REVENUE PROTECTION

Optimizing Your Meter Site Performance

POWERMETRIX

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WHY METERING ACCURACY?

- It's the law

- To ensure that a meter is meeting the accuracy requirements mandated by the PSC and management, we test it in the lab under conditions mandated by ANSI C12.20 and the metering manufacturer.

- Generally, for a Class 20 CT Rated meter this means testing:
  - Full Load ... 120V, 2.5A, PF=1
  - Light Load ... 120V, 0.25A, PF=1
  - Power Factor ... 120V, 2.5A, PF=.5
  - These points do not match real world conditions

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WHY METERING ACCURACY?

- ANSI testing covers limited conditions
  - Sinusoidal waveforms
  - Generally, only (2) Current Amplitudes (FL and LL)
  - Generally, only (2) Power Factors (Unity and 0.5 PF)

- Electronic meters generally either work correctly or fail drastically.

- It should be a **RARE OCCASION** that a meter fails to meet these accuracy standards in the lab.

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WHY METERING ACCURACY?

If the meter is functioning accurately, what does that say about whether the customer is getting the correct bill?

NOT MUCH!

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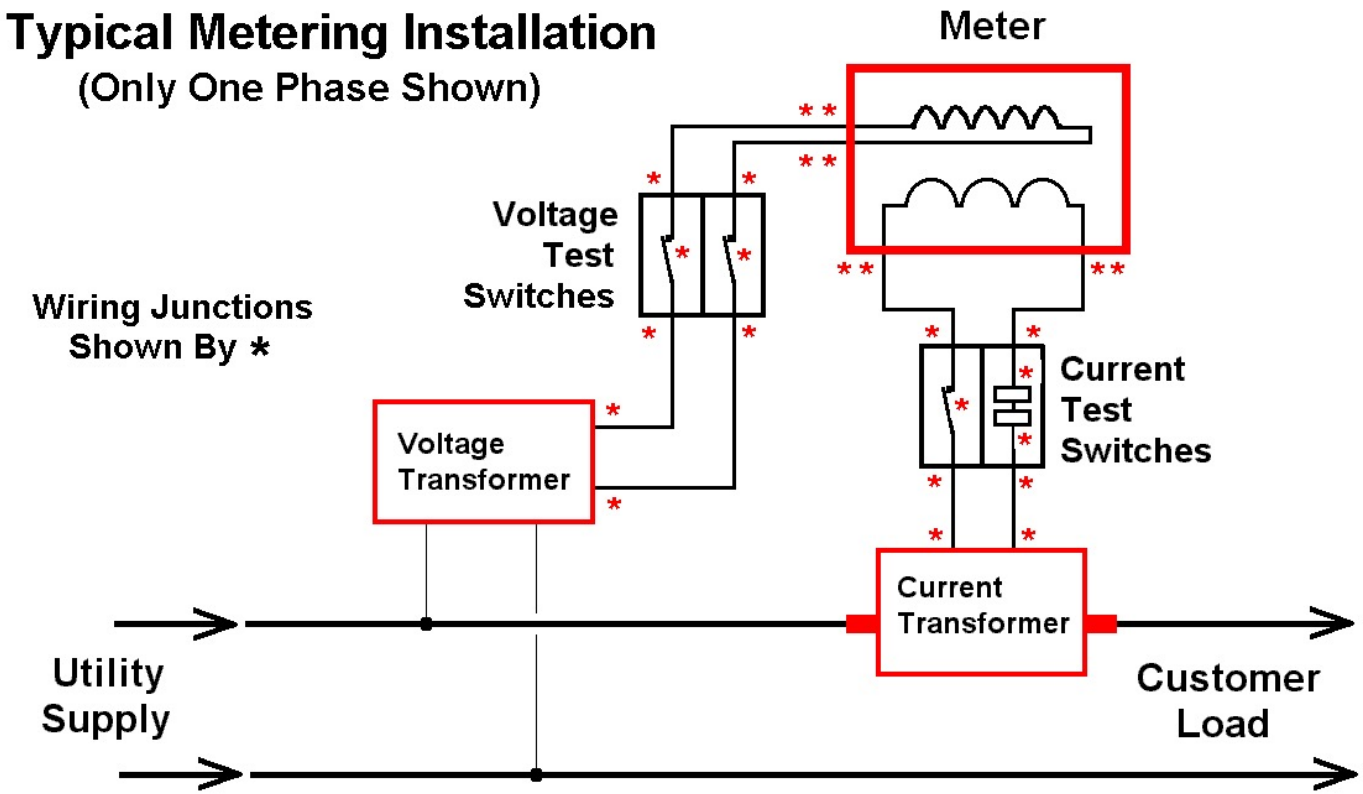
CONSIDER A TYPICAL METERING INSTALLATION

Wiring errors, meter errors, CT errors, PT errors, administrative errors and theft can all lead to lost revenue and decrease in customer confidence.



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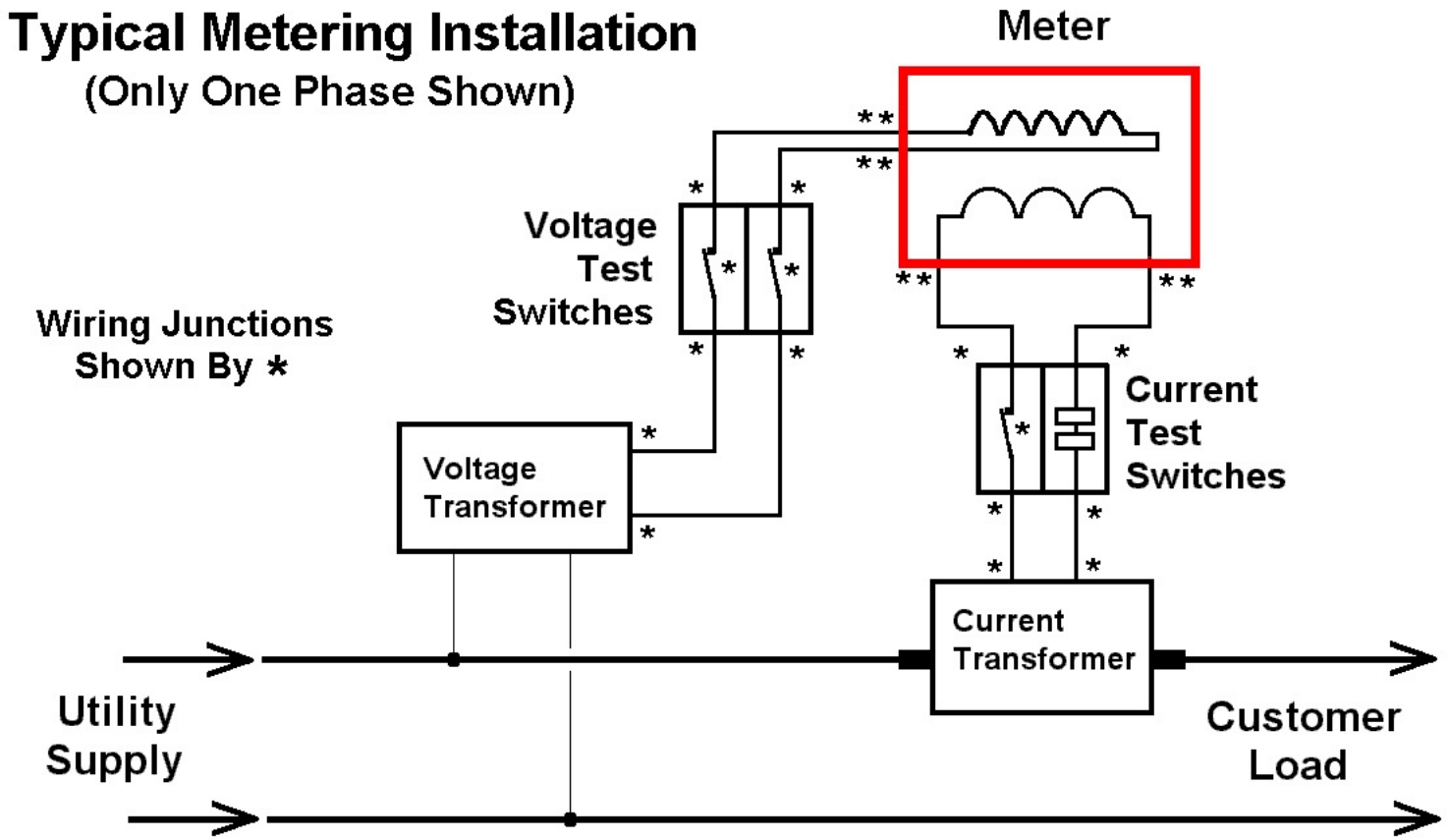
BUT TRADITIONALLY, ONLY THE METER IS TESTED.

The meter can **ONLY** measure what reaches its terminals.



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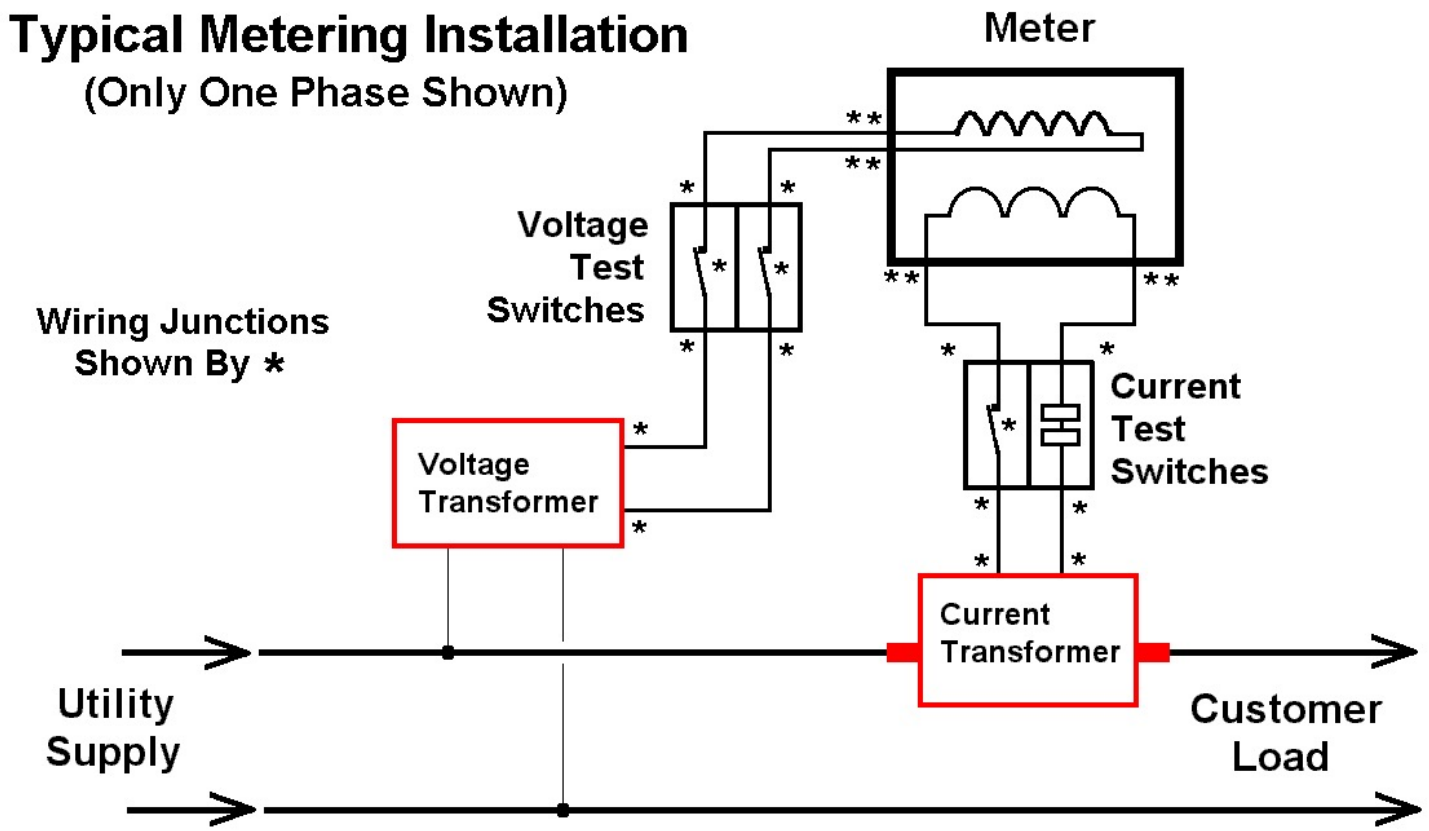
INSTRUMENT TRANSFORMERS CONTROL METERED VALUES

But what if they do not produce the expected outputs?



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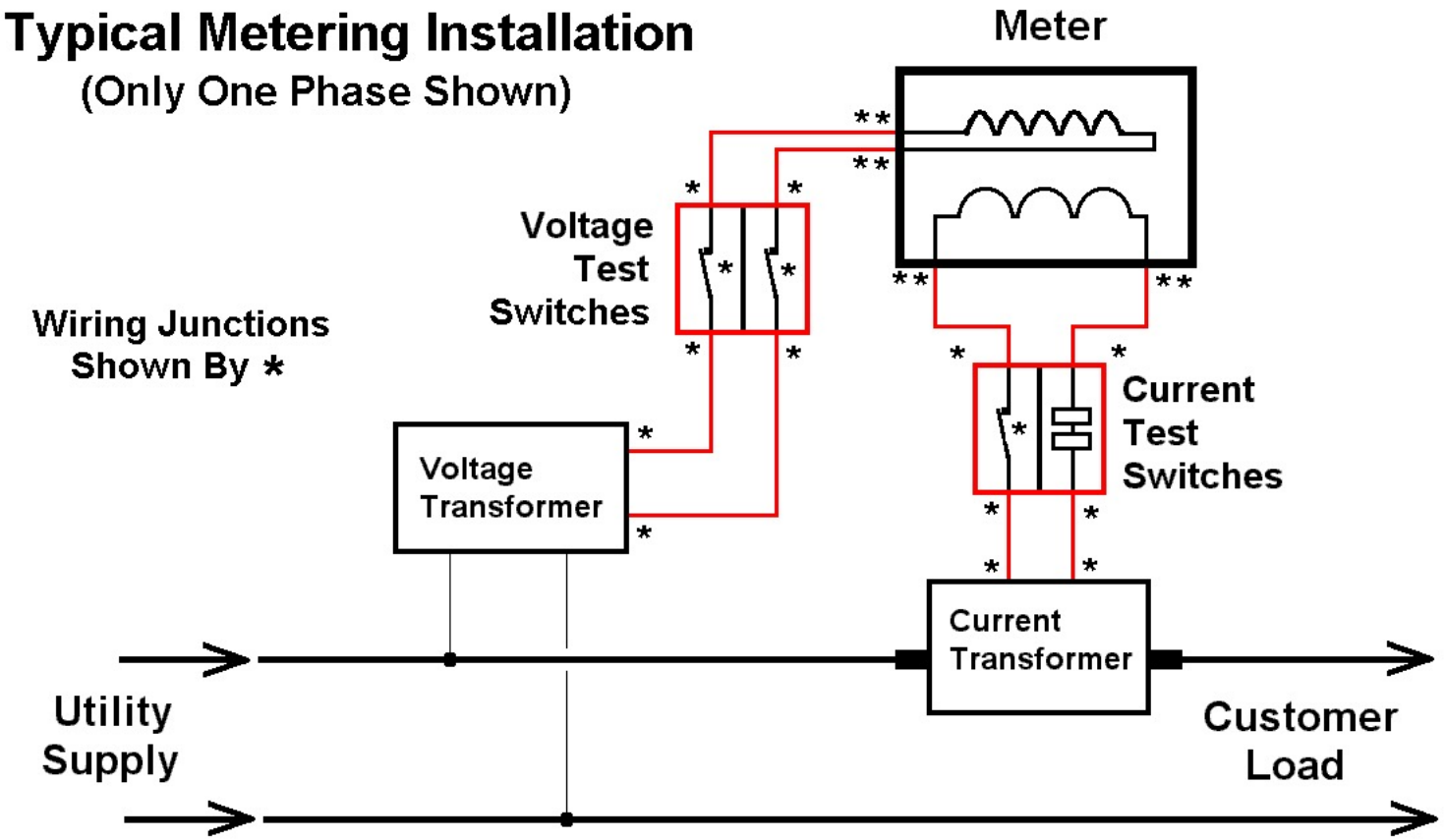
WIRING AND JUNCTIONS CONNECT THE METER

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



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WHY BILLING ACCURACY?

Even if the meter is perfect, the billing may not be correct.

