Meter Site Design

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Objectives of this Class

- Be able to identify the main parts of a meter site
- Learn the basics about what must be considered for each piece of equipment
- Go over a “real world” example of a meter site installation

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What makes up a meter site?

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What makes up a meter site?

- Meter socket, enclosure, and test switches
- Instrument transformers
- Wire
- AMI/AMR Module
- Power quality and site test equipment
- **And of course, the meter!**

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Meter Selection

- Service Type and Meter Form
- Self-Contained vs Transformer Rated
- Voltage and Current Rating
- Accuracy
- Measurement Modes – Whr, VAhr, VARhr, Demand
- AMI / AMR Compatibility

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What makes up a service type?

- Single or Polyphase? (2 or 3 phases)
- Delta vs Wye?
- 3 or 4 wire?
- Power rating of service determines how much current to be metered

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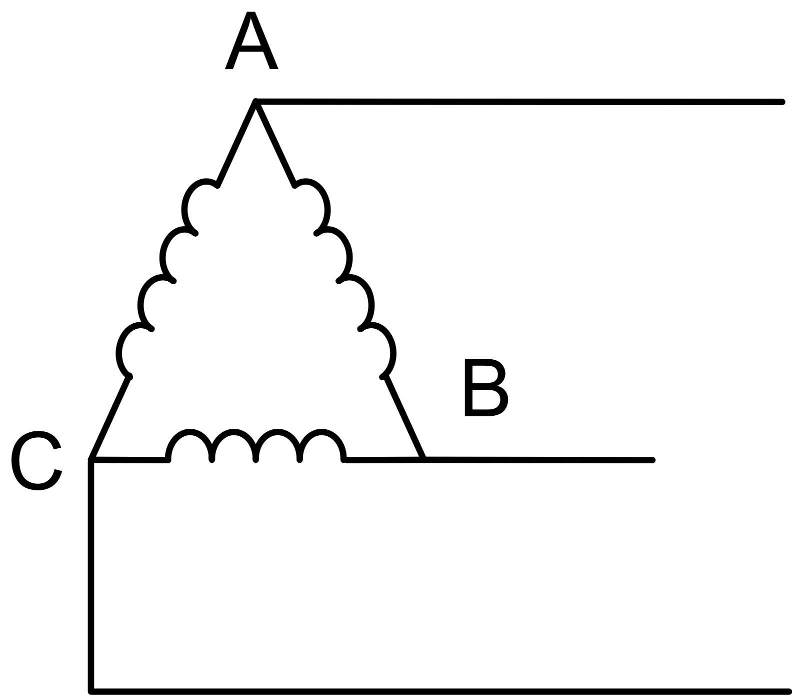
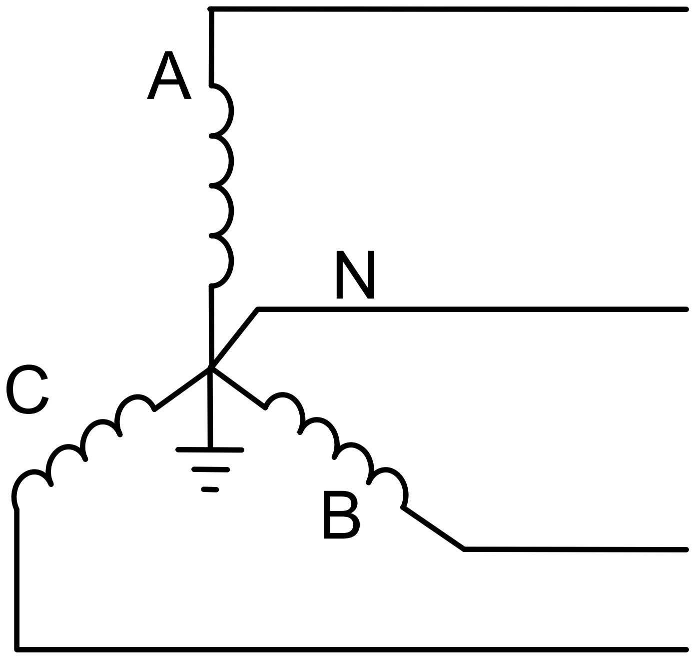
Electrical Service Type

Delta vs Wye



Delta



Wye

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Three Phase Transformers

Delta vs Wye

- Delta is commonly used for power transmission as it only requires three lines
- Delta is better for a balanced load like a motor and has greater reliability if a winding failure occurs
- Wye offers two voltages – line to neutral and line to line
- Wye is used when a single phase load is required

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Service Type and Meter Form

- Over 30 types of meter forms due to many kinds of connections!
- Service type will determine meter form
- Modern meters can be setup for many forms
- Typically only a few meters used by most utilities

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Common Meter Forms

Self Contained

Meter Form	# Wires	# Elements	# Phases	Delta / Wye	Class
1S	2	1	1	N/A	200
2S	3	1	1	N/A	200/320
12S	3	2	2	Delta	200/320
16S	4	3	3	Wye	200/320
16S	4	3	3	Delta	200/320

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Common Meter Forms

Transformer Rated

Meter Form	# Wires	# Elements	# Phases	Delta / Wye	Class
3S	2	1	1	N/A	20
5S	3 or 4	2	3	Delta	20
6S	4	2.5	2	Wye	20
9S	4	3	3	Wye	20

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Self-Contained vs Transformer Rated Meters

- **Transformer Rated**
  - Up to 480V, typically 120V
  - Current up to 50A, typically 20A
  - Requires CTs
  - Optionally uses PTs
  - Higher cost due to more equipment
  - Possibly lower accuracy due to ITs

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Self-Contained vs Transformer Rated Meters

- **Self-Contained**
  - Voltage up to 480V
  - Current up to 100, 200, 320, or 400A
  - Requires larger gauge wire
  - Does not require ITs so typically less expensive
  - More accurate

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How much current?

Example:

277 / 480V 3 phase 4 wire service

750KVA

Current per phase = Total Site Power / # of phases / Voltage

Current = 750000 / 3 / 277 =900 A per phase

What kind of meter will we use –

Self contained or transformer rated?

