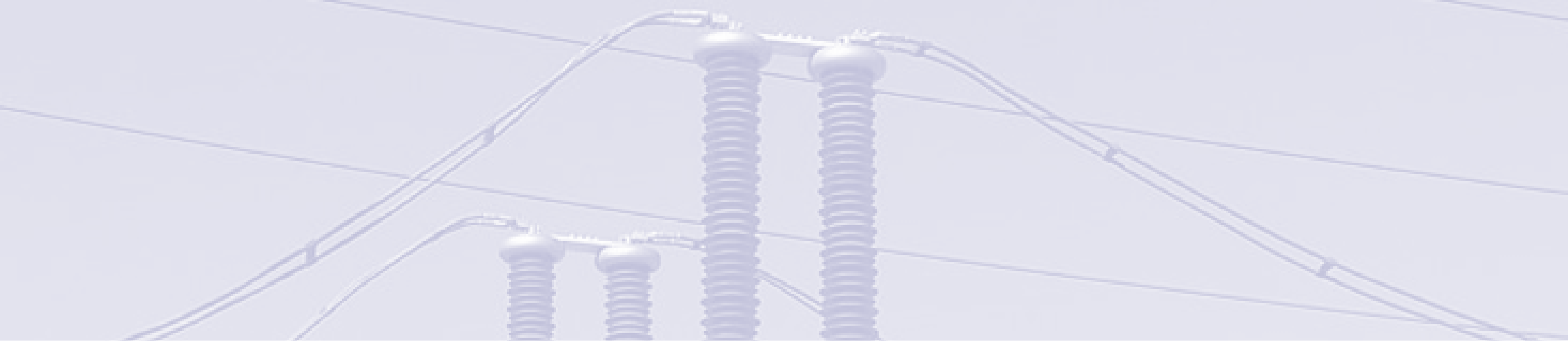


Instrument Transformers

Following the Money:

Best Practices in a Post AMI World

Prepared for the NYSEMC Spring 2018 Meeting

Prepared by Tom Lawton

TESCO - The Eastern Specialty Company

Knopp, Inc. – A TESCO Company

for the New York State Electric Meter Engineers Conference

23 May, 2018

Objective

- Discuss best practices regarding the need to ensure that all transformers used for metering circuits are properly sized.
    - Discuss the ability to optimize revenue regardless of customer usage over time.
- Discuss best practices to ensure that transformers and meters have been installed correctly in the field and that they continue to perform in the same fashion.
- Discuss best practices for certifying the accuracy class of the transformers and how to best set up a shop testing and field testing/verification program.
- Discuss what the costs of implementing such a system and what the costs of not implementing such a system can be.

Knopp, Inc – A TESCO Company

- Founded in 1928 by Otto Knopp – Metering Engineer for Pacific Gas & Electric in Oakland, CA
- 1958 – Built existing 10,000 sq.ft. facility in Emeryville section of Oakland, CA
- 1976 Knopp family sold the business to a spin off of Sangamo Meter
- Primary products – Transformer test sets
- Additional products over the years
  - Meter test sets for the lab
  - Field test kits
  - Hand instruments – Voltage Testers and Phase Sequence Indicators
  - Third Rail Voltage Tester
  - Specialty Equipment for Utilities
- 2018 Purchased by TESCO – The Eastern Specialty Company. Building still leased from the Knopp family.

Current Transformer Testing System

KCTS-8000

The Knopp Current Transformer Testing System (Type KCTS-8000) is designed to measure the accuracy of instrument transformers having 1 or 5 ampere secondaries and primaries of up to 8000 amperes. The system uses a high accuracy multi-range current transformer as a reference standard. All ANSI standard burdens are included. The phase angle and ratio errors of the transformer-under-test (TUT) are measured by the built-in Knopp Automatic Transformer Comparator.

Current Transformer Testing System

KC-1500

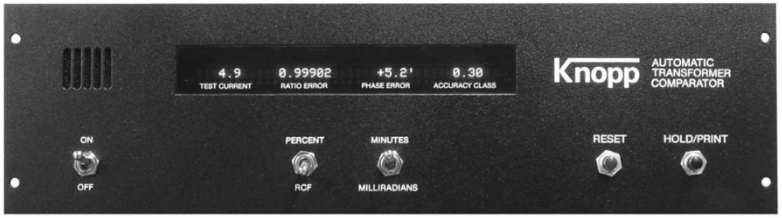
The Knopp Type KC-1500 Current Transformer Testing System is designed to measure the accuracy of instrument transformers having 1 and 5 ampere secondaries and primaries of up to 1500 amperes. The KC-1500 is capable of testing transformers with 1 or 5 ampere secondaries. The system uses a high accuracy multi-range current transformer as a reference standard.

The system is well suited for utilities whose current transformer testing needs include primary currents up to and including 1500 amperes. The phase angle and ratio errors of the transformer-under-test (TUT) are measured by the built-in Knopp Automatic Transformer Comparator.