Sources of billing errors include:

- CTs - bad, overburdened, shunted, not correct accuracy class or correct size & rating for the installation
- PTs - bad, overburdened, not correct accuracy class
- Faulty or incorrect wiring
- Meter not accurate under actual customer load conditions
- Multiplier error
- Theft

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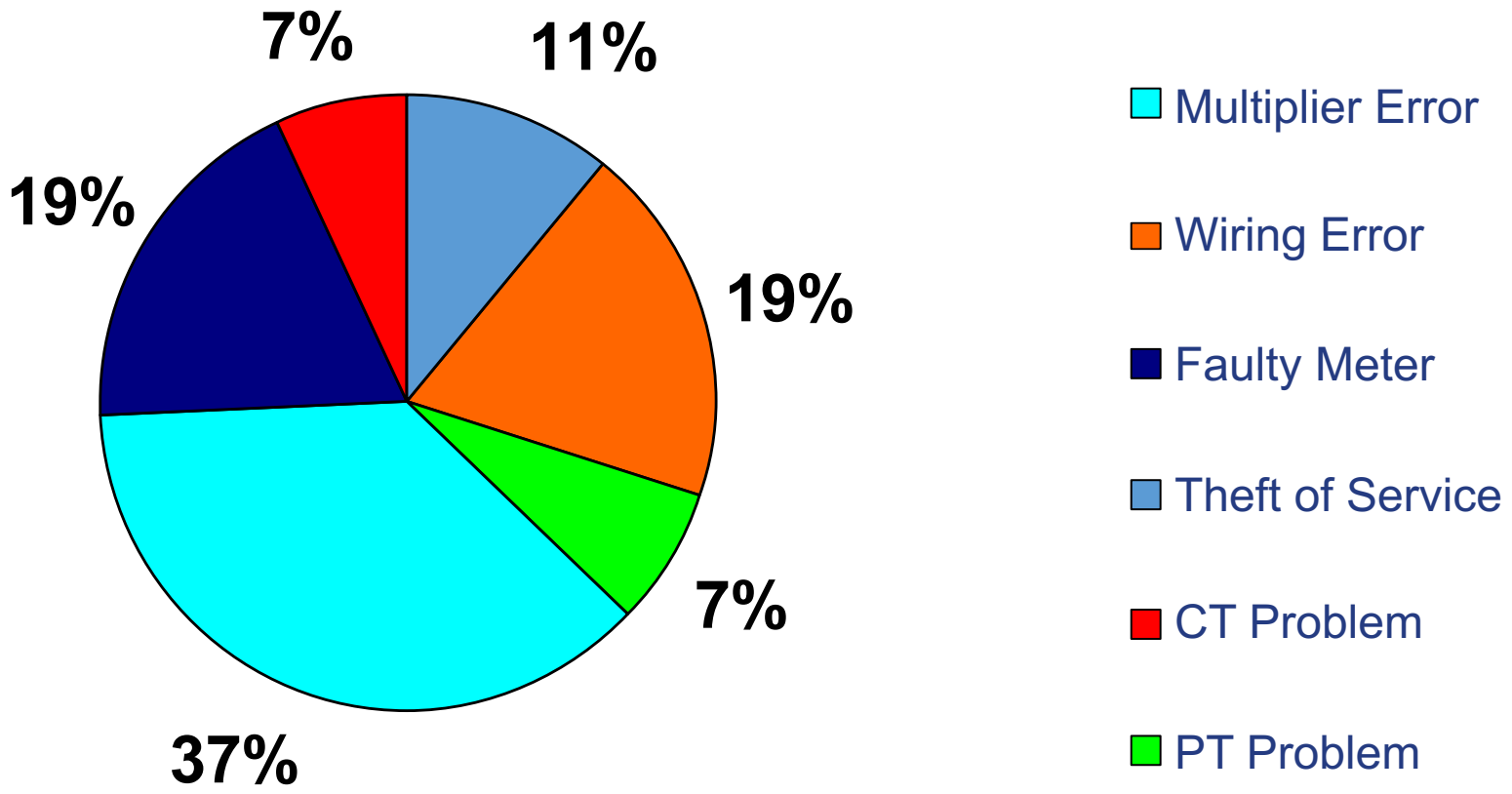
3 Year Study from a Municipal with 35,000 Transformer Rated Installations



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:

3,500 / 96 ≈ 2.7%

Total Lost Revenue Found:

$2,248,354

Average Lost Revenue Found per Problem:

≈ $23,420

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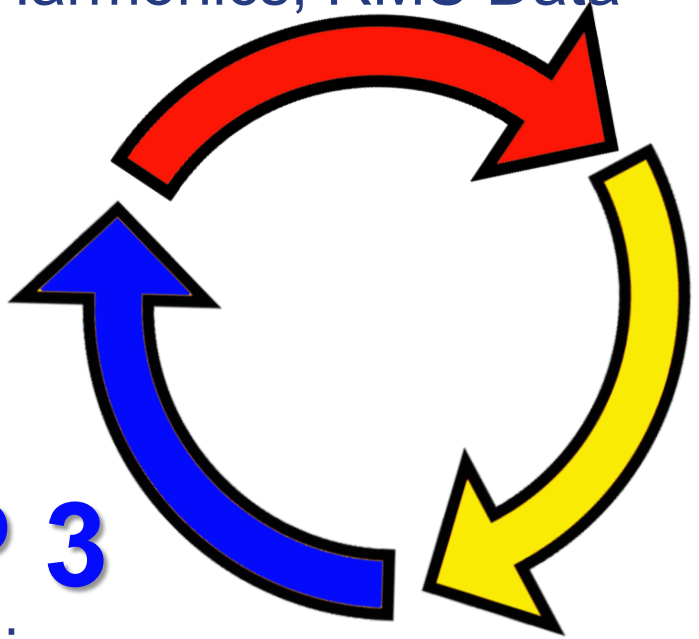
INTEGRATED SITE TEST PHILOSOPHY

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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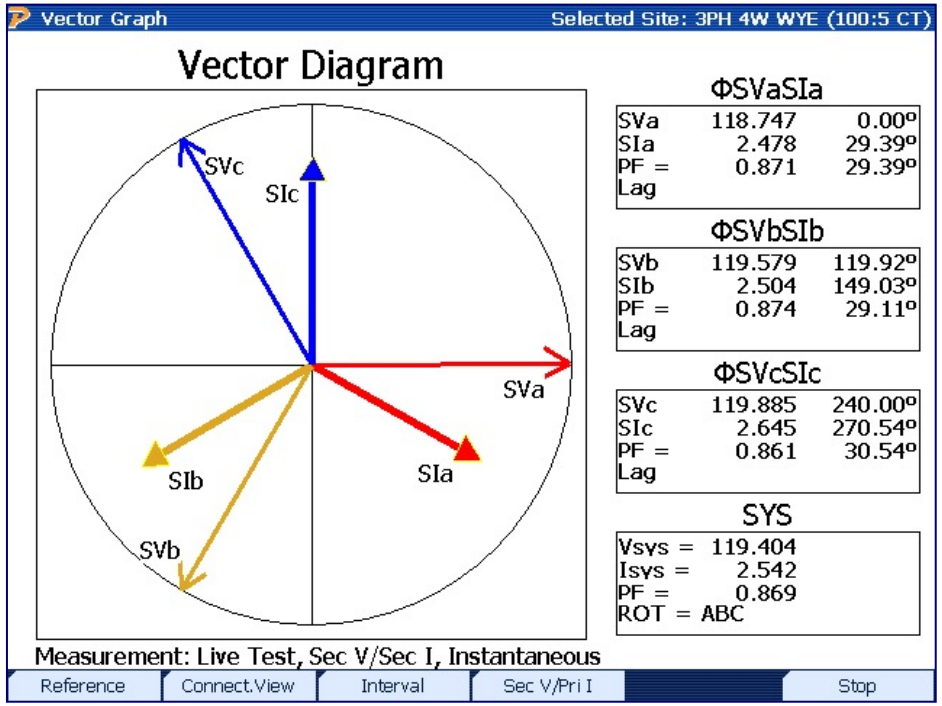
STEP 1: SITE ANALYSIS

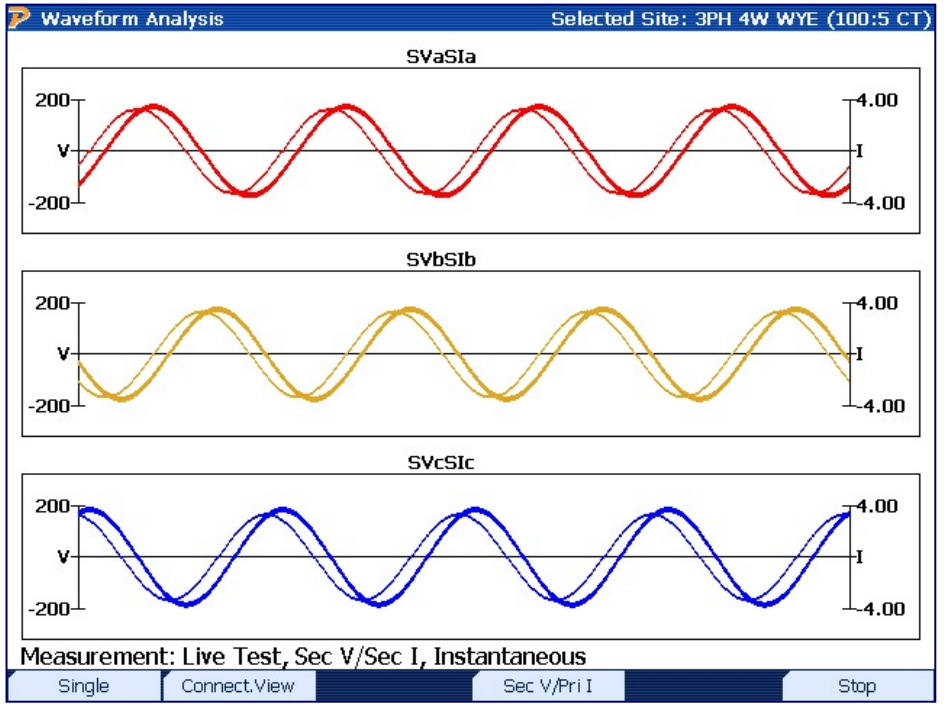
Wiring Verification and Site Diagnostics

The largest percentage of errors on sites
You can diagnose many errors just by looking at signals.

VECTOR DIAGRAMS



WAVEFORMS



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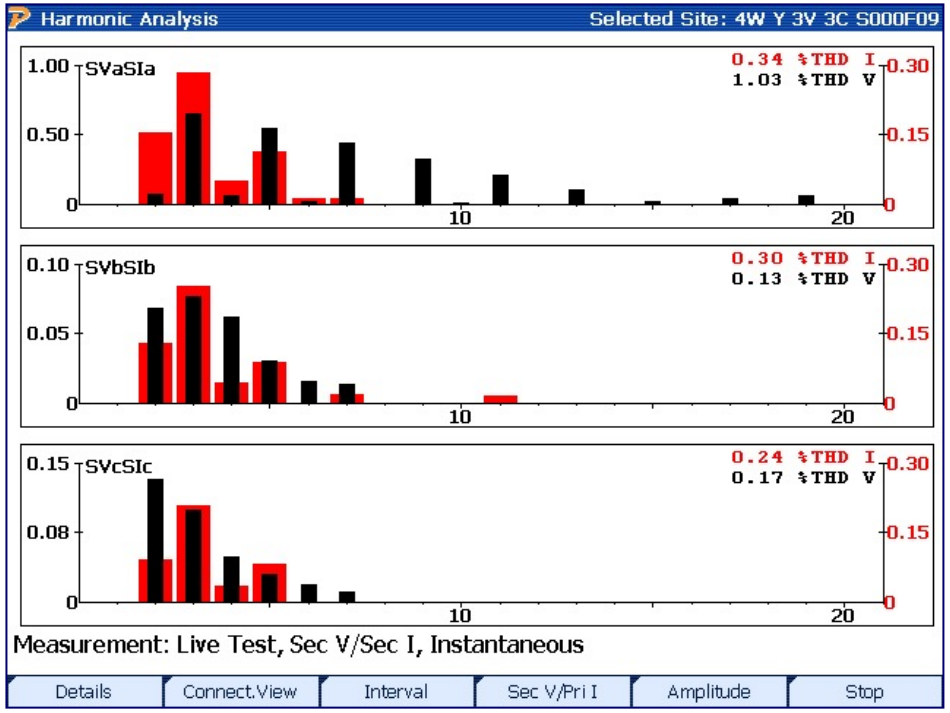
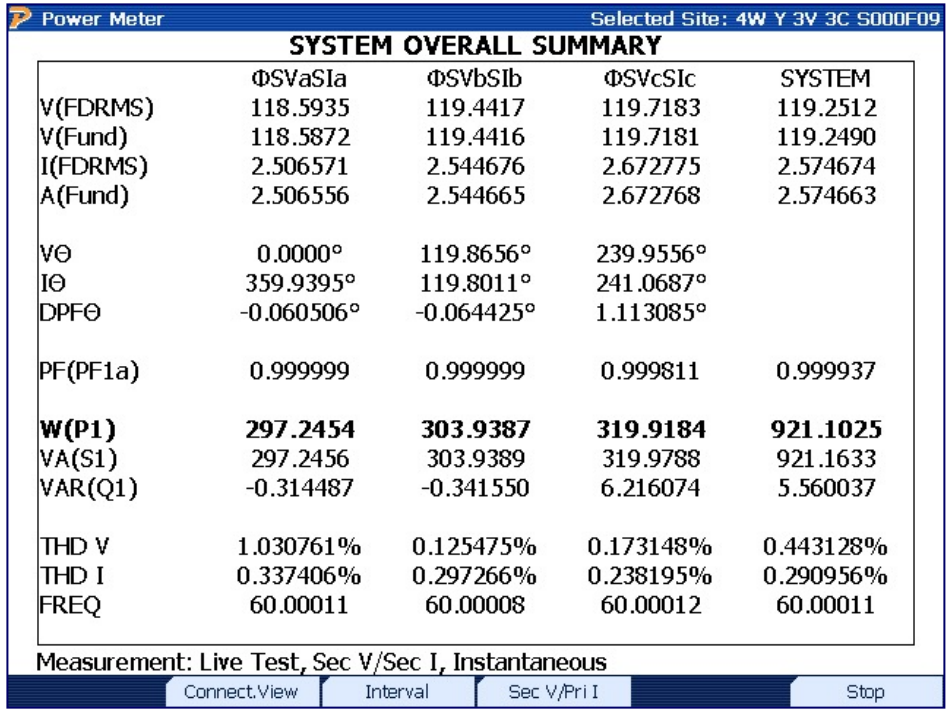
HARMONICS ANALYSIS



RMS DATA TABLE



	ΦSVaSIa	ΦSVbSIb	ΦSVcSIc	SYSTEM
V(FDRMS)	118.5935	119.4417	119.7183	119.2512
V(Fund)	118.5872	119.4416	119.7181	119.2490
I(FDRMS)	2.506571	2.544676	2.672775	2.574674
A(Fund)	2.506556	2.544665	2.672768	2.574663
VΘ	0.0000°	119.8656°	239.9556°	
IΘ	359.9395°	119.8011°	241.0687°	
DPFΘ	-0.060506°	-0.064425°	1.113085°	
PF(PF1a)	0.999999	0.999999	0.999811	0.999937
W(P1)	**297.2454**	**303.9387**	**319.9184**	**921.1025**
VA(S1)	297.2456	303.9389	319.9788	921.1633
VAR(Q1)	-0.314487	-0.341550	6.216074	5.560037
THD V	1.030761%	0.125475%	0.173148%	0.443128%
THD I	0.337406%	0.297266%	0.238195%	0.290956%
FREQ	60.00011	60.00008	60.00012	60.00011

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STEP 2: CT TESTING

- CTs influence the accuracy of your metering installation, depending on your selection.
- Extended Range CTs are highly accurate and constitute 33% of the market.
- Test CTs in accordance with the IEEE C57.13 standard.
- Correctly specifying CTs for their installation is of paramount importance when trying to improve billing accuracy.
  - Ratio
  - Accuracy Class
  - Rating Factor
  - Temperature
  - Burden Rating

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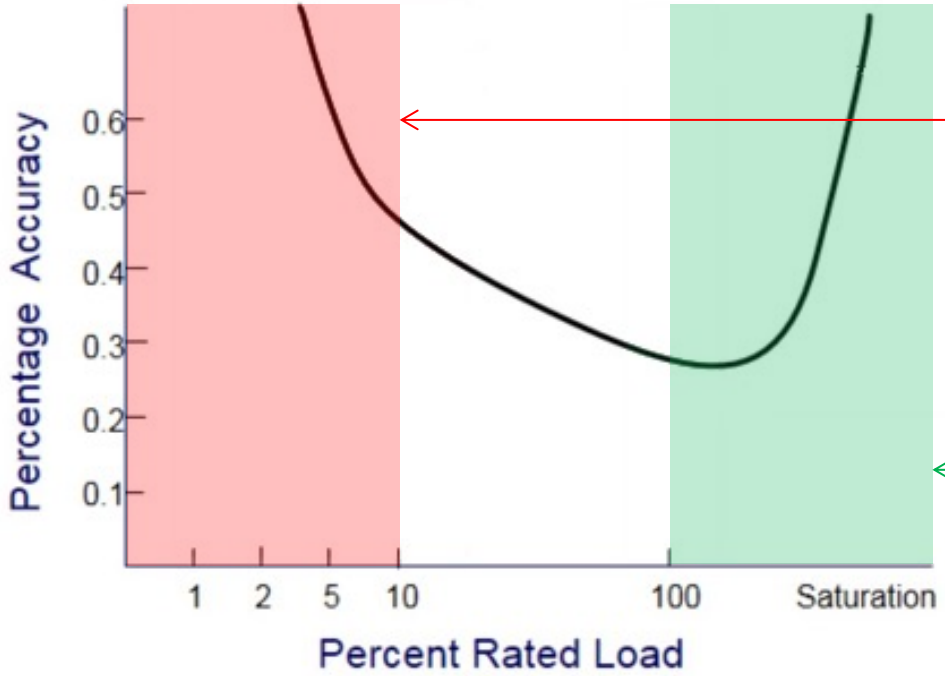
STEP 2: CT TESTING

How does the LOAD on a CT influence its accuracy?

