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.
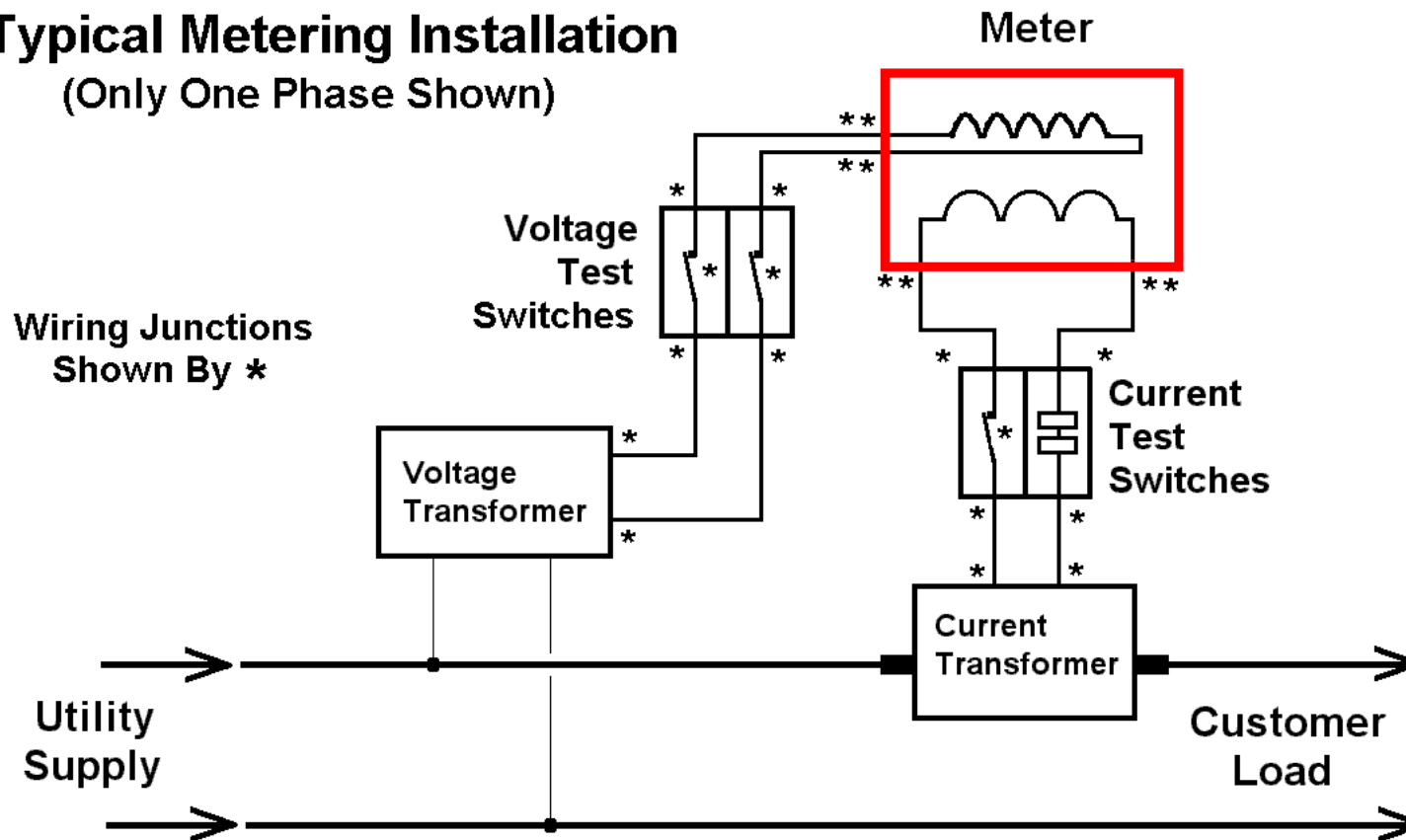

Typical Metering Installation
(Only One Phase Shown)

POWERMETRIX
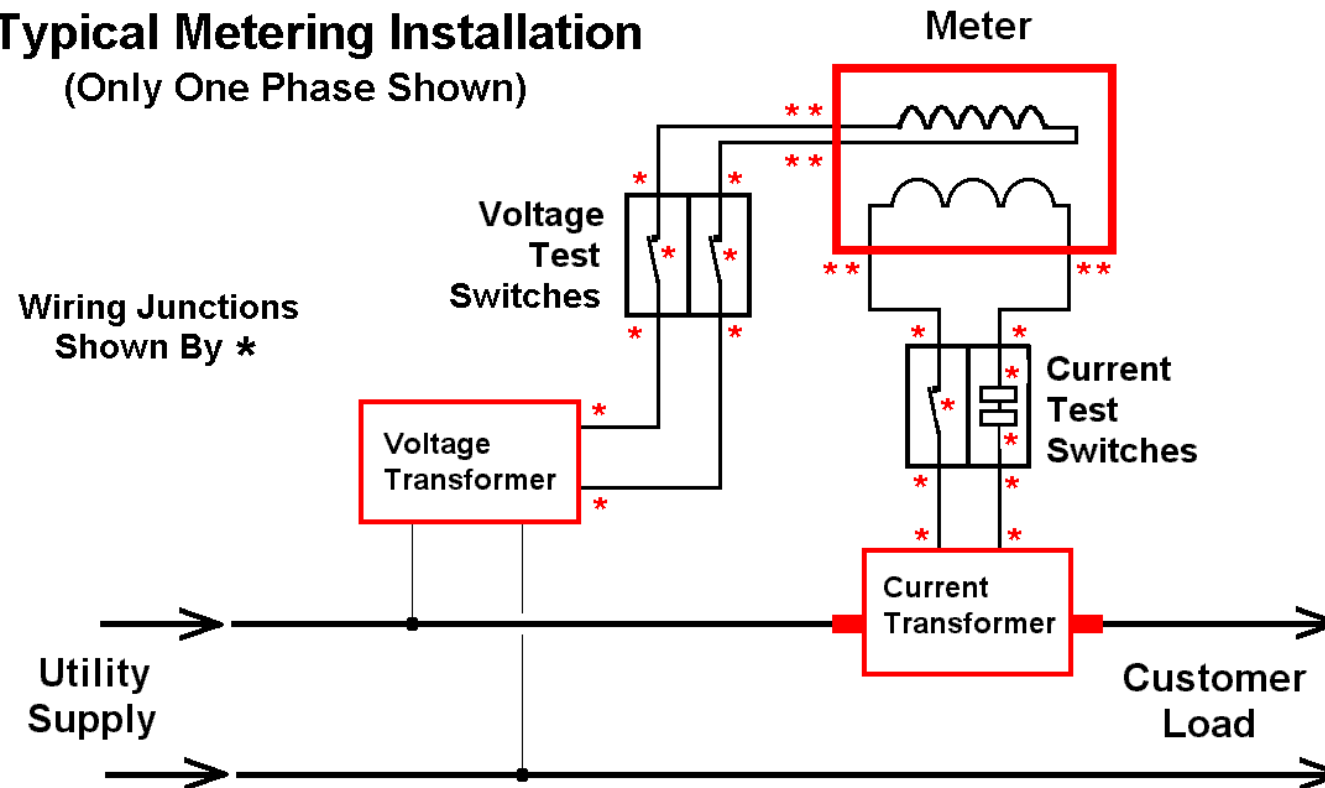
BUT TRADITIONALLY,
ONLY THE METER IS TESTED.
The meter can ONLY measure what reaches its terminals.
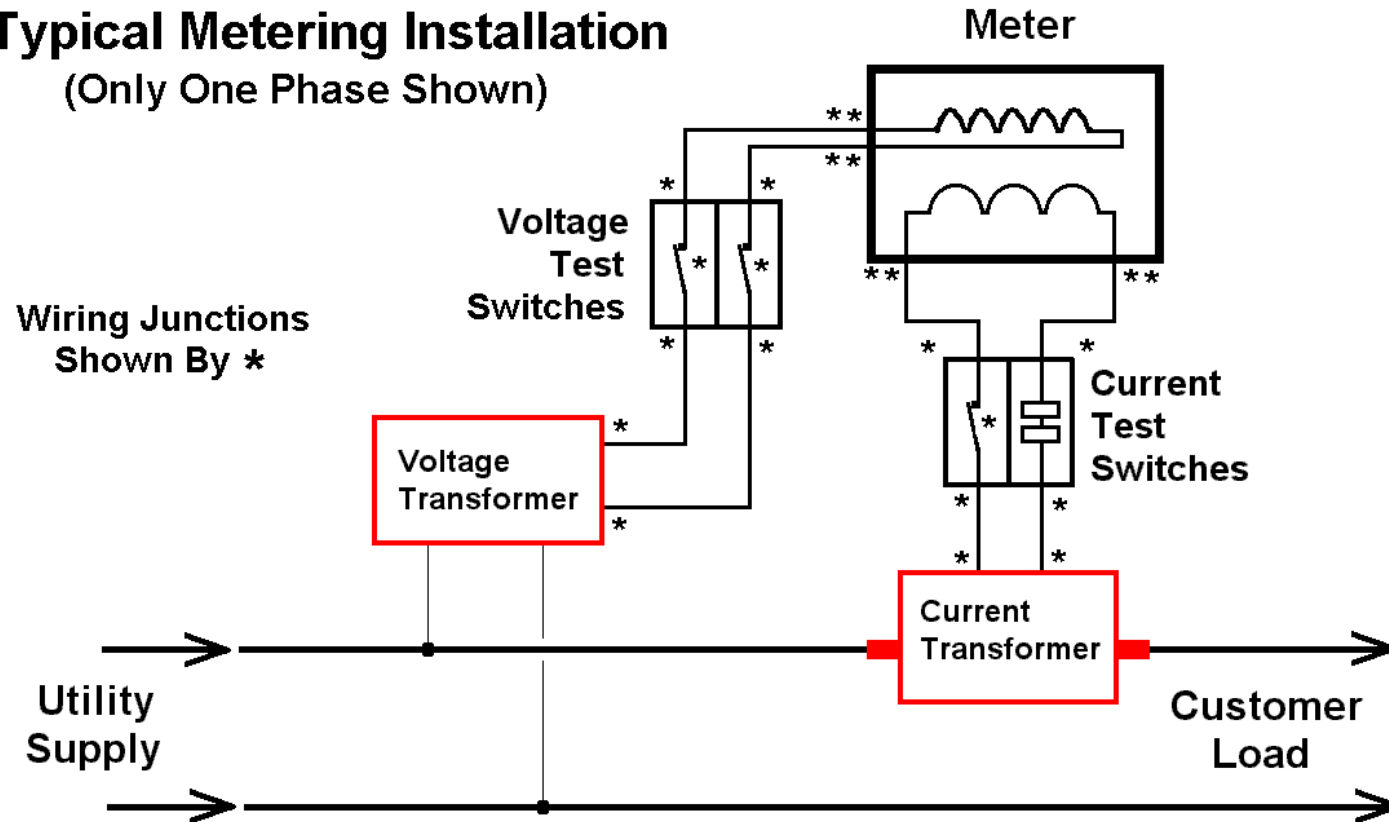

Typical Metering Installation
(Only One Phase Shown)

Meter

Voltage
Test
Switches

Wiring Junctions
Shown By *

Voltage
Transformer

Current
Test
Switches

Current
Transformer

Utility
Supply

Customer
Load

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INSTRUMENT TRANSFORMERS CONTROL METERED VALUES

But what if they do not produce the expected outputs?