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Meter Accuracy

- Accuracy rating of 0.5, 0.2, and 0.1% under IDEAL conditions
- TR Sites may require a higher accuracy meter due to ITs
- There is no standard for VAR and VA
- Harmonics and power quality can affect meter accuracy

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Meter Measurement Modes

- Early mechanical meters could only measure one mode - Whr
- Solid-state meters can measure many different modes at the same time
- Meters must be programmed for the desired display modes and outputs
- Advanced functions – power quality, harmonic analysis

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Automatic Meter Reading (AMR)
Advanced Metering Infrastructure (AMI)

- Many communication options – Ethernet, Cellular, Power Line Carrier, RF, Modem
- Many different kinds of connections – pulse outputs, RS-232, RS-485
- Check what type of AMI or AMR support is required by your utility

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Selecting a Meter Cabinet

There are many shapes and sizes!

Photos courtesy of the Durham Company

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Selecting a Meter Cabinet

- Self-contained or transformer rated
- Current rating
- Socket type – number of terminals
- Pad mount or pole mounted
- Ganged sockets

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Self-contained Meter Cabinet

- 125, 200, or 320A cabinets available
- 4, 5, or 7 terminals depending on meter form
- Lever bypass for easier testing
- Ganged sockets for apartments

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Lever Bypass Meter Socket

- Easy install and removal of meter
- Bypass power during meter testing
- More expensive and larger cabinet

Ganged Sockets

- Used for apartments and duplexes
- Single point of entry

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Transformer Rated Meter Cabinet

- Typical TR meter is rated for 20A
- 5 to 13 terminals depending on meter form
- Lever bypass available
- Larger cabinets for CTs available to prevent weather damage

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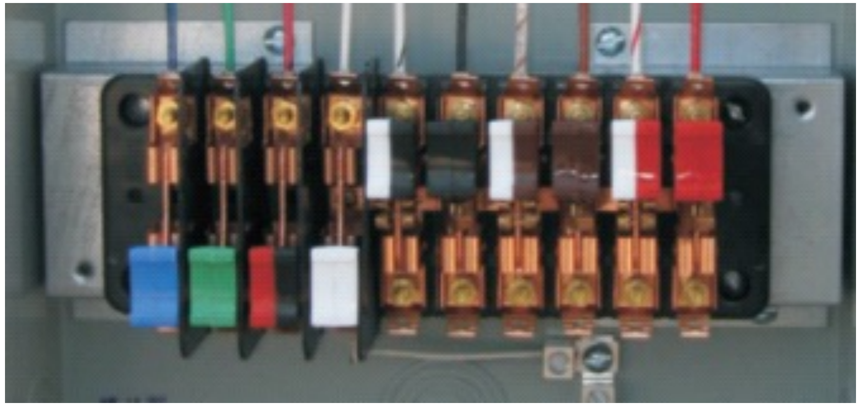
Meter Test Switches



- Test switches allow for easy testing of the meter and CTs
- Meter can be bypassed without interrupting customer's service

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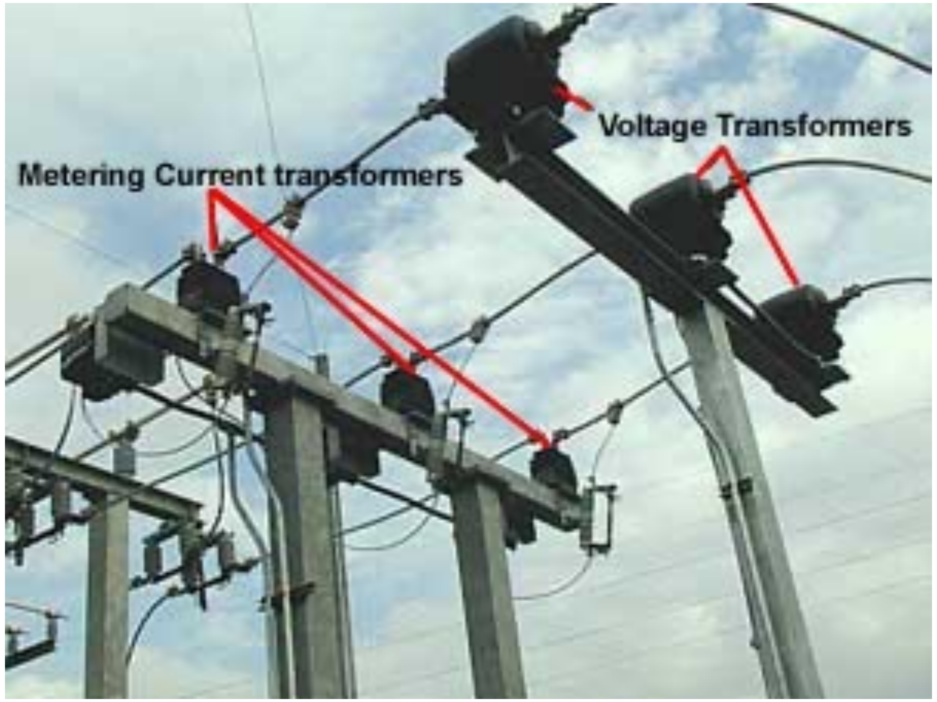
What is an Instrument Transformer?

Instrument Transformers convert signal levels from dangerous (high voltage) or inconvenient (high current, or current at high voltage) to levels appropriate for metering.



There are two fundamental types:

CTs (Current Transformers)

PTs (Potential Transformers)

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Potential Transformers (PTs)

- PTs step down high voltages to the voltage needed by the meter (usually 120V occasionally 67V).
- They come in many shapes and sizes for different applications
- They come in various power ratings expressed in VA.
- VA rating must be determined by how much power will be drawn on the secondary.
- They come in various accuracy classes, however the 0.3% accuracy class is generally used in North America.