If you're constantly seeing less than 5A secondary current on your CT rated sites, your billing accuracy is probably compromised.
What's the point of investing money in highly accurate meters if the CTs feeding that meter are 0.6% ... 1% ... even 2% inaccurate *or worse*?



Are you normally operating down at these levels?

When you should be at these levels?

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STEP 2: CT TESTING

How does the LOAD on a CT influence its accuracy?

The solution:

- Make sure you are not oversizing CTs.
- Re-evaluate CT size if a new customer moves in.
- Use Rating Factors to your advantage.
- Be aware that temperature effects Rating Factor.

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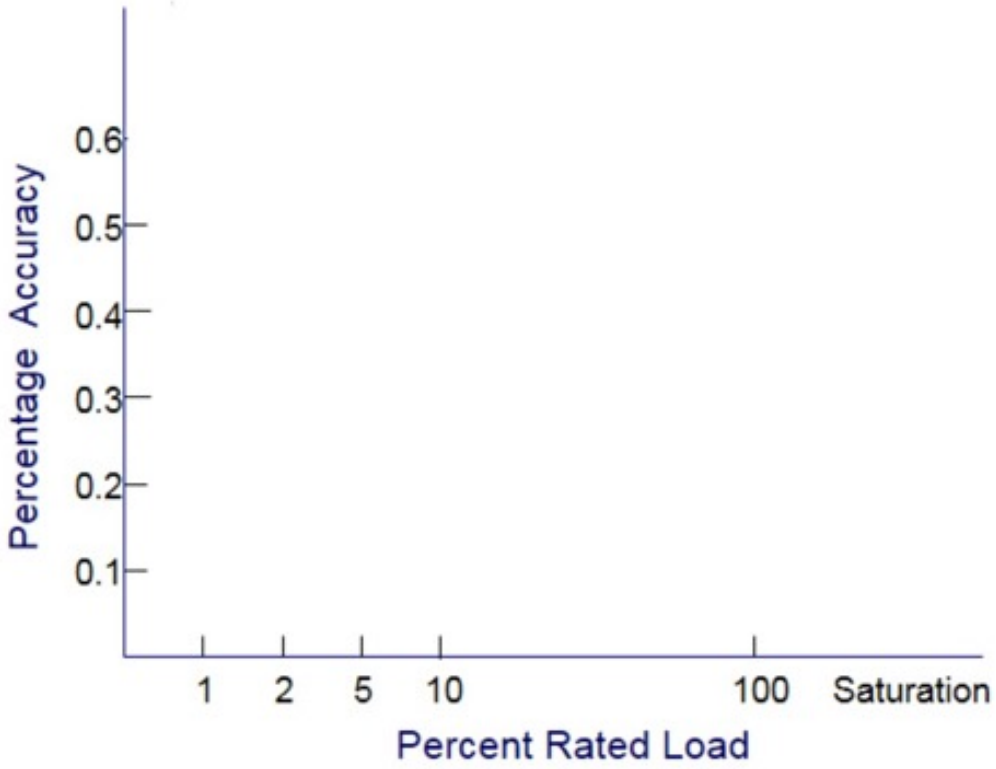
STEP 2: CT TESTING

How does the BURDEN on a CT influence its accuracy?

You can get much better accuracy out of your CTs if you can limit the amount of burden on the secondary with respect to its rating.
Example: 0.3% Accuracy Class CT with 1.80 Burden Rating



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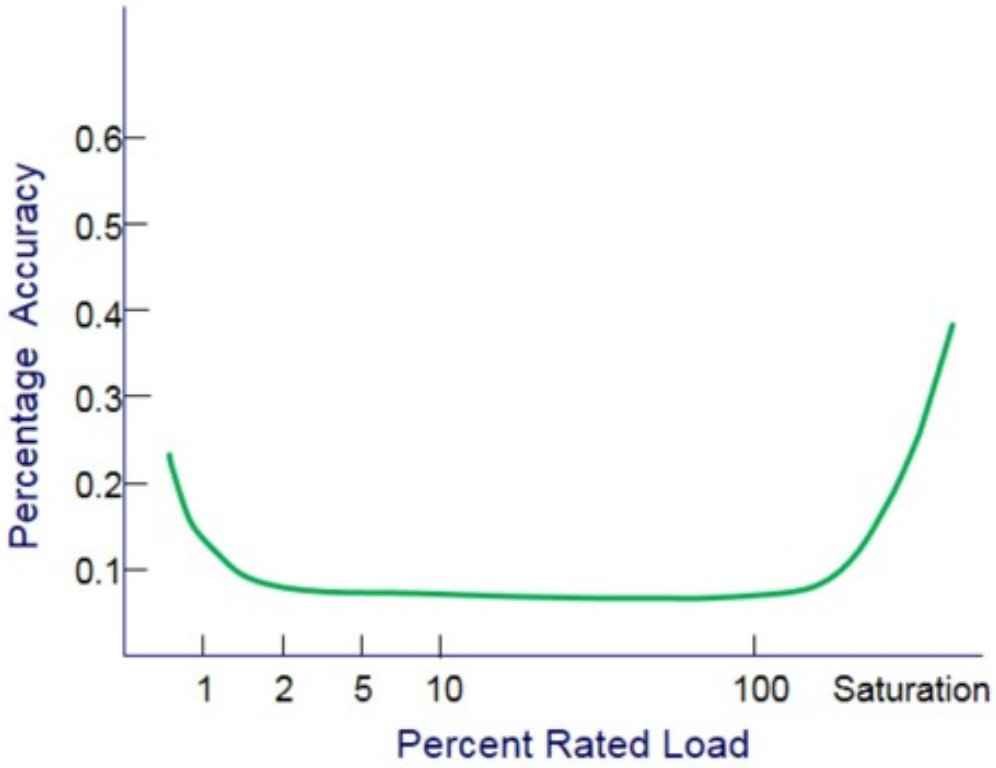

0.05Ω of Burden Present

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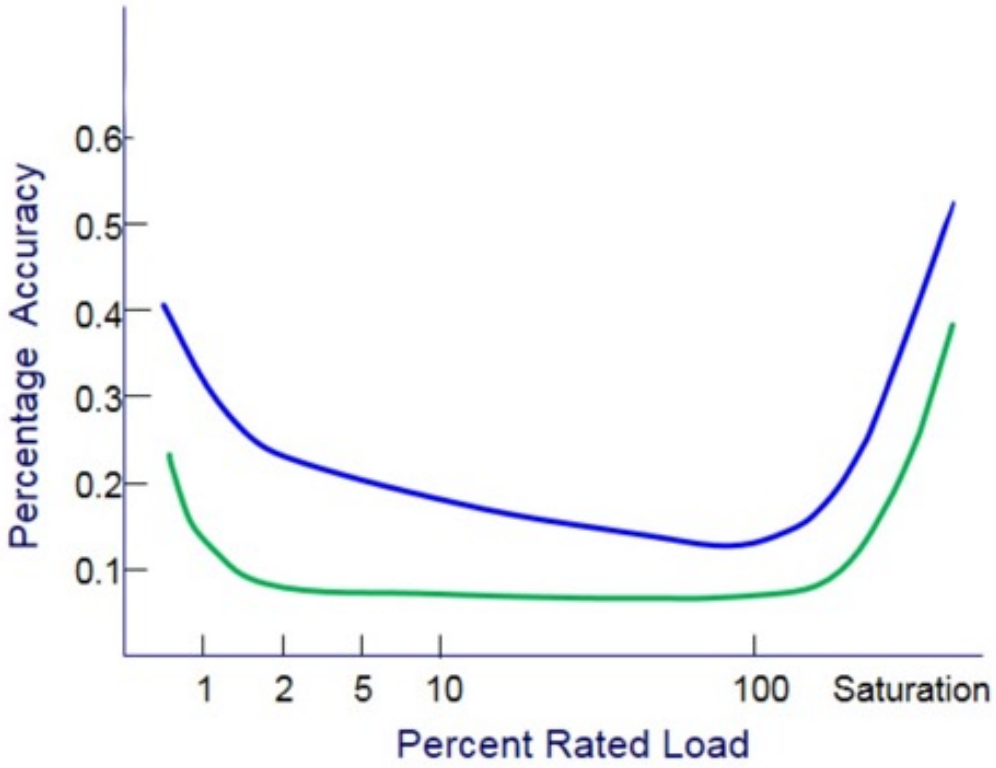

0.2Ω of Burden Present
0.05Ω of Burden Present

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STEP 2: CT TESTING

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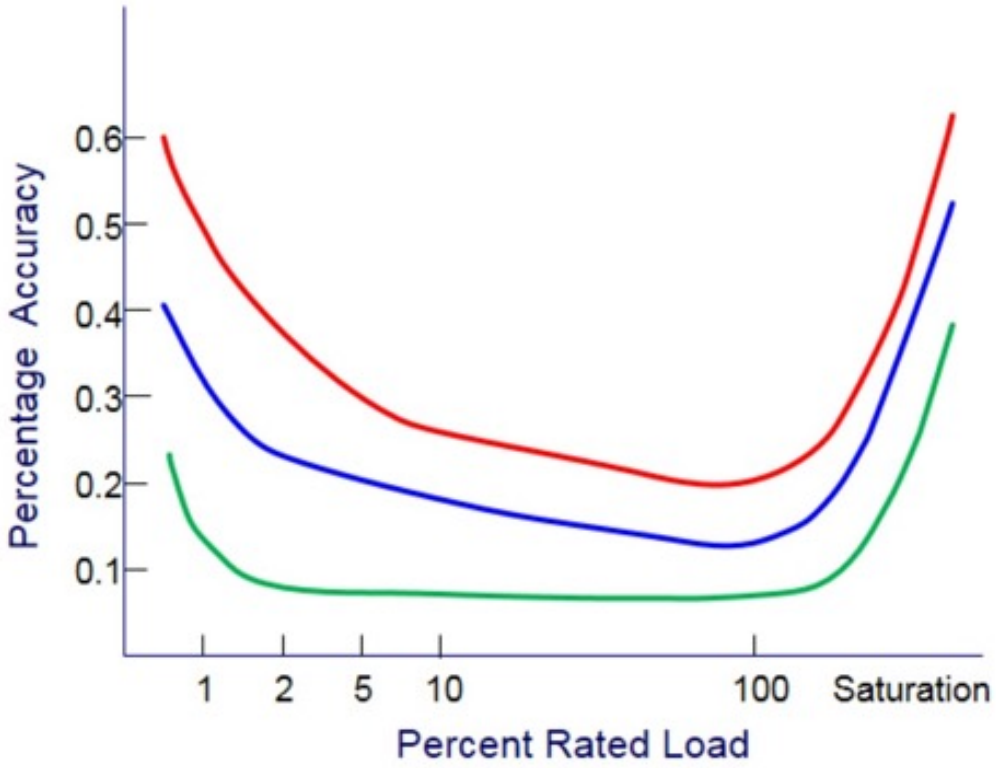

0.9Ω of Burden Present
0.2Ω of Burden Present
0.05Ω of Burden Present

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STEP 2: CT TESTING

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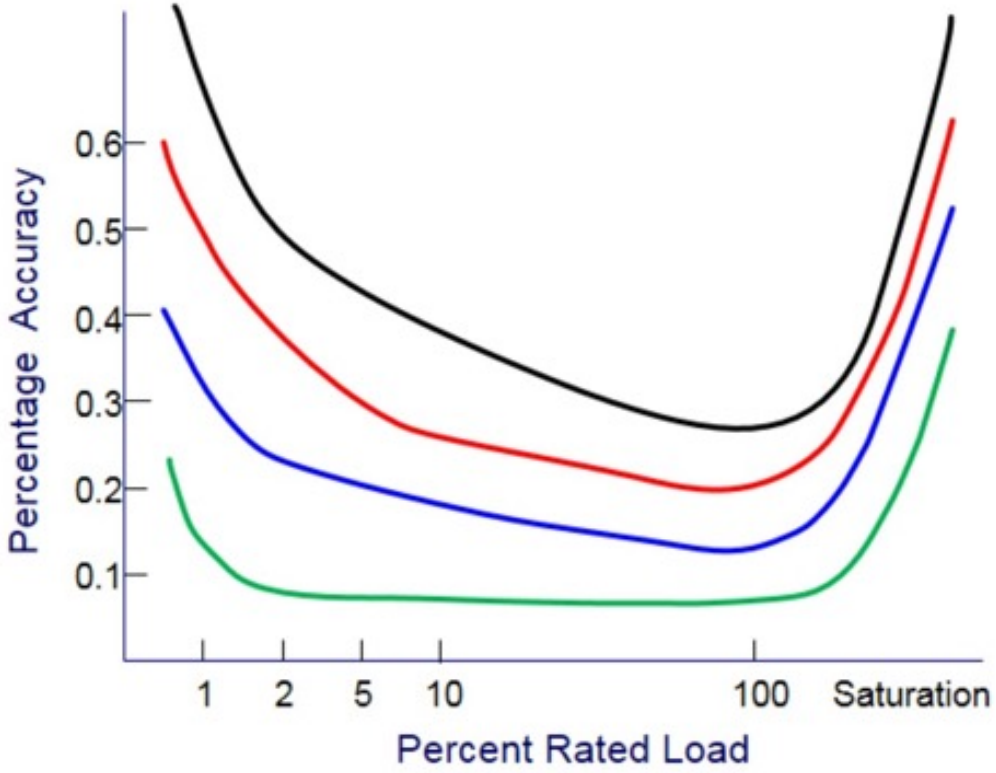

1.8Ω of Burden Present
0.9Ω of Burden Present
0.2Ω of Burden Present
0.05Ω of Burden Present

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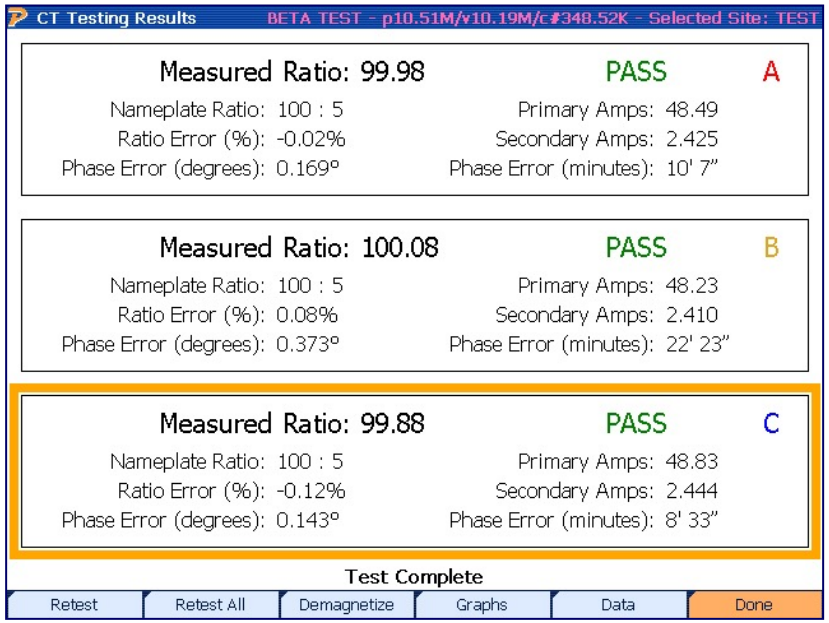
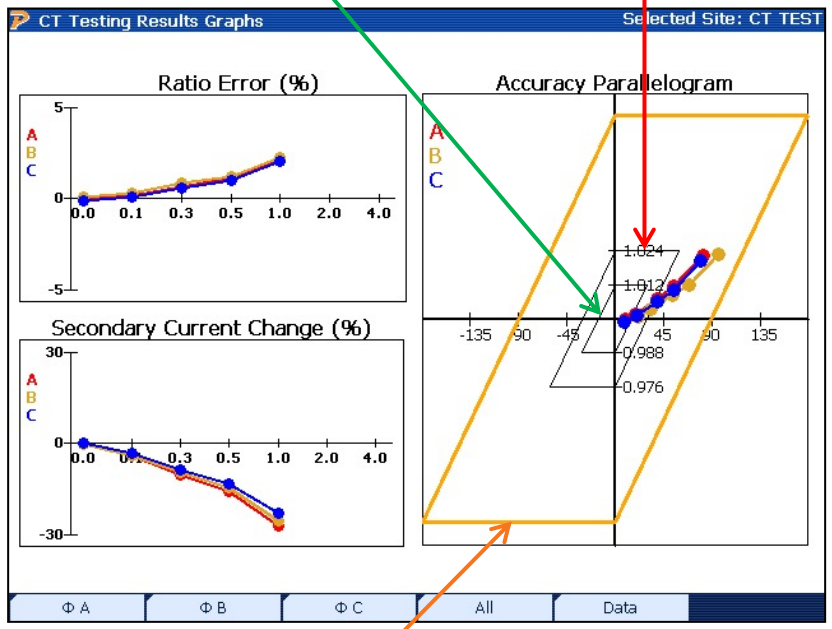
STEP 2: CT TESTING

By performing an IN-SERVICE test and plotting against the IEEE parallelogram you can see the accuracy of the CT taking into effect all its installed data ... burden, temp, etc.