Automatic Transformer Comparator

The Knopp KATC Automatic Transformer Comparators (KATC series) provide the most convenient means available to measure instrument transformer ratio and phase angle errors. Some of the comparator features are:

- Reduced testing time - test results are typically available within three seconds
- Automatic operation (no manual "nulling" or adjustments required)
- Microprocessor control
- Autoranging capability
- Digital display
- Calculation and display of ANSI accuracy class
- Fully protected circuitry
- RS-232C output
- Interchangeable with other Knopp comparators



KATC-C

KATC-C1

The KATC-C1 Automatic Transformer Comparator is an enhanced version of the popular KATC-C Comparator. Features of the KATC-C1 include:

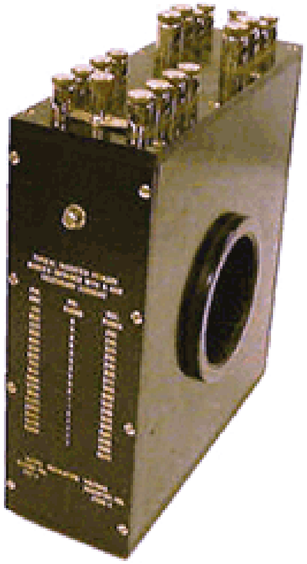
- The ability to test transformers with 1 or 5 ampere secondaries
- Automatic sensing of 50 or 60 Hertz current
- Improved data handling capabilities including the ability to be controlled by a remote computer
- Improved resistance to damage from excessive test current

Precision Multirange Current Transformer

P-5000

The P-5000 transformer is a laboratory standard. The unit's excellent accuracy and the Knopp One-to-One calibrating feature make this precision transformer well-suited as a standard for calibration work. This transformer can provide a very accurate determination of the ratio and phase angle characteristics of current instrument transformers having ratios from 5 to 5,000 amperes. This transformer also can accurately extend the range of a 5 ampere ammeter or wattmeter to cover all current values up to 5,000 amperes.

The P-500 provides eight self-contained primary ranges from 5 to 100 amperes. These ranges are brought out to binding posts on the top of the transformer. A 240 turn secondary is provided for use with these primary taps; other secondary taps are provided for other ranges as described below. Ranges above 100 amperes are obtained by passing a primary conductor through the transformer window. Various primary ranges are obtainable by varying the number of through-turns and choosing from among the available secondary taps.



Precision Multirange Voltage Transformer

This Type WP-14000 Transformer is primarily a laboratory standard. Its excellent accuracy and the Knopp one-to-one calibrating feature make it well-suited as a standard for precision calibrating work. This transformer makes possible very accurate determination of the ratio and phase angle characteristics of voltage instrument transformers having ratings from 120 to 14,400 volts. This transformer also makes it possible to accurately extend the range of a 120 volt voltmeter or wattmeter to cover all voltage values up to 14,400 volts.

The WP-1400 Transformer, like other Knopp Precision Multirange Transformers, has excellent ratio and phase angle characteristics with respect to both inter-range accuracy and overall accuracy. This is made possible through a properly engineered design and through exclusive, highly perfected compensating and winding methods.

Voltage Transformer Testing System

KVTS

The Knopp Voltage Transformer Testing System is designed to measure the accuracy of instruement transformers having 120 volt secondaries and up to 14,400 volt primaries (special order for up to 36,000 volt primaries is available). The system includes a control console which contains the control circuitry, ANSI standard burdens, and the Knopp Automatic Transformer Comparator. The Knopp precision and loading transformer set is also included (as pictured) and is connected to the console via a special cable.

Loading Transformer: CL-6

This readily portable Knopp Loading Transformer weighs only 60 pounds and measures 12" long, 9" wide, and 10" high. Its sturdy enclosure provides protection and adequate ventilation. Two convenient carrying handles are provided.

The insulating terminal panel is rigidly secured to the transformer frame, and heavy-current, bus-bar-type terminals are securely bolted to the panel. The two outpout terminals each have two connection surfaces, one on a vertical plane and one on a horizontal plane, for maximum convenience in connecting the heavy current leads and in changing, when necessary, the series-parallel links. The links and the output connections cannot interfere with each other. All terminals and connection links are plated Both the primary and the secondary are insulated for a 4,000 volt, 60 cycle, one-minute test. A grounding stud is provided on the enclosure.

ANSI Standard Burden Sets

Testing and calibrating instrument transformers often requires standard burdens of reliable accuracy and stability, and burdens that are immune to stray fields and harmonics. The burden sets Knopp offers have been carefully designed to meet these requirements. They provide the standard burdens required for the testing of current and voltage transformers for metering service, and for the testing (within the current rating provided by the sets) of current transformers for relaying applications, all as called for by ANSI/IEEE C57.13-2016.

All the current burden sets are designed to be used with external leads consisting of a 5-foot pair of #8 copper conductors. This becomes very significant at the lower burden values, since the external leads constitute a significant part of the total burden.

ANSI Standard Burden Sets
Voltage and Current

Voltage Tester: K-60

FOR AC AND DC 120 TO 600 VOLTS
CAT III RATED UL 61010-1
K-60 KNOPP VOLTAGE TESTER for AC and DC with polarity indicator. Double safety indication is by solenoid and by neon lamp.
Knopp Voltage Testers offer portability and ease of use with full protection. These exceptionally versatile and useful tools are backed by a reputation for quality in the design and manufacture of electrical test equipment
Knopp Voltage Testers are designed and built with safety, the **key** criteria!
Dual voltage indication is provided by solenoid and neon lamp, operating **independently.** The lamp gives a bright warning signal. Voltages are shown by a positive, easy-to-read, moving indicator. There is a signal by hum and vibration; and the user is protected by high-grade, properly applied insulation, and by separation of incoming leads (the do not cross over each other within the housing). Interior separation of the circuit is a basic design feature of the case.
Nylon insulation covers prod tips to within 9/16" of end to prevent shorts across tips. The K-60 has no exposed metal parts. The scale and plate are both of insulating material.
Each K-60 order includes the K-60 voltage tester, Cordura carrying case, and leads.

