# Meter Testing Concepts

## Integrated Site Testing


Southwest Electrical Metering Association

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# Why do we test a site?

- To protect OUR revenue stream.
- To ensure we fairly bill the customer.
- To assure site is wired safely and to codes.
- To meet PSC mandated requirements

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# What do we need to know to succeed?

- What service type site we are testing?
- What form meter we are using?
  - What is the Kt?
- Do we have CTs?
  - What is the ratio?
  - Burden class?
- Do we have PTs?
  - What is the ratio?
  - Burden class?

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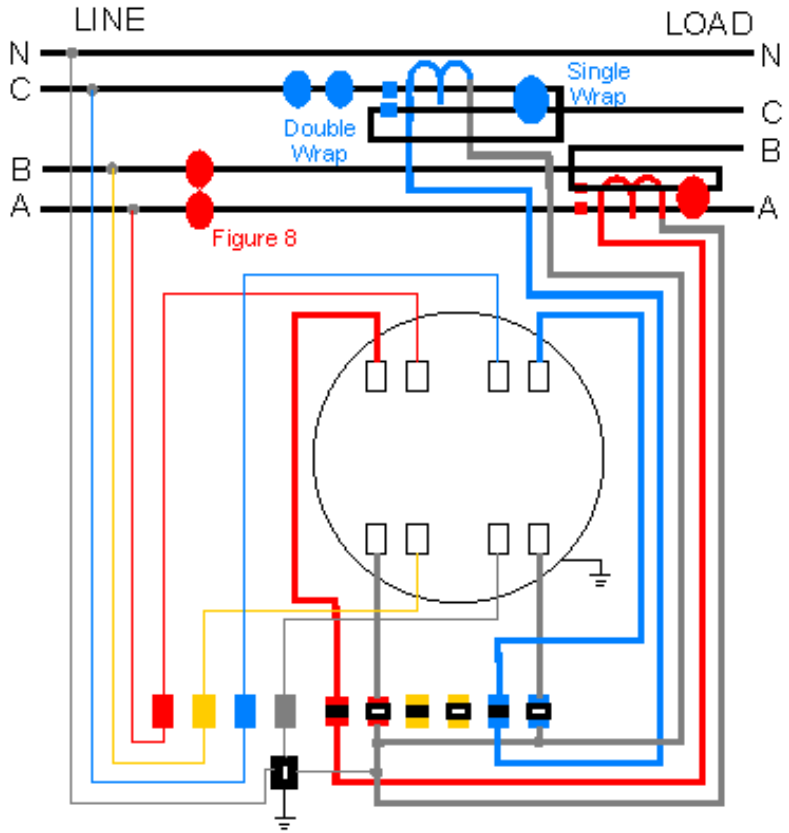
# What is the Service Type?

- To understand a vector diagram we must understand the service type.
- Service type is defined by:
  - The transformer configuration: 4-Wire Wye, 3-Wire Delta, etc
  - The form of meter: 5S, 8S, 9S, etc.
  - The configuration of CTs & PTs
  - The wiring




**4-Wire Wye, Form 5, 2 CT, No PT, Wired Z-Coil**

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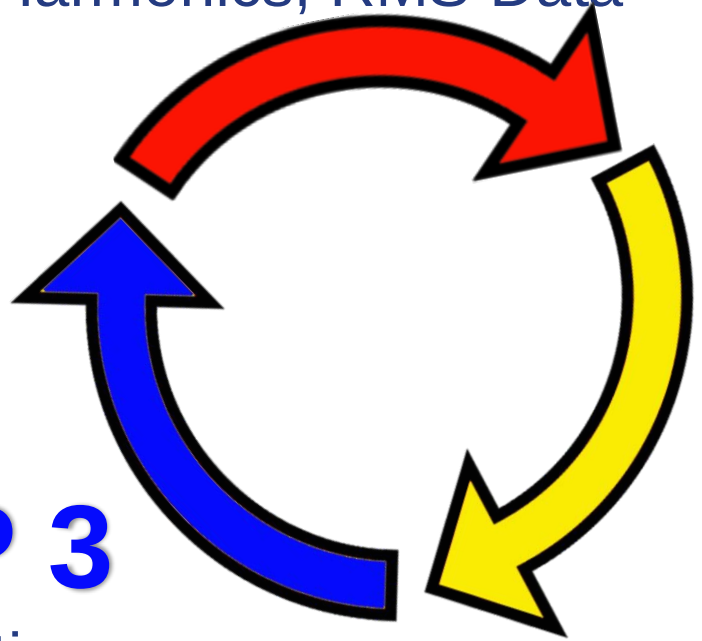
# INTEGRATED SITE TEST PHILOSOPHY

## 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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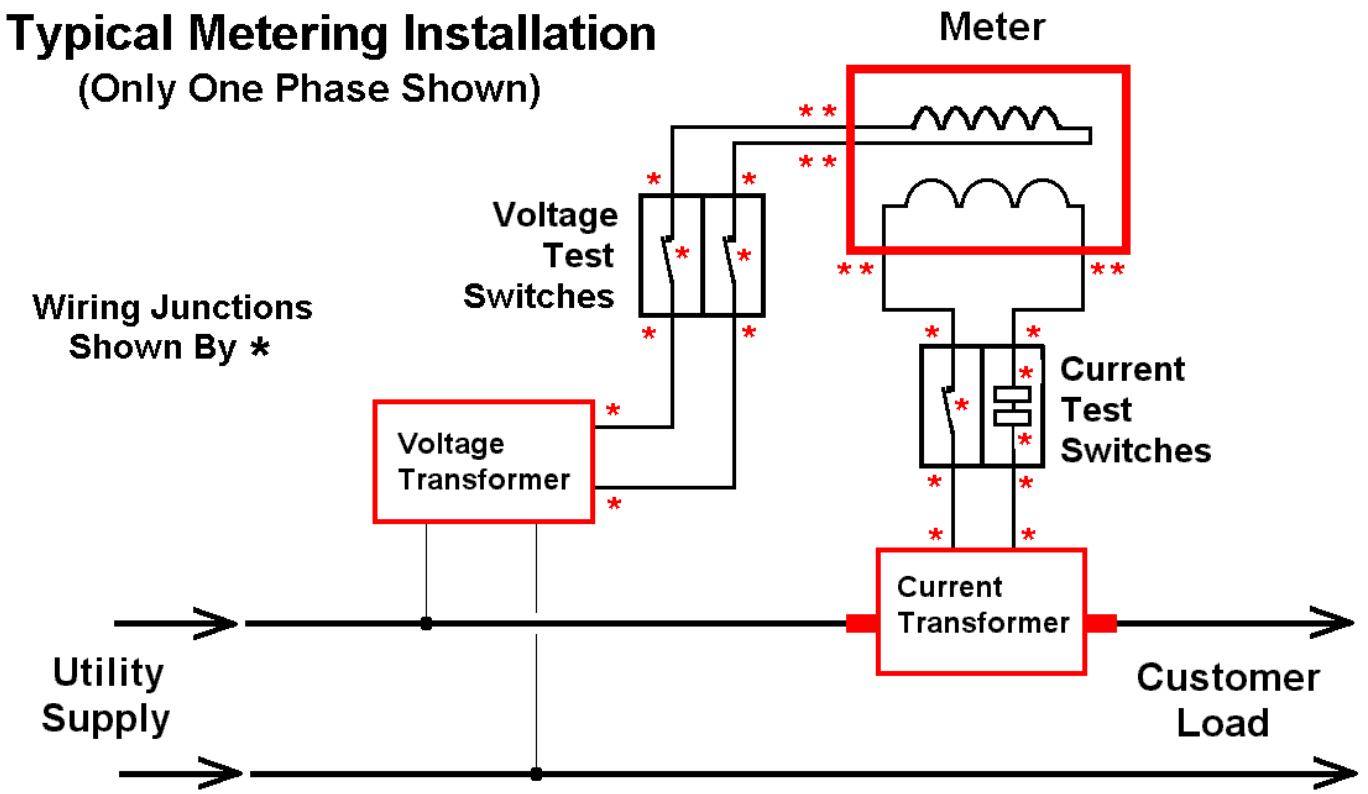
# Consider a Typical Metering Installation

A complex system with many opportunities for error.

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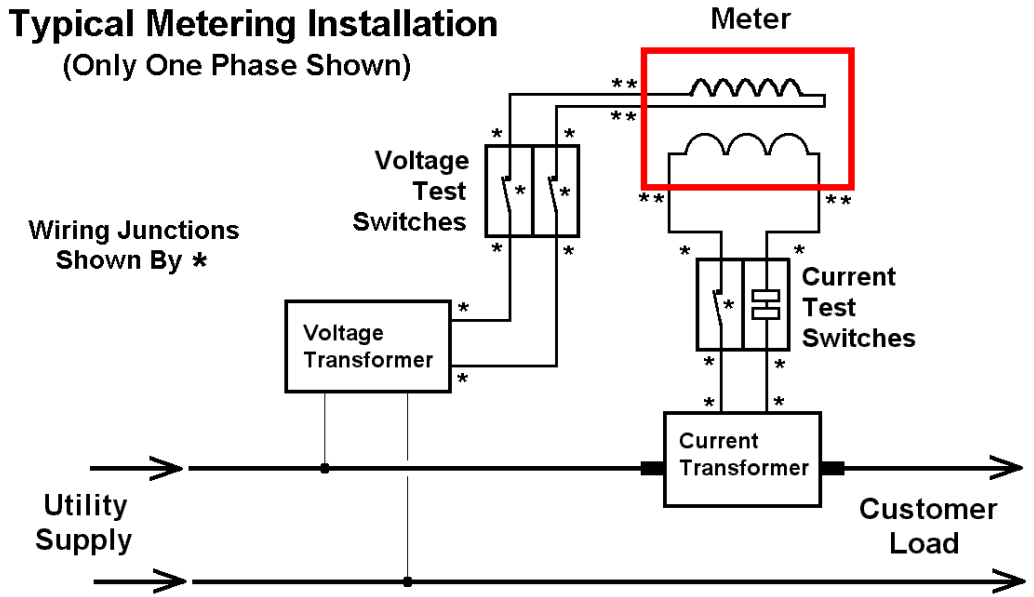
# YET - Traditionally Only The Meter Is Tested

… But the meter measures only what reaches its terminals




How do we know that the signals are correct?