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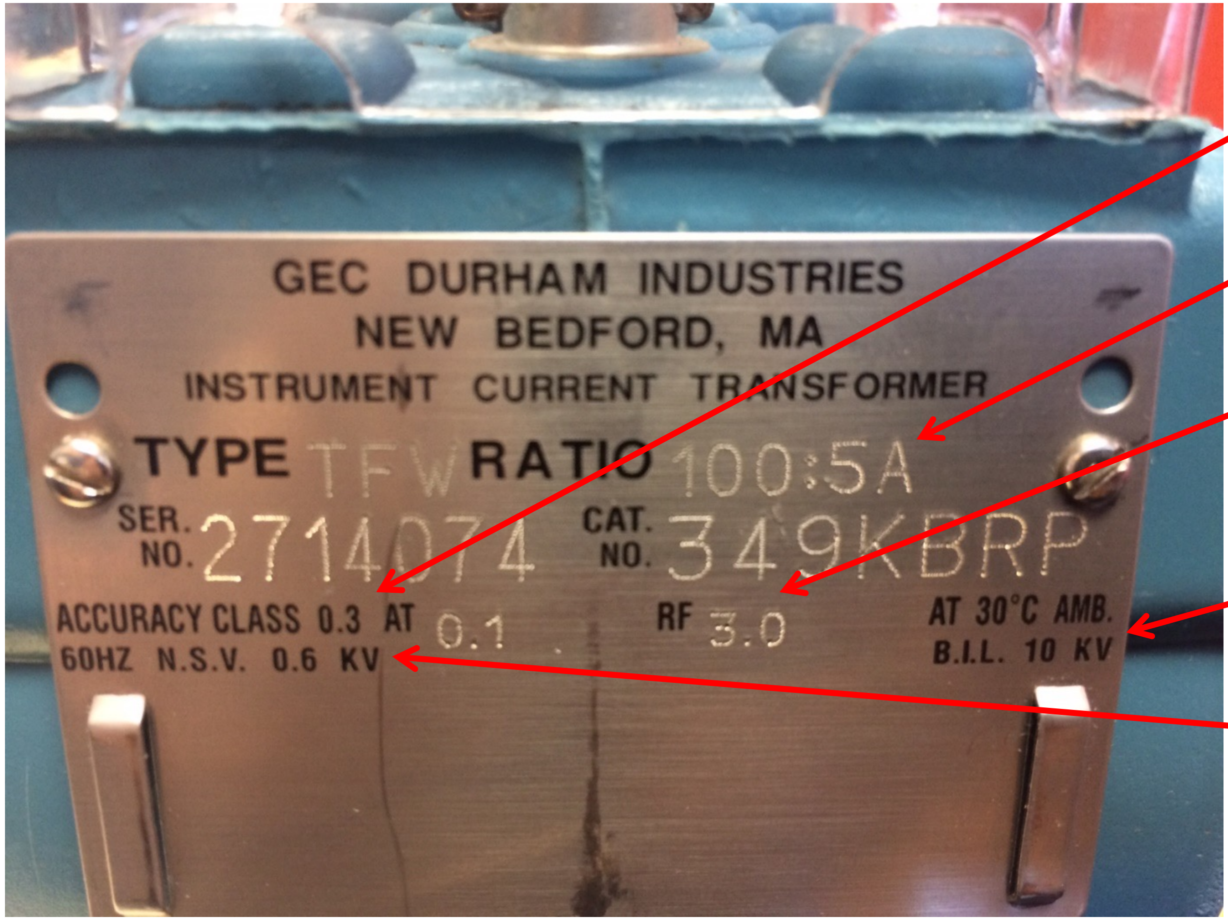
Current Transformers (CTs)

- CTs allow the measurement of high currents at potentially high voltages.
- They come in many shapes and sizes for different applications

Important Characteristics of CTs



ACCURACY CLASS

RATIO

RATING FACTOR

PRIMARY VOLTAGE

SECONDARY VOLTAGE

Important Characteristics of CTs

- Ratio is the primary to secondary current ratio
- Accuracy is measured in percent for a rated burden
- Voltage rating is the working voltage that can be applied to the primary and secondary sides of the CT
- Rating factor determines the maximum current through the CT. It is a multiplier times the 100% current rating.

  RF Example:

  200:5 CT with a rating factor of 3

  3 x 200A = 600A (Maximum Current)

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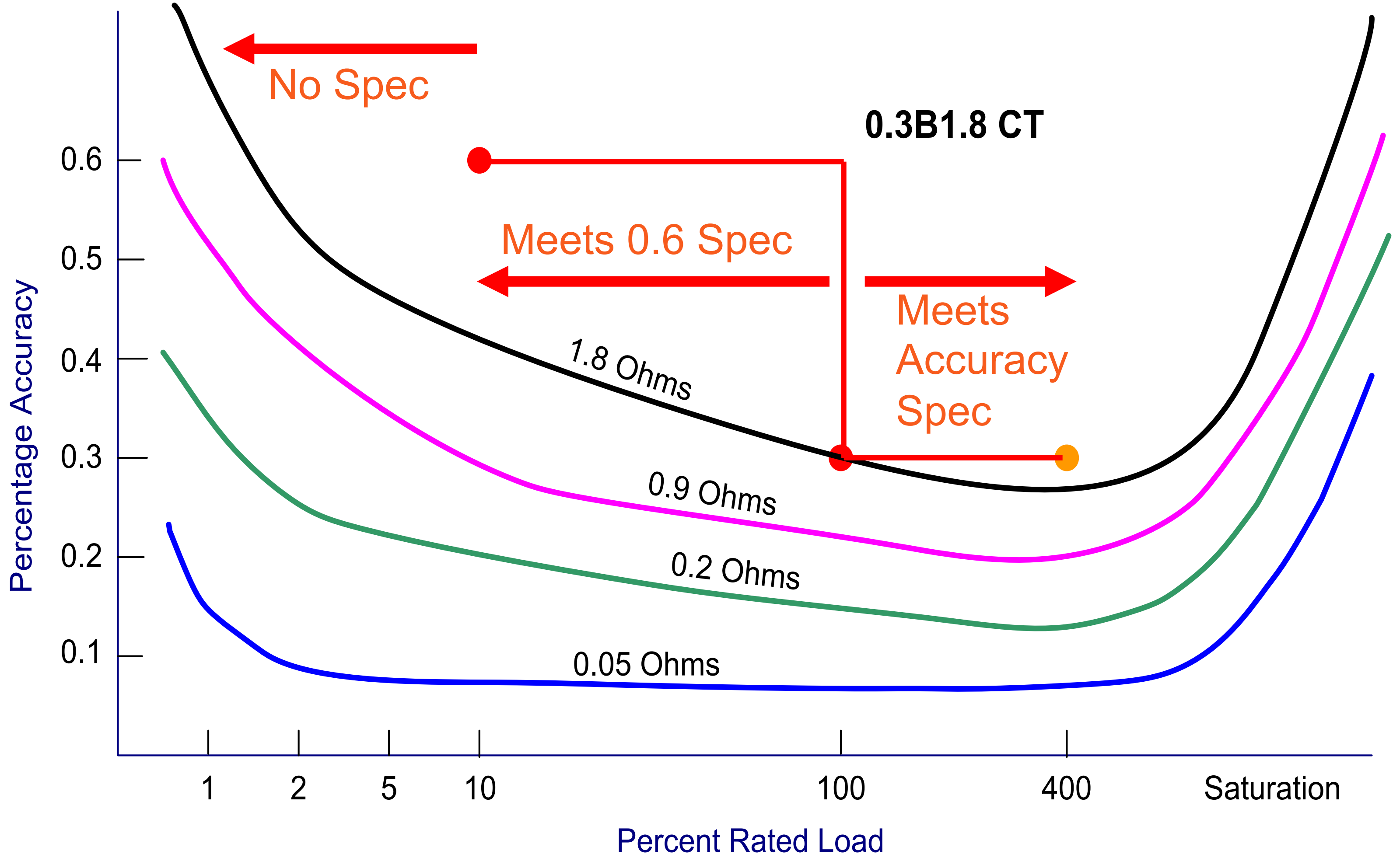
CT – Accuracy – Burden - Load