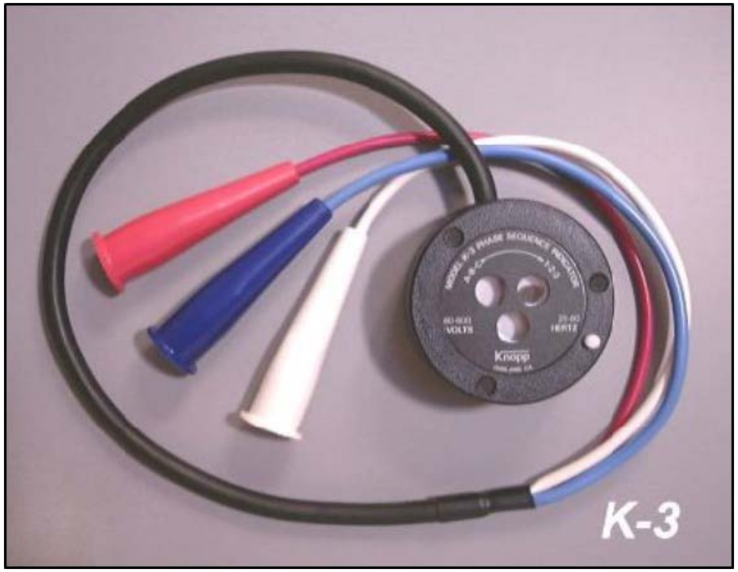
Phase Sequence Indicator

ROTARY TYPE • NO LAMPS • RELIABLE • RUGGED • VERSATILE • TIME SAVING

POSITIVE, STRAIGHTFORWARD SEQUENCE INDICATION IS PROVIDED over a wide variety of voltage and frequency by direction of rotor rotation. No need for range switching or terminal charging. Also indicates an open phase.

MODEL K-3: 60-600 volts, 25-60 Hz
MODEL K-6: 24-480 volts, 400 Hz

Use of the Knopp Phase Sequence Indicator saves man-hours and protects valuable equipment against damage. It pays for itself in a short time.



Third Rail Tester: 4E2-1

The Knopp 4E2-1 Voltage Tester is designed to detect electrial potential (voltage) between the third rail and ground on high voltage electrified transit systems. Two, redundant neon bulbs are used to indicate the presence of voltage.

Features of the 4E2-1 include:

- Can be used on AC or DC
- Can be used up to 1,500 volts
- Can span a distance of up to four (4) feet
- Uses a dual neon lamp principle for double safety protection

Poperly sizing Conventional and Extended Range CT's

- CT Ratings/Parameters
- Standard Accuracy Classes
- Extended-Range Ratings/Types
- Applying ERCTs
- Advantages of ERCT
- The historic revenue metering class is 0.3, with 0.15 being used with increasing frequency.
- 0.15 "high accuracy" classes were introduced under IEEE C57.13.6.


Current Transformers Terms

Ratio
The ratio of rated primary current to rated secondary current - 200:5 A.

Burden
The total load connected to the CT’s secondary terminals (meter plus round-trip leads). Essentially defines the max distance from CT to meter.

Rating Factor (Continuous Thermal Current Rating Factor)
The factor that the rated primary current can be multiplied by to obtain the maximum allowable continuous primary current without exceeding the temperature rise limits at a standard 30C ambient (ratings at 55C and 85C commonly available). Also used in the accuracy class limitations.

Accuracy Rating
Defines the accuracy class and maximum applicable burden, i.e. 0.3B1.8.

CT ACCURACY PARAMETERS

Ratio Correction Factor (RCF)
Factor by which the marked ratio must be multiplied by to obtain the true ratio. Defined as RCF = 1 – (%error).
Example: -0.2% ratio error $\Rightarrow$ RCF = 1.002

Phase Angle Error (PA)
Measured phase angle difference between primary and secondary currents. Normally expressed in angular minutes.