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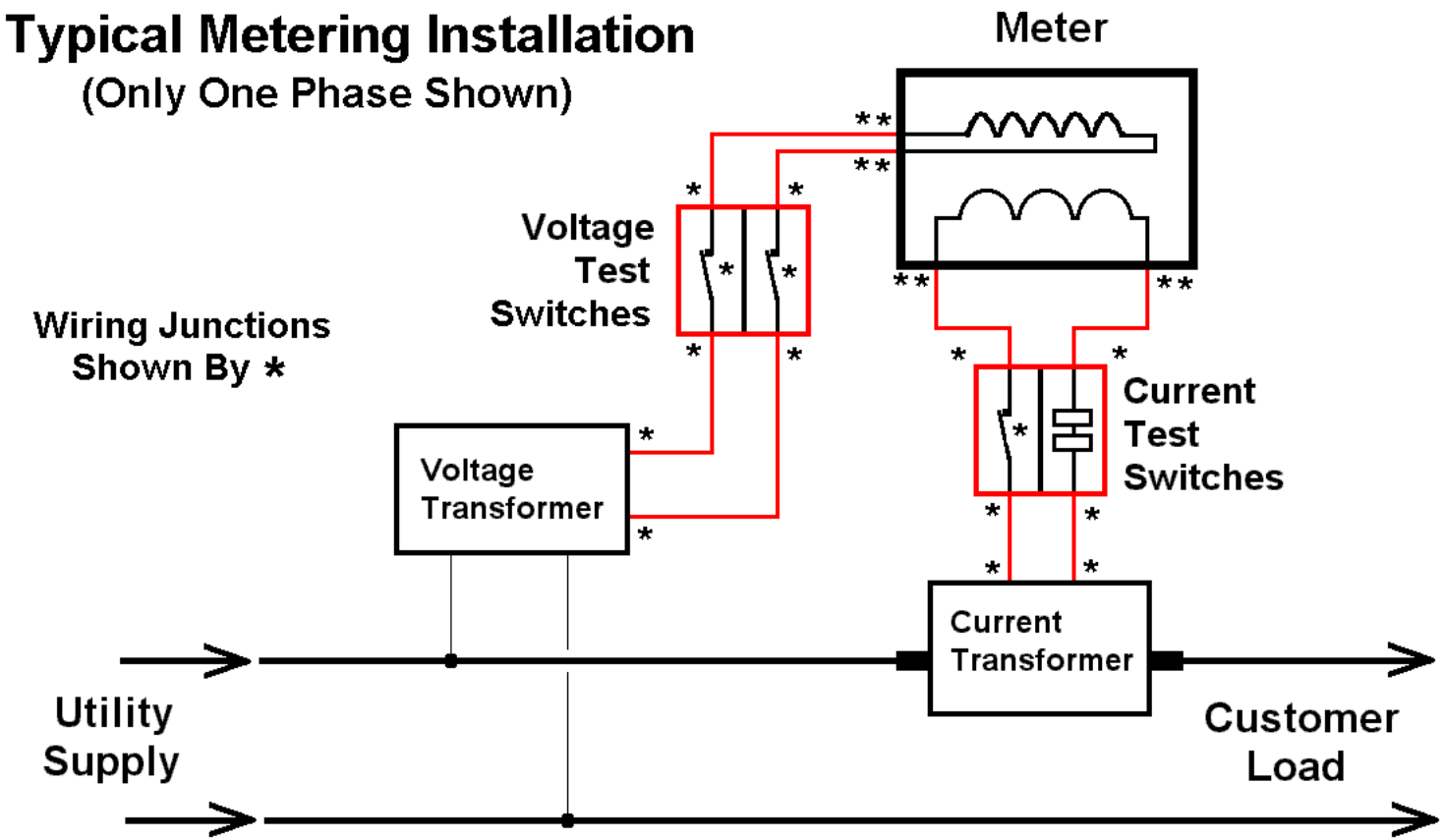
# Wiring And Junctions Connect The Meter

## … What If There Are Wiring Errors Or Poor Connections
## Poor Junctions Will Over-Burden The CTs And Reduce Revenue

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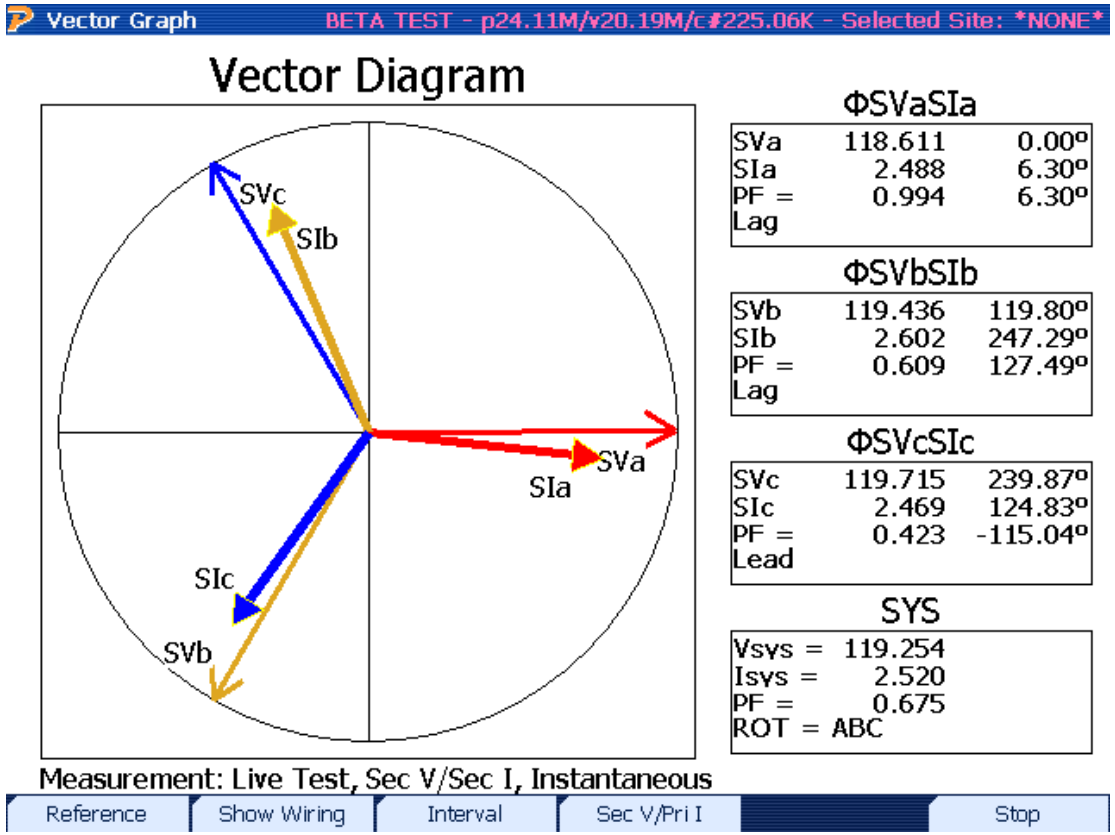
# The Vector Diagram

## Your best site analysis tool




**Site Analysis**

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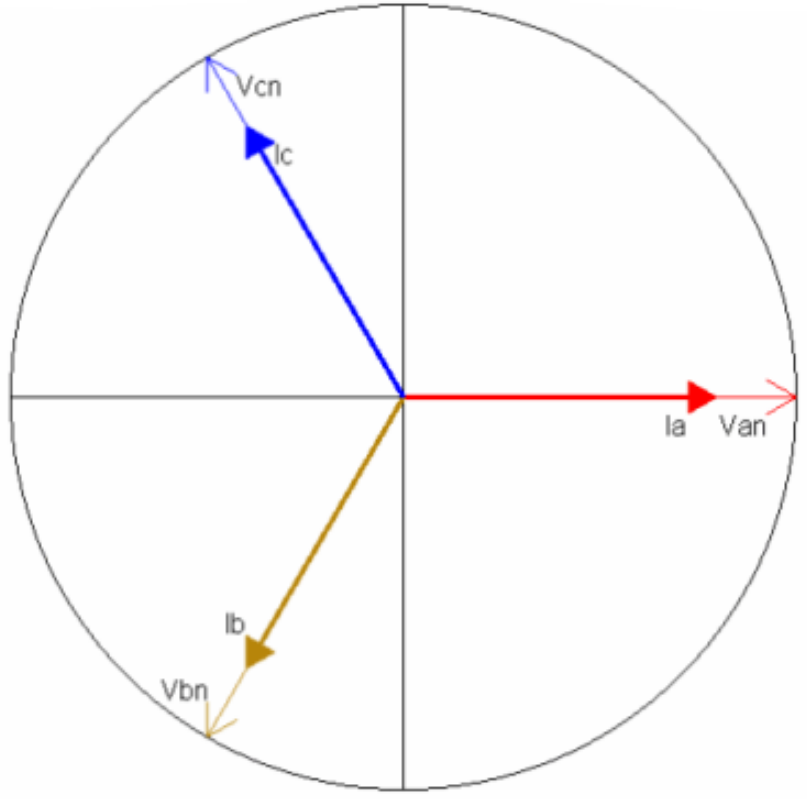
# Vector Diagrams are a Powerful Tool

## 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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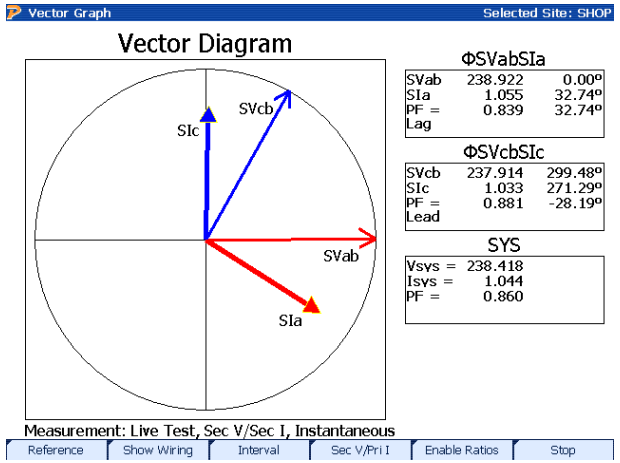
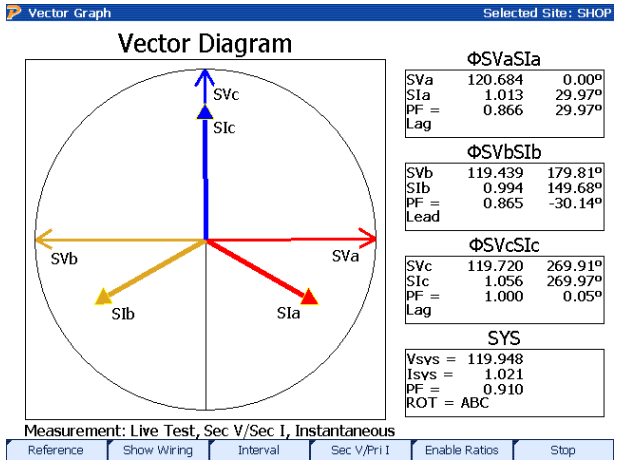
# What should the vector diagram look like?