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

Typical Metering Installation
(Only One Phase Shown)

Meter

Wiring Junctions Shown By *

Voltage Test Switches

Current Test Switches

Voltage Transformer

Current Transformer

Utility Supply

Customer Load
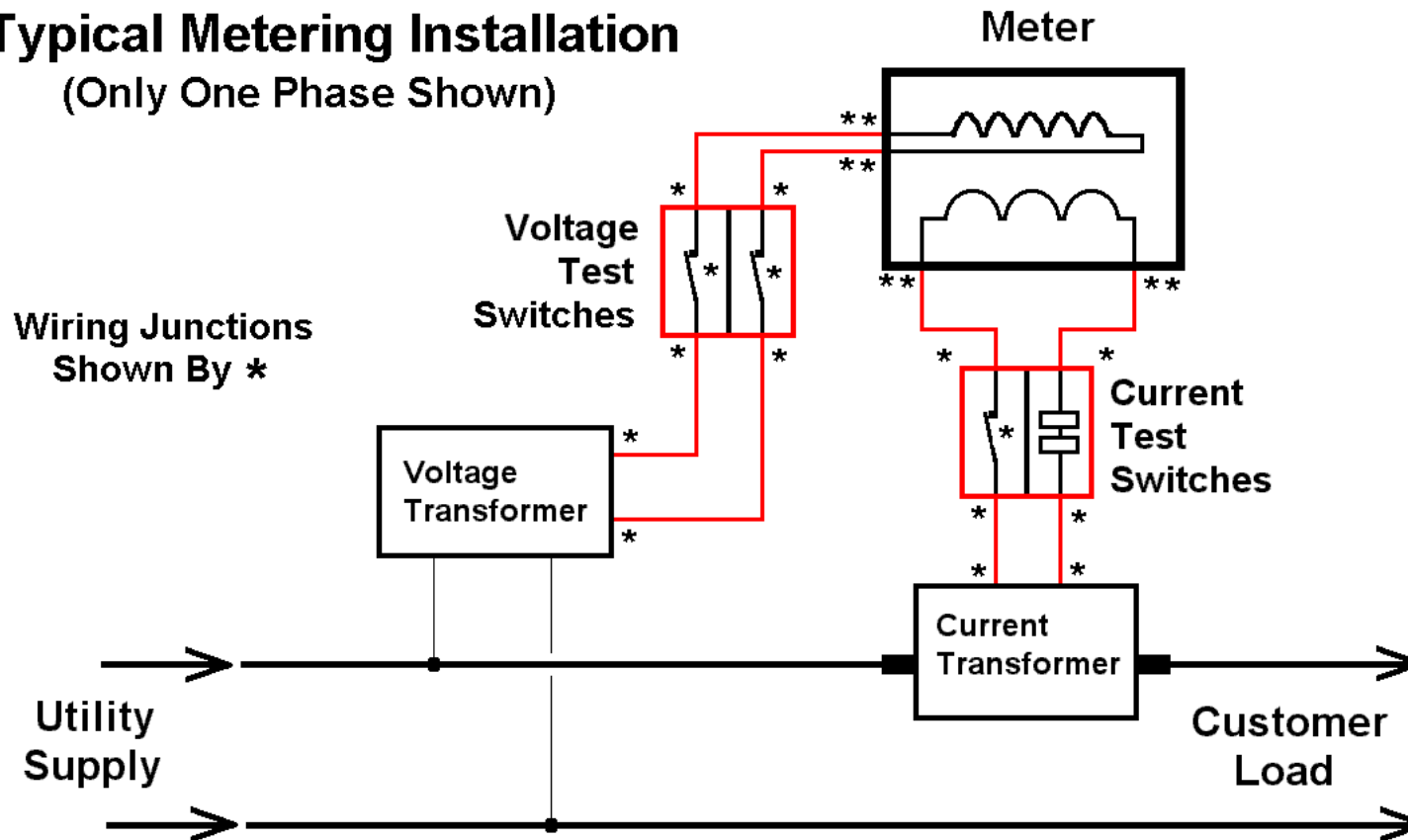
WHY BILLING ACCURACY?

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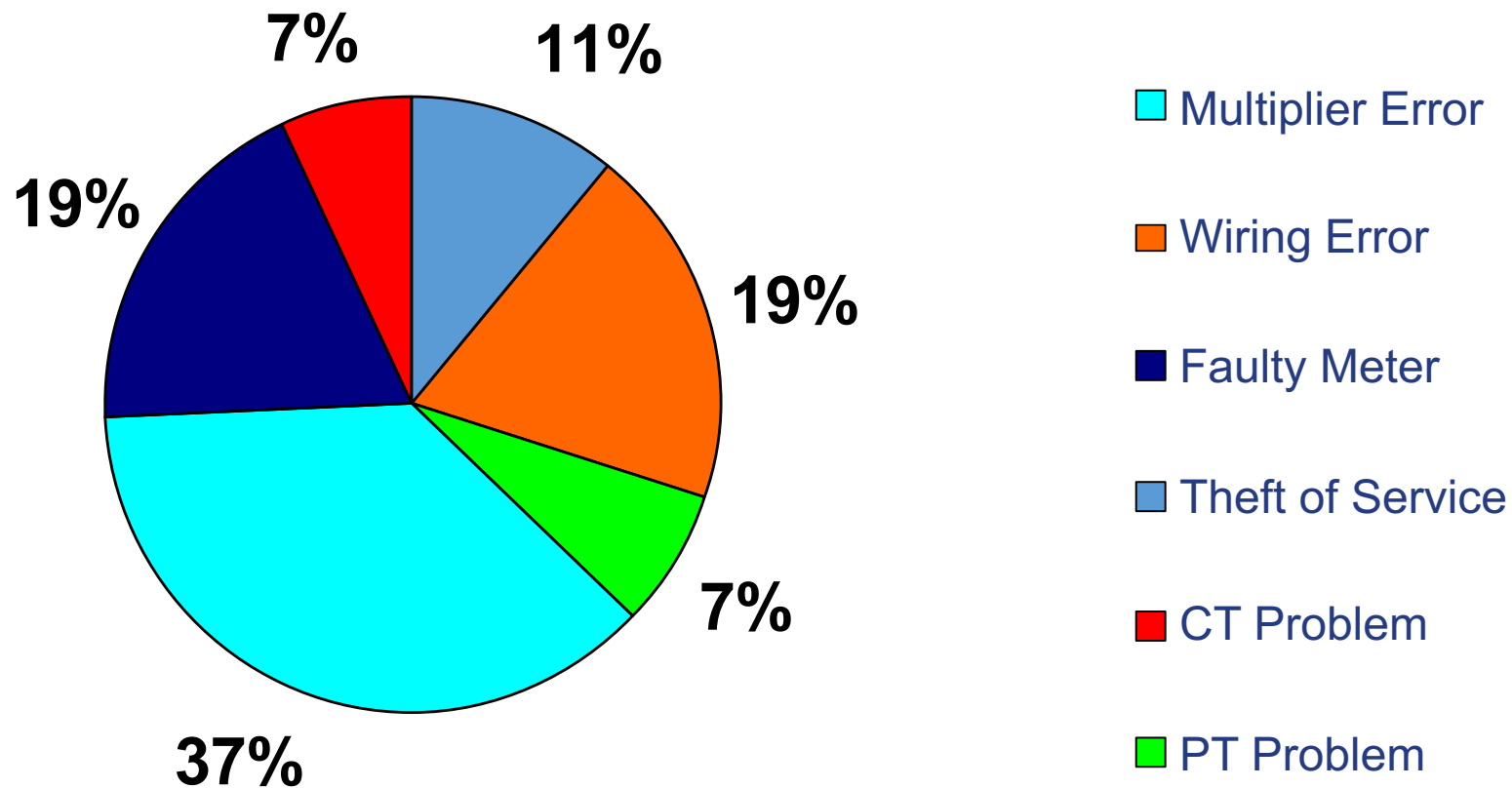
3 Year Study from a Municipal
with 35,000 Transformer Rated Installations

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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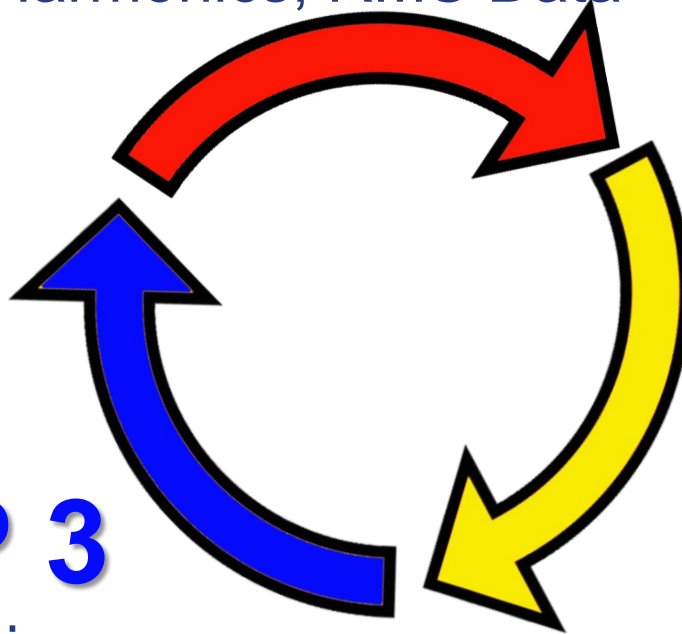# INTEGRATED SITE TEST PHILOSOPHY