.3% Limit

.6% Limit

User Defined Limit

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STEP 3: METER TESTING

How should we test the meter to best confirm BILLING accuracy?

Our options are:

- In the lab with a test board (ANSI points)
- In the field with "load box" voltage and/or current (ANSI points)
- In the field under customer load (site voltage and current)

In reality, you should do all of the above, but...
CUSTOMER LOAD testing will give you the best reflection of billing accuracy because you are testing under the real world conditions the meter is using to calculate watthours.

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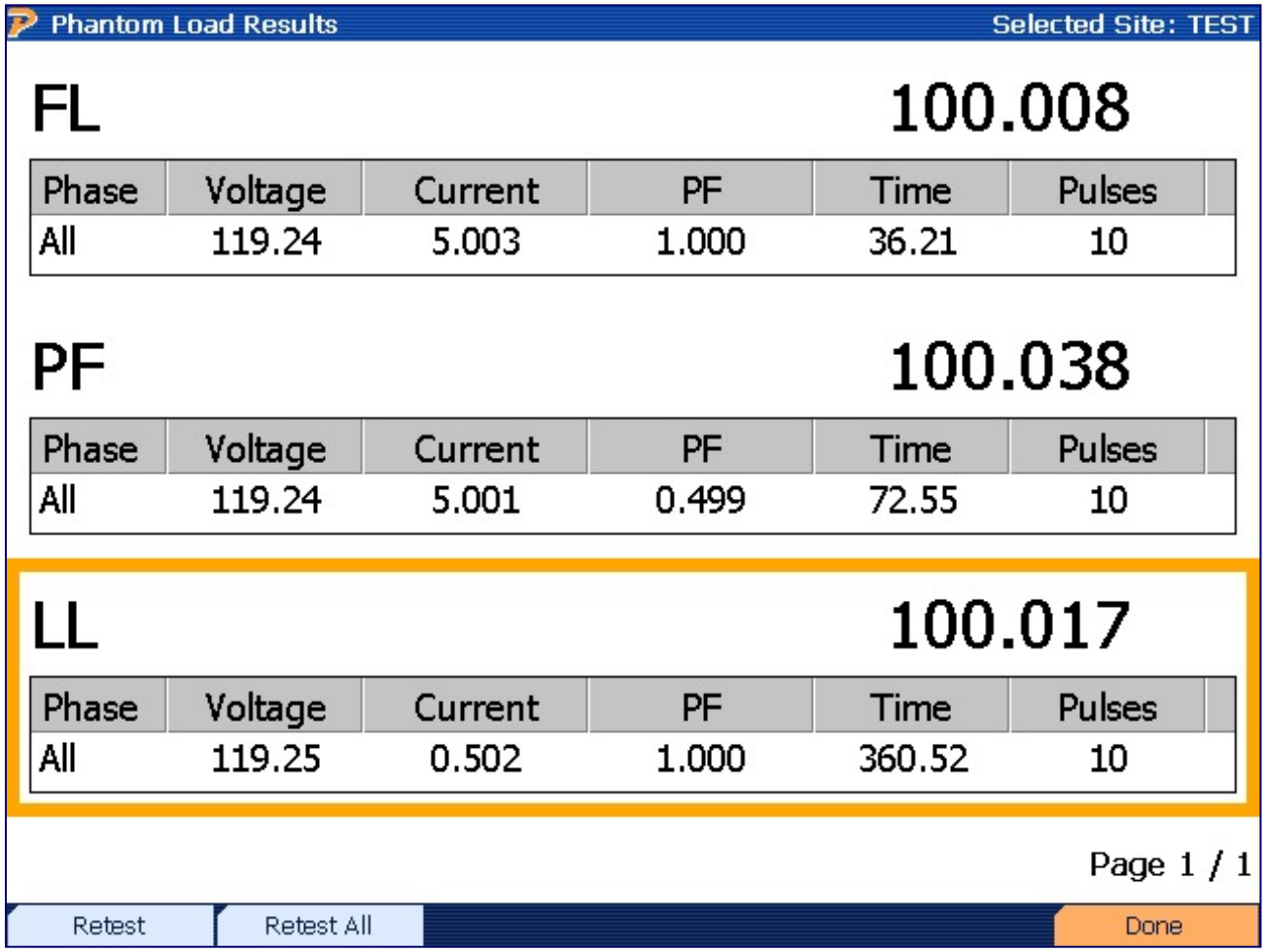
STEP 3: METER TESTING

You can mirror lab testing by using modern "load box" and reference standard combinations in the field.



ANSI Test Points
FL, PF, LL
Element Tests
Forward/Reverse Energy
VARhour

But still does NOT test under BILLING conditions

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STEP 3: METER TESTING

Shouldn't we want to know if the meter is accurate under the conditions that we are actually calculating the customer's usage?

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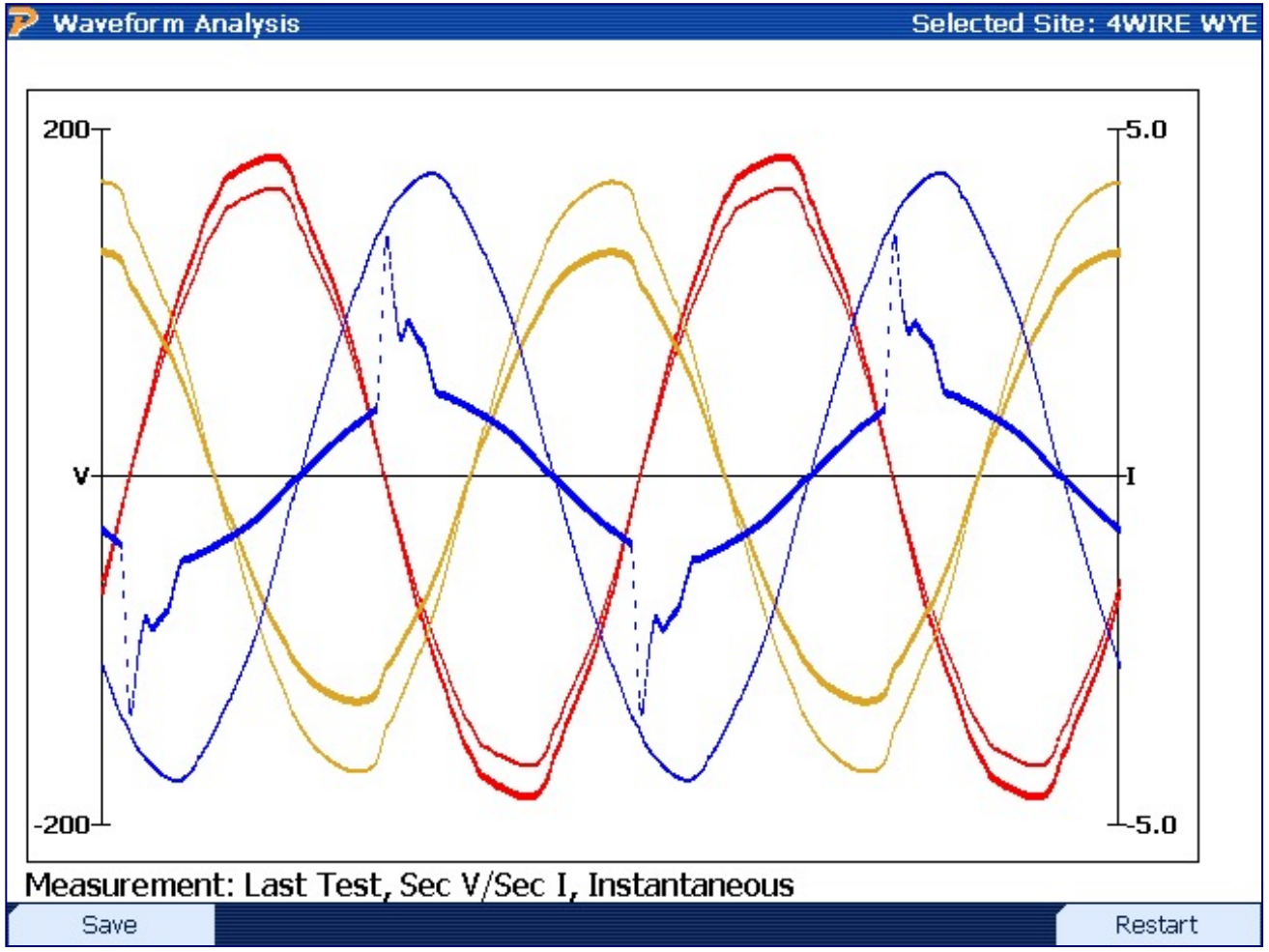

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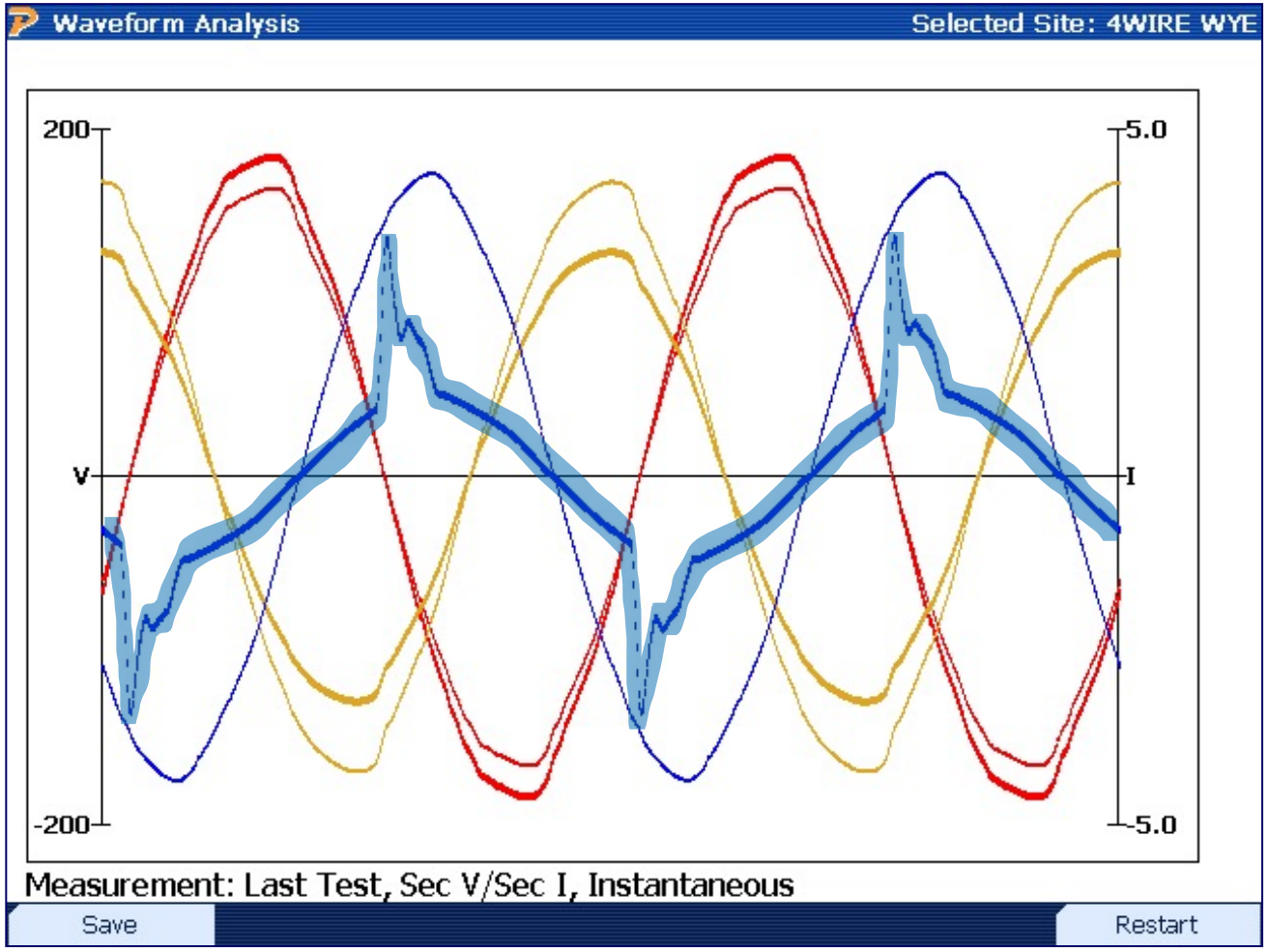

Would an ANSI test tell us if these signals were being properly calculated by the meter?

Of course not...

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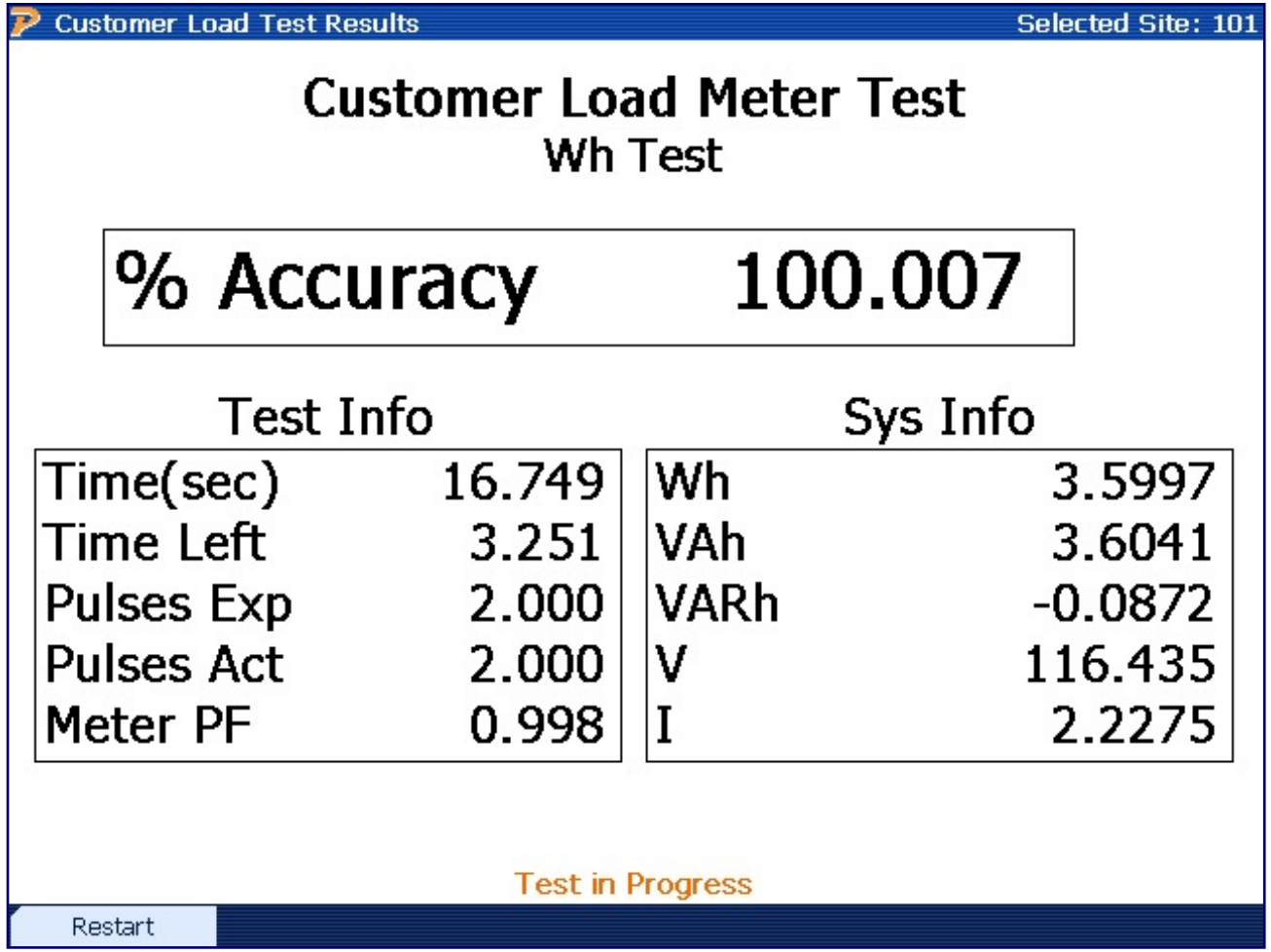
STEP 3: METER TESTING

Shouldn't we want to know if the meter is accurate under the conditions that we are actually calculating the customer's usage?