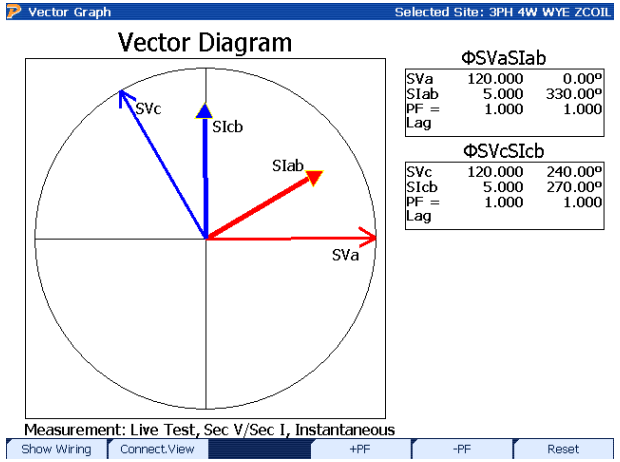
## 3-Wire Delta  Form 5S 2CT 2V




## 4-Wire Delta  Form 9S 3CT 3V

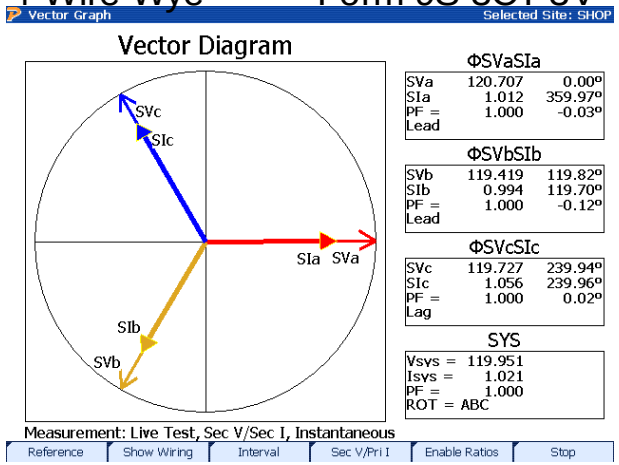



## 4-Wire Wye  Form 6S 3CT 2V




Connect View

## 4-Wire Wye  Form 9S 3CT 3V

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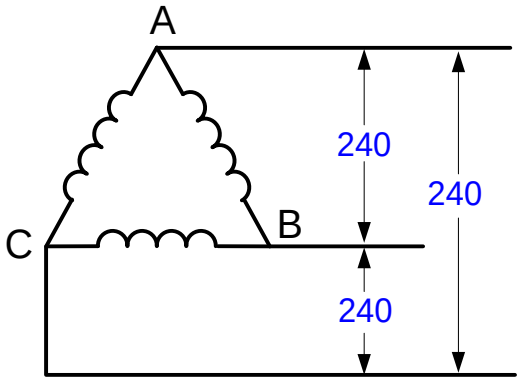
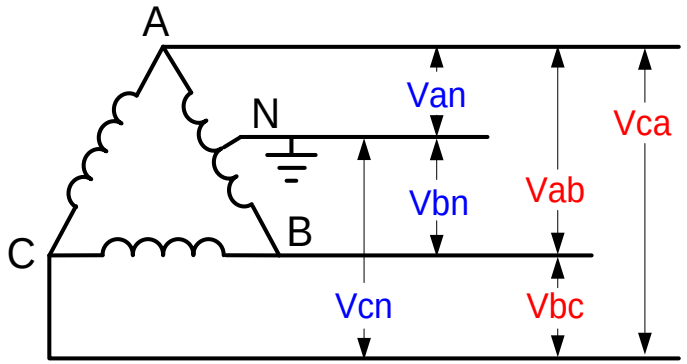
# Services are Generally Simple

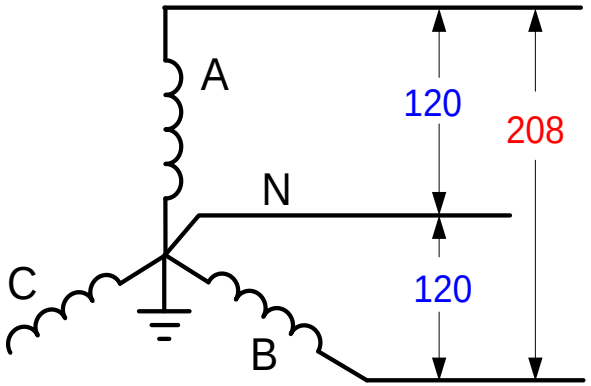
3-Wire Delta



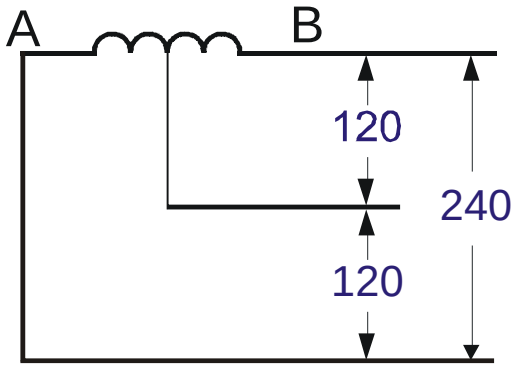

4-Wire Delta




4-Wire Wye




Single Phase




Our metering choices make them complex.

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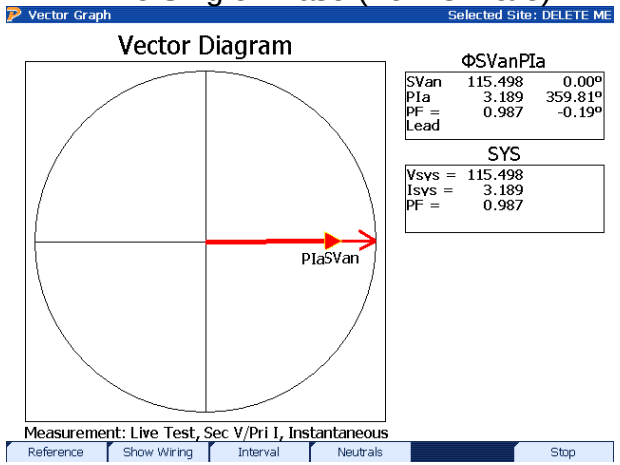
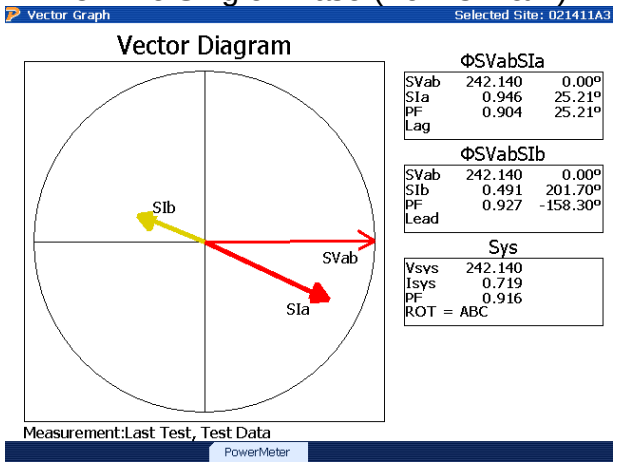
# Vector Diagrams Can be Confusing

## But they show everything you need

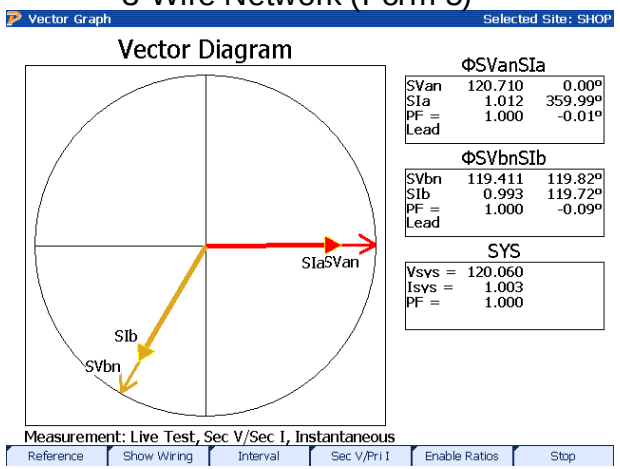
### 2-Wire Single Phase (Forms 1 & 3)



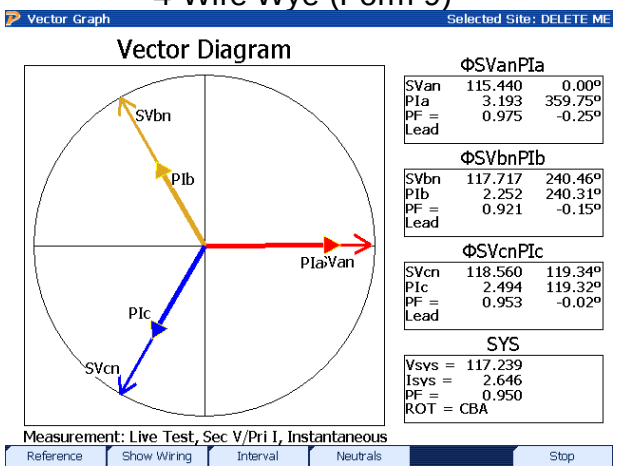

### 3-Wire Single Phase (Forms 2 & 4)




### 3-Wire Network (Form 5)




### 4-Wire Wye (Form 9)

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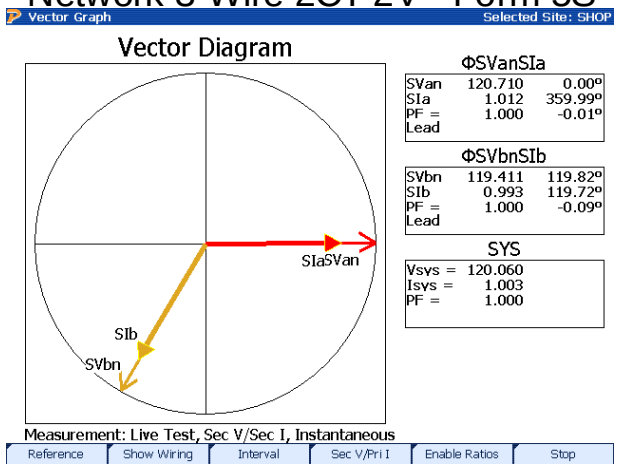
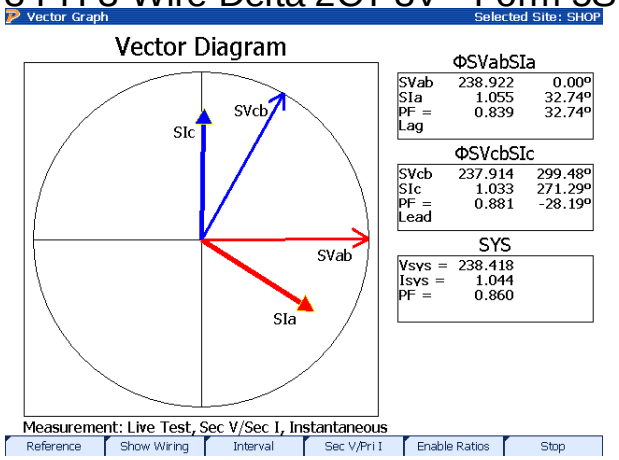
# Vector Diagrams Tell You Everything