STEP 1

Site Analysis:
Vectors, Waveforms, Harmonics, RMS Data

STEP 2

CT & PT Testing

STEP 3

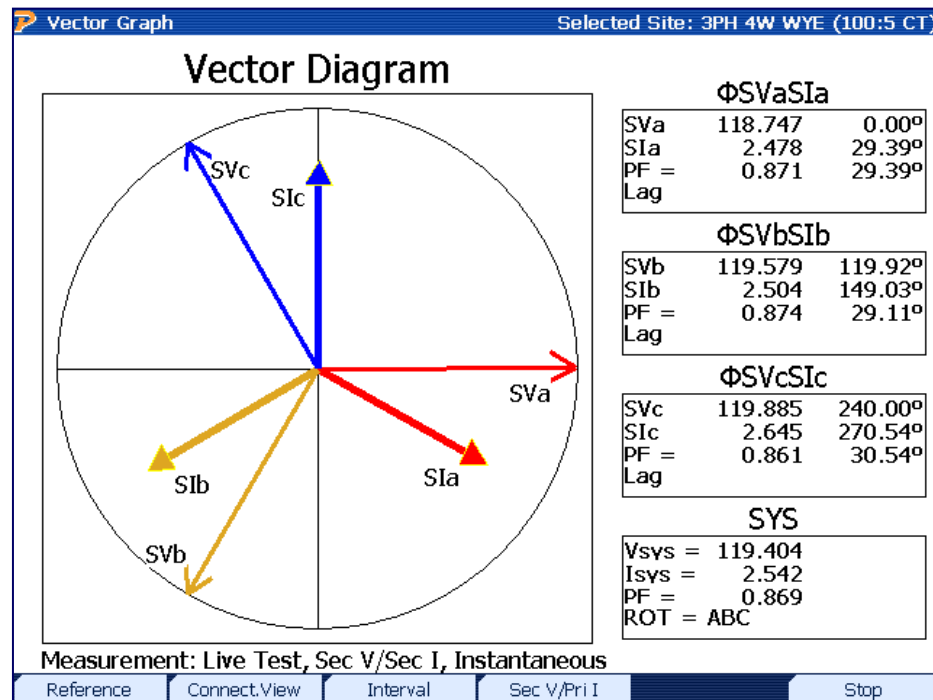Meter Testing:
Customer Load & Phantom Load
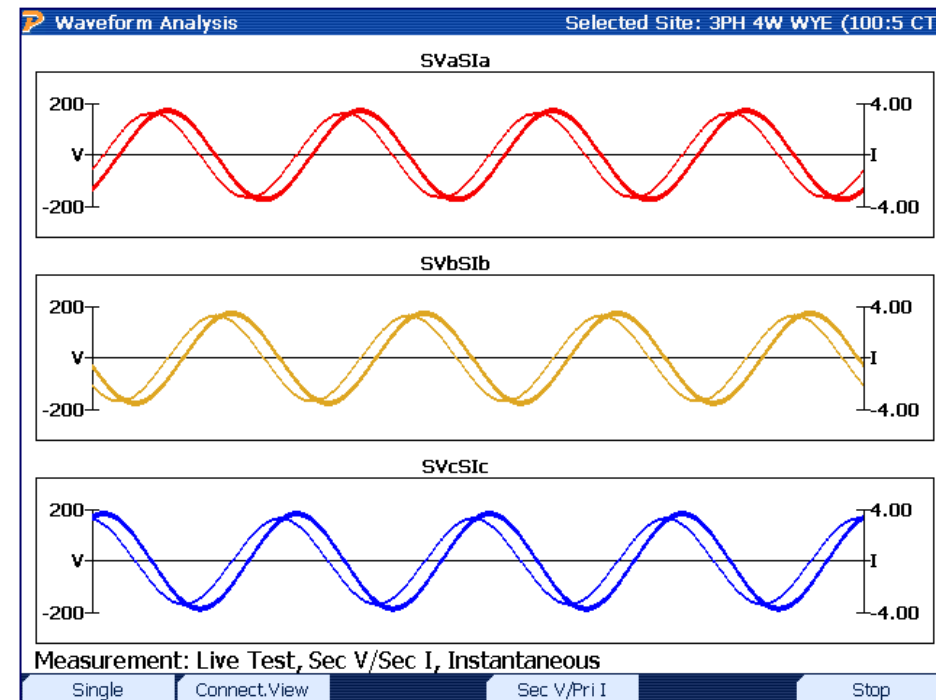
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STEP 1: SITE ANALYSIS
Wiring Verification and Site Diagnostics

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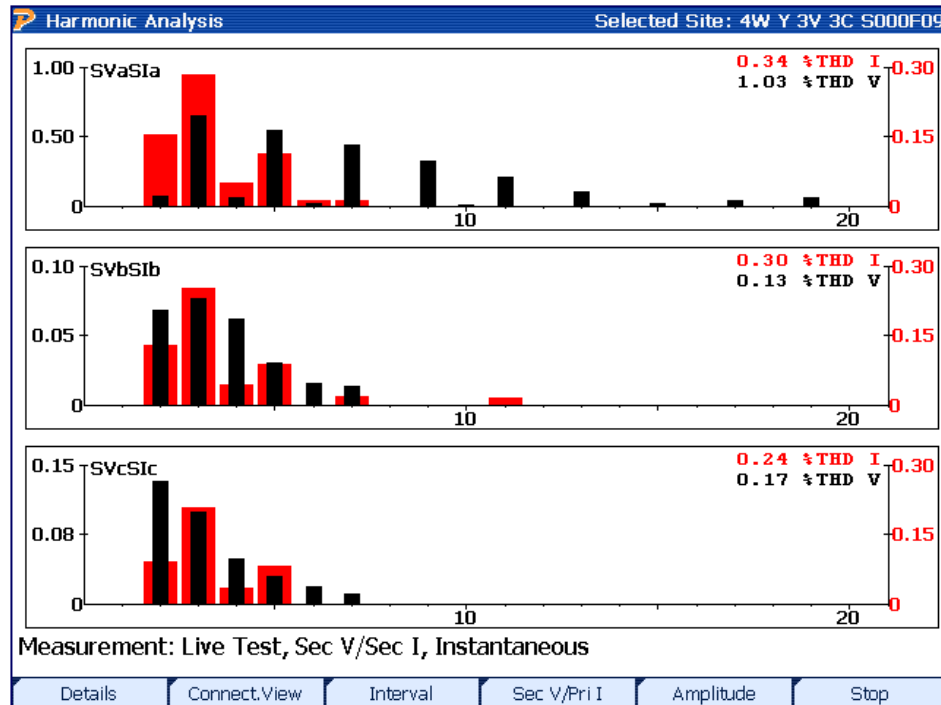
VECTOR DIAGRAMS

WAVEFORMS

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.

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

Measurement: Live Test, Sec V/Sec I, Instantaneous

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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*?
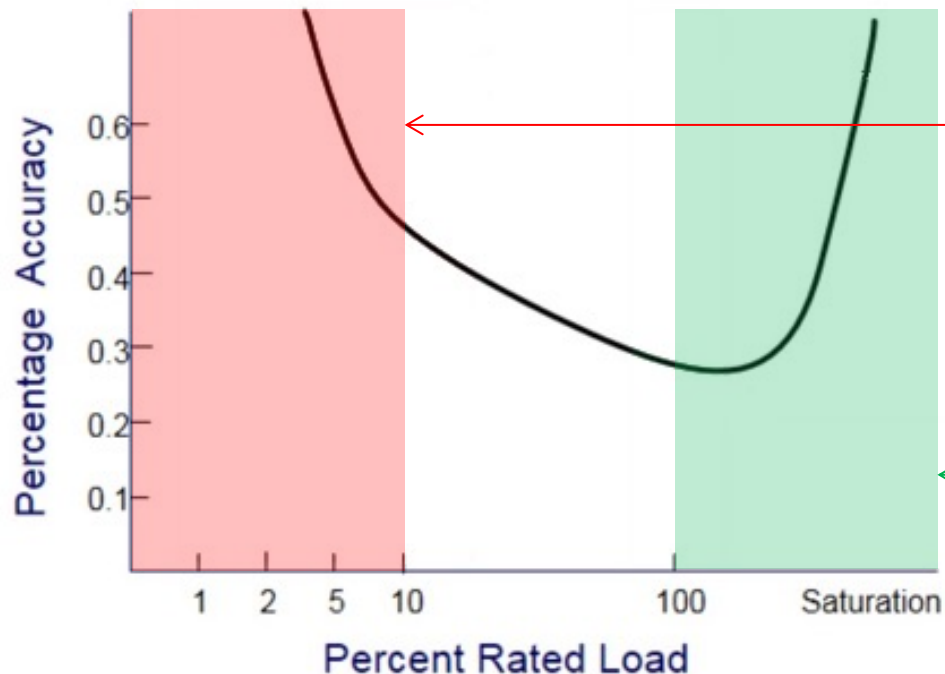
Are you normally operating down at these levels?

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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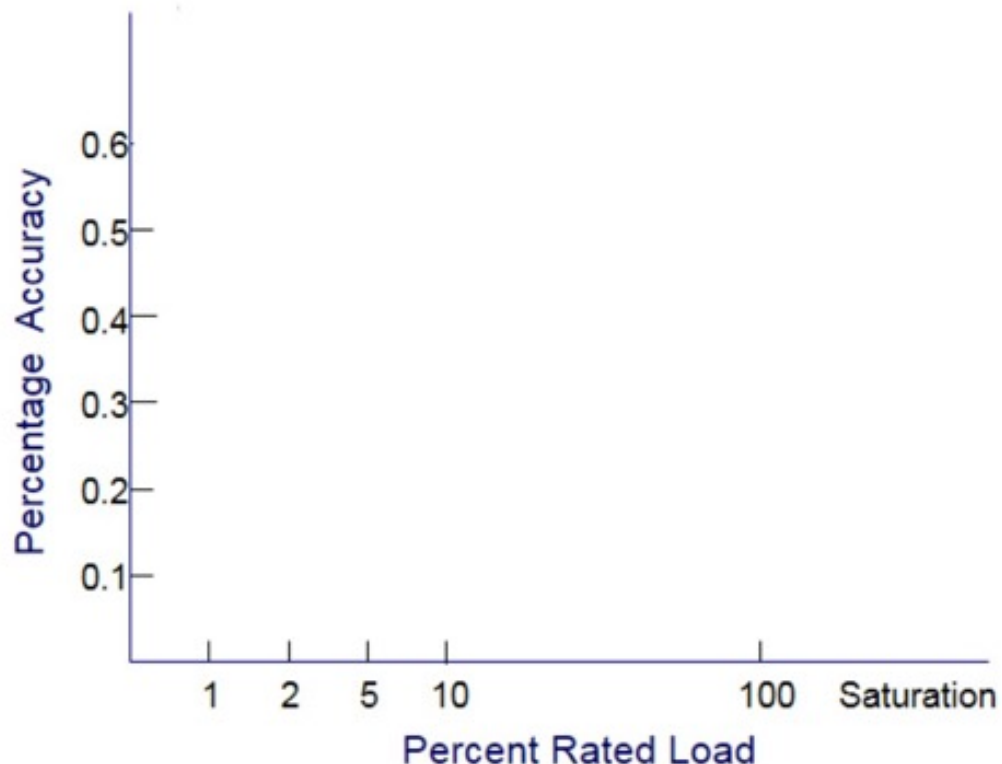
STEP 2: CT TESTING
How does the BURDEN on a CT influence its accuracy?

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

0.05Ω of Burden Present

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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

0.2Ω of Burden Present
0.05Ω of Burden Present

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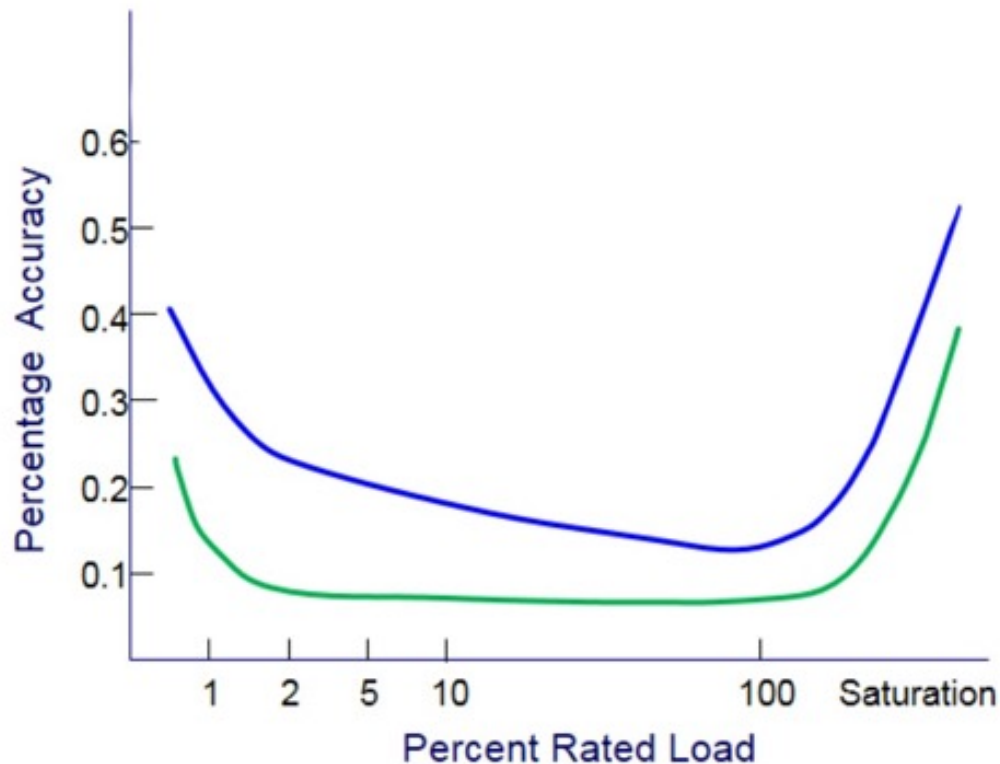
STEP 2: CT TESTING

How does the BURDEN on a CT influence its accuracy?