But a CUSTOMER LOAD meter test would.

Is the meter accurate when the following are present?

Imbalanced Loads
Varying Loads
Large Harmonic Distortion
Large Power Factors
Extreme Temperatures

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STEP 3: METER TESTING

If you are testing for VARh or VAh, it is extremely important to test under customer load conditions.

- Large "errors" can occur in the calculation of VA and VARS when PF#-1
- There is no "official" definition in the presence harmonics
- Different meters may implement different definitions
- Variations can be as large as 15-30 percent between two meters each of which is "working properly"

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MULTIPLIER ERRORS

Clerical errors can be the largest of all!

- Wrong billing multipliers entered into the system
- Can cause HUGE customer relations and media problems
- No amount of testing will detect them by itself
- Care and careful procedures can lessen these errors
- Having testing databases linked to billing databases can help alleviate these errors

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THEFT

The current recession has dramatically increased incidences of revenue theft.

- Self Contained Services
  - Diversion prior to the meter
  - Meter by-passing
- Transformer Rated Services
  - Diversion prior to CT
  - Tampering with the CT
  - Tampering with PT
  - Tampering with meter wiring

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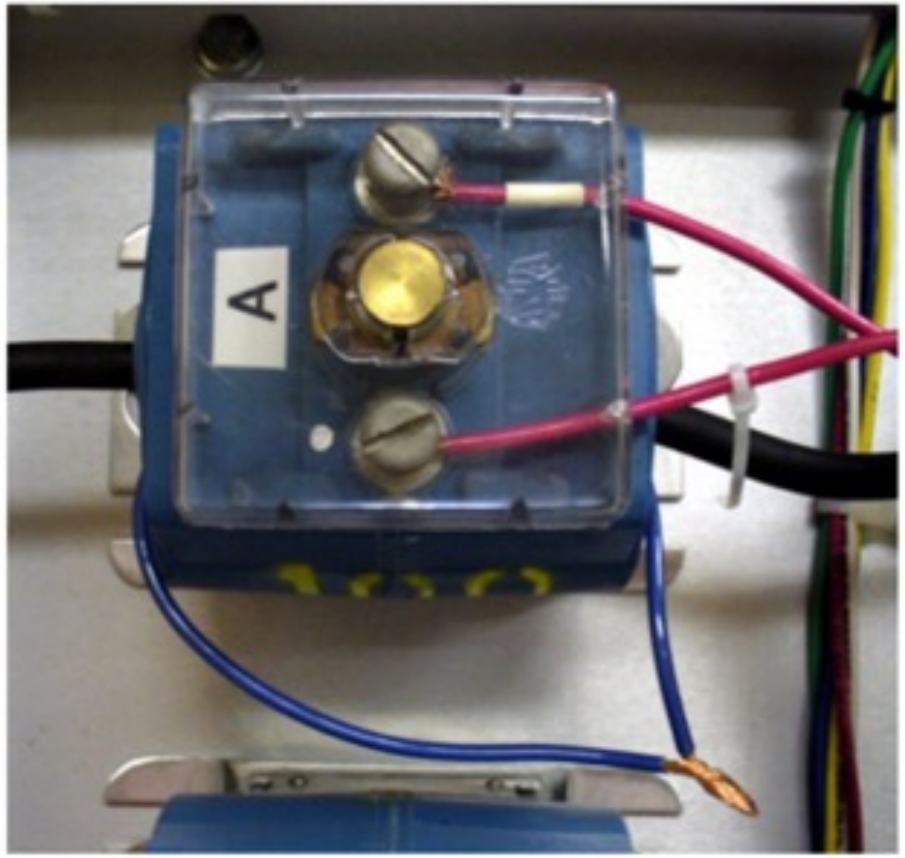
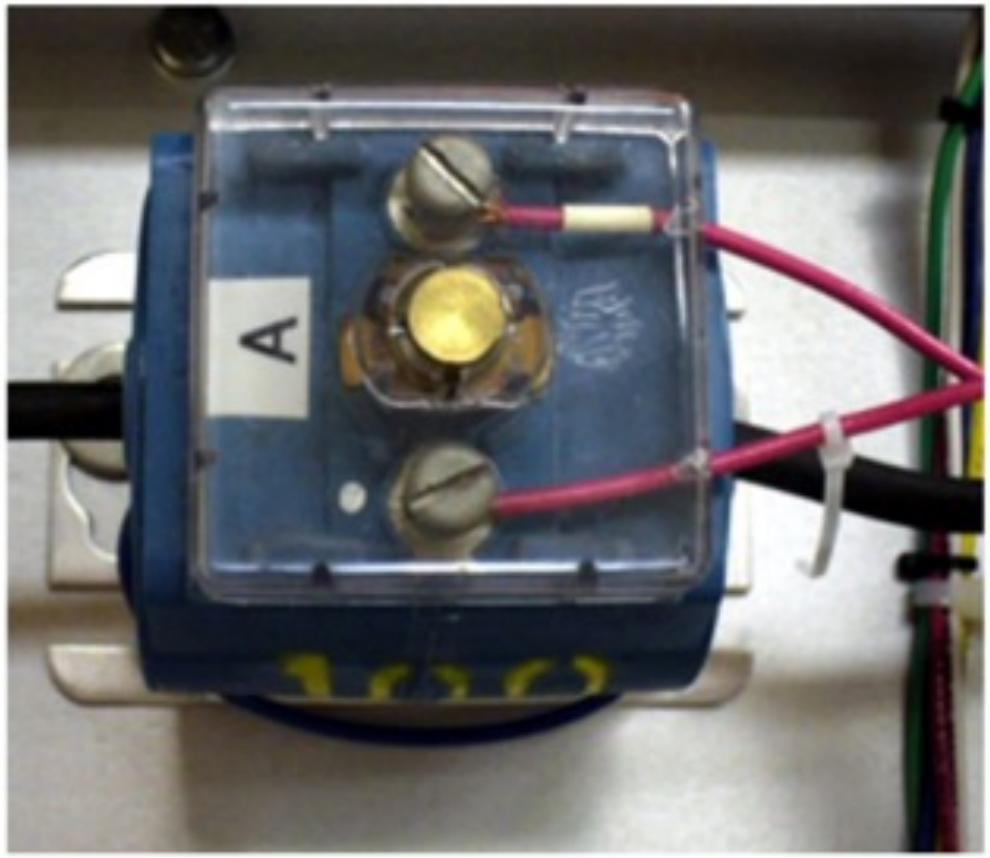
TESTING CURRENT TRANSFORMERS

What's Wrong?





POWER THEFT!

A simple piece of wire wrapped around a CT.

Would you spot it?

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EXAMPLES OF REVENUE LOSS

All examples will be based upon and compared to a medium sized commercial account wired in a Transformer Rated 9S configuration under the following assumptions:

Constant Load (120V and 5A per phase at the meter)
CT Ratios are 300:5 (60:1 Multiplier)
PT Ratios are 4:1 (4:1 Multiplier)
→ Billing Multiplier is 240 (60*4)

Facility is in operation 20 days per month
Facility is in operation for 8 hours per day
→ Hours per month is 160 (20*8)

Average price per kWh is $0.15

Average monthly bill is calculated as follows:

At the meter

[(Va*Ia*Cosθa)+(Vb*Ib*Cosθb)+(Vc*Ic*Cosθc)]'*Billing Multiplier*hours per month*price per kWh/1000
At unity power factor= [(120*5*1) + (120*5*1) + (120*5*1)]*240*160*$0.15/1000 =
1800*240*160*$0.15/1000
= $10,368 per month or $124,416 per year (with absolutely no errors in the system)

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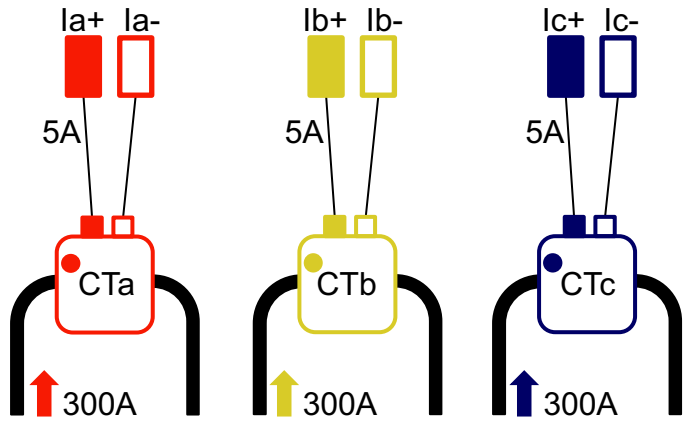
EXAMPLE #1

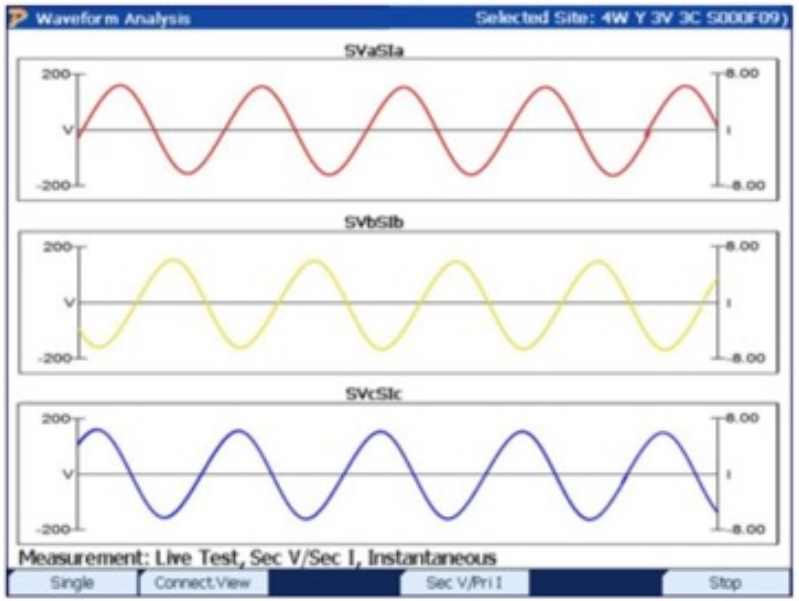
Typical 9S Meter Installation
4:1 PTs
300:5 CTs
Billing Multiplier of 240
WITH NO ERRORS
Monthly Bill of $10,368
Yearly Bill of $124,416

Secondary Current Signals to Test Switch

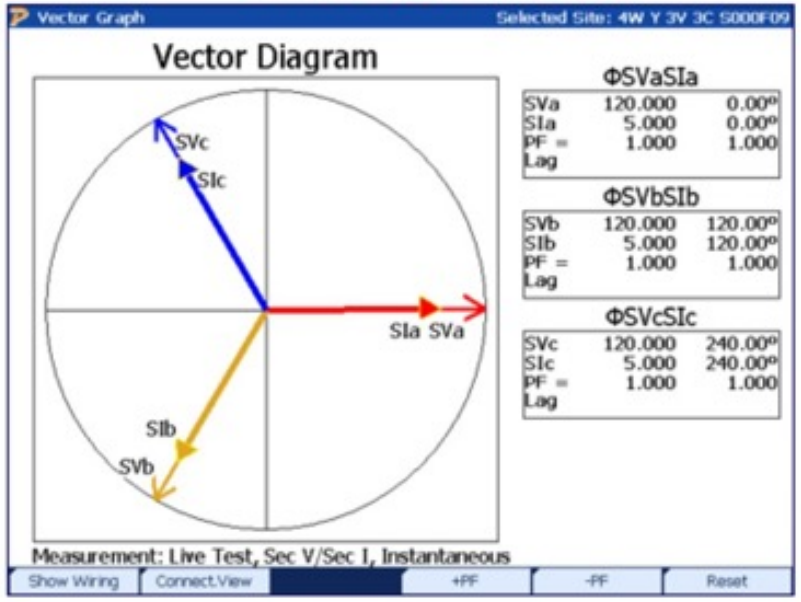


Primary Signals from Utility

Waveforms Perfect



Vector Diagram Perfect



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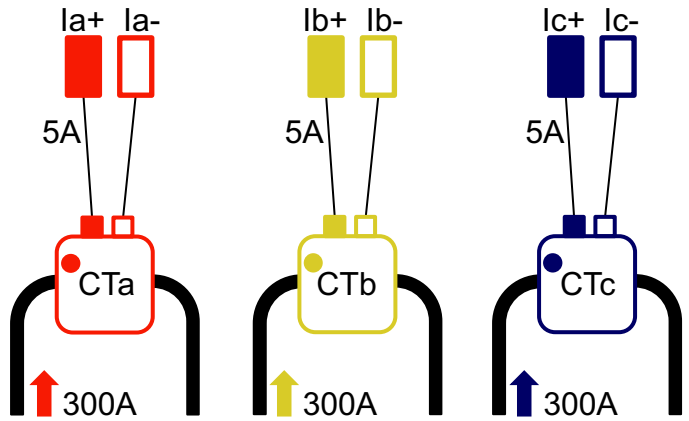
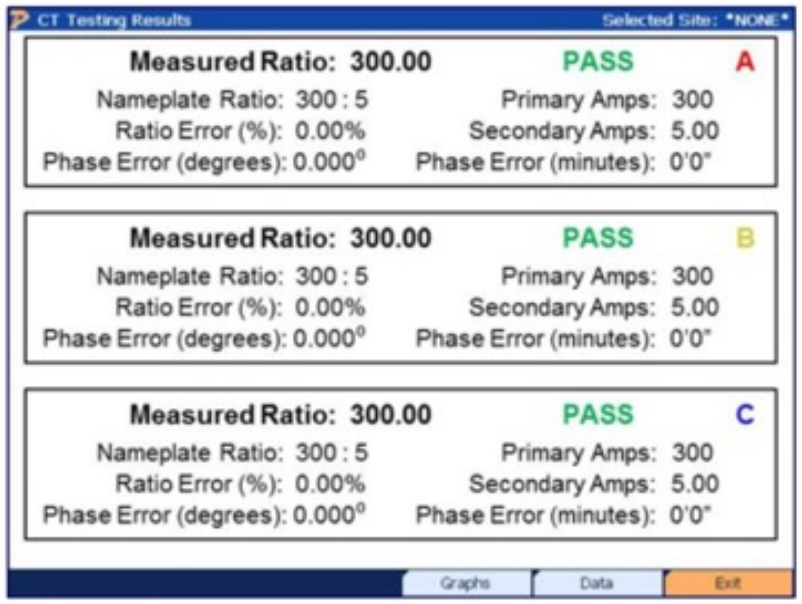
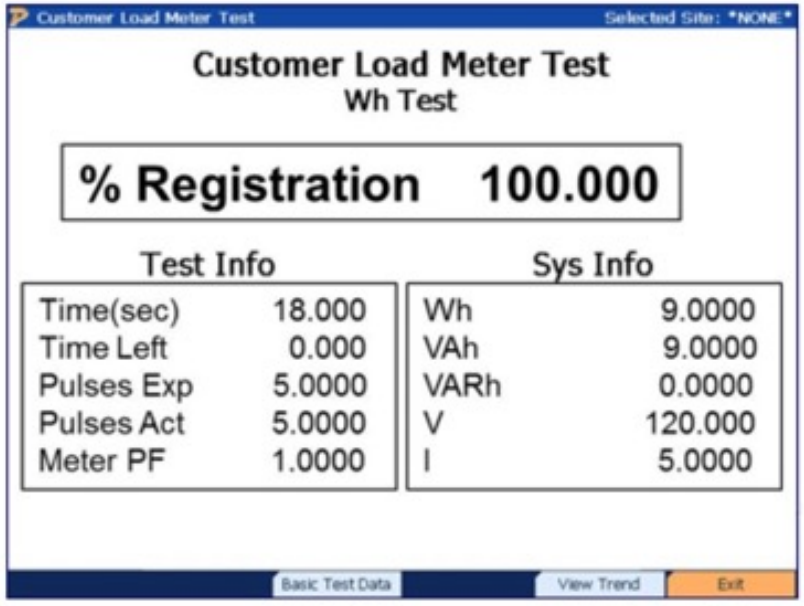


Primary Signals from Utility

CT Test Perfect



Meter Test Perfect



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EXAMPLE #2

WHERE IS THE ERROR?