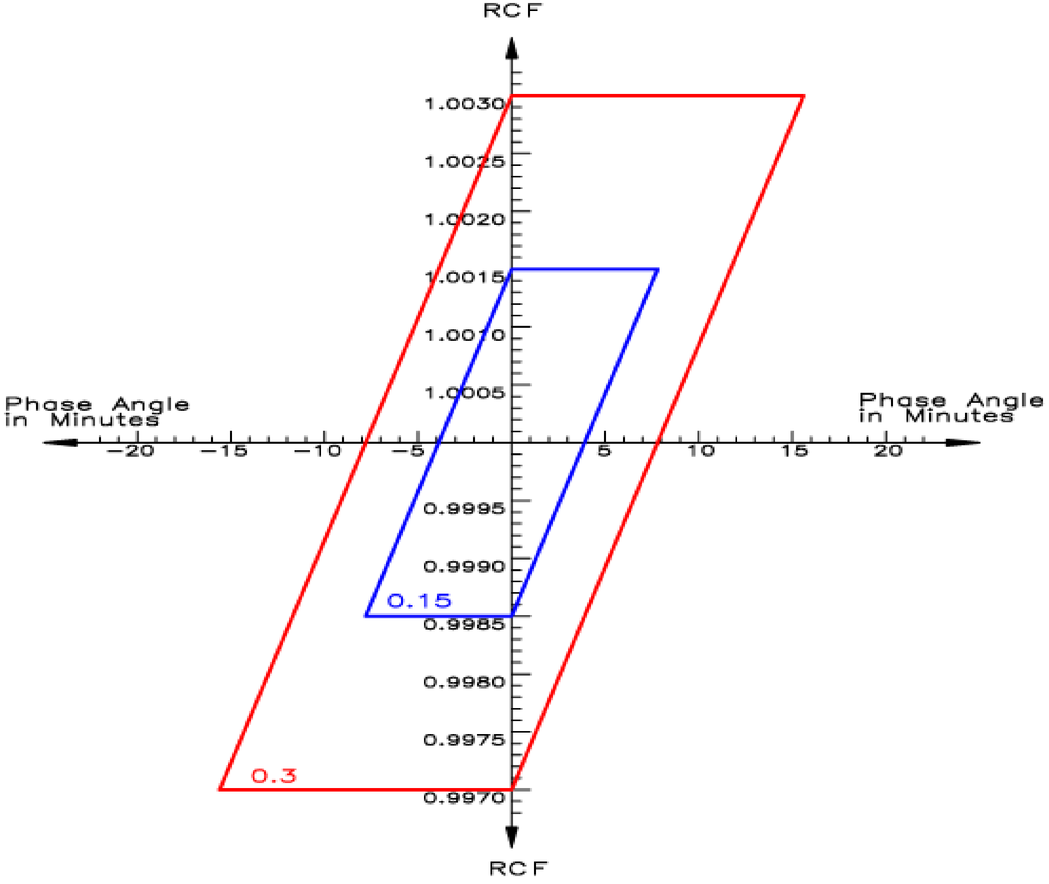
Transformer Correction Factor (TCF)
Factor by which a watt-hour meter reading must be multiplied by to correct for the RCF and PA errors.
TCF = RCF – (PA/2600)

METERING ACCURACY RATING

0.3B1.8

Accuracy Class	Burden Designation
0.15S (High Accuracy)	B0.1
0.15 (High Accuracy)	B0.2
0.3 (Metering Accuracy)	B0.5
0.6 (Indication Accuracy)	B0.9
1.2 (Indication Accuracy)	B1.8

Current Transformer Accuracy Classes



CT Error

CT error is typically negative…meaning less current in the secondary than there "should" be by the defined ratio.

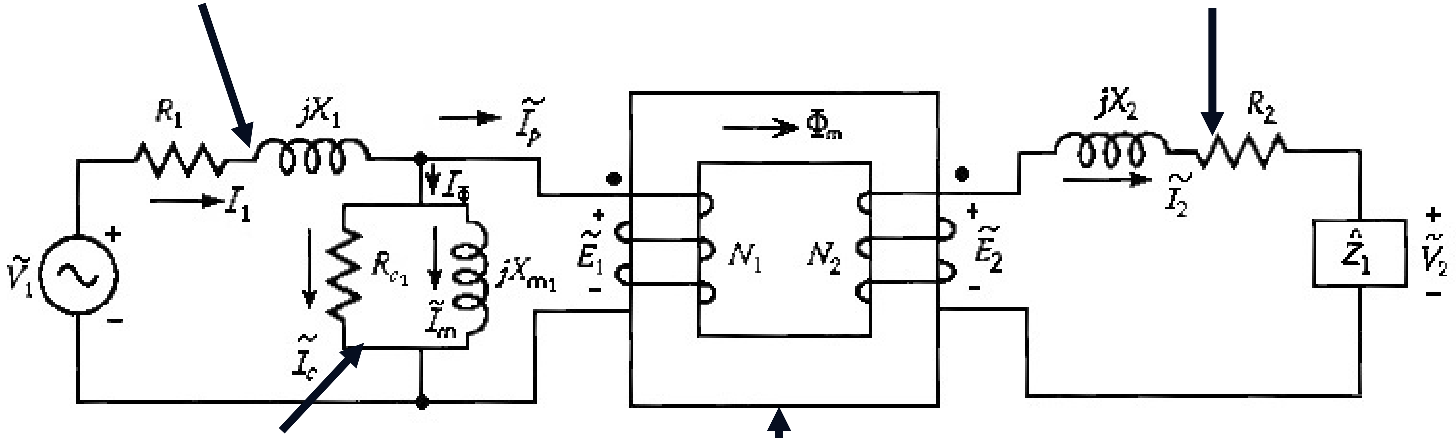
CT error becomes increasingly negative as the primary current level decreases.