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CT Rating Factor

The MOST Misunderstood Spec

- Rating Factor has absolutely nothing to do with burden.
- If a CT has a rating factor of 4 it means that at 30°C it can be used up to 4X its label current and maintain its accuracy Class.

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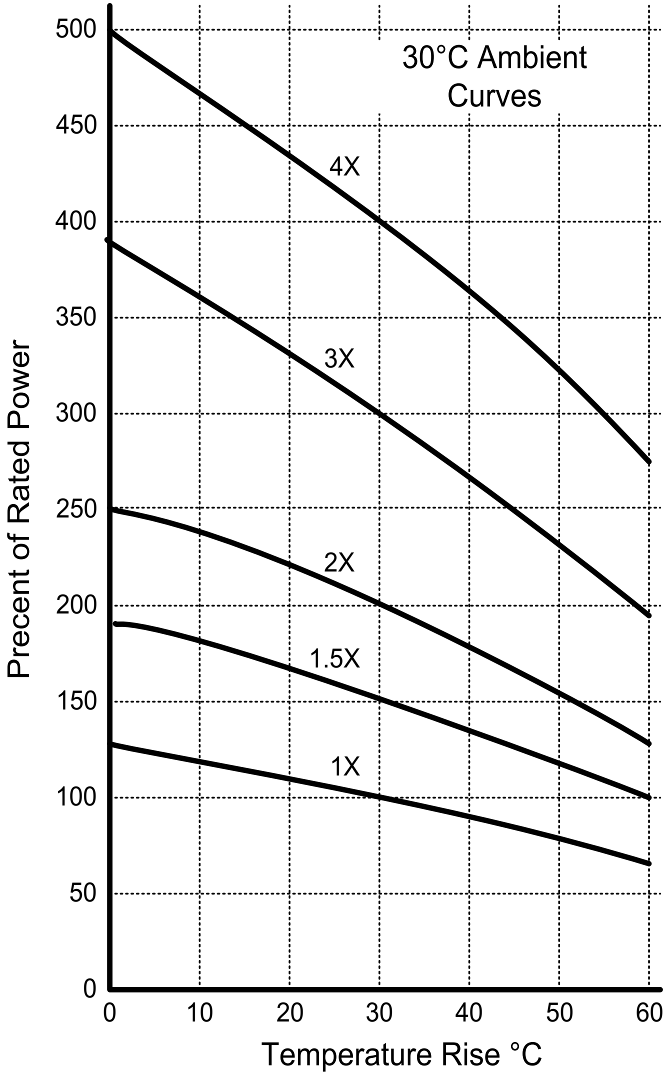
CT Rating Factor

- Rating Factor is a strong function of temperature.
- If a CT has a rating factor of 4 it means that at 30°C it can be used up to 4X its label current and maintain its accuracy Class.
- Operating temperature affects Rating Factor significantly.
  - A CT with RF=4 at 30°C (86°F) is only RF=3 at 55°C (131°F)



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What Size Current Transformer?

Previous example required 900 Amps per phase

Typical 9S meter can only measure 20A MAX!

CT Ratio = Primary amps / secondary amps

= 900 / 20 = 45

CTs are rated using test amps – typically 5A

Primary side = 45 * 5 = 225 Amps

Use a 300:5 CT with a rating factor of 3-4

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What’s the #1 most ignored problem at a meter site?

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What's the #1 most ignored problem at a meter site?

THE WIRING!

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Bad Wiring on Current Circuit

- **A faulty connection can easily add a few tenths of an Ohm burden**
- **Improper wiring**
- **Missing commons**
- **Multiple Grounds**

- **Almost all wiring errors result in reduced billing.**

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Bad Wiring on Voltage Circuit

- **For 50 ft of #14 wire to the meter, normally we would have:**
  - Vu = 120V, I = 0.2A, R1+R2 = 0.036Ω => 0.0075V =>0.006% Error
- **Consider a bad connection with resistance 4.0 Ω, then**
  - Vu = 120V, I = 0.2A, R1+R2 = 4.036Ω => 0.843V =>0.7% Error
- **A significant error**

$$V_m = V_u - I * (R_1 + R_2)$$

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Bad Wiring on Current Circuit

- **Using too small a gauge wire can result in over burden**
  - 50 ft of #14 wire is 0.14Ω this is more burden than is allowable for a 0.1B class CT.
  - 50 ft of #12 wire is 0.09Ω this is almost the total burden allowable for a 0.1B class CT.
- **Without any bad connections or other problems using too small a wire size can insure you get the worst performance from your CTs.**