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Example: 0.3% Accuracy Class CT with 1.80 Burden Rating

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

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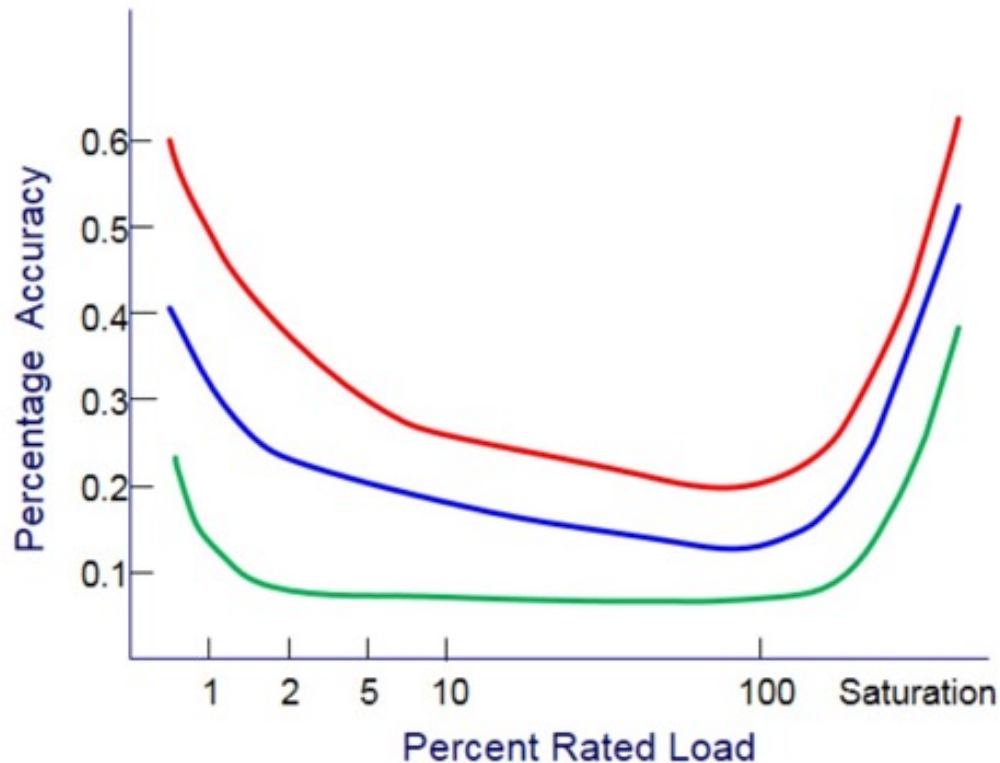
STEP 2: CT TESTING
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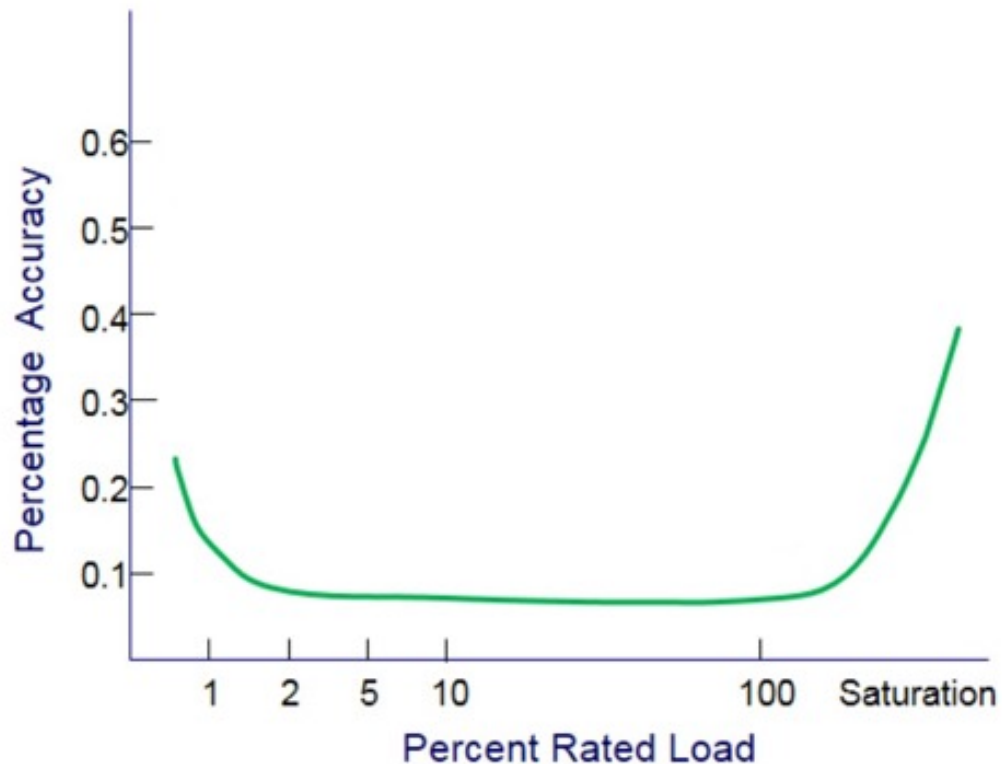Example: 0.3% Accuracy Class CT with 1.80 Burden Rating
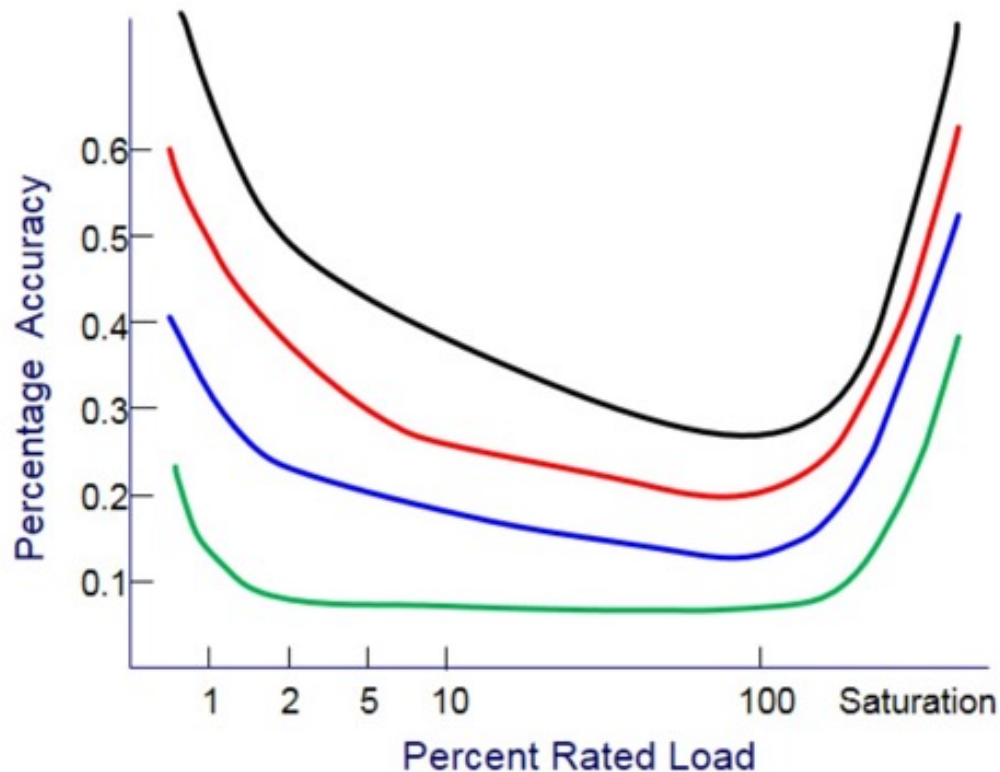
1.8Ω of Burden Present
0.9Ω of Burden Present
0.2Ω of Burden Present
0.05Ω of Burden Present

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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
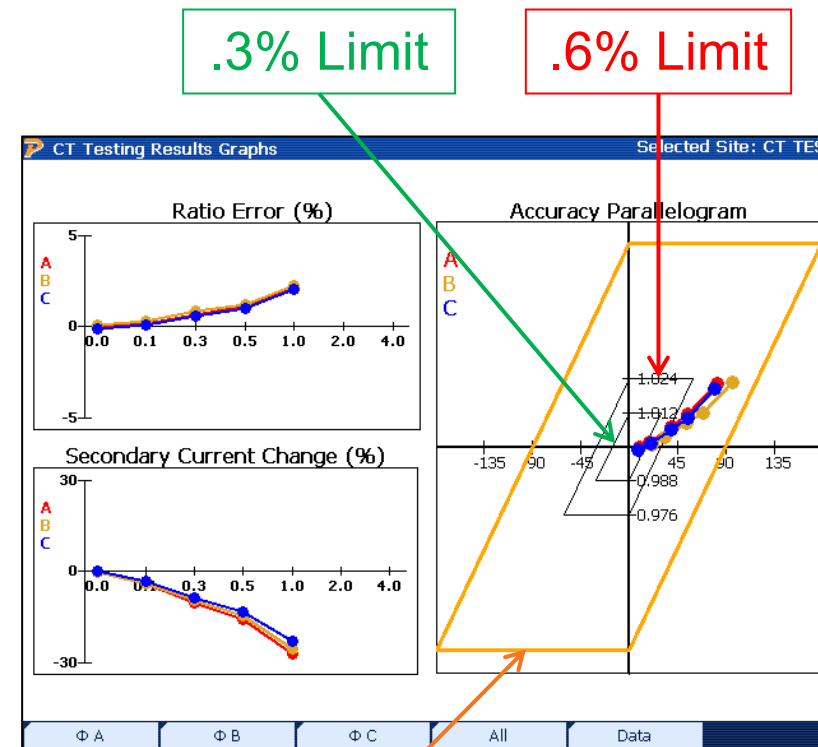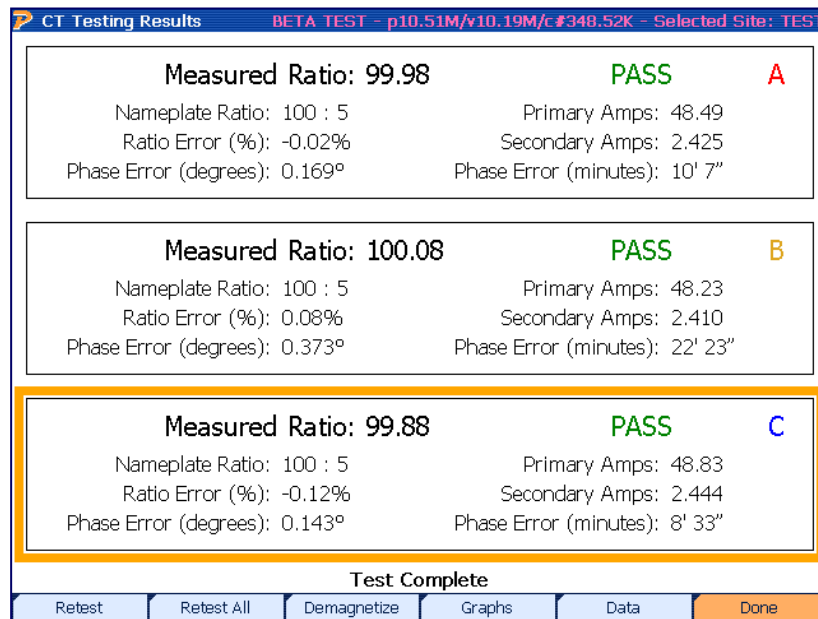
STEP 3: METER TESTING