MISLABELED CT

CTb is actually 600:5

This causes the billing multiplier to be incorrect.

What is the billing implication?

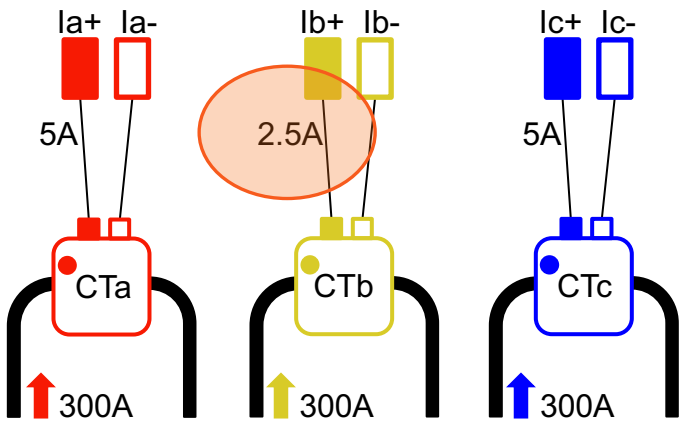
16.7% Drop in revenue

$1,728 per month in lost revenue.

$20,736 per year in lost revenue.

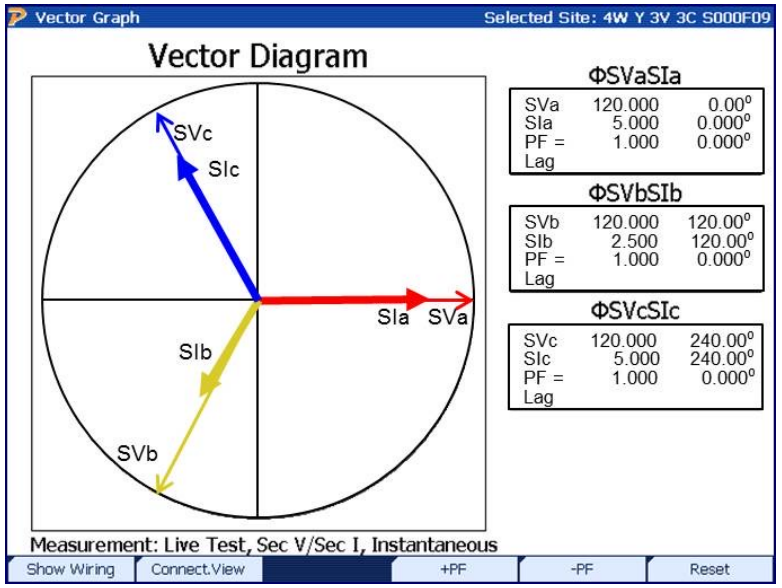
How can you find the error?

Secondary Current Signals to Test Switch

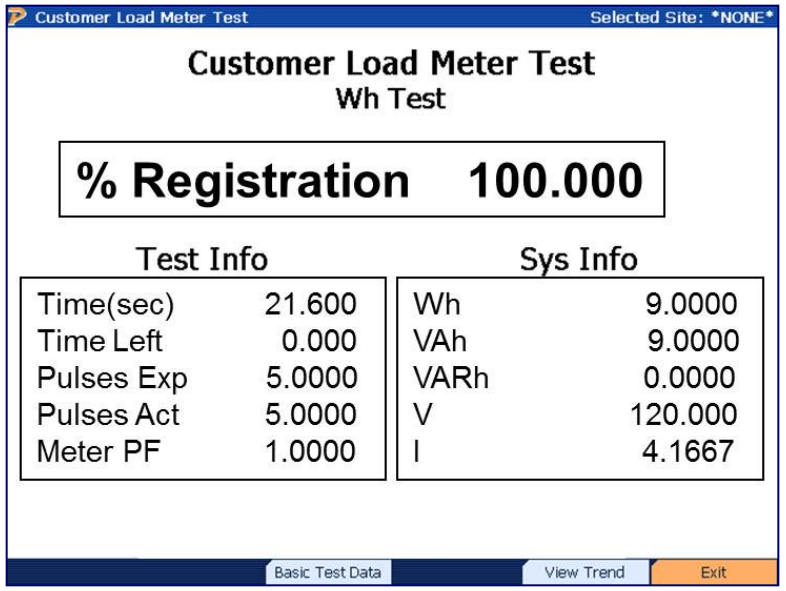


Primary Signals from Utility

On the Vector Diagram? PROBABLY NOT



During a Meter Test? NO



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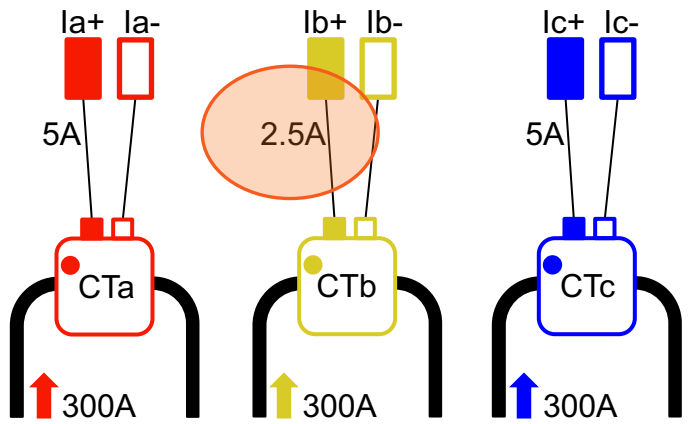
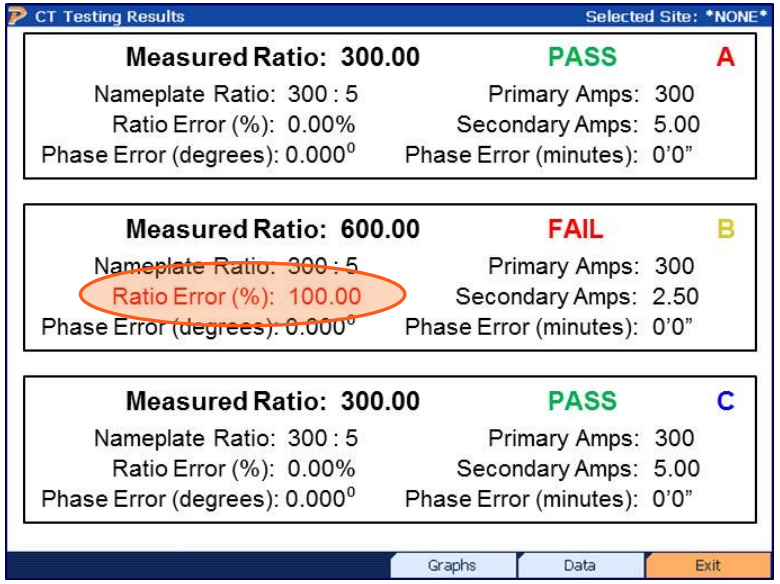
Secondary Current Signals to Test Switch



Primary Signals from Utility

During a CT Test? ABSOLUTELY



POWERMETRIX

EXAMPLE #3

WHERE IS THE ERROR?

OVERBURDENED CT

On CTc there might be a loose connection, degraded wire, too long of a secondary run, wire too small, etc.

This causes the secondary current to drop

What is the billing implication?

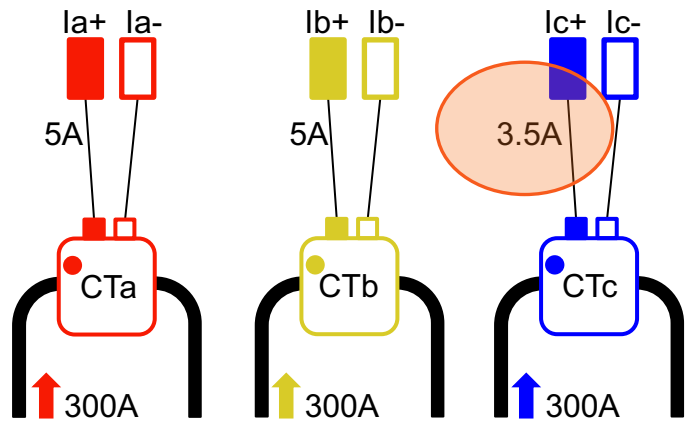
10% Drop in revenue

$1,036 per month in lost revenue.

$12,435 per year in lost revenue.

How can you find the error?

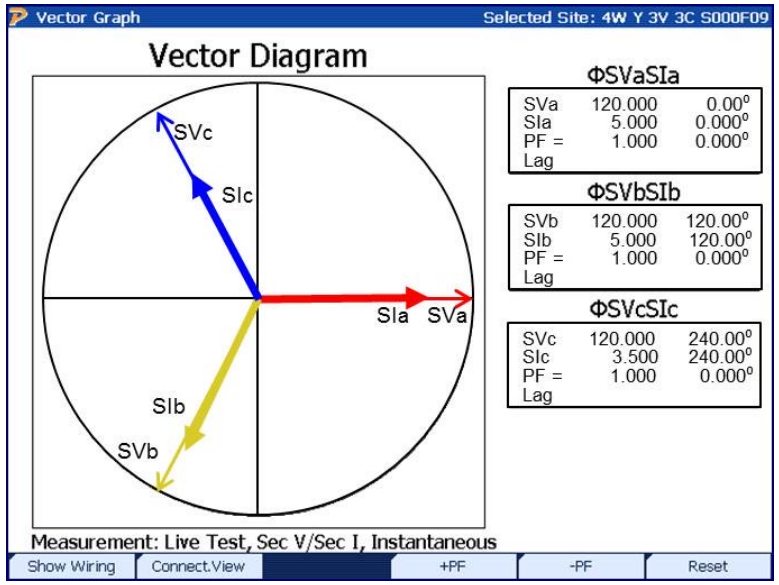
Secondary Current Signals to Test Switch

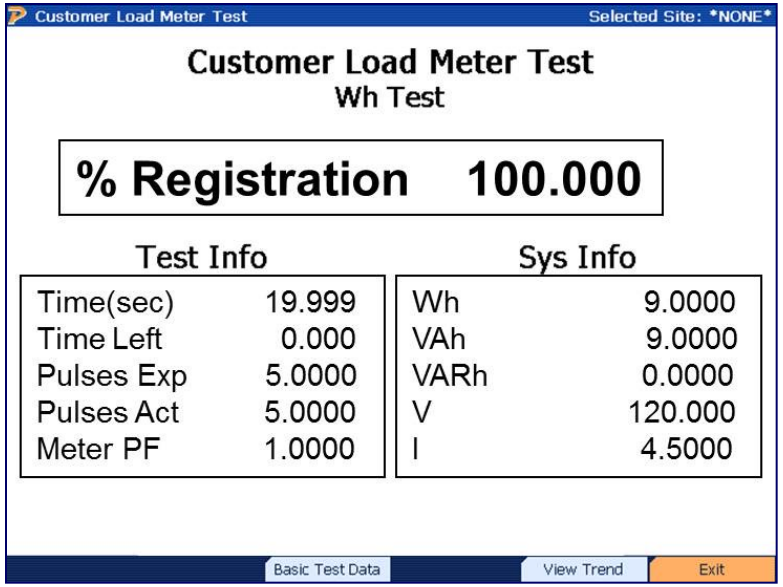


Primary Signals from Utility

On the Vector Diagram? PROBABLY NOT

During a Meter Test? NO





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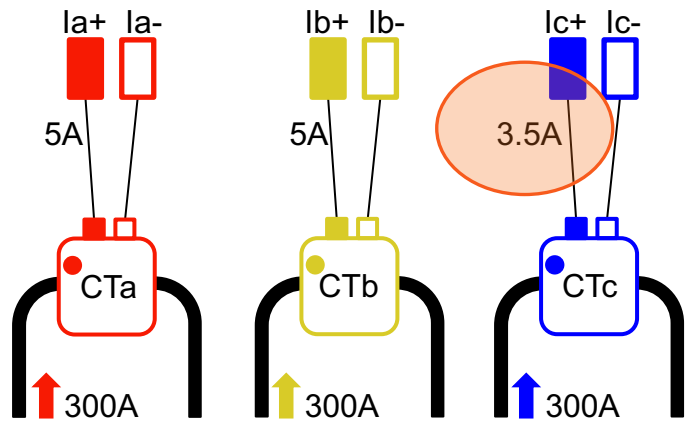
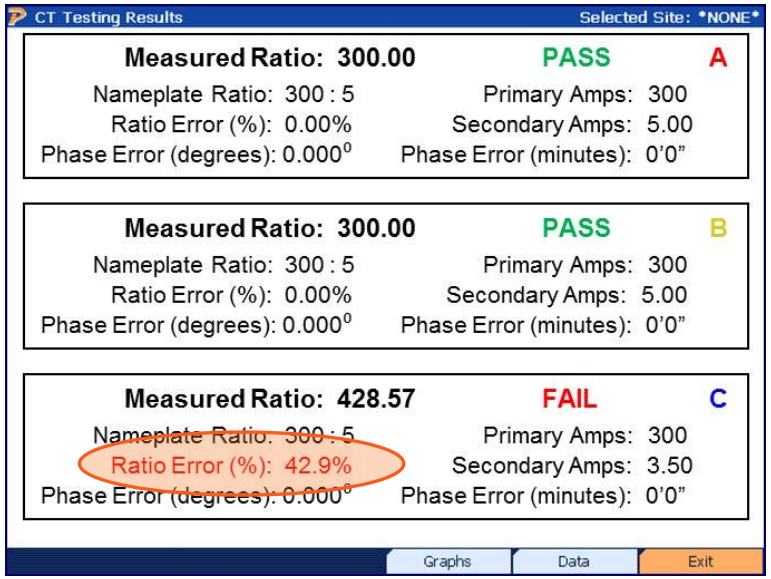


Primary Signals from Utility

During a CT Test? ABSOLUTELY



POWERMETRIX

EXAMPLE #4

WHERE IS THE ERROR?

CT INSTALLED BACKWARDS

CTa polarity is wrong

This causes reverse current/power/energy on the phase

What is the billing implication?

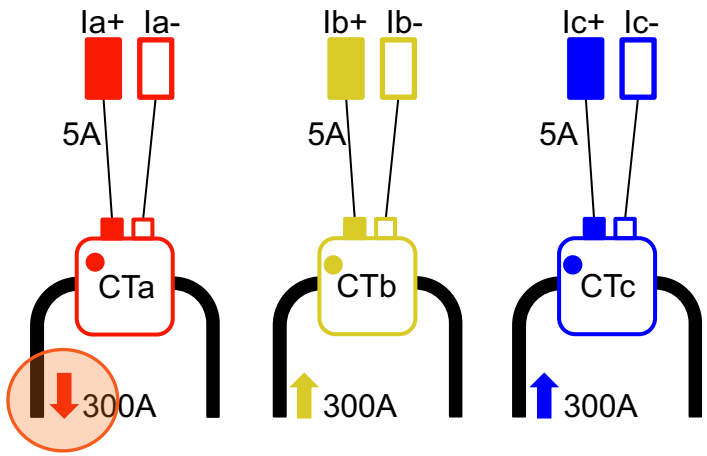
66.7% Drop in revenue

$6,912 per month in lost revenue.

$82,944 per year in lost revenue.

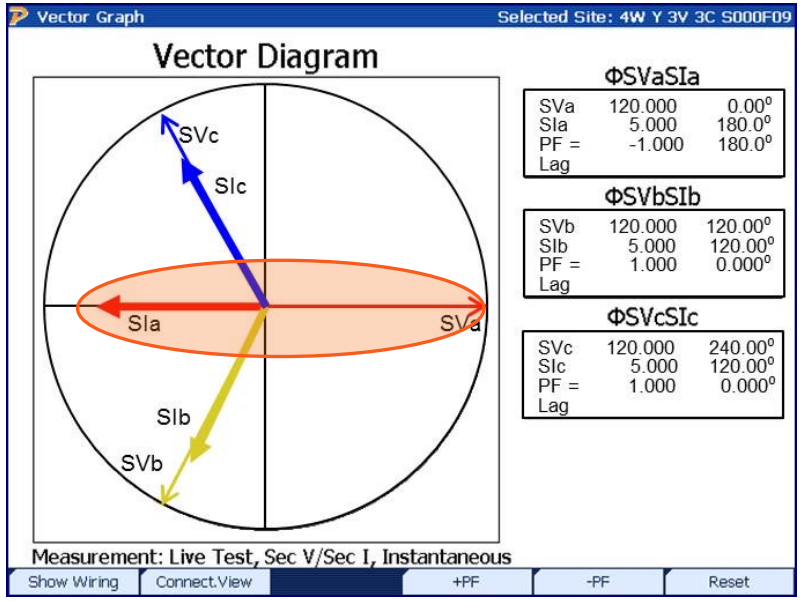
How can you find the error?