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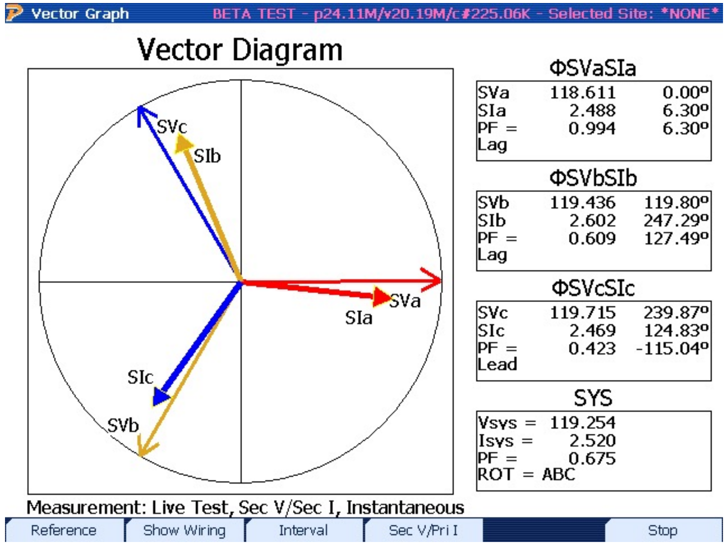
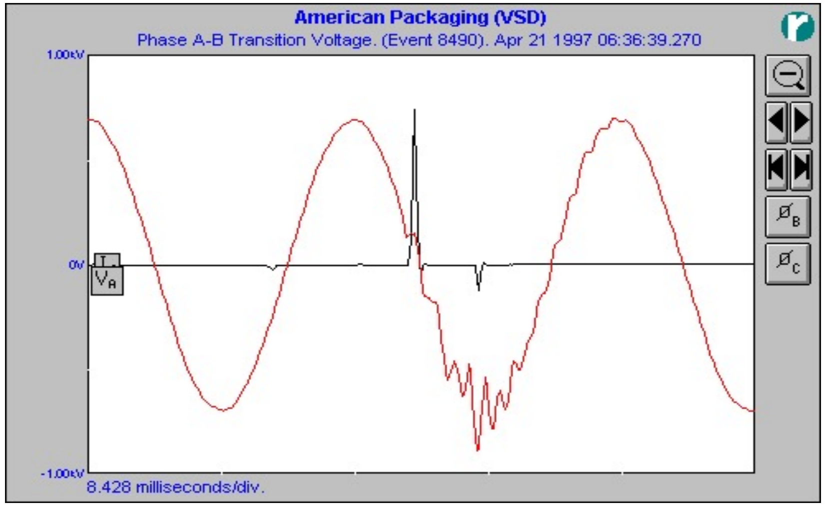
Site Testing and Power Quality





- A site can be made much easier to test if this planning takes place during the design stage of the metering site!

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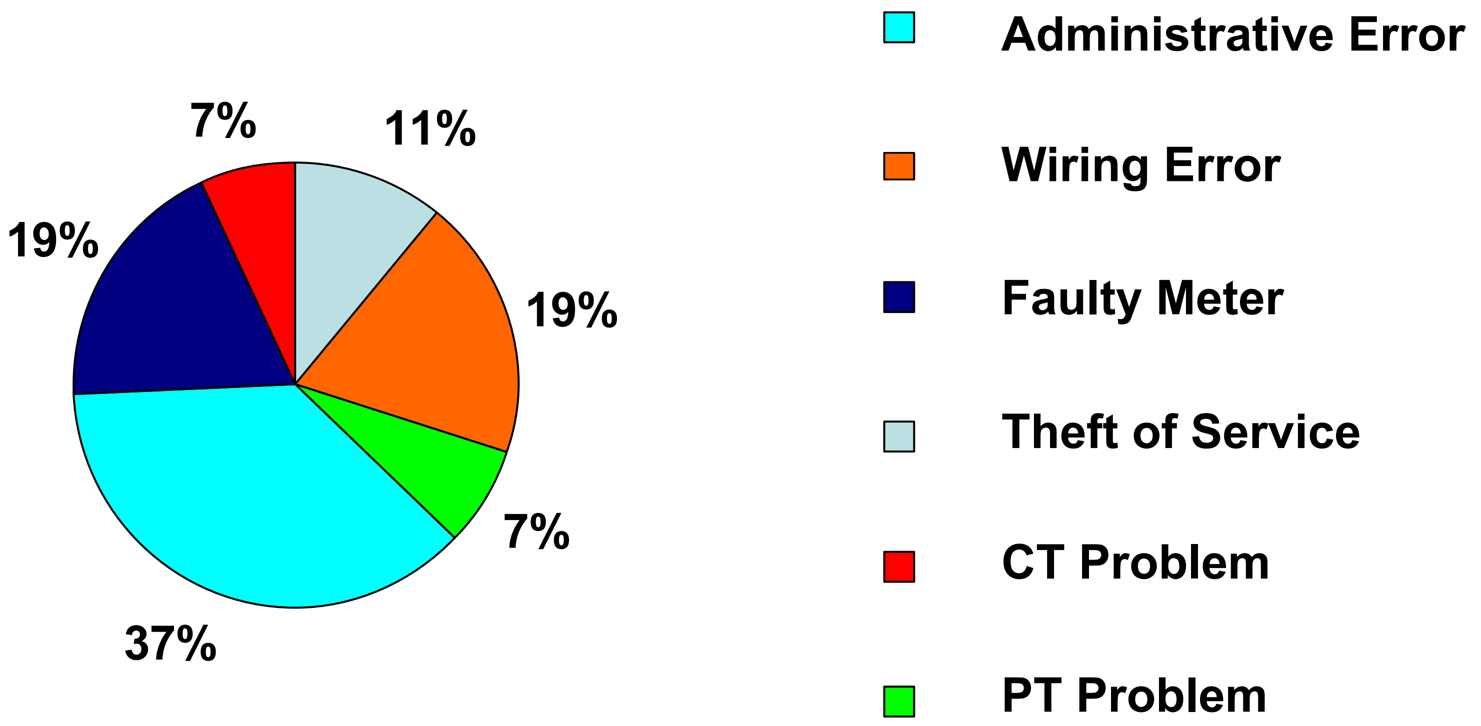
3 Year Study from a Municipal with 35,000 Transformer Rated Installations