Negative Error = Lost Revenue

Idealized Transformer Circuit

Primary Winding Impedance

Secondary Winding Impedance



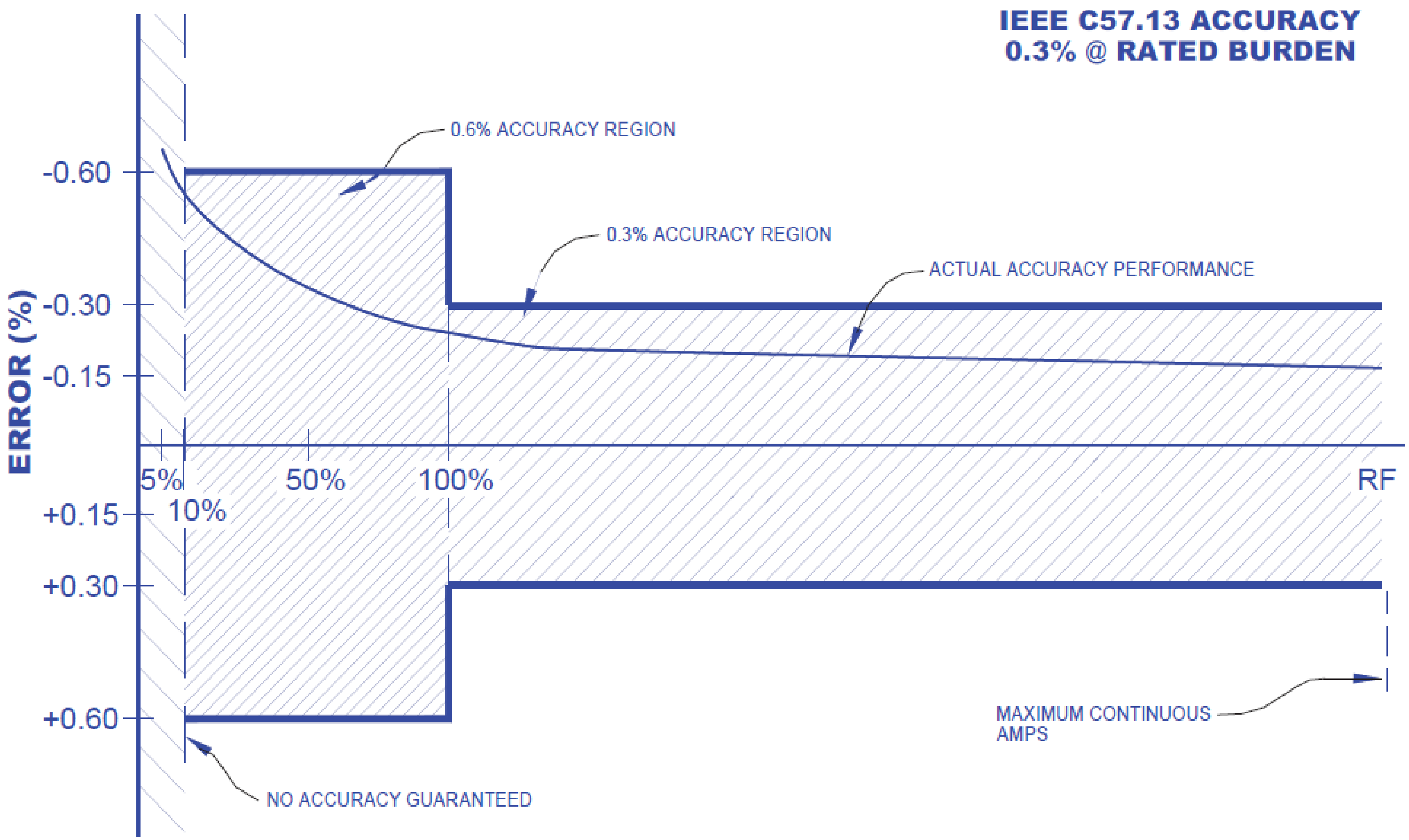
Core Loss Branch

(function of core mat’l, core size, number of sec turns)