## One Meter Form – Many Diagrams

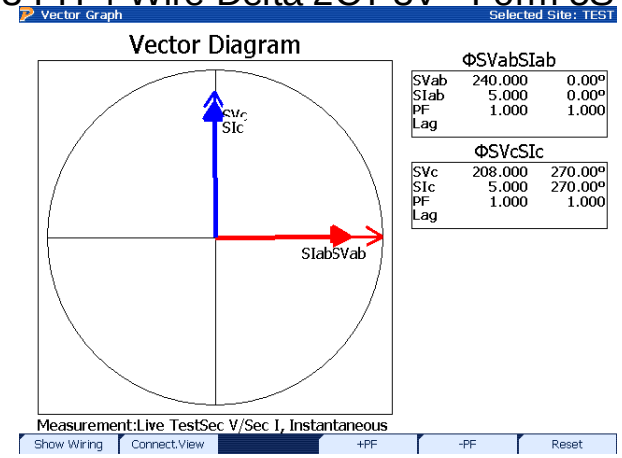
### Network 3-Wire 2CT 2V - Form 5S



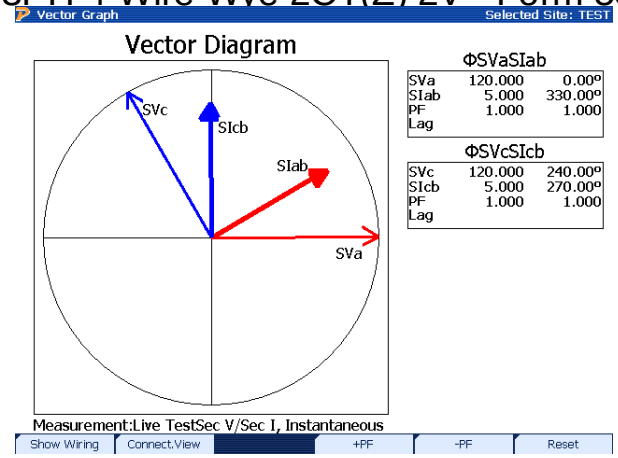

### 3 PH 3-Wire Delta 2CT 3V - Form 5S




### 3 PH 4-Wire Delta 2CT 3V - Form 5S




### 3PH 4-Wire Wye 2CT(Z) 2V - Form 5S

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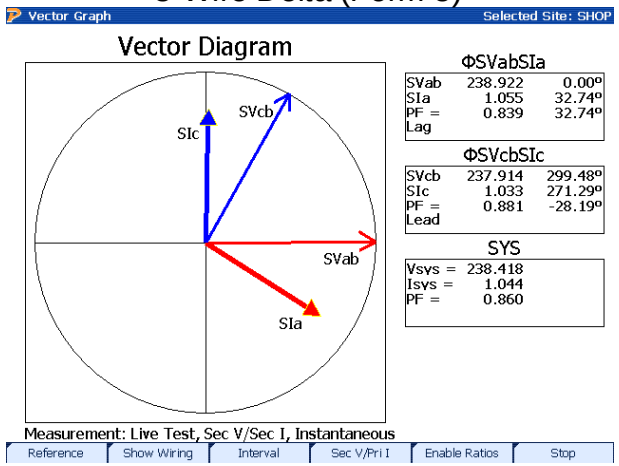
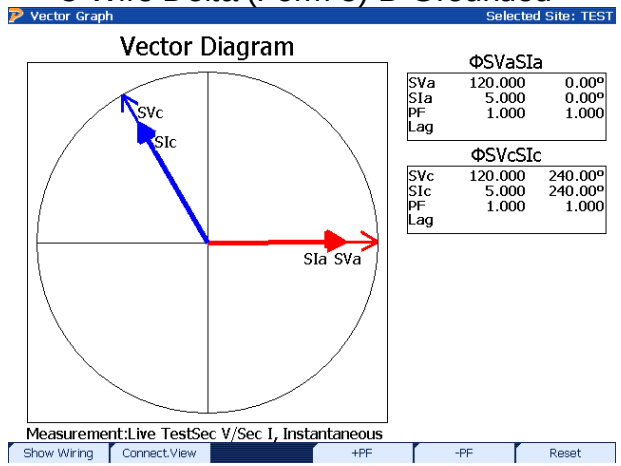
# Vector Diagrams are a Powerful Tool

## They show everything you need

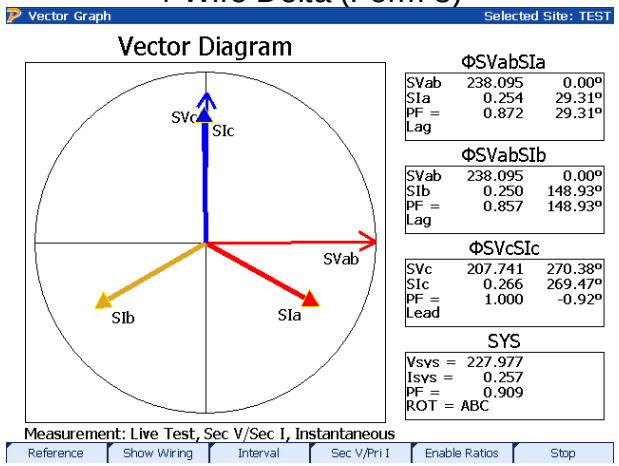
3-Wire Delta (Form 5)



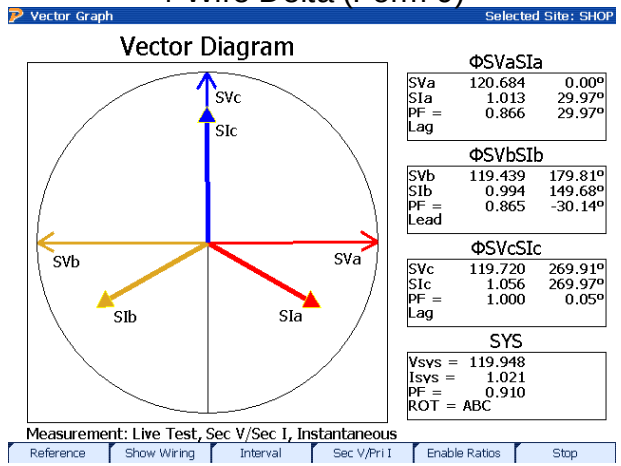

3-Wire Delta (Form 5) B-Grounded




4-Wire Delta (Form 8)




4-Wire Delta (Form 9)

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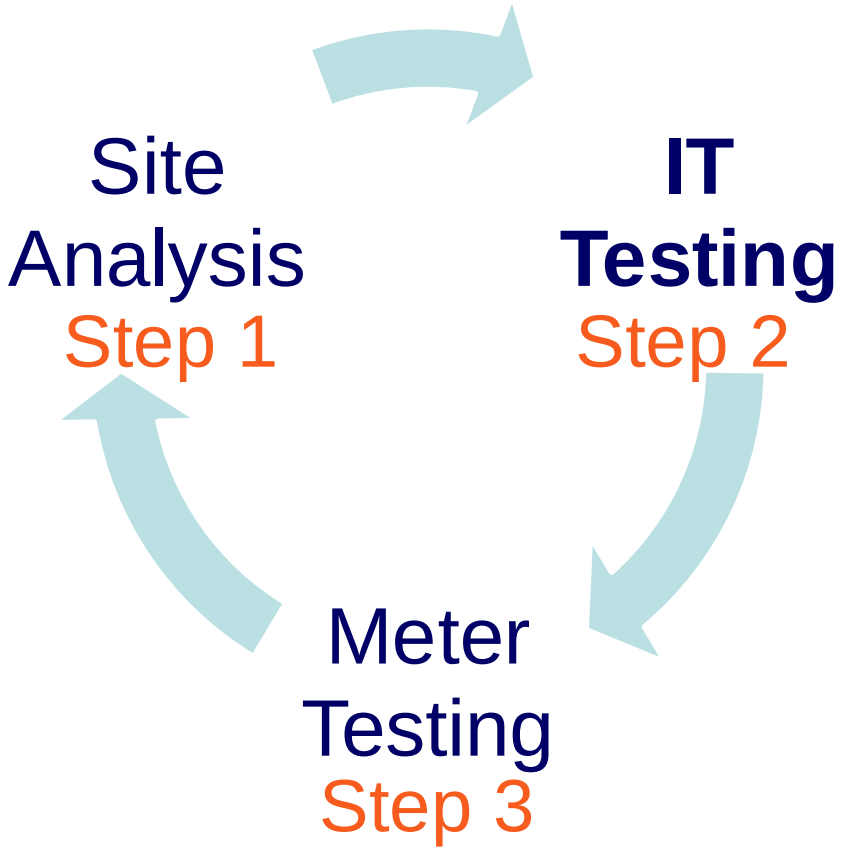
# Integrated Site Test Philosophy

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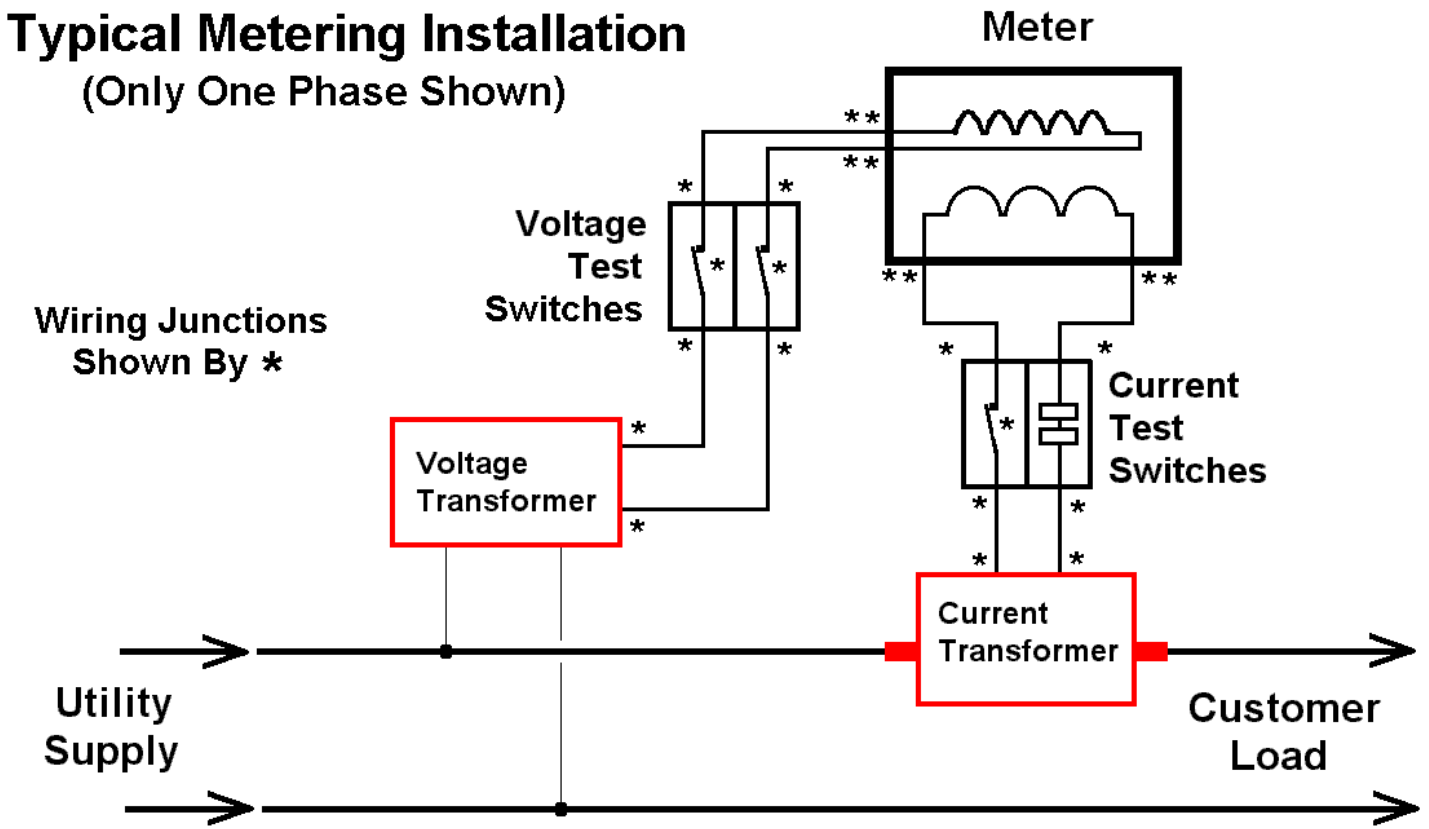
# Instrument Transformers Control Metered Values