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3 Year Study from a Municipal with 35,000 Transformer Rated Installations

Total Problems Found after 10% of Sites Tested:

96

Percentage of Sites found to have a Problem:

96 ÷ 3,500 ≈ 2.7%

Total Lost Revenue Found:

$ 2,248,354

Average Lost Revenue Found per Problem:

≈ $ 23,420

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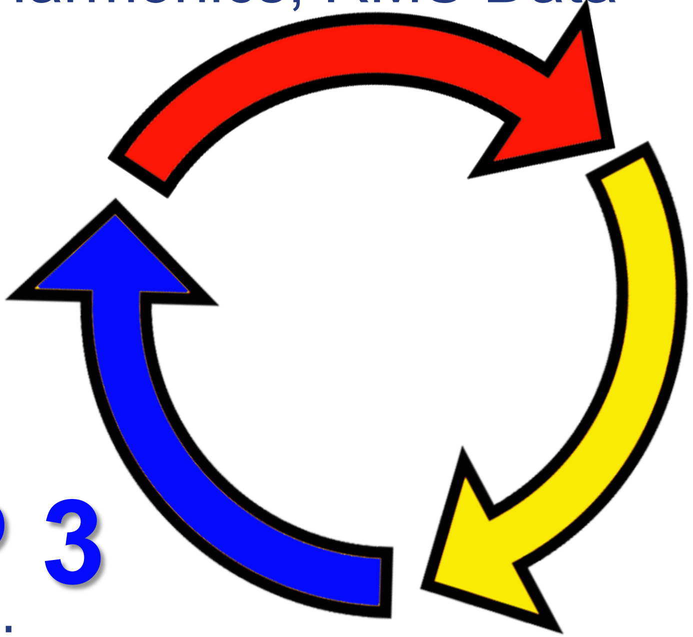
Integrated Site Test Philosophy

STEP 1

Site Analysis:
Vectors, Waveforms, Harmonics, RMS Data



STEP 2

CT & PT Testing

STEP 3

Meter Testing:
Customer Load & Phantom Load

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Integrated Site Test Philosophy

Phantom Load Results　　Selected Site: TEST

FL 99.954

Phase	Voltage	Current	PF	Time	Pulses
All	238.54	4.995	0.868	4.18	2

PF 99.913

Phase	Voltage	Current	PF	Time	Pulses
All	238.54	4.995	0.441	8.24	2

LL 99.966

Phase	Voltage	Current	PF	Time	Pulses
All	238.51	0.497	0.868	42.03	2

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Retest　Retest All　Done

Meter Testing

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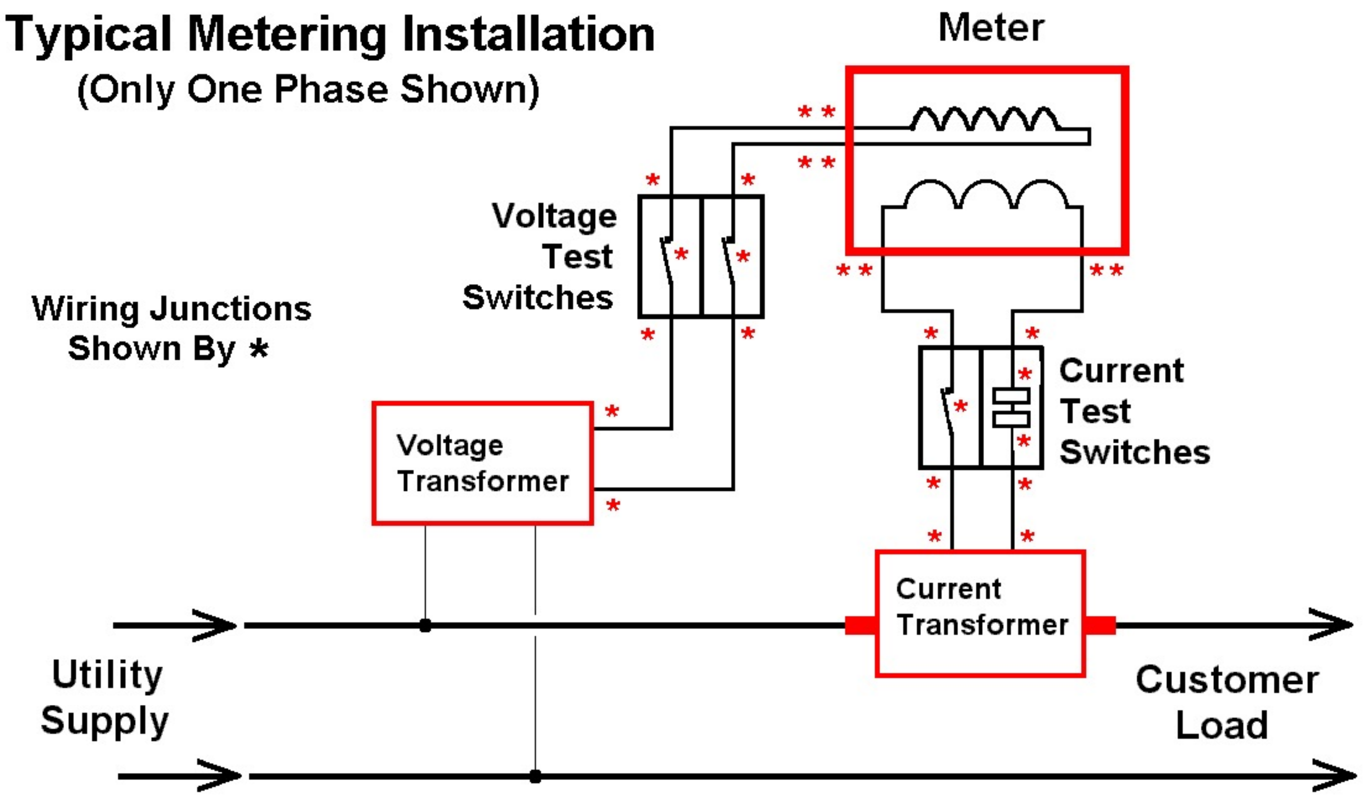
Consider a Typical Metering Installation

The meter measures ONLY the voltage and current reaching the meter terminals. Wiring errors result in incorrect metering. Degraded wiring overburdens CTs or allows current to bypass the meter.