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

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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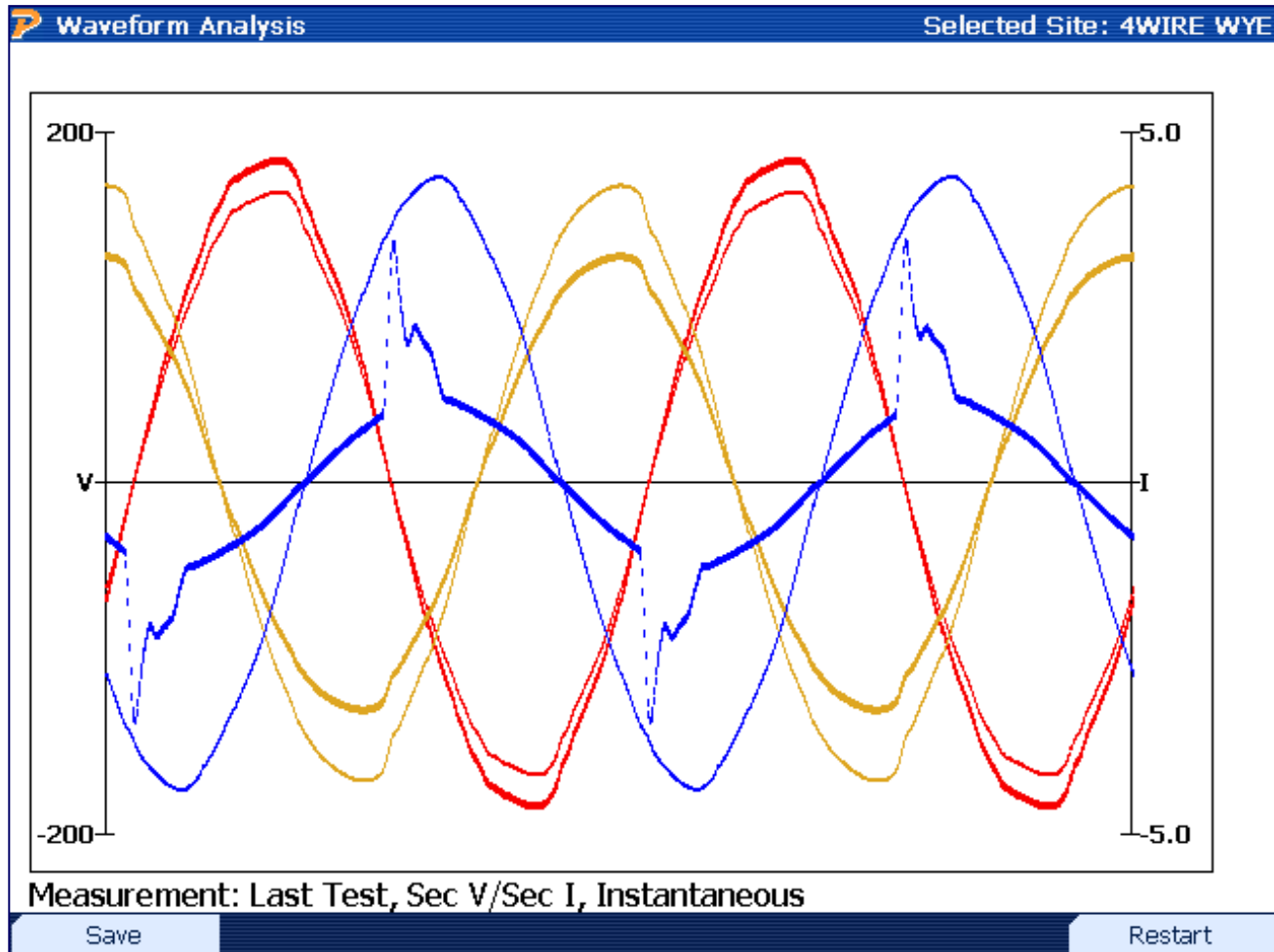
STEP 3: METER TESTING

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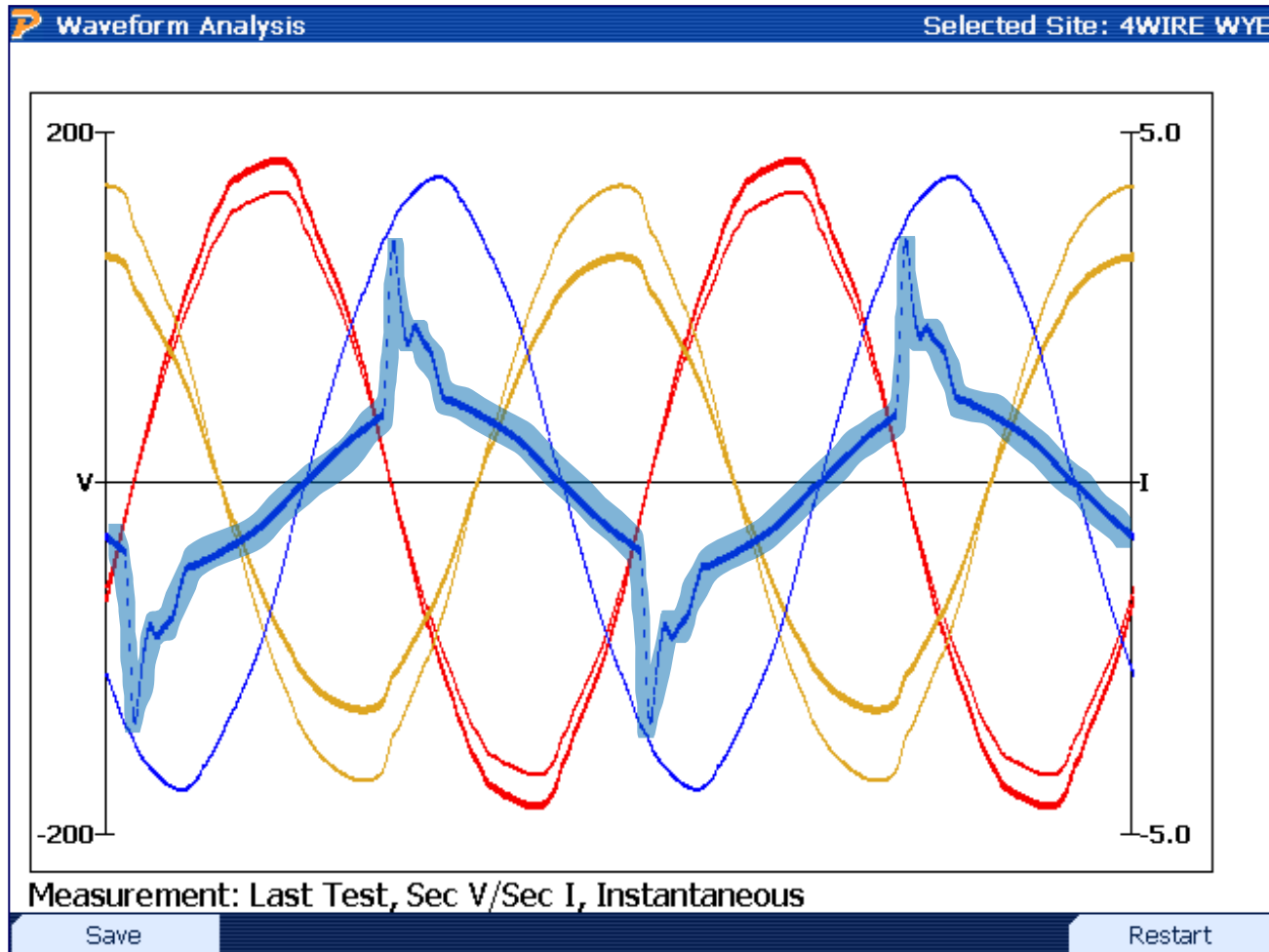
Would an ANSI test tell us if these signals were being properly calculated by the meter?

Of course not...

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

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"

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?
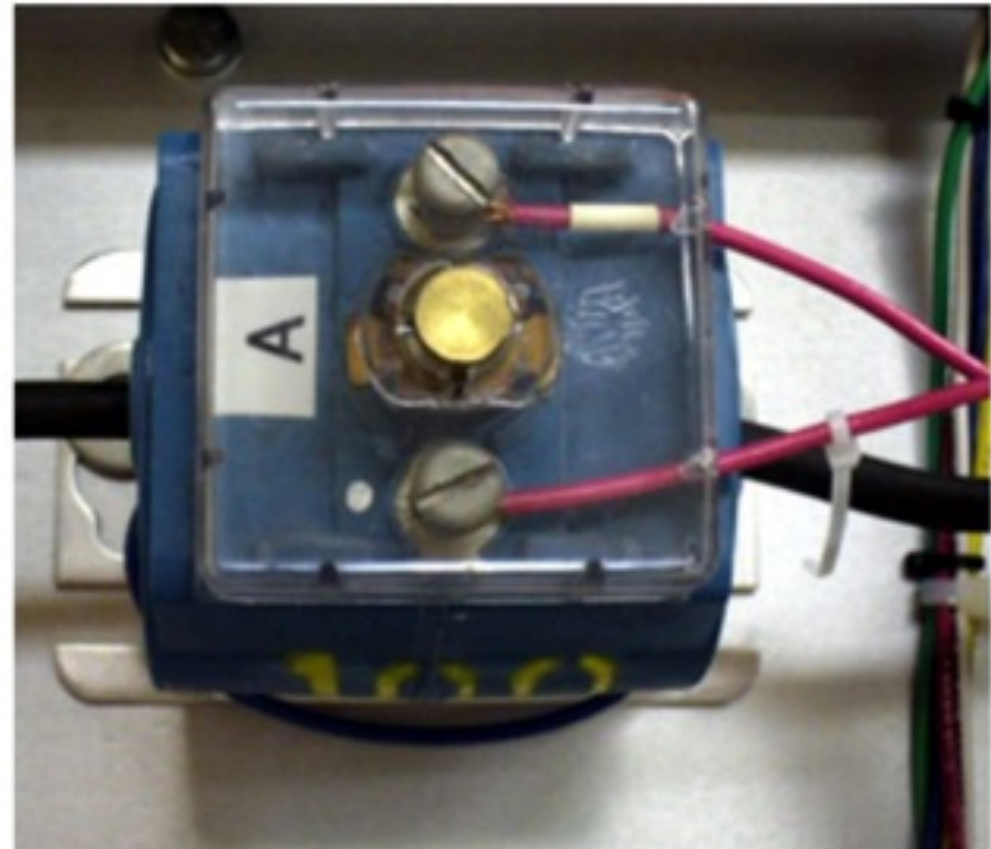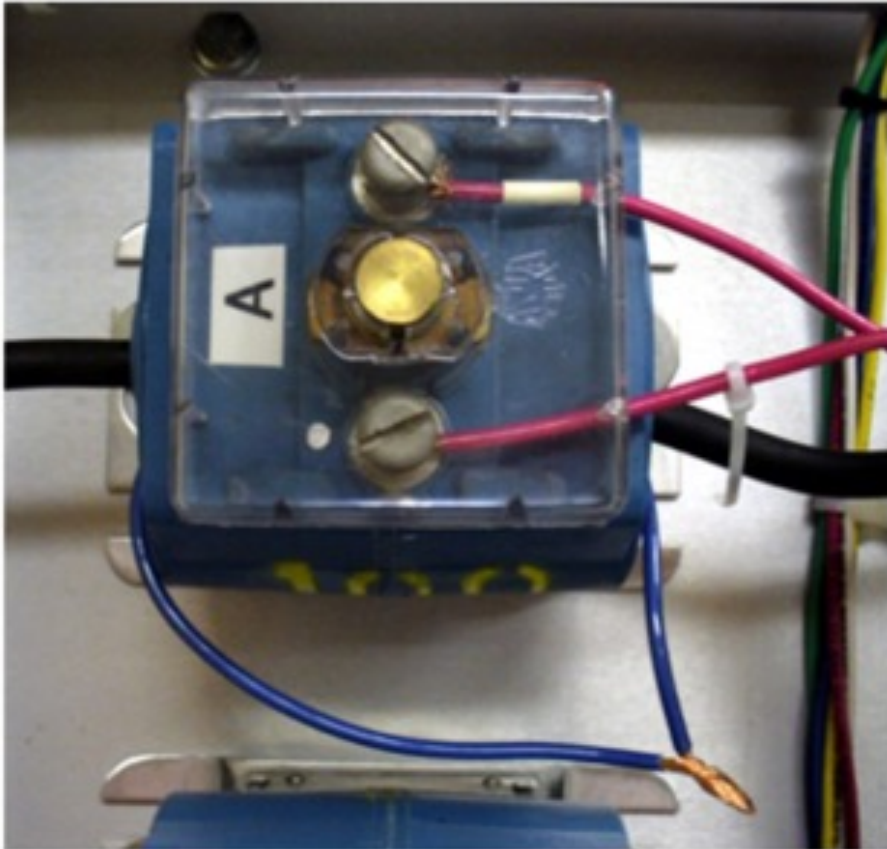
POWER THEFT!
A simple piece of wire wrapped around a CT.
Would you spot it?