## … What If They Do Not Produce The Expected Outputs

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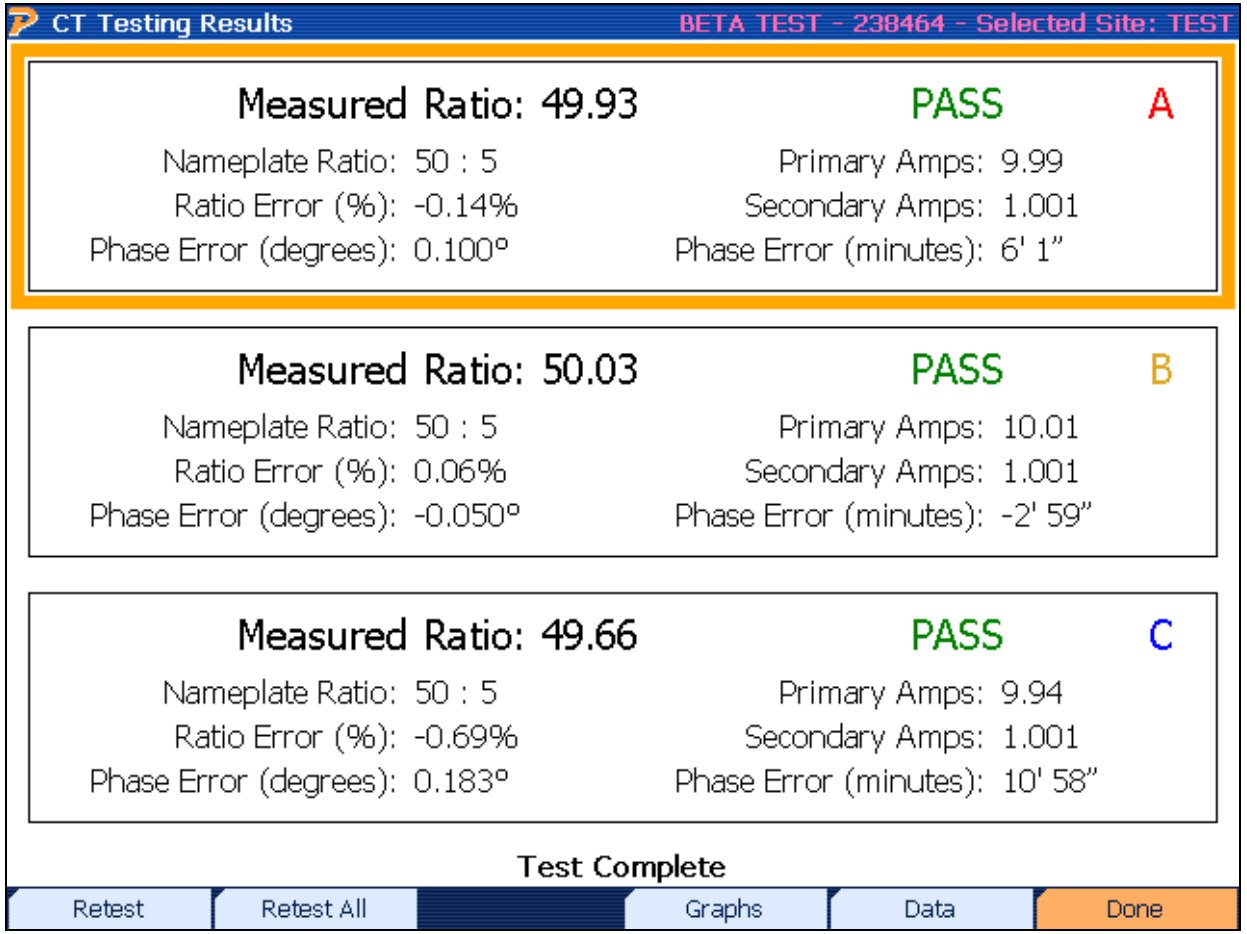
# Integrated Site Test Philosophy




**CT Testing**

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# CT Ratio with Burden Testing

- Ratio Testing is the preferred approach when we can gain access to the CT primary.
- Various types of probes can be used for primary side.
  - Flex
  - HV

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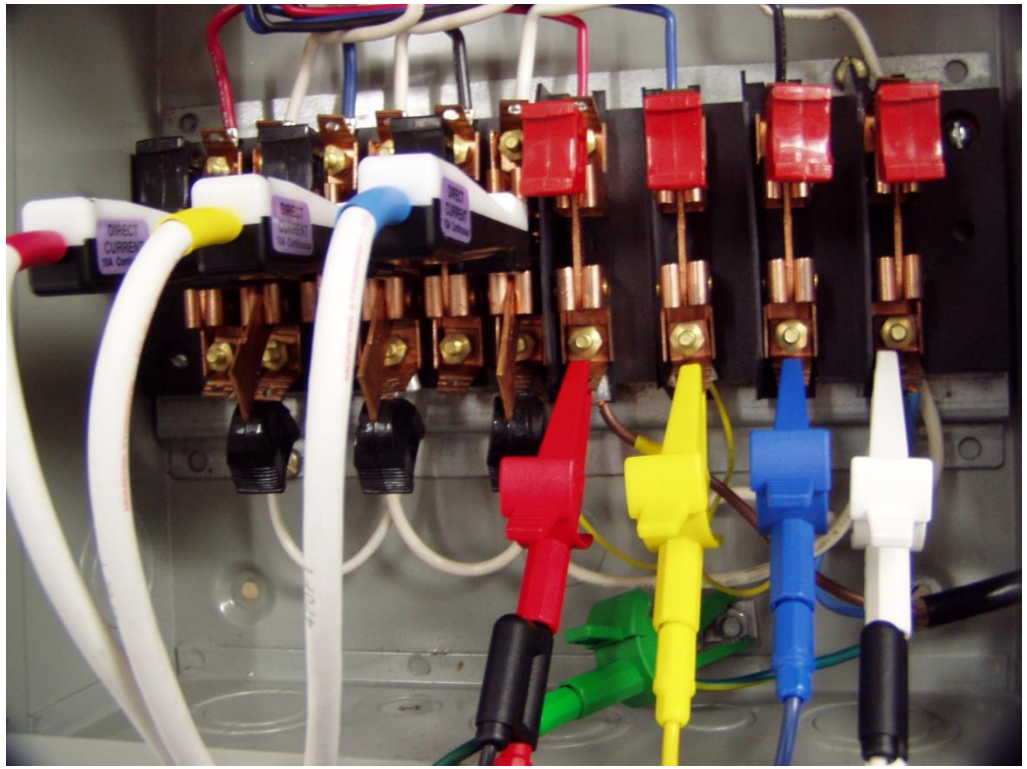
# CT Ratio with Burden Testing



- 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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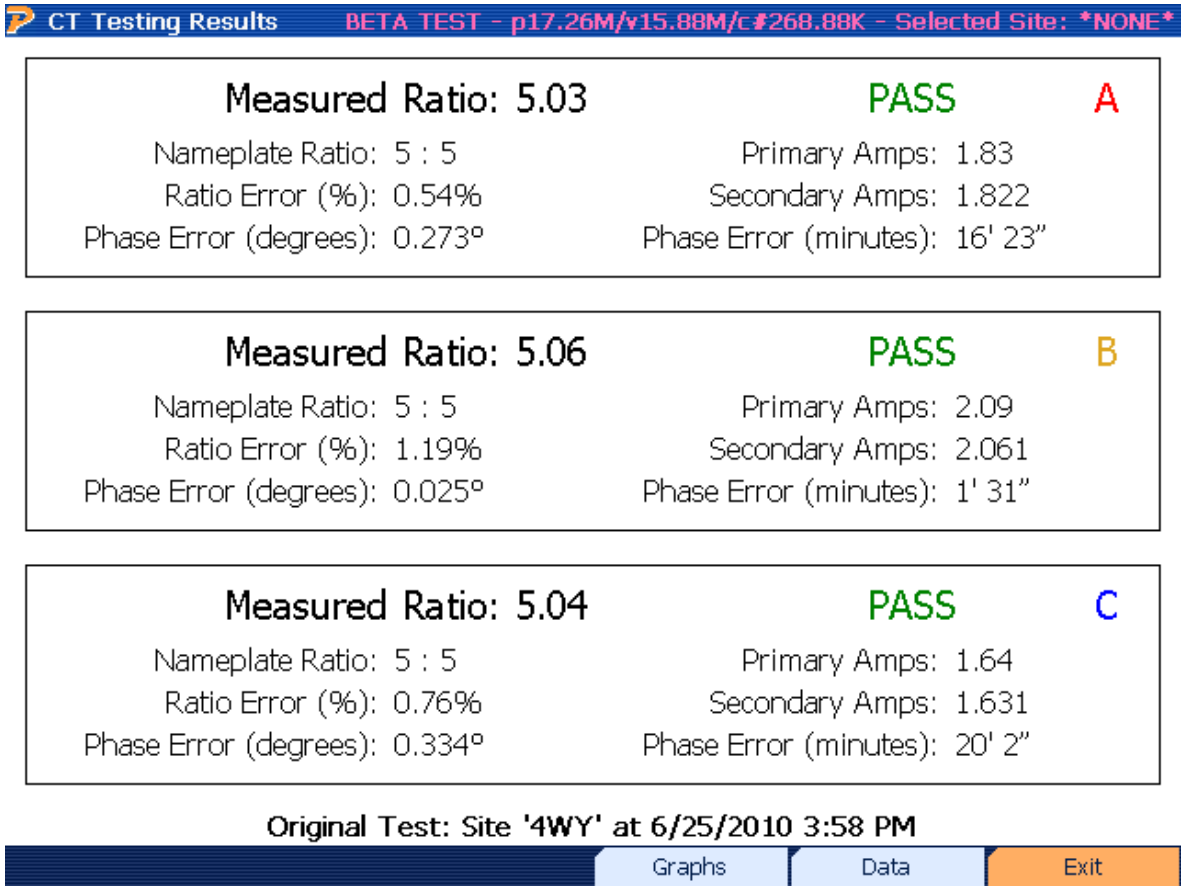
# Testing Current Transformers

## Ratio vs Applied Burden

- CTs installations can be fully verified in the field




Without the harmonic load this CT passed its test.