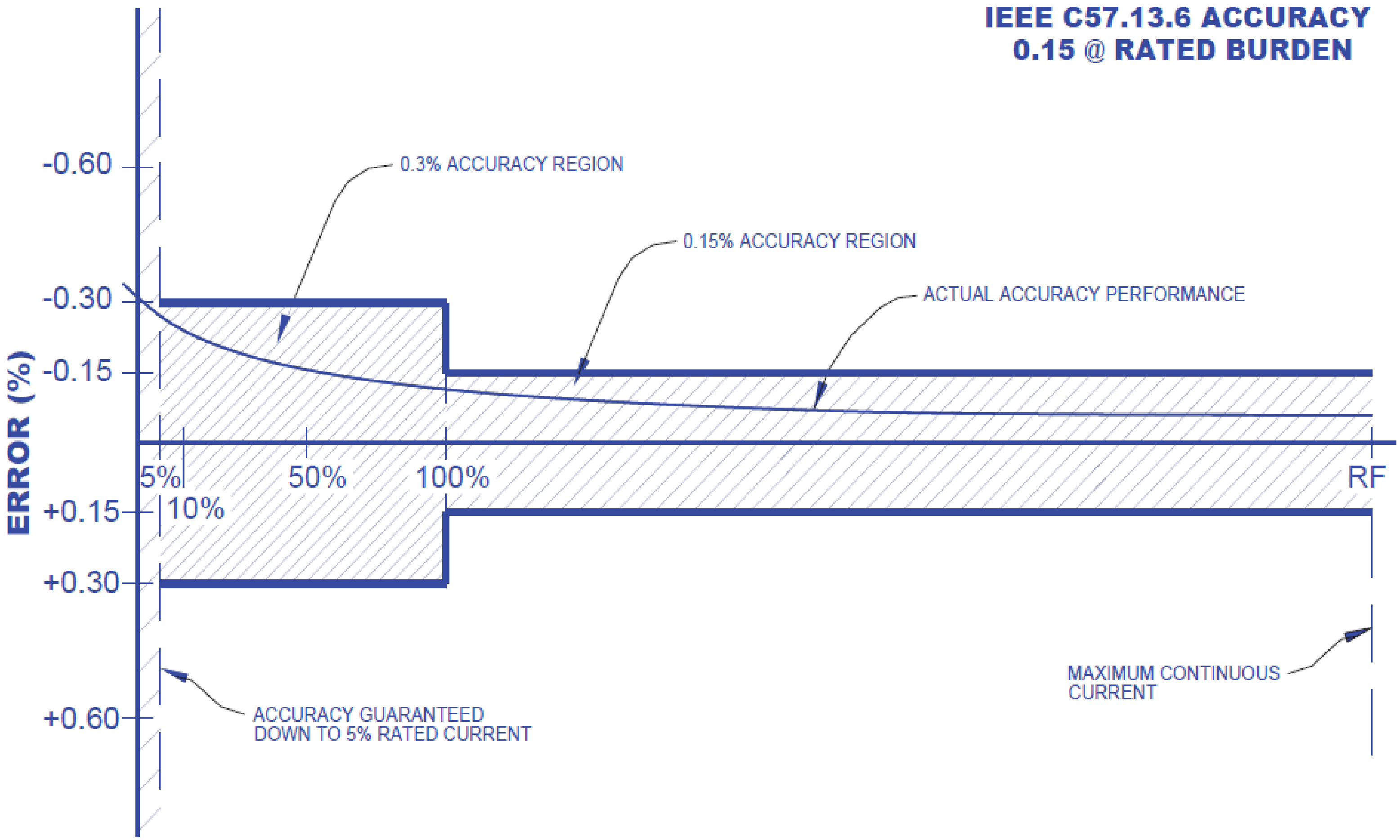
Ideal Transformer

This is an illustration that the excitation current is the current lost from the primary current that does not get to the meter. Accuracy is largely a function of minimizing this excitation current and why transformer accuracy is typically negative.