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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

Ia+ Ia-   Ib+ Ib-   Ic+ Ic-

5A   5A   5A

CTa   CTb   CTc

300A   300A   300A
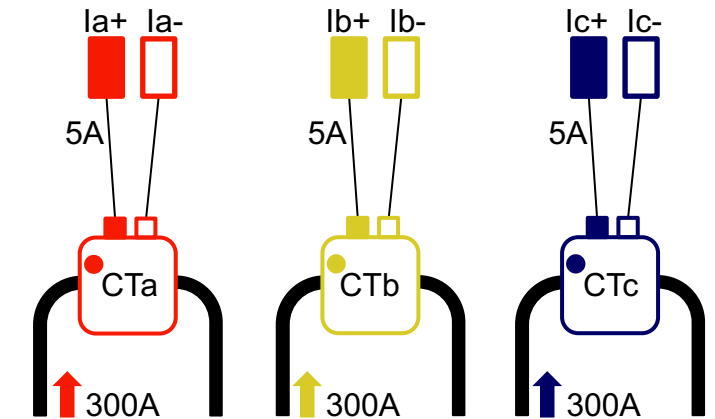
Primary Signals from Utility

Waveforms Perfect
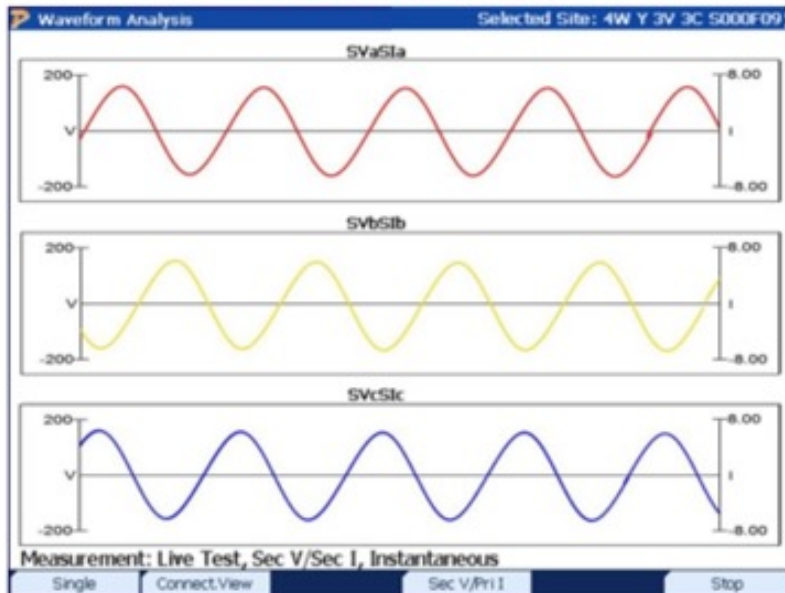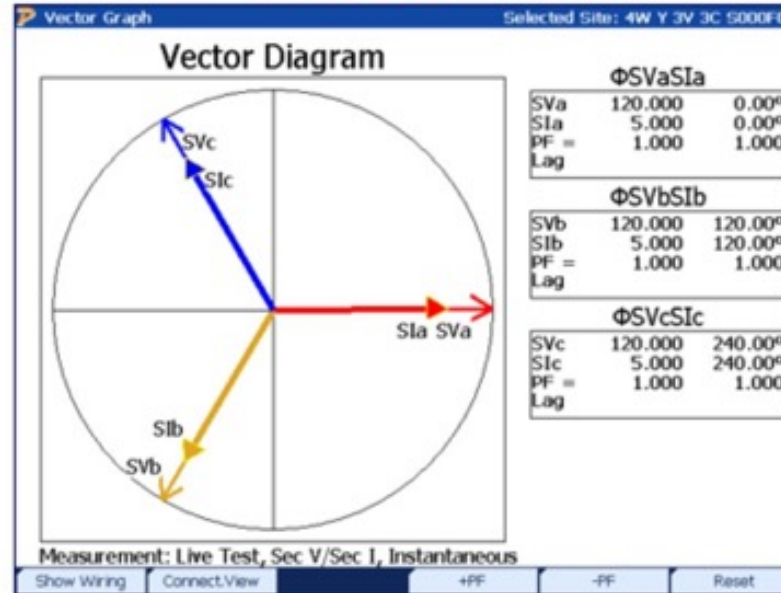
Waveform Analysis — Selected Site: 4W Y 3V 3C S000F09)

SVaSIa

SVbSIb

SVcSIc

Measurement: Live Test, Sec V/Sec I, Instantaneous

Single | Connect.View | Sec V/Pri I | Stop

Vector Diagram Perfect

Vector Graph — Selected Site: 4W Y 3V 3C S000F09

Vector Diagram

	ΦSVaSIa	
SVa	120.000	0.00°
SIa	5.000	0.00°
PF =	1.000	1.000
Lag		

	ΦSVbSIb	
SVb	120.000	120.00°
SIb	5.000	120.00°
PF =	1.000	1.000
Lag		

	ΦSVcSIc	
SVc	120.000	240.00°
SIc	5.000	240.00°
PF =	1.000	1.000
Lag		

Measurement: Live Test, Sec V/Sec I, Instantaneous

Show Wiring | Connect.View | +PF | -PF | Reset

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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

Ia+ Ia-   Ib+ Ib-   Ic+ Ic-

5A   5A   5A

CTa   CTb   CTc

300A   300A   300A
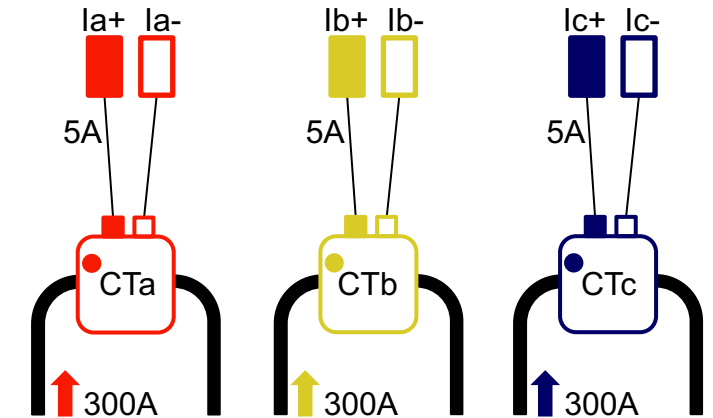
Primary Signals from Utility

CT Test Perfect

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

Meter Test Perfect

Customer Load Meter Test   Selected Site: *NONE*

Customer Load Meter Test
Wh Test

% Registration   100.000

Test Info		Sys Info	
Time(sec)	18.000	Wh	9.0000
Time Left	0.000	VAh	9.0000
Pulses Exp	5.0000	VARh	0.0000
Pulses Act	5.0000	V	120.000
Meter PF	1.0000	I	5.0000

Basic Test Data   View Trend   Exit

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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

Ia+ Ia-   Ib+ Ib-   Ic+ Ic-

5A   2.5A   5A

CTa   CTb   CTc

300A   300A   300A

Primary Signals from Utility

On the Vector Diagram? PROBABLY NOT   During a Meter Test?   NO

Vector Graph   Selected Site: 4W Y 3V 3C S000F09

Vector Diagram

ΦSVaSIa

SVa	120.000	0.00°
SIa	5.000	0.000°
PF =	1.000	0.000°
Lag		

ΦSVbSIb

SVb	120.000	120.00°
SIb	2.500	120.00°
PF =	1.000	0.000°
Lag		

ΦSVcSIc

SVc	120.000	240.00°
SIc	5.000	240.00°
PF =	1.000	0.000°
Lag		

Measurement: Live Test, Sec V/Sec I, Instantaneous

Show Wiring | Connect.View | | +PF | -PF | Reset

Customer Load Meter Test   Selected Site: *NONE*

Customer Load Meter Test
Wh Test

% Registration   100.000

Test Info		Sys Info	
Time(sec)	21.600	Wh	9.0000
Time Left	0.000	VAh	9.0000
Pulses Exp	5.0000	VARh	0.0000
Pulses Act	5.0000	V	120.000
Meter PF	1.0000	I	4.1667

Basic Test Data | View Trend | Exit

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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

Ia+ Ia-   Ib+ Ib-   Ic+ Ic-

5A   2.5A   5A

CTa   CTb   CTc

300A   300A   300A

Primary Signals from Utility

During a CT Test?   ABSOLUTELY

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: 600.00   **FAIL**   B
Nameplate Ratio: 300 : 5   Primary Amps: 300
Ratio Error (%): 100.00   Secondary Amps: 2.50
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

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EXAMPLE #3

WHERE IS THE ERROR?   10% Drop in revenue
OVERBURDENED CT $1,036 per month in lost
On CTc there might be a loose   revenue.
connection, degraded wire, too $12,435 per year in lost
long of a secondary run, wire   revenue.
too small, etc.
This causes the secondary   How can you find the error?
current to drop
What is the billing implication?