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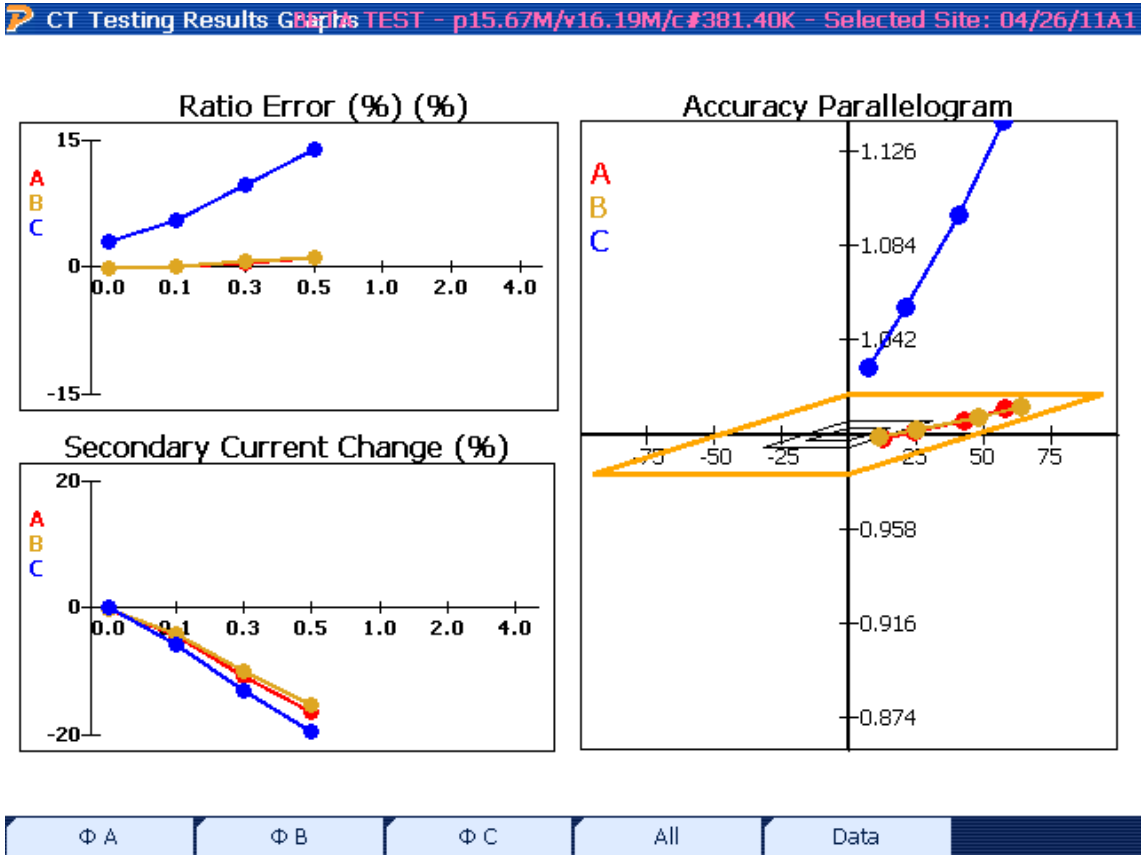
# Testing Current Transformers

## Ratio vs Applied Burden

- Arrived at site and ran a CT test




- Now Phase C looks really bad.

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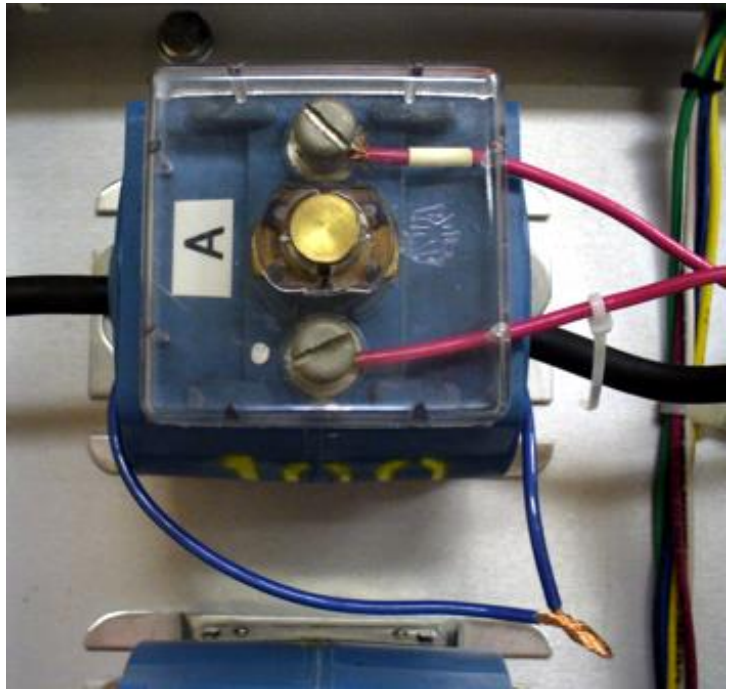
# Testing Current Transformers

## What's Wrong? → Power Theft

**A simple piece of wire wrapped around the CT.**





**Would you spot it?**

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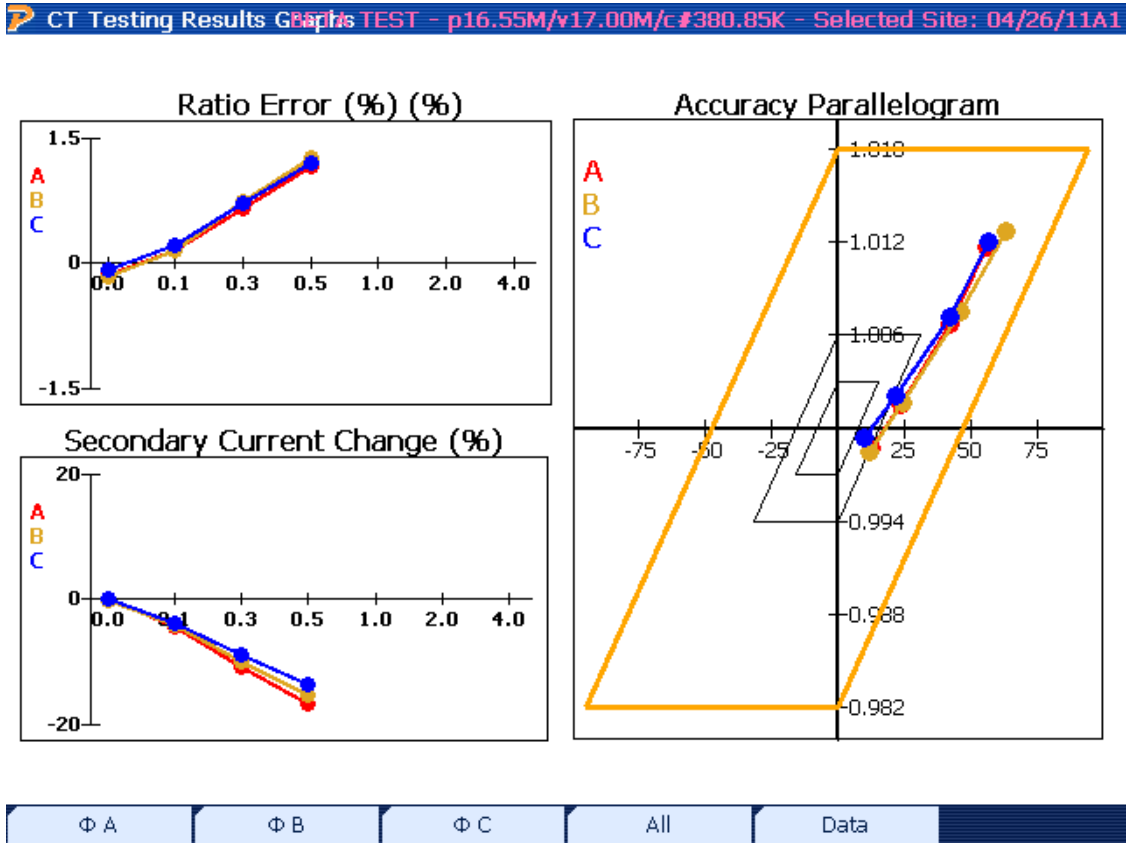
# Testing Current Transformers

## Ratio vs Applied Burden

- Removed wire.




- Everything tests OK.

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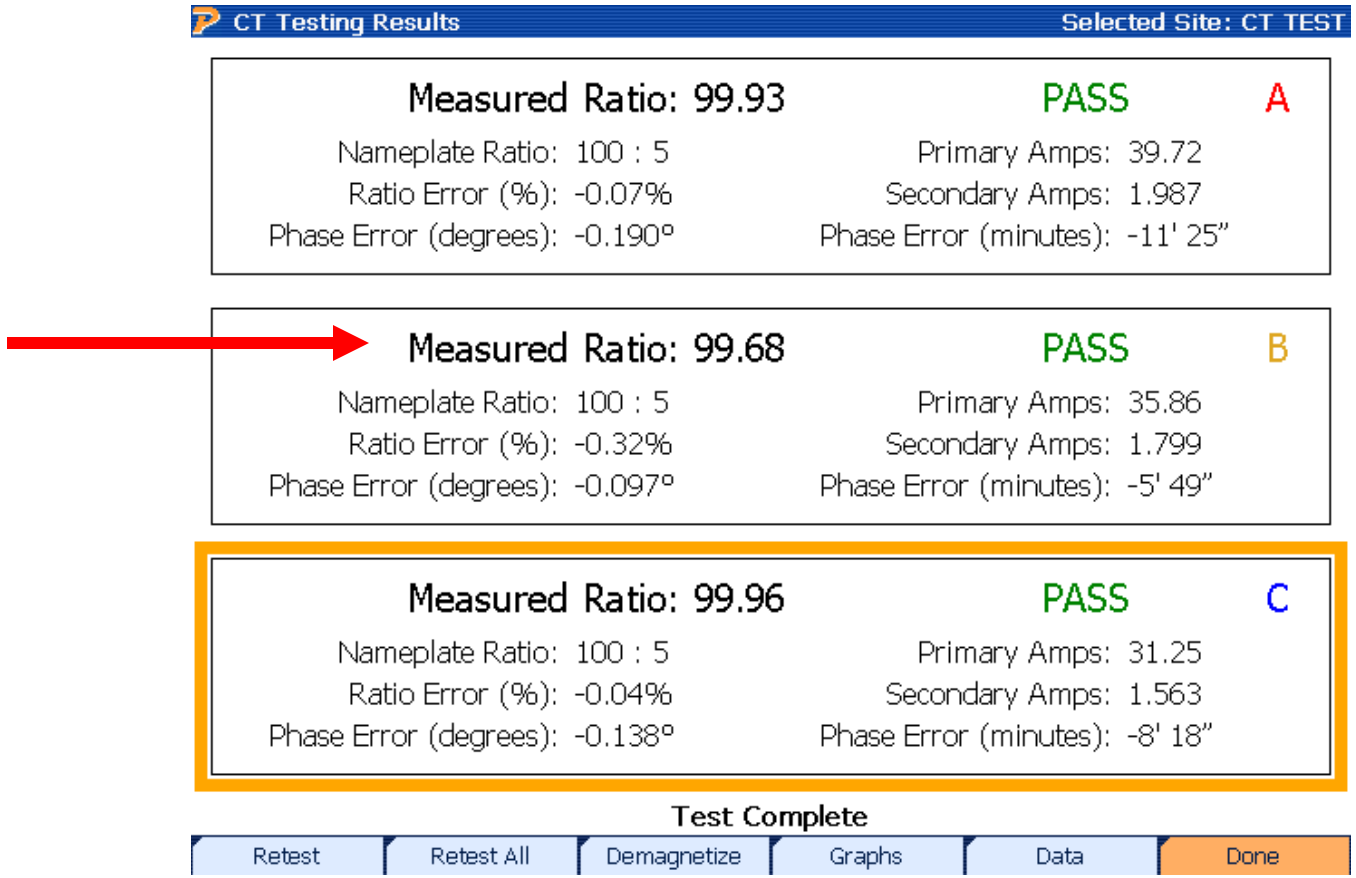
# Testing Current Transformers

## Ratio Error – In Whose Favor?

**I did at CT ratio test. What does it mean when I measure a ratio of 99.68:5 on a 100:5 CT?**

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# Testing Current Transformers

## Ratio Error – In Whose Favor?

In the phase B test we measured 35.86 amps on the primary and 1.799 secondary amps.