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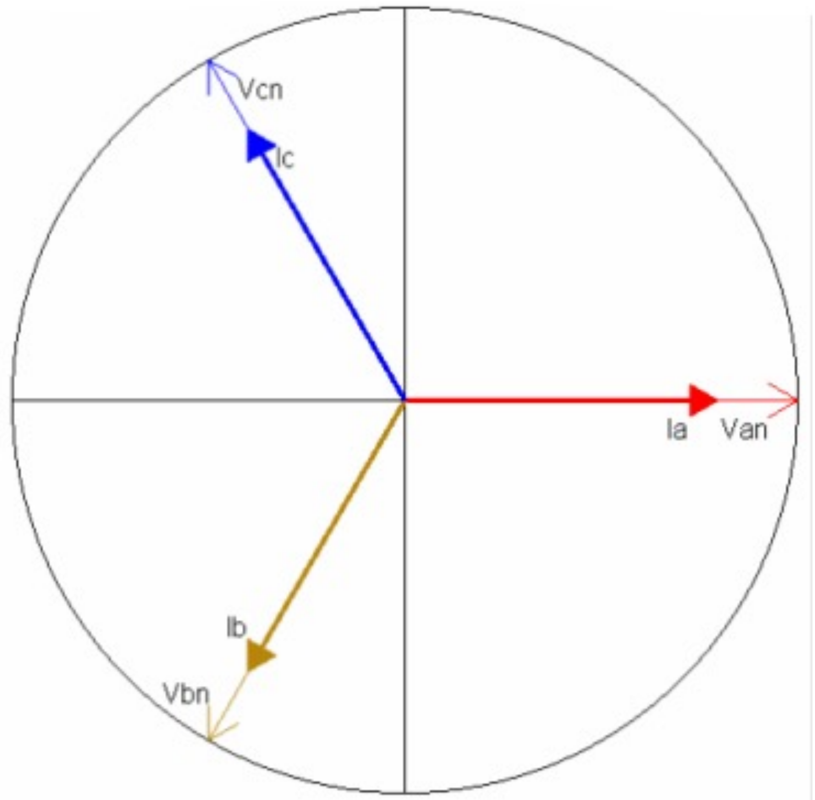
Vector Diagrams are a Powerful Tool

They show everything you need

- Voltage Amplitude
- Voltage Phases
- Current Amplitudes
- Current Phases
- Relationship of Voltage to Current

- If we know what we should see
- We can detect many problems



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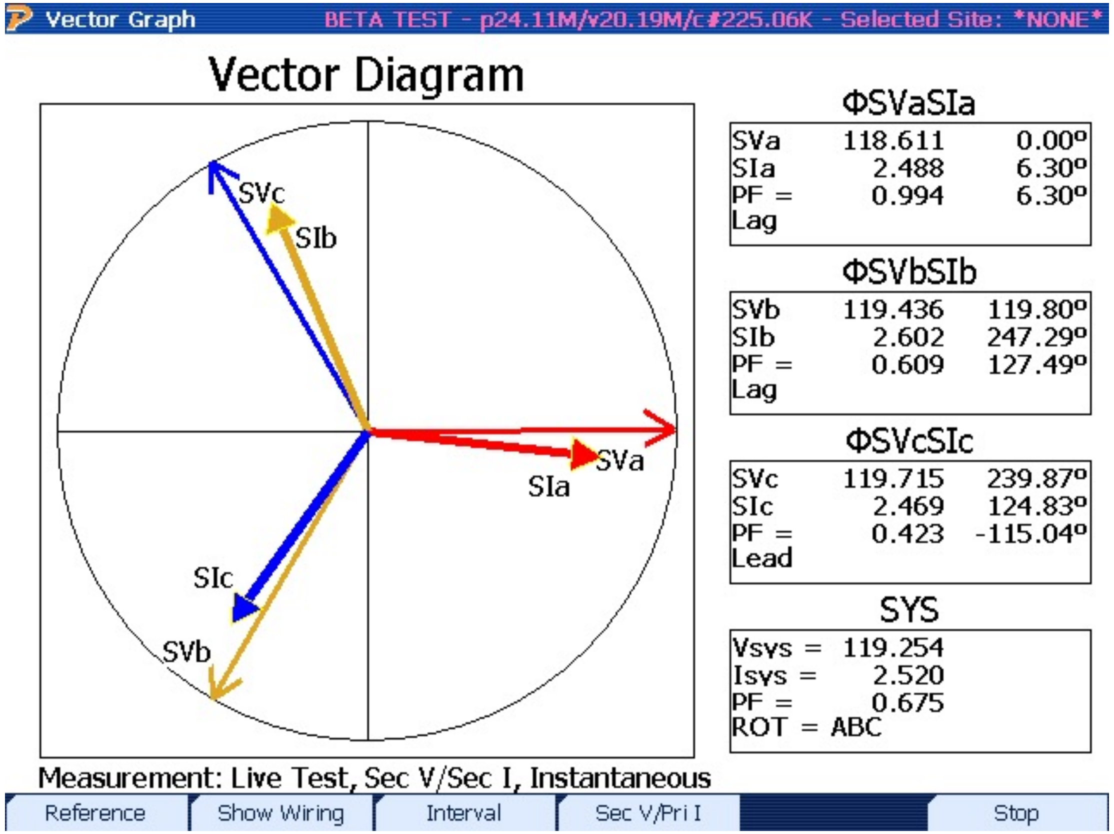
Integrated Site Test Philosophy

Vector Diagram

Site Analysis



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CT Testing

- Four Approaches in use today
  - Direct burden measurement – gives an accurate measurement of the real burden
  - Direct RATIO measurement with applied burden
    - Most accurate approach tells us exactly what we want to know
    - Measures directly the quantity we care about CT Ratio
    - Is more complicated to perform.