CT 0.3 Accuracy Class



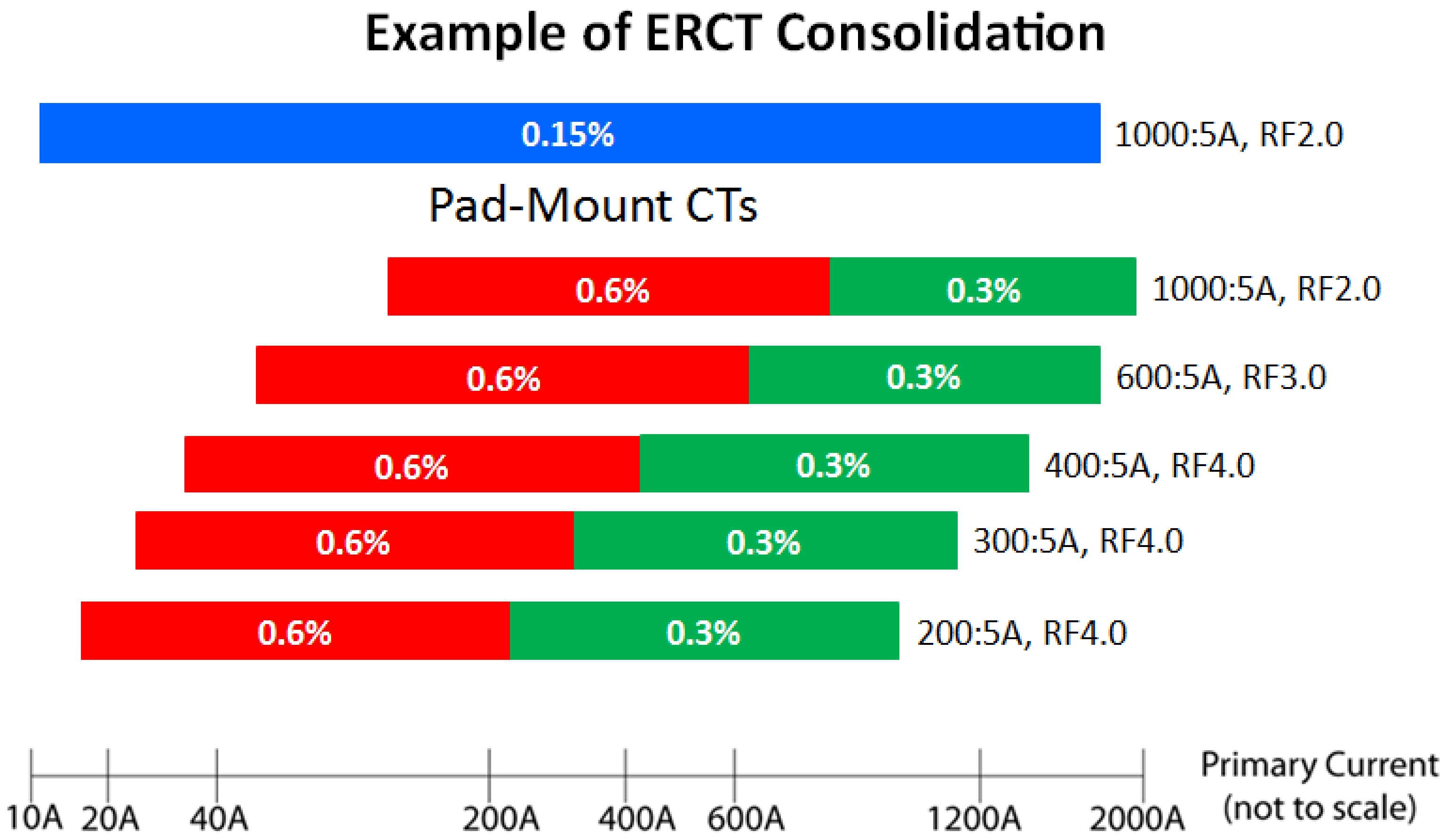
CT 0.15 Accuracy Class



Extended-Range Advantages

- Enables utility to standardize on 1 or 2 designs per voltage class or form factor
- Greatly reduces the chance of CTs being misapplied
- Offers improved accuracy across a wide current range – increased revenue
- Reduces total cost of inventory by allowing utilities to stock fewer total units
- Simplifies multipliers

Stock Consolidation



Revenue Recovery Case Study

This story is based on real life events. No animals were harmed during the preparation of this slide and any resemblance to real life characters and installations is purely intentional

Existing Metering
200:5A
0.3B1.8
RF1.5

Duplicate Metering
1000:5A ERCT
0.15B1.8
10A to 1500A

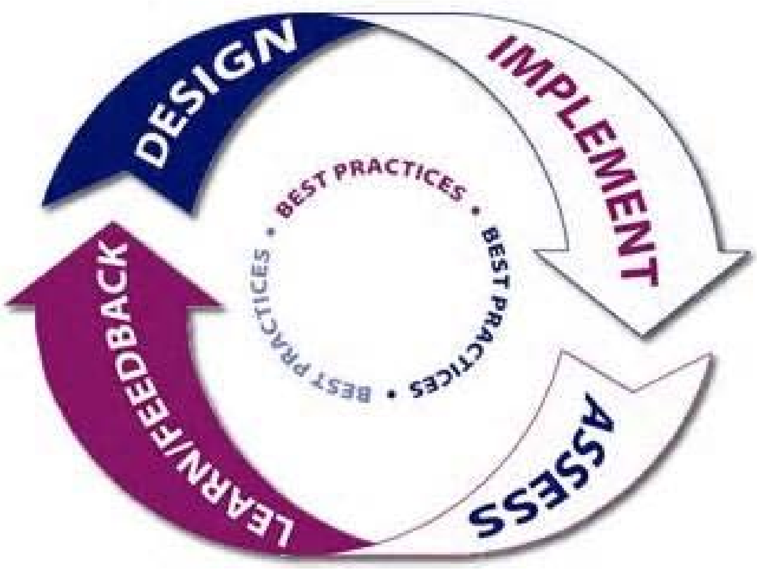
6 months of duplicate meter data annualized to over $7,000 of lost revenue using traditionally unmonitored transformers

Using AMI Data

- **AMI data can provide actual usage**
- **Site Verification data can provide a correlation to the Transformers installed at the installation**
- **Not a very difficult analysis to determine how often any one particular installation is operating outside of the operationg parallelogram for the installed transformers**
- **This allows the utility to replace these transformers with transformers that operate more accurately over a larger range of operating conditions. This is especially true as no utility can ever know who the next tenant in a building will be or how they will utilize the service or even how an existing company's needs will change over time.**
- **Look for missing current on a single leg or intermittent data**

Best Practices

- Residential vs Commercial
- Self-Contained vs Transformer Rated
- Follow the money and be as proactive as possible



Self Contained

- Use AMI analytics on self-contained services to determine where there are problems
- Look for technical and non-technical losses through these analytics
- Minimize the use of field resources in checking these services
- Free up as many field and shop resources as possible to check on and be as proactive as possible with your Transformer Rated services

Why?

Because the Transformer Rated Services are where the money is!!!!

Potential Site Check List

- Double check the meter number, the location the test result and the meter record.
- Perform a visual safety inspection of the site. This includes utility and customer equipment. Things to look for include intact down ground on pole, properly attached enclosure, unwanted voltage on enclosure, proper trimming and site tidiness (absence of discarded seals, etc.).
- Visually inspect for energy diversions (intentional and not). This includes broken or missing wires, jumpers, open test switch, unconnected wires and foreign objects on meters or other metering equipment. Broken or missing wires can seriously cause the under measurement of energy. A simple broken wire on a CT or VT can cause the loss of 1/3 to 1/2 of the registration on either 3 element or 2 element metering, respectively.
- Visually check lightning arrestors and transformers for damage or leaks.
- Check for proper grounding and bonding of metering equipment. Poor grounding and bonding practices may result in inaccurate measurements that go undetected for long periods of time. Implementing a single point ground policy and practice can reduce or eliminate this type of issue.
- Burden test CTs and voltage check PTs.
- Ratio Test CT's