Ratio = 5.0 * (Primary / Secondary) = 99.68

If the ratio had been 100:5 then, and the primary was 35.86 amps we should have measured 1.793 amps on the secondary.

We measured 1.799 – MORE than we should have.

Therefore a tested ratio of 99.68 means that we are measuring more current than we should. This error is in our favor.

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# Testing Current Transformers

## Ratio Error – In Whose Favor?

**Suppose we add burden to the metering circuit.**

CT Testing Results — Selected Site: CT TEST

% Change in Secondary Amps

| Phase | Ref | 0.0Ω | 0.1Ω | 0.3Ω | 0.5Ω | 1.0Ω | 2.0Ω | 4.0Ω |
|---|---|---|---|---|---|---|---|---|
| A | | 0.000 | -4.468 | -10.751 | -16.377 | N/A | N/A | N/A |
| B | | 0.000 | -4.072 | -9.727 | -14.820 | N/A | N/A | N/A |
| C | | 0.000 | -3.490 | -8.405 | -12.873 | N/A | N/A | N/A |

Ratio Data

| Phase | Ref | 0.0Ω | 0.1Ω | 0.3Ω | 0.5Ω | 1.0Ω | 2.0Ω | 4.0Ω |
|---|---|---|---|---|---|---|---|---|
| A | 100:5 | 99.93 | 100.20 | 100.85 | 101.42 | N/A | N/A | N/A |
| B | 100:5 | 99.68 | 99.96 | 100.54 | 101.01 | N/A | N/A | N/A |
| C | 100:5 | 99.96 | 100.17 | 100.71 | 101.23 | N/A | N/A | N/A |

Ratio Error (%)

| Phase | Ref | 0.0Ω | 0.1Ω | 0.3Ω | 0.5Ω | 1.0Ω | 2.0Ω | 4.0Ω |
|---|---|---|---|---|---|---|---|---|
| A | | -0.07 | 0.20 | 0.85 | 1.42 | N/A | N/A | N/A |
| B | | -0.32 | -0.04 | 0.54 | 1.01 | N/A | N/A | N/A |
| C | | -0.04 | 0.17 | 0.71 | 1.23 | N/A | N/A | N/A |

Relative Phase Data (degrees)

| Phase | Ref | 0.0Ω | 0.1Ω | 0.3Ω | 0.5Ω | 1.0Ω | 2.0Ω | 4.0Ω |
|---|---|---|---|---|---|---|---|---|
| A | | -0.19 | -0.51 | -0.89 | -1.17 | N/A | N/A | N/A |
| B | | -0.10 | -0.38 | -0.79 | -1.11 | N/A | N/A | N/A |
| C | | -0.14 | -0.42 | -0.81 | -1.07 | N/A | N/A | N/A |

Graphs

Notice that the ratio increases as we apply burden. With 0.3 Ohms of burden the ratio switches from less than 100:5 to greater than 100:5. This is the point where things swing to being in favor of the customer.

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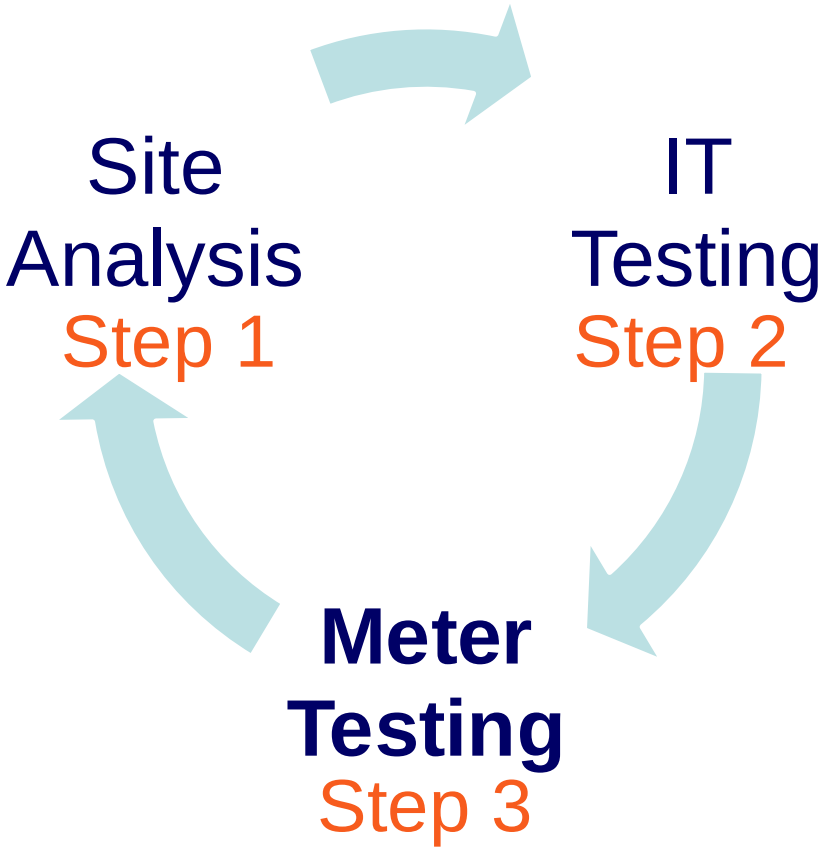
# Integrated Site Test Philosophy

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# Integrated Site Test Philosophy

**Meter Testing**

## Customer Load Test

Real - World Conditions
Voltage and Current Harmonics
Current and Phase Angle Balance

## Load Box Test

Ideal Current and Voltage Waveforms
ANSI Full Load, Power Factor & Light Load
Custom Test Sequences for Special Applications

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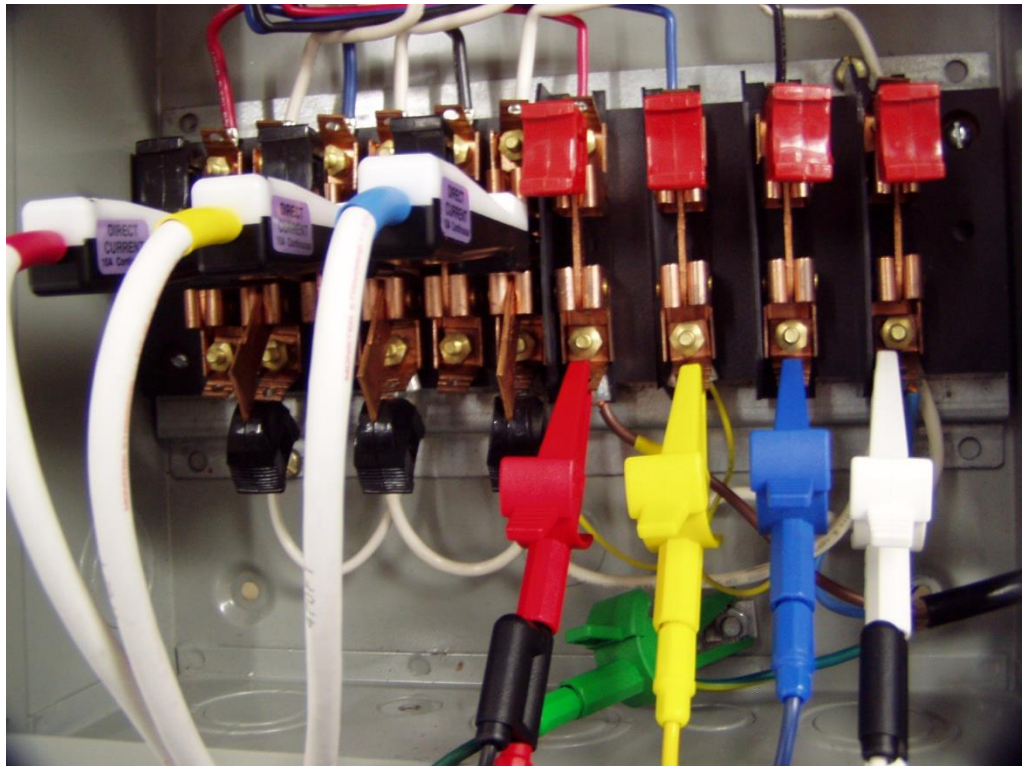
# Customer Load Meter Test



- Secondary connection is made through the test switch
- Same connection that is used for CT testing.

**We measure the voltage and current that the meter sees.**

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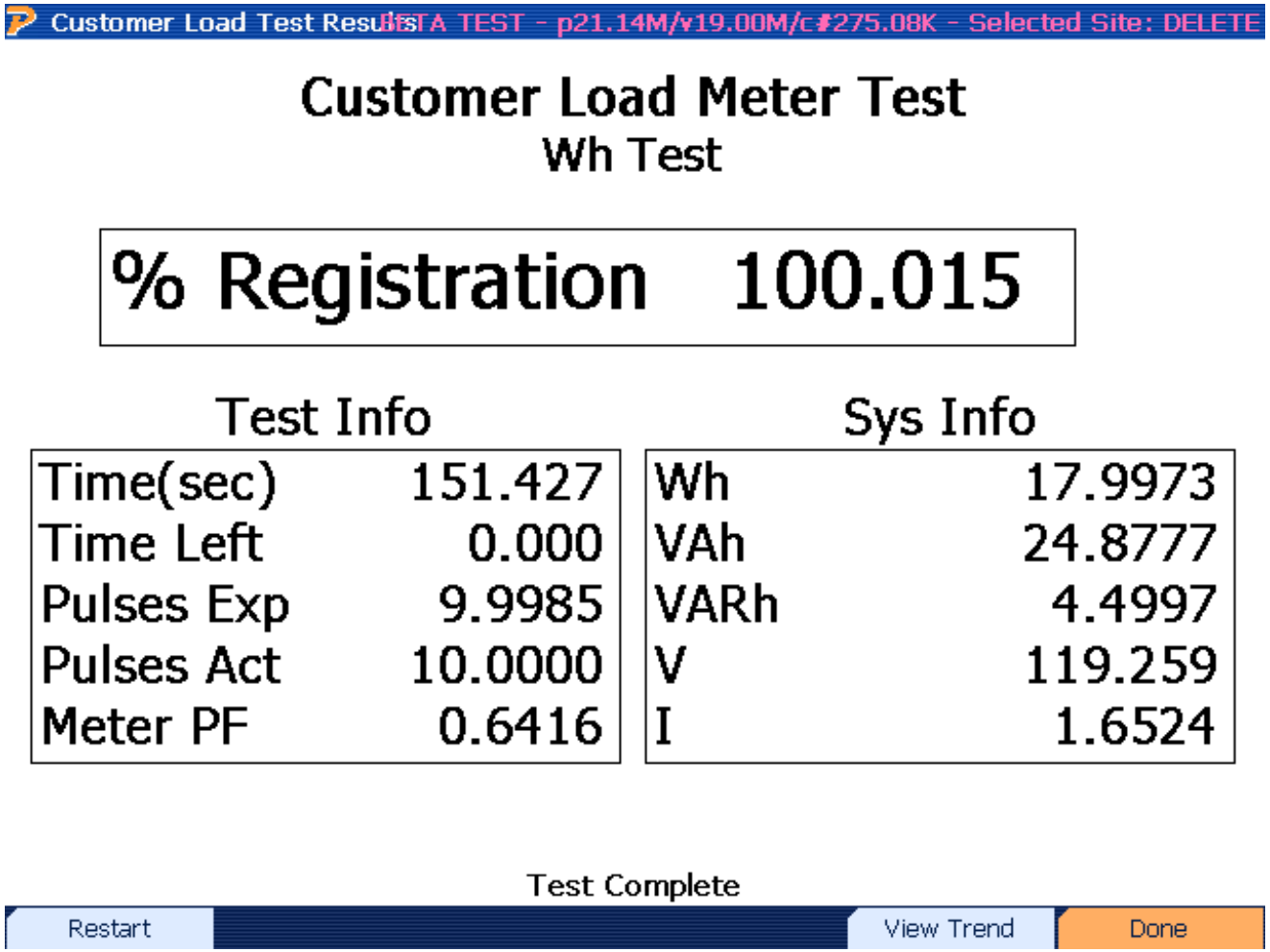
# Customer Load Meter Test