On the Vector Diagram? PROBABLY NOT   During a Meter Test?   NO

Secondary Current Signals to Test Switch

Ia+ Ia-   Ib+ Ib-   Ic+ Ic-

5A   5A   3.5A

CTa   CTb   CTc

300A   300A   300A

Primary Signals from Utility

Vector Graph — Selected Site: 4W Y 3V 3C S000F09

Vector Diagram

ΦSVaSIa		
SVa	120.000	0.00⁰
SIa	5.000	0.000⁰
PF =	1.000	0.000⁰
Lag		

ΦSVbSIb		
SVb	120.000	120.00⁰
SIb	5.000	120.00⁰
PF =	1.000	0.000⁰
Lag		

ΦSVcSIc		
SVc	120.000	240.00⁰
SIc	3.500	240.00⁰
PF =	1.000	0.000⁰
Lag		

Measurement: Live Test, Sec V/Sec I, Instantaneous

Show Wiring | Connect.View | +PF | -PF | Reset

Customer Load Meter Test — Selected Site: *NONE*

Customer Load Meter Test
Wh Test

% Registration   100.000

Test Info		Sys Info	
Time(sec)	19.999	Wh	9.0000
Time Left	0.000	VAh	9.0000
Pulses Exp	5.0000	VARh	0.0000
Pulses Act	5.0000	V	120.000
Meter PF	1.0000	I	4.5000

Basic Test Data | View Trend | Exit

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EXAMPLE #3

WHERE IS THE ERROR?   10% Drop in revenue
OVERBURDENED CT $1,036 per month in lost
On CTc there might be a loose revenue.
connection, degraded wire, too $12,435 per year in lost
long of a secondary run, wire   revenue.
too small, etc.
This causes the secondary   How can you find the error?
current to drop
What is the billing implication?

During a CT Test?   ABSOLUTELY

Secondary Current Signals to Test Switch

Ia+ Ia-   Ib+ Ib-   Ic+ Ic-

5A   5A   3.5A

CTa   CTb   CTc

↑ 300A   ↑ 300A   ↑ 300A

Primary Signals from Utility

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: 428.57   **FAIL**   C
Nameplate Ratio: 300 : 5   Primary Amps: 300
Ratio Error (%): 42.9%   Secondary Amps: 3.50
Phase Error (degrees): 0.000°   Phase Error (minutes): 0'0"

Graphs   Data   Exit

POWERMETRIX

EXAMPLE #4

WHERE IS THE ERROR?

CT INSTALLED BACKWARDS

CTa polarity is wrong

This causes reverse current/power/energy on the phase
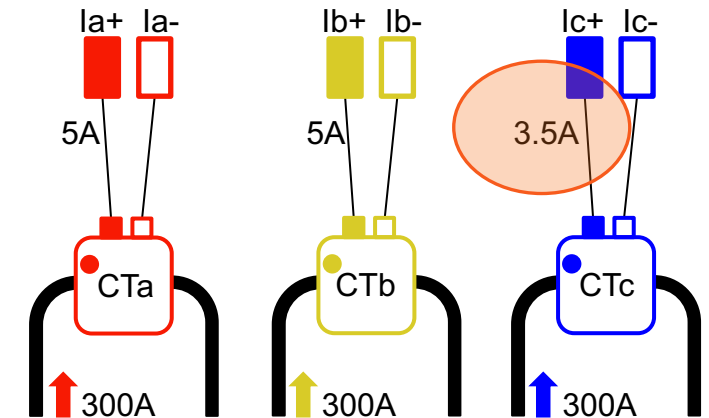
What is the billing implication?

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

Ia+ Ia-   Ib+ Ib-   Ic+ Ic-

5A   5A   5A

CTa   CTb   CTc

300A   300A   300A

Primary Signals from Utility

On the Vector Diagram?   YOU SHOULD

During a Meter Test?   NO

Vector Graph   Selected Site: 4W Y 3V 3C S000F09

Vector Diagram

ΦSVaSIa
SVa	120.000	0.00°
SIa	5.000	180.0°
PF =	-1.000	180.0°
Lag		

ΦSVbSIb
SVb	120.000	120.00°
SIb	5.000	120.00°
PF =	1.000	0.000°
Lag		

ΦSVcSIc
SVc	120.000	240.00°
SIc	5.000	120.00°
PF =	1.000	0.000°
Lag		

Measurement: Live Test, Sec V/Sec I, Instantaneous

Show Wiring | Connect.View | +PF | -PF | Reset

Customer Load Meter Test   Selected Site: *NONE*

Customer Load Meter Test
Wh Test

% Registration   100.000

Test Info		Sys Info	
Time(sec)	54.000	Wh	9.0000
Time Left	0.000	VAh	9.0000
Pulses Exp	5.0000	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 #4

WHERE IS THE ERROR?   66.7% Drop in revenue
CT INSTALLED BACKWARDS $6,912 per month in lost
CTa polarity is wrong   revenue.
This causes reverse $82,944 per year in lost
current/power/energy on the   revenue.
phase
What is the billing implication?   How can you find the error?

Secondary Current Signals to Test Switch

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
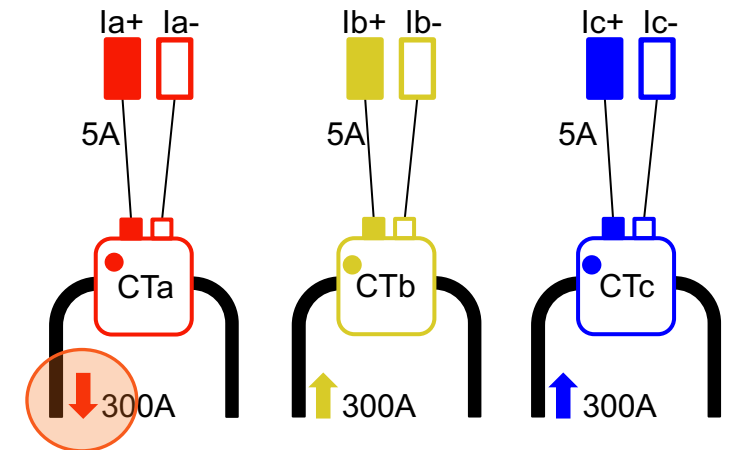This causes reverse current/power/energy on the phase
What is the billing implication?

66.7% Drop in revenue
$6,912 per month in lost revenue.
$82,944 per year in lost revenue.

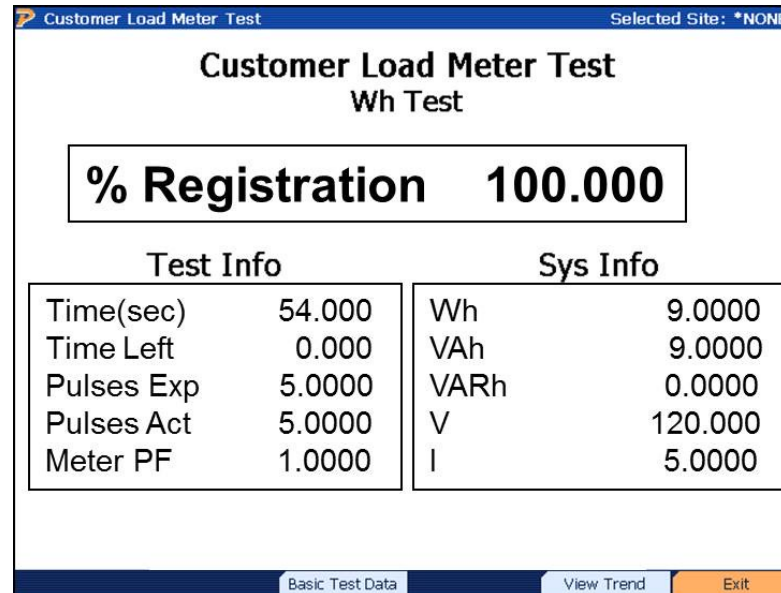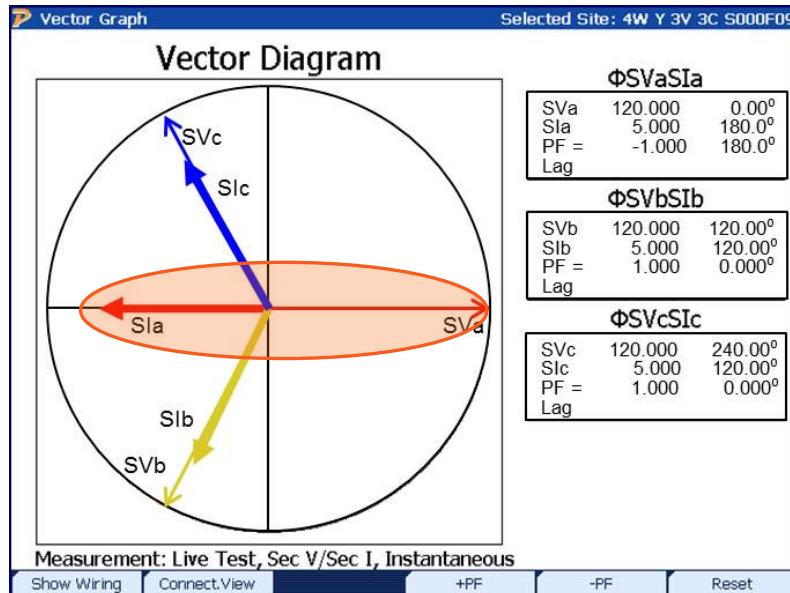How can you find the error?

Secondary Current Signals to Test Switch

Ia+ Ia-   Ib+ Ib-   Ic+ Ic-

5A   5A   5A

CTa   CTb   CTc

300A   300A   300A

Primary Signals from Utility

On the Vector Diagram?   YOU SHOULD

During a Meter Test?   NO

Vector Graph   Selected Site: 4W Y 3V 3C S000F09

Vector Diagram

ΦSVaSIa

SVa	120.000	0.00⁰
SIa	5.000	180.0⁰
PF =	-1.000	180.0⁰
Lag		

ΦSVbSIb

SVb	120.000	120.00⁰
SIb	5.000	120.00⁰
PF =	1.000	0.000⁰
Lag		

ΦSVcSIc

SVc	120.000	240.00⁰
SIc	5.000	120.00⁰
PF =	1.000	0.000⁰
Lag		

Measurement: Live Test, Sec V/Sec I, Instantaneous

Show Wiring | Connect.View | +PF | -PF | Reset

Customer Load Meter Test   Selected Site: *NONE*

Customer Load Meter Test
Wh Test

% Registration   100.000

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

Basic Test Data | View Trend | Exit

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EXAMPLE #5

WHERE IS THE ERROR?

REVERSE SECONDARY WIRING

CTc secondary is wired backwards at the test switch or directly at the CT
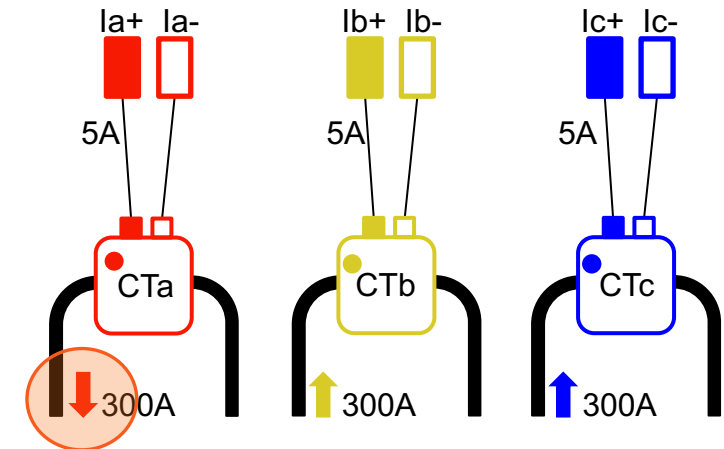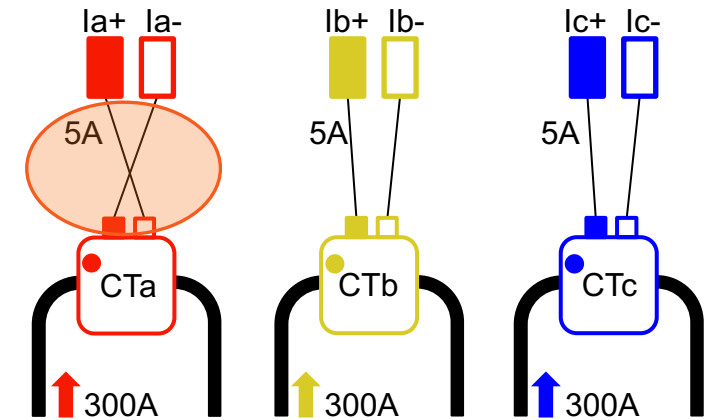
This causes reverse current/power/energy on the phase

What is the billing implication?