Potential Site Check List (con't)

- Verify service voltage. Stuck regulator or seasonal capacitor can impact service voltage.
- Verify condition of metering control wire. This includes looking for cracks in insulation, broken wires, loose connections, etc.
- Compare the test switch wiring with the wiring at the CTs and VTs. Verify CTs and VTs not cross wired. Be sure CTs are grounded in one location (test switch) only.
- Check for bad test switch by examining voltage at the top and bottom of the switch. Also verify amps using amp probe on both sides of the test switch. Verify neutral connection to cabinet (voltage).
- Check rotation by closing in one phase at a time at the test switch and observing the phase meter for forward rotation. If forward rotation is not observed measurements may be significantly impacted as the phases are most likely cancelling each other out.
- Test meter for accuracy. Verify demand if applicable with observed load. If meter is performing compensation (line and/or transformer losses) the compensation should be verified either through direct testing at the site or by examining recorded pulse data.
- Loss compensation is generally a very small percentage of the overall measurement and would not be caught under utilities normal high/low checks. However, the small percentages when applied to large loads or generation can really add up overtime. Billing adjustments can easily be in the $million range if not caught early.

Potential Site Check List (con't)

- Verify metering vectors. Traditionally this has been done using instruments such as a circuit analyzer. Many solid state meters today can provide vector diagrams along with volt/amp/pf and values using meter manufacturer software or meter displays. Many of these desired values are programmed into the meters Alternate/Utility display. Examining these values can provide much information about the metering integrity. It may also assist in determining if unbalanced loads are present and if CTs are sized properly. The vendor software generally has the ability to capture both diagnostic and vector information electronically. These electronic records should be kept in the meter shop for future comparisons.

- If metering is providing pulses/EOI pulse to customers, SCADA systems or other meters for totalization they also should be verified vs. the known load on the meter.

- Verify meter information including meter multiplier (rework it), serial number, dials/decimals, Mp, Ke, Primary Kh, Kr and Rate. Errors in this type of information can also cause a adverse impact on measured/reported values.

- Verify CT shunts are all opened.

Shop Testing

- Accuracy Testing
- Meter Communications Performance
- Software & Firmware Verification
- Setting Verification
- Functional Testing
- Disconnect/Reconnect Functionality and as left setting
- Ratio and accuracy testing
- Polarity checking
- Accuracy class determination

Shop Testing Programs

- 100% of all Transformers
  - If not possible then sample testing of all and 100% of all those over a certain size for CT’s and all VT’s (generally not a large volume)
- Transformer testing should include
  - Ratio and accuracy testing
  - Polarity checking
  - Accuracy class determination
- 100% of all transformer rated meters
  - If not possible then sample testing of all transformer rated meters and 100% of all those going into a certain size service and over
- Meter testing should include
  - Software & Firmware Verification
  - Setting Verification
  - Functional Testing
  - Disconnect/Reconnect Functionality and as left setting

Why do this work?

Why do this work?

Because that is what we have always done

No Really, why do this work?

No Really, why do this work?

So we can set a baseline

- We will know that what went out to the field is correct.
- We will have AMI data that corresponds with a known, good condition.
- We can now use our AMI data to determine if and when the metering goes bad.
- Does not mean we can stop this work, but with this work done on an ongoing basis in combination with good analytic tools, we can determine when to roll a truck in the shortest time possible after an issue arises.

What is the cost?

“To Do or not To Do”, that is the question.

- A crew of 20 technicians and two supporting engineers and a manager and all their gear may cost a utility $10 Million to $15 Million Dollars per year.
- Assuming 16 in the field and 4 in the shop the field guys can perform on average 10,000 to 15,000 site verifications of Transformer rated services in a year.
- Finding issues in between 0.2 and 0.5% of the sites verified can pay for this budget every year.
- A single mismarked transformer found in a shop test can pay for the entire program for several years if that transformer were to have gone onto one of the largest accounts for the utility.

Are we done yet?

Does not mean we can stop this work, but with this work done on an ongoing basis in combination with good analytic tools, we can determine when to roll a truck in the shortest time possible after an issue arises.

Metering is becoming the center of operations and will continue to play a more and more important role in every Utility – as long as we continue to think about how else we can use this data in a meaningful way (think revenue and issue avoidance).

Objective Review

- Discuss best practices regarding the need to ensure that all transformers used for metering circuits are properly sized.
  - Discuss the ability to optimize revenue regardless of customer usage over time.
- Discuss best practices to ensure that transformers and meters have been installed correctly in the field and that they continue to perform in the same fashion.
- Discuss best practices for certifying the accuracy class of the transformers and how to best set up a shop testing and field testing/verification program.
- Discuss what the costs of implementing such a system and what the costs of not implementing such a system can be.

Summary

- Perform a shop test of every meter going into a transformer rated service. This includes a functional test as well as an accuracy test.
- Perform a shop test of every CT going into a transformer rated service.
- Perform a shop test of every VT going into a transformer rated service.
- Perform a base line site verification of every transformer rated service in your service territory.
- Use your AMI analytics to determine where there are misses:
  - No draw on one leg
  - Intermittent draw on one leg
  - Performing outside the rated range for the installed transformers
  - Reversed polarity
- Start checking for field issues all over again.

Questions and Discussion

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This presentation can also be found
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