CT Testing

- Alternate Approaches
  - Burden only
    - A compromise: tells us if circuit is stable under excess burden
    - Can’t give us the ratio which is what we really care about.
  - Admittance Testing
    - Allows us to look for changes from previous measurements.
    - Doesn’t directly give ratio
    - Accuracy typically ±5%

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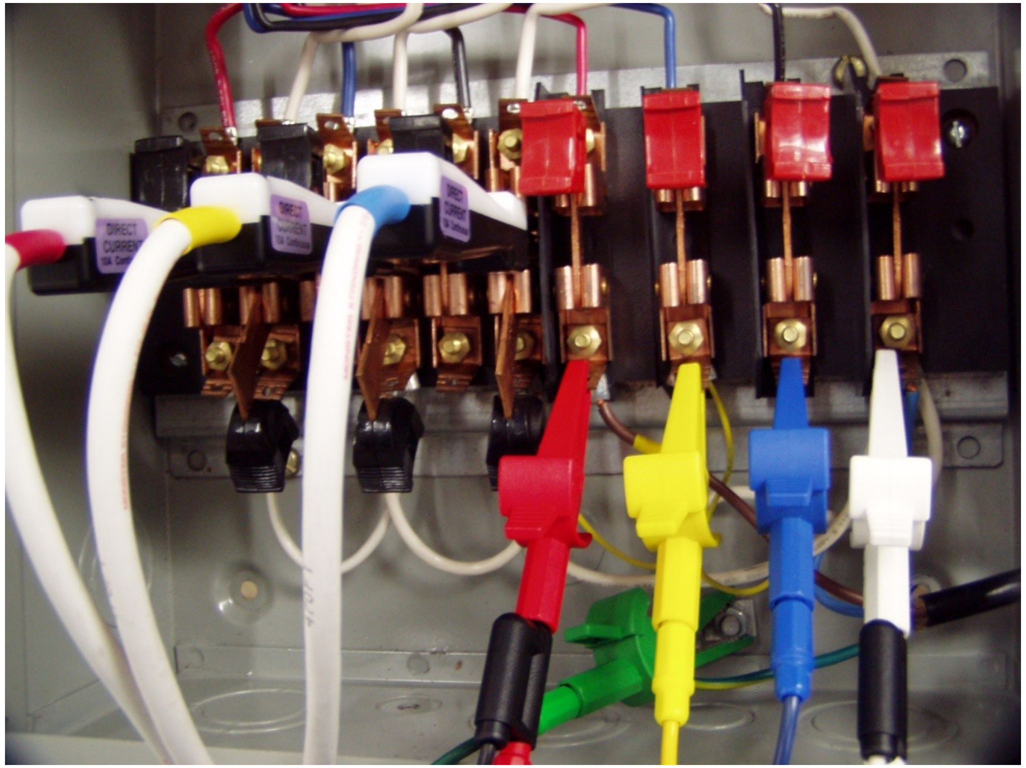
CT Ratio with Burden Testing



- Secondary connection is made through the test switch
- Same connection that is used for the rest of the site testing.

Ratio Testing with applied burden is the most accurate and complete approach for testing at CT in service.

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What is Power Quality?

- Customer’s view of power quality
  - Flickering lights
  - Equipment reset
  - Tripping of breakers
  - Motors or transformers running hot
  - Lightning or other weather related issues

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What is Power Quality?

- Utility's view of power quality - Deviation from a pure sinusoidal voltage supply at a frequency of 60 Hz (US).
  - Sags, dips, swells
  - Transient voltages
  - Harmonics
  - Voltage Regulation
  - Frequency Variations

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What is a Power Analyzer?

- A power analyzer is a device used to measure the components of power:
  - Voltage
  - Current
  - Phase
  - Power Factor
  - Frequency
  - Harmonics

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Power Analyzer

- Measure data over a period of time to establish a trend
- Normally logs data to a PC or may be self-contained
- Used to determine ways to reduce energy usage and find and eliminate power quality issues

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Real World Example

- New Service at Big-Box-Mart
- Service Configuration: 3ph 4W padmount
- Voltage: 277/480V
- Expected Load:

  MAX - 2000kW @ 85%PF

  MIN - 150kW @ 85% PF

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Current Calculation

- Current = Power / # phases / P-N voltage
- Voltage: 277V phase-neutral
- Expected Load:

MAX: 2000kW @ 85%PF

PF = W / VA -> VA = W / PF

VA = 2000kW / 0.85 = 2353 kVA

MAX I = 2353kVA / 3 / 277 = 2831A

What kind of meter do we use?

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Meter Selection

- Current > 400A, so it must be

  TRANSFORMER RATED
- Voltage: 277/480V
- 3 phase, 4 wire wye

- Best meter is a form 9S, 120-480V, 0.2% accuracy class

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Should we use PTs?

- PTs may be used to step down 480V sites to 120V for safety
- PTs must be sized for the proper VA rating
- PTs have an accuracy rating that affects the overall site accuracy
- PTs add cost to the installation

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CT Selection

MAX I: 2000kW @ 85%PF

VA = 2000 / 0.85 = 2353kVA

I = 2353000 / 3 / 277 = 2831 A

MIN I: 150kW @ 85% PF

VA = 150 / 0.85 = 176kVA

I = 176000 / 3 / 277 = 180A

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CT Selection

MAX I = 2831 A

MIN I = 180A

1000:5 CT with rating factor of 3-4, 0.3% accuracy at 0.1 ohm burden

Watch how RF is affected by temperature if the CTs are mounted inside the meter can!

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Wire Selection

- Secondary side rated for 20A
- 12 AWG wire has 0.0016 ohm / foot
- Short run (<25ft) should be OK
- What if CTs are pole mounted?

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Overall Site Accuracy

- Meter is 0.2% accuracy class
- CT is 0.3% accuracy class

- Worst case error = meter error + CT error

  = 0.2 + 0.3 = 0.5%

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