Meter Testing

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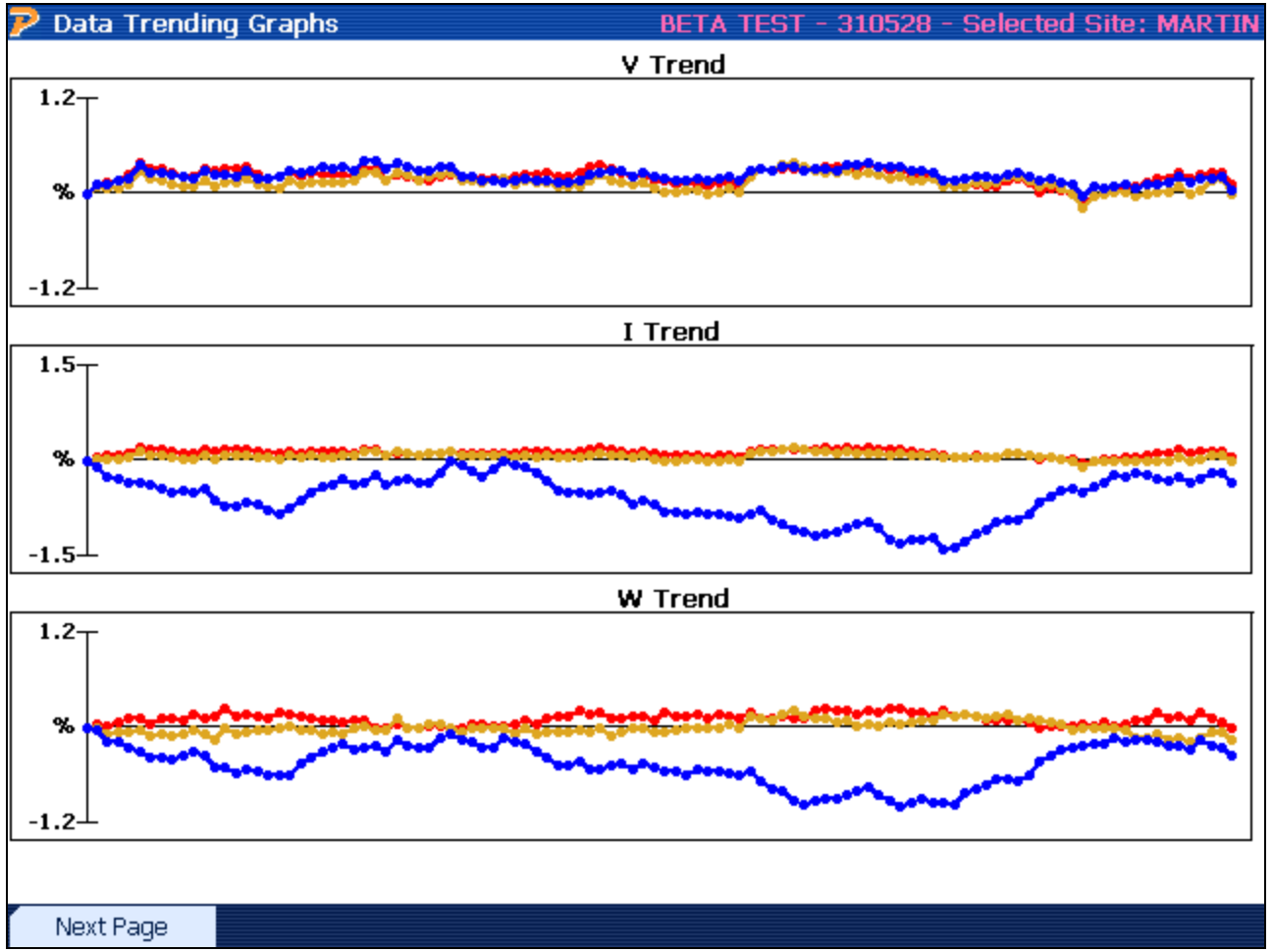
# Customer Load Meter Test




**Meter Testing**

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# Phantom Load Meter Test

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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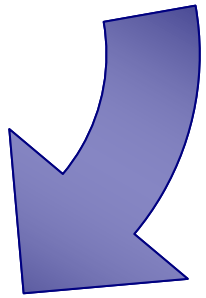
Retest | Retest All | Done

Meter Testing



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# Phantom Load Meter Test
# Demand Test

Demand Test Results — BETA TEST - 229360 - Selected Site: MARTIN

## Demand Test Results

| | |
|---|---|
| Estimated Time Remaining in Interval: | 0:09 |
| Estimated Total Time Remaining: | 0:09 |
| Intervals Remaining: | 1 |

| Int | Start Time | Pulses | Voltage | Current | PF | Wh | VAh | mVARh | %REG |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 10:45 AM | 35.97 | 116.580 | 2.256 | 0.998 | 64.77 | 64.84 | -1660.17 | 99.96 |
| 2 | 10:50 AM | 35.95 | 116.566 | 2.255 | 0.998 | 64.74 | 64.81 | -1639.85 | 99.96 |
| 3 | 10:55 AM | 35.91 | 116.480 | 2.255 | 0.998 | 64.66 | 64.73 | -1633.58 | 99.96 |
| | | | | | | | | | |
| | | | | | | | | | |
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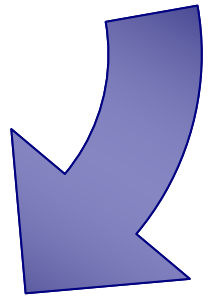
| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Demand Interval | 116.542 | 2.256 | 0.998 | 194.16 | 194.37 | -4933.60 | 99.96 |
| Minimum | 116.480 | 2.255 | 0.998 | 64.66 | 64.73 | -1660.17 | 99.96 |
| Maximum | 116.580 | 2.256 | 0.998 | 64.77 | 64.84 | -1633.58 | 99.96 |

Test Complete - Data Saved

View Trend | Meter Reg. | Done

**Meter Testing**



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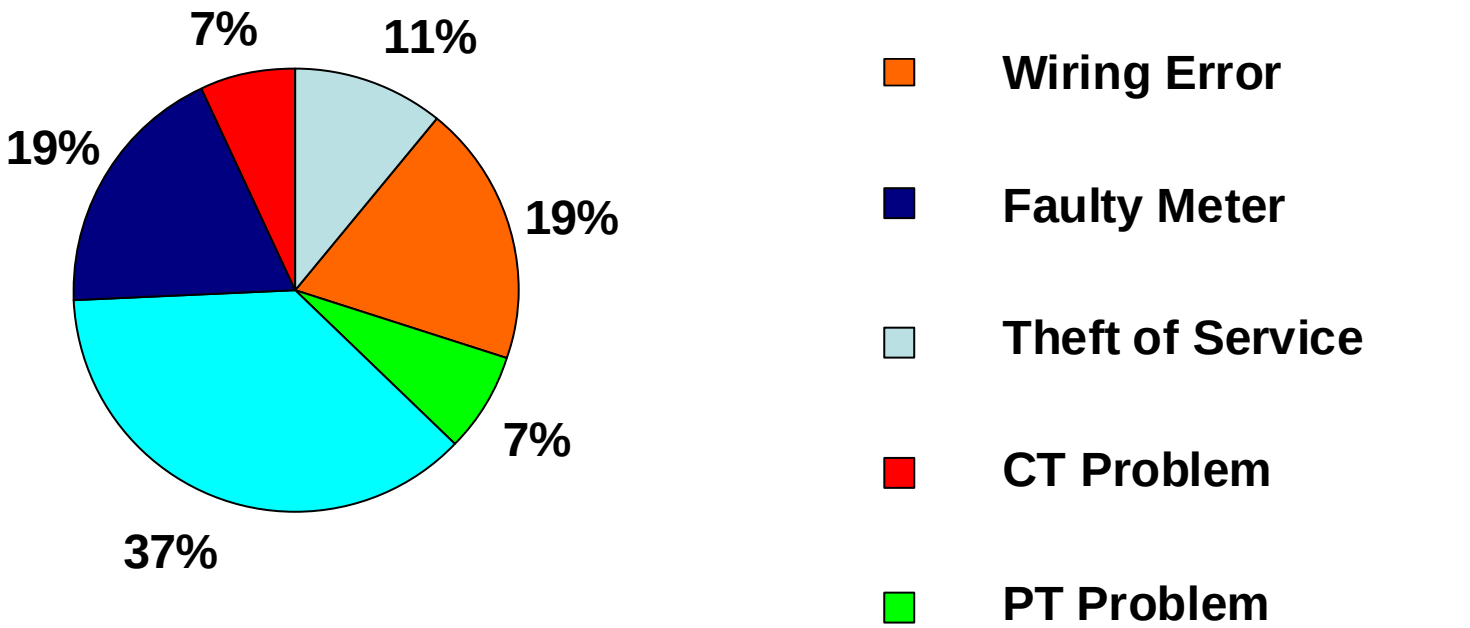
# 3 Year Study from a Municipal with 35,000 Transformer Rated Installations




Any guesses???

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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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# Estimating Errors

- **Uncertainty When Nothing is Wrong**
  - Meter – 0.2% or 0.5% accuracy class
  - CT - 0.3% probably 0.6%
  - PT – 0.3%
- **Worse Case Error Estimate**
  - 0.2% + 0.3% + 0.3% = 0.8%
  - 0.2% + 0.6% + 0.3% = 1.1%
- **If everything is working correctly about 1.0% is the worst error we should find.**

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**Thank you for your time!**

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