Secondary Current Signals to Test Switch

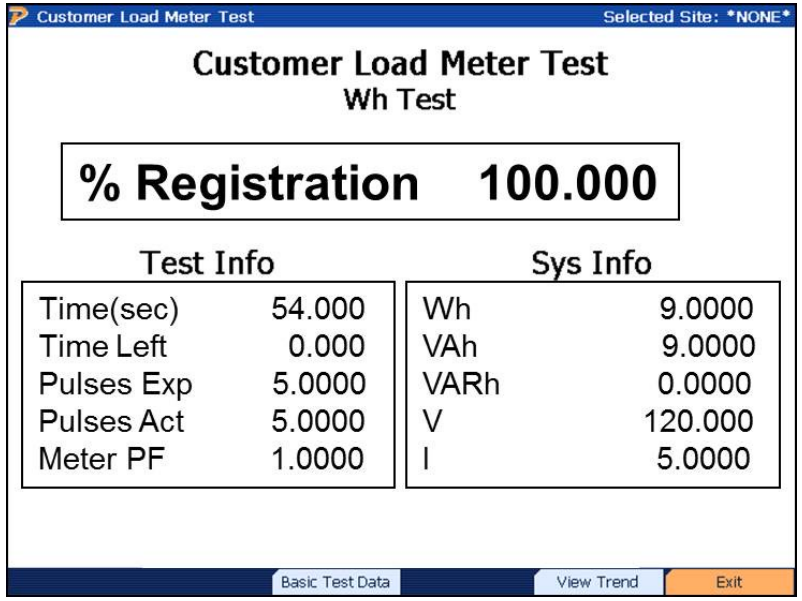


Primary Signals from Utility

On the Vector Diagram? YOU SHOULD



During a Meter Test? NO



POWERMETRIX

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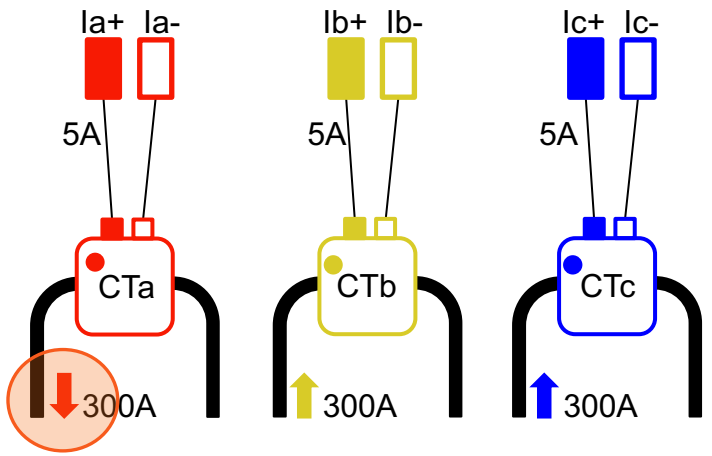
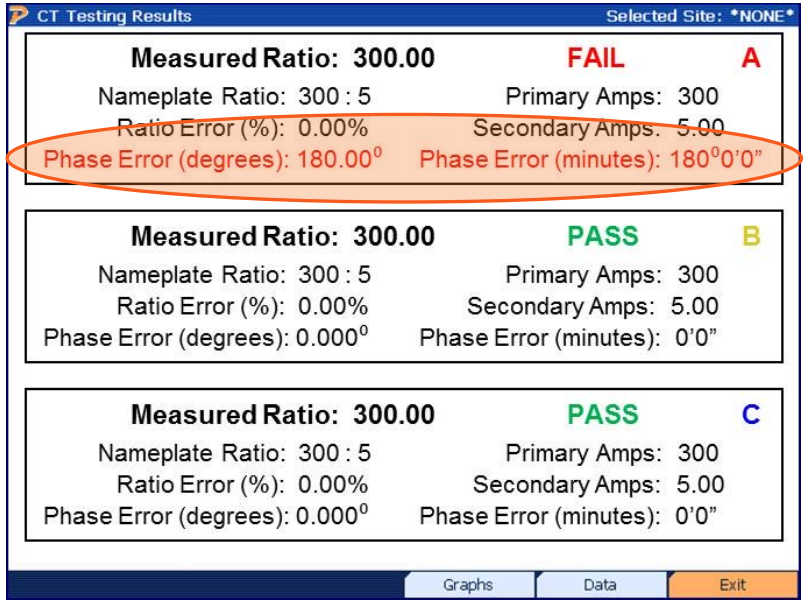


Primary Signals from Utility

During a CT Test? ABSOLUTELY



POWERMETRIX

EXAMPLE #5

WHERE IS THE ERROR?

REVERSE SECONDARY WIRING

CTa secondary is wired backwards at the test switch or directly at the CT

This causes reverse current/power/energy on the phase

What is the billing implication?

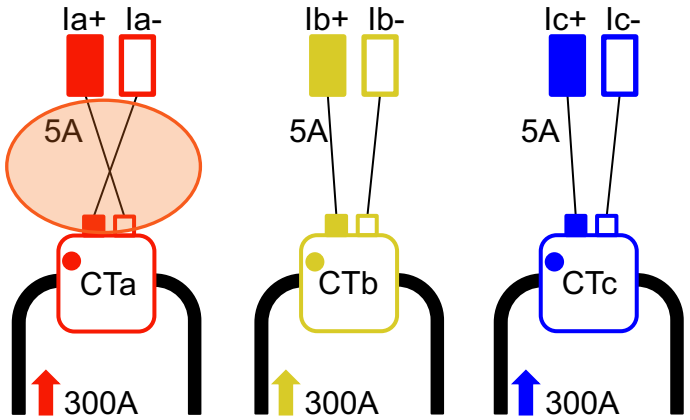
66.7% Drop in revenue

$6,912 per month in lost revenue.

$82,944 per year in lost revenue.

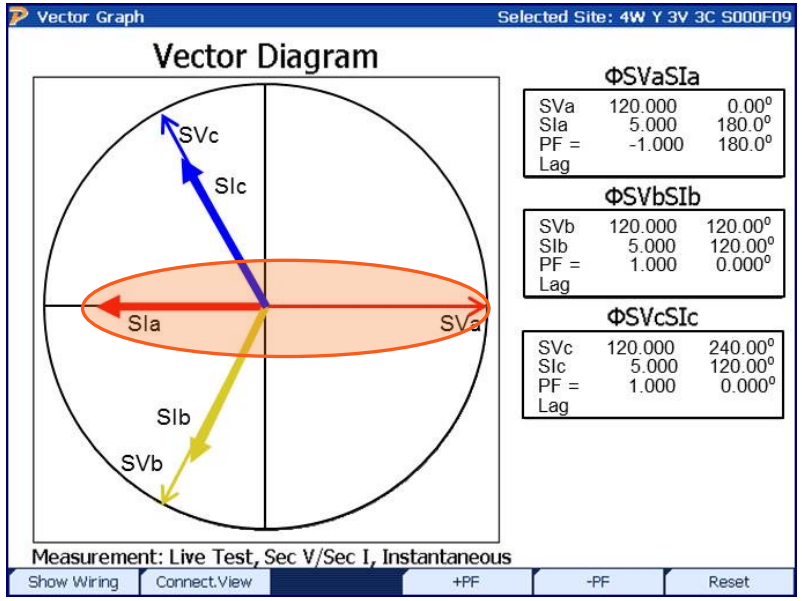
How can you find the error?

Secondary Current Signals to Test Switch

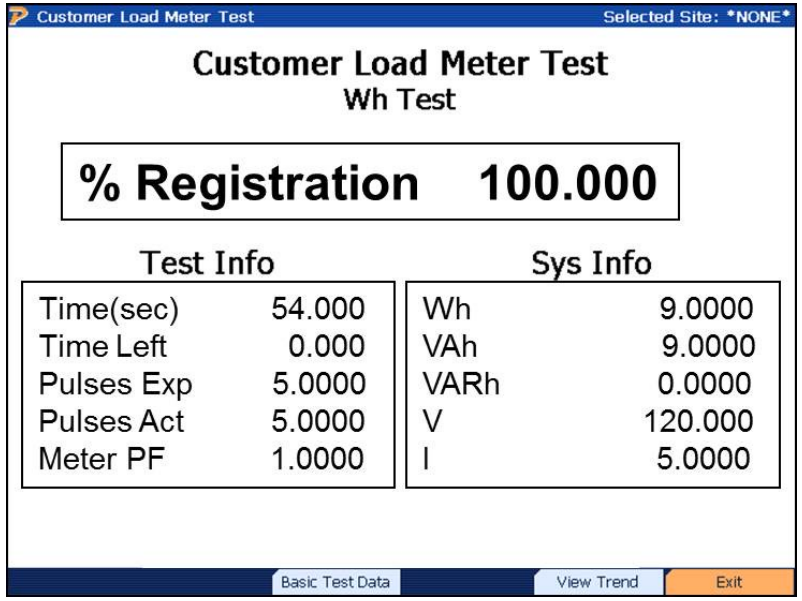


Primary Signals from Utility

On the Vector Diagram? YOU SHOULD



During a Meter Test? NO



POWERMETRIX

EXAMPLE #5

WHERE IS THE ERROR?

REVERSE SECONDARY WIRING

CTc secondary is wired backwards at the test switch or directly at the CT

This causes reverse current/power/energy on the phase

What is the billing implication?

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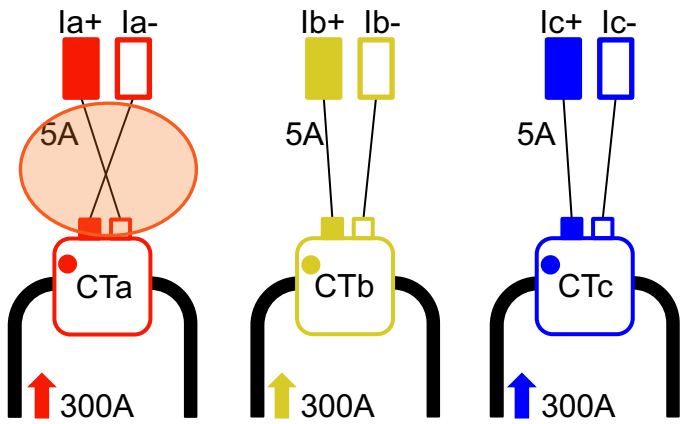
$6,912 per month in lost revenue.

$82,944 per year in lost revenue.

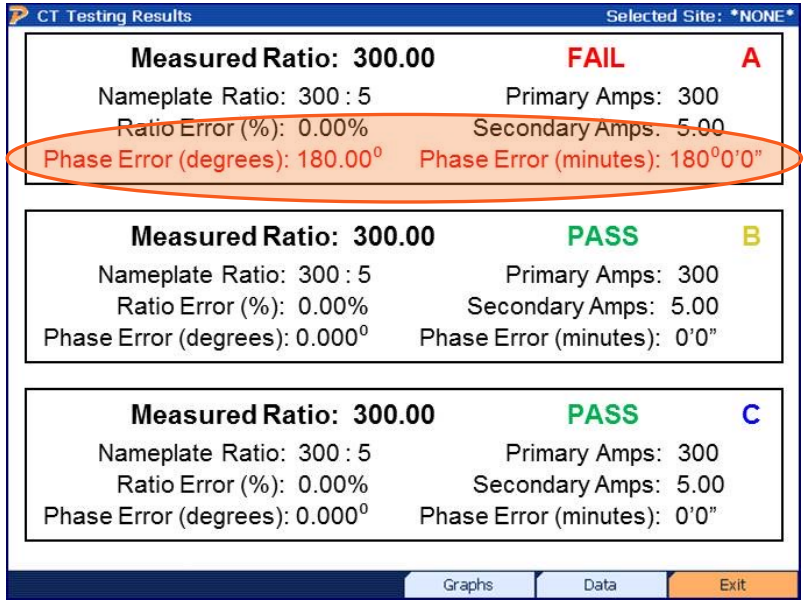
How can you find the error?

Secondary Current Signals to Test Switch



Primary Signals from Utility

During a CT Test? ABSOLUTELY



POWERMETRIX

EXAMPLE #6

WHERE IS THE ERROR?

CROSS PHASE WIRING

CTb and CTc are wired to wrong phases of the test switch

This causes -50% power/energy on both phases B and C

What is the billing implication?

With a totally balanced load, there would be ZERO energy accumulating on the meter.

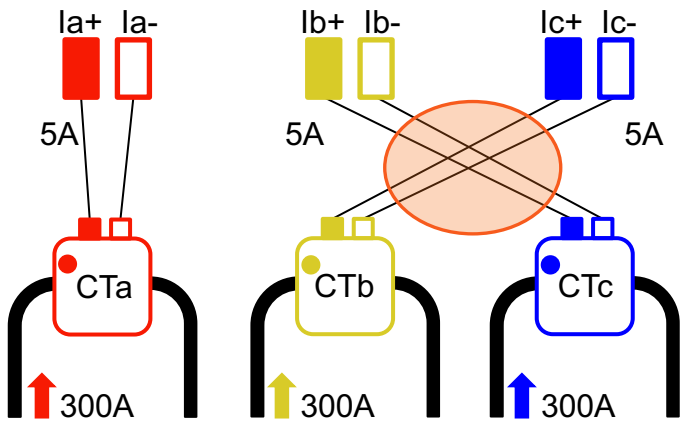
100% drop in revenue.

$10,368 per month in lost revenue.

$124,416 per year in lost revenue.

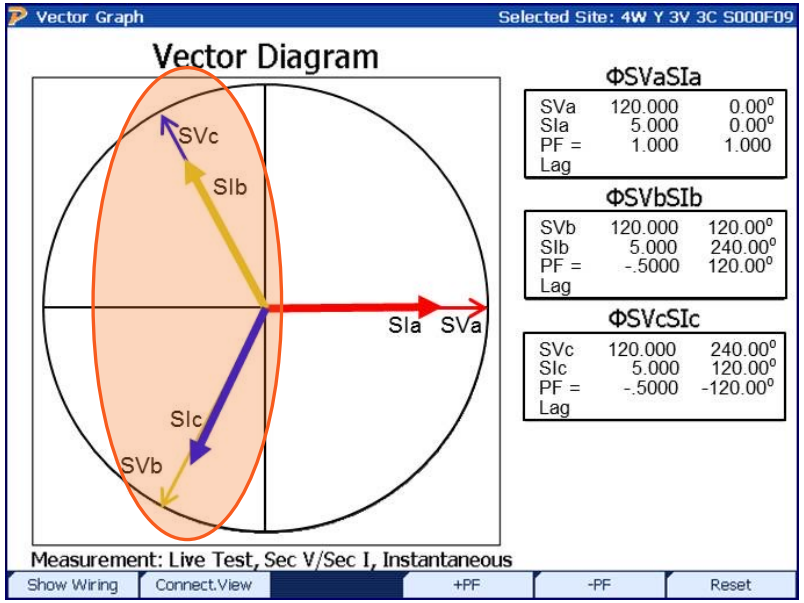
How can you find the error?

Secondary Current Signals to Test Switch

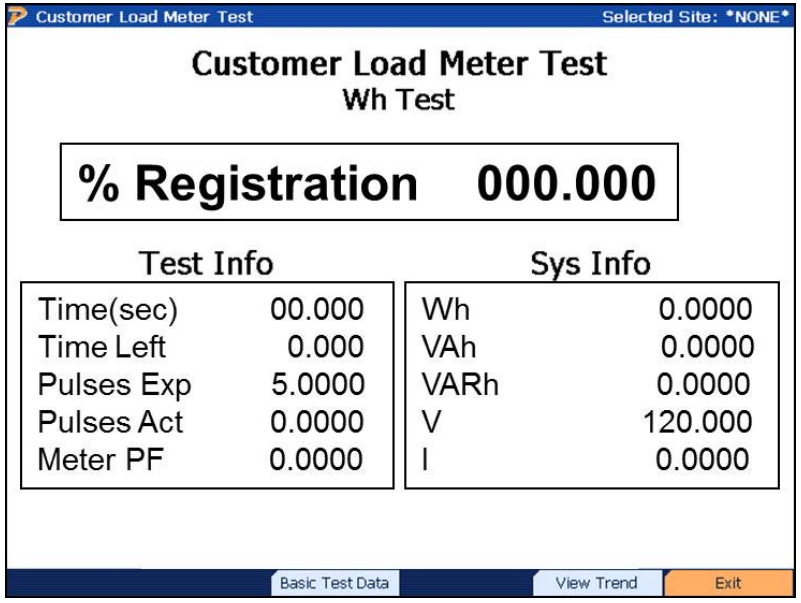


Primary Signals from Utility

On the Vector Diagram? YOU SHOULD



During a Customer Load Meter Test?
NO PULSES (with balanced load)



POWERMETRIX

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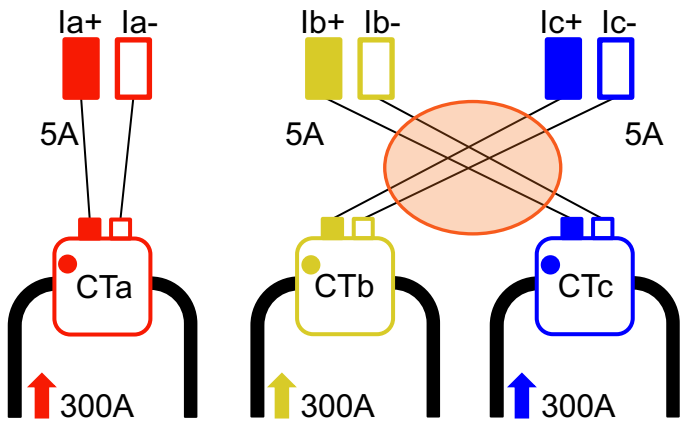
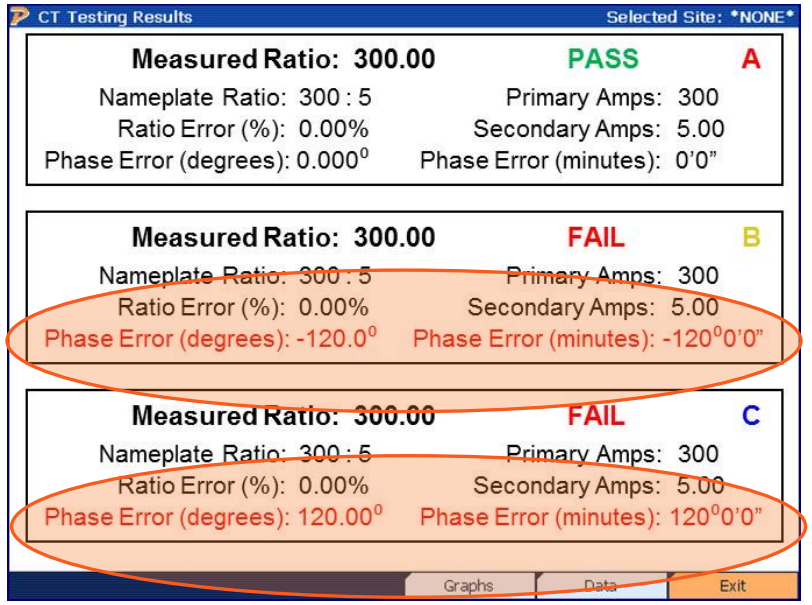


Primary Signals from Utility

During a CT Test? ABSOLUTELY



POWERMETRIX

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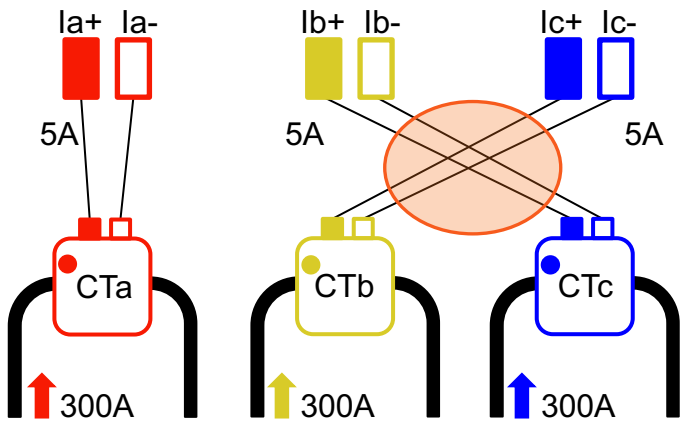


Primary Signals from Utility

What if you don't have a true balanced load? In a real-world situation, you might have:

5A on Phase A

4A on Phase B

3.5A on Phase C

The meter will STILL turn!

With these currents:

90% Drop in revenue

$7,776 per month in lost revenue

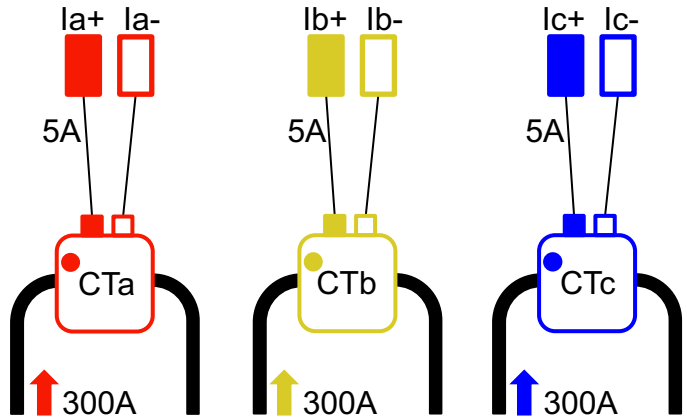
$93,312 per year in lost revenue

POWERMETRIX

EXAMPLE #7

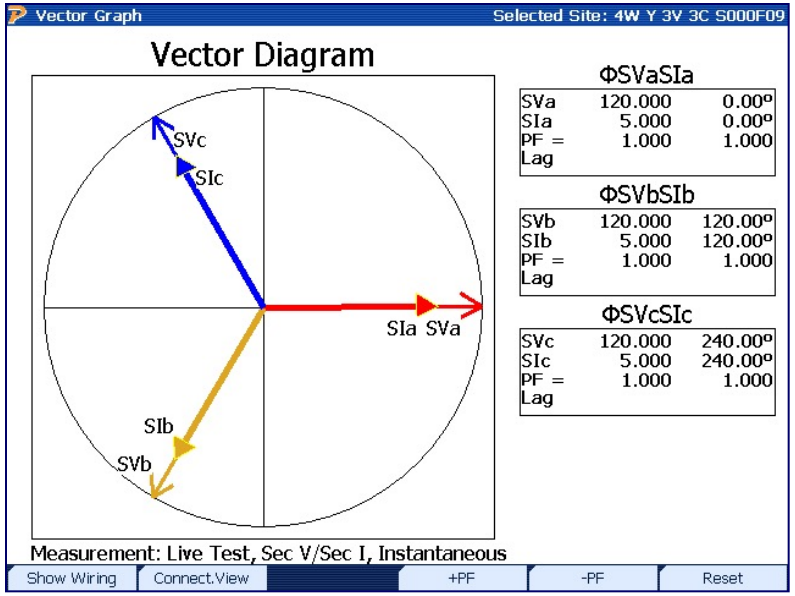
WHAT IS GOING ON?

Secondary Current Signals to Test Switch

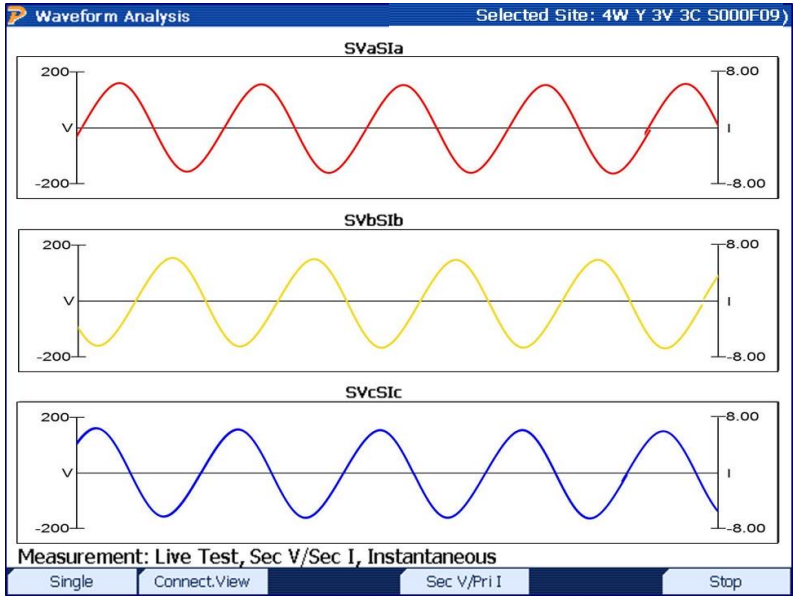


Primary Signals from Utility

Vector Diagram looks OK



Waveforms look OK



POWERMETRIX

EXAMPLE #7

WHAT IS GOING ON?

Wrong Kh?

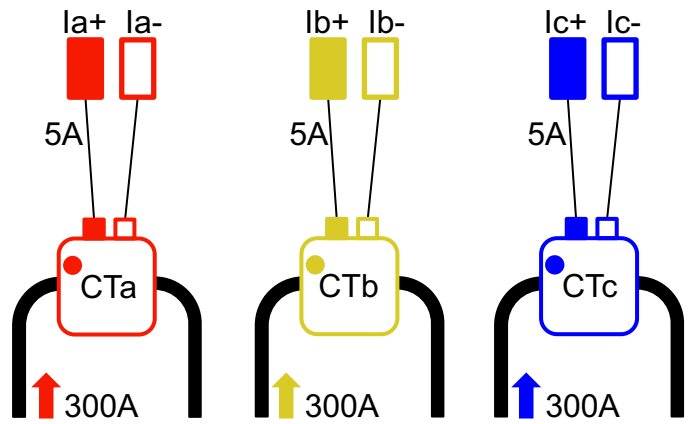
Bad Meter?

Bad element on the meter?

Something else?

Let's test the meter in the lab with the same Kh and see what happens.

Secondary Current Signals to Test Switch



Primary Signals from Utility

CT Tests are OK

CT Testing Results — Selected Site: *NONE*

Measured Ratio: 300.00	**PASS**	**A**
Nameplate Ratio: 300 : 5	Primary Amps: 300	
Ratio Error (%): 0.00%	Secondary Amps: 5.00	
Phase Error (degrees): 0.000°	Phase Error (minutes): 0'0"	
Measured Ratio: 300.00	**PASS**	**B**
Nameplate Ratio: 300 : 5	Primary Amps: 300	
Ratio Error (%): 0.00%	Secondary Amps: 5.00	
Phase Error (degrees): 0.000°	Phase Error (minutes): 0'0"	
Measured Ratio: 300.00	**PASS**	**C**
Nameplate Ratio: 300 : 5	Primary Amps: 300	
Ratio Error (%): 0.00%	Secondary Amps: 5.00	
Phase Error (degrees): 0.000°	Phase Error (minutes): 0'0"	

Graphs | Data | Exit

Customer Load Meter Test is really bad

Customer Load Meter Test — Selected Site: *NONE*

Customer Load Meter Test
Wh Test

% Registration 33.333

Test Info		Sys Info	
Time(sec)	54.000	Wh	9.0000
Time Left	0.000	VAh	9.0000
Pulses Exp	15.0000	VARh	0.0000
Pulses Act	5.0000	V	120.000
Meter PF	1.0000	I	5.0000

Basic Test Data | View Trend | Exit

POWERMETRIX

EXAMPLE #7

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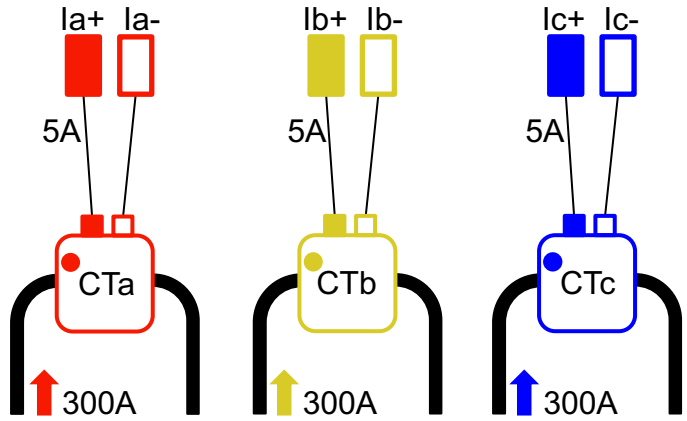
Something else?

Let's test the meter in the lab with the same Kh and see what happens.

Secondary Current Signals to Test Switch



Primary Signals from Utility

Phantom Load Meter Test is OK

Phantom Load Results — Selected Site: TEST

FL 100.000

Phase	Voltage	Current	PF	Time	Pulses
All	120.00	5.000	1.000	18.00	5

PF 100.000

Phase	Voltage	Current	PF	Time	Pulses
All	120.00	5.000	0.500	36.00	5

LL 100.000

Phase	Voltage	Current	PF	Time	Pulses
All	120.00	0.500	1.000	36.00	1

Page 1 / 1

Retest | Retest All | Done

Element Phantom Load Meter Test is OK

Phantom Load Results — Selected Site: TEST

FL 100.000

Phase	Voltage	Current	PF	Time	Pulses
A	120.00	5.000	1.000	54.00	5

FL 100.000

Phase	Voltage	Current	PF	Time	Pulses
B	120.00	5.000	1.000	54.00	5

FL 100.000

Phase	Voltage	Current	PF	Time	Pulses
C	120.00	5.000	1.000	54.00	5

Page 1 / 1

Retest | Retest All | Done

POWERMETRIX

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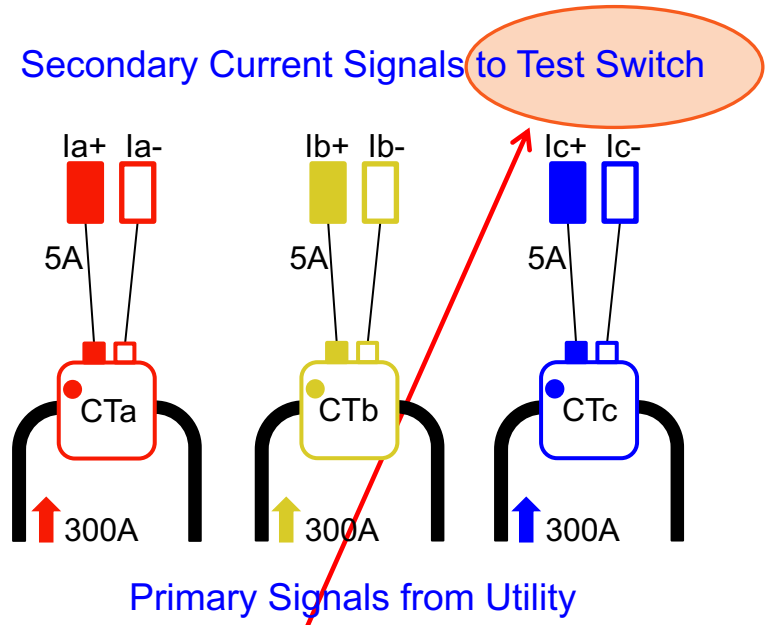
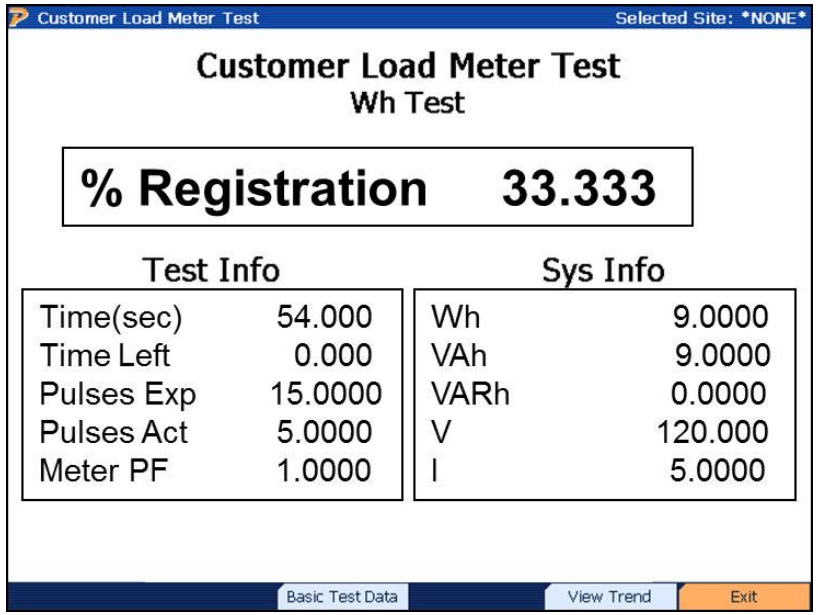


SAME RESULTS



ANY LAST GUESSES? HERE'S A HINT!

Meter can was wired backwards on one phase between test switch and meter terminals.

Virtually nothing will show this error but a CUSTOMER LOAD METER TEST!

66.7% Drop in revenue

$6,912 per month in lost revenue.

$82,994 per year in lost revenue.

POWERMETRIX

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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SUMMARY

- Meter Accuracy is just a link in the chain of ensuring accurate billing
- Choosing the right CT for the installation is of paramount importance
- No single test can ensure correct billing
- Look at all the data from the site you can
- Test under customer load if possible
- Accurate billing improves customer confidence and helps to limit bad press
- Site testing should be a continual process

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Thank you for your time!

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