66.7% Drop in revenue

$6,912 per month in lost revenue.

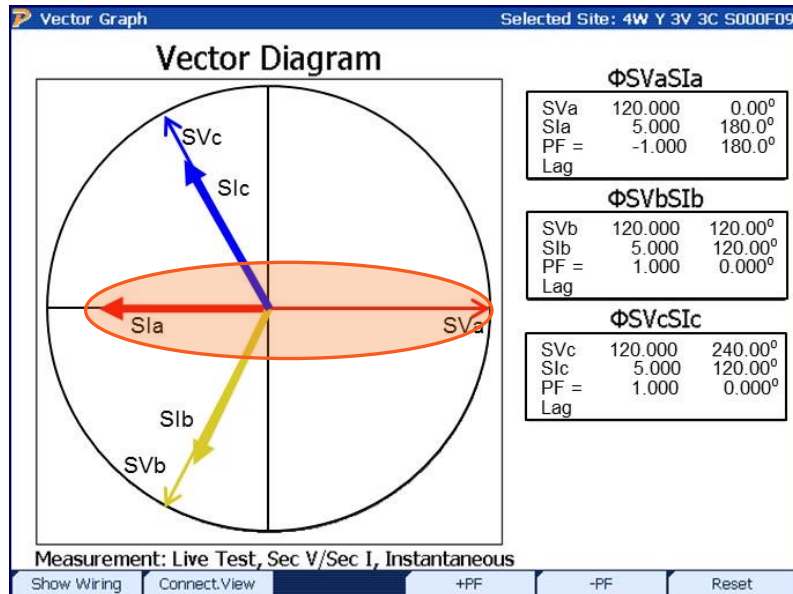$82,944 per year in lost revenue.

How can you find the error?

Secondary Current Signals to Test Switch
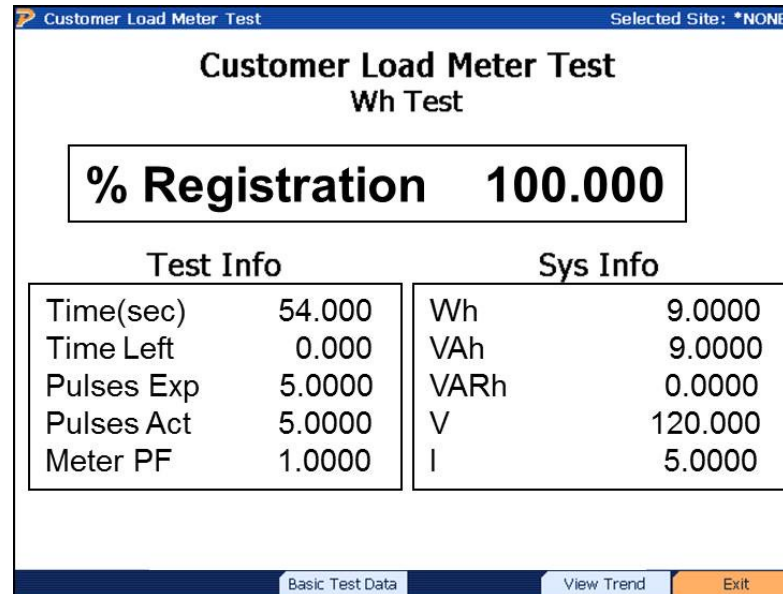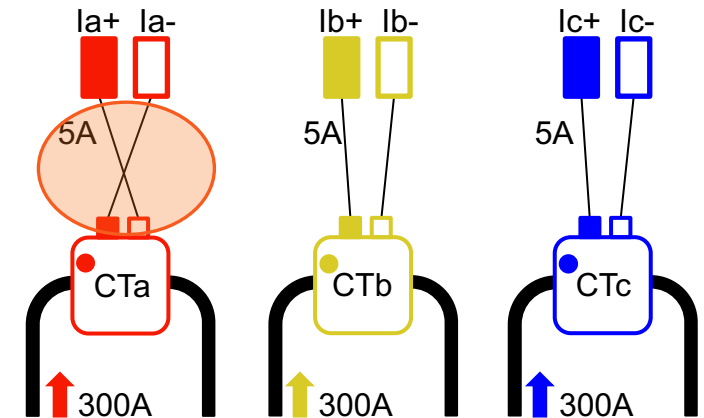

Primary Signals from Utility

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

Ia+ Ia-   Ib+ Ib-   Ic+ Ic-

5A   5A   5A

CTa   CTb   CTc

300A   300A   300A

Primary Signals from Utility

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

On the Vector Diagram?   YOU SHOULD

Vector Graph — Selected Site: 4W Y 3V 3C S000F09

Vector Diagram

	ΦSVaSIa	
SVa	120.000	0.00°
SIa	5.000	0.00°
PF =	1.000	1.000
Lag		

	ΦSVbSIb	
SVb	120.000	120.00°
SIb	5.000	240.00°
PF =	-.5000	120.00°
Lag		

	ΦSVcSIc	
SVc	120.000	240.00°
SIc	5.000	120.00°
PF =	-.5000	-120.00°
Lag		

Measurement: Live Test, Sec V/Sec I, Instantaneous

Show Wiring | Connect.View | +PF | -PF | Reset

Customer Load Meter Test — Selected Site: *NONE*

Customer Load Meter Test
Wh Test

% Registration   000.000

Test Info		Sys Info	
Time(sec)	00.000	Wh	0.0000
Time Left	0.000	VAh	0.0000
Pulses Exp	5.0000	VARh	0.0000
Pulses Act	0.0000	V	120.000
Meter PF	0.0000	I	0.0000

Basic Test Data | View Trend | Exit

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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

Ia+ Ia-   Ib+ Ib-   Ic+ Ic-

5A   5A   5A

CTa   CTb   CTc

↑ 300A   ↑ 300A   ↑ 300A

Primary Signals from Utility

During a CT Test?   ABSOLUTELY

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   **FAIL**   **B**
Nameplate Ratio: 300 : 5   Primary Amps: 300
Ratio Error (%): 0.00%   Secondary Amps: 5.00
Phase Error (degrees): -120.0°   Phase Error (minutes): -120°0'0"

Measured Ratio: 300.00   **FAIL**   **C**
Nameplate Ratio: 300 : 5   Primary Amps: 300
Ratio Error (%): 0.00%   Secondary Amps: 5.00
Phase Error (degrees): 120.00°   Phase Error (minutes): 120°0'0"

Graphs   Data   Exit

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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?

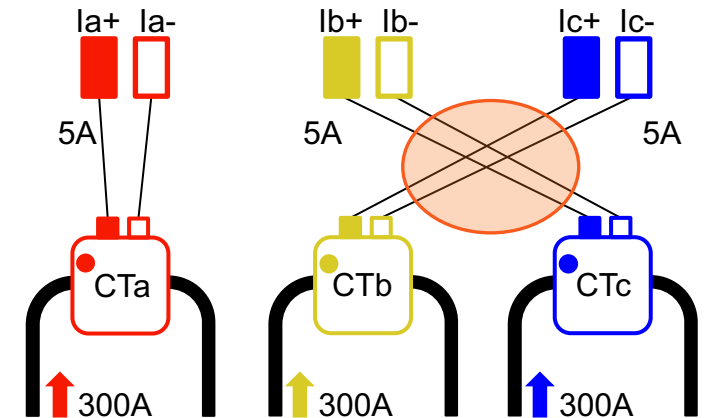With a totally balanced load, there would be ZERO energy accumulating on the meter.
100% drop in revenue.
$10,368 per month in lost revenue.
$124,416 per year in lost revenue.
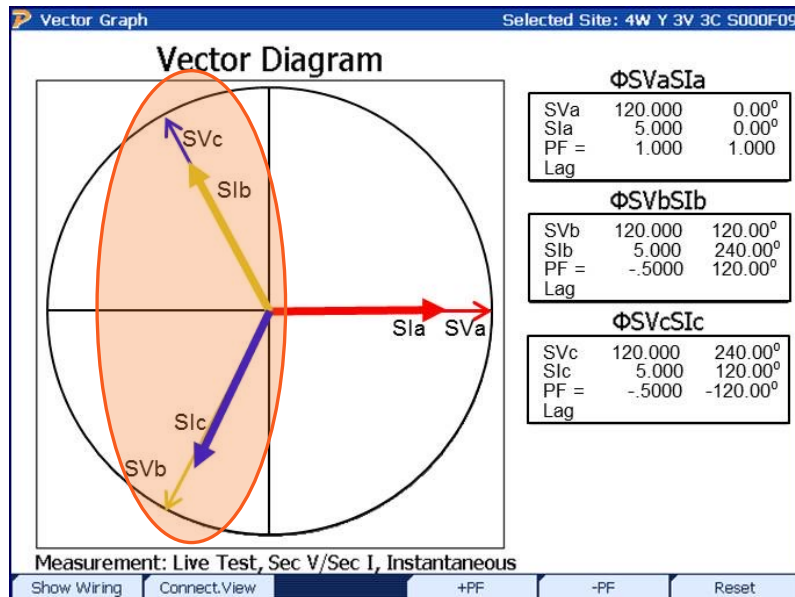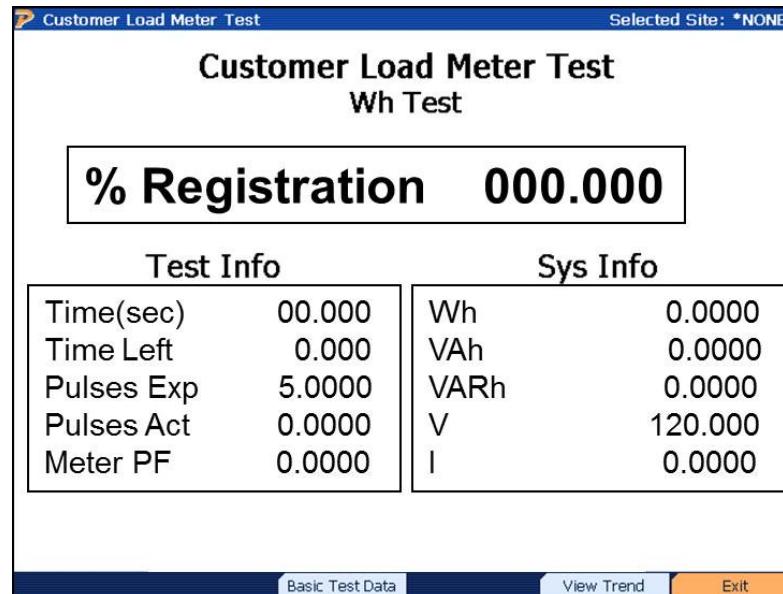How can you find the error?

Secondary Current Signals to Test Switch

Ia+ Ia-   Ib+ Ib-   Ic+ Ic-

5A   5A   5A

CTa   CTb   CTc

300A   300A   300A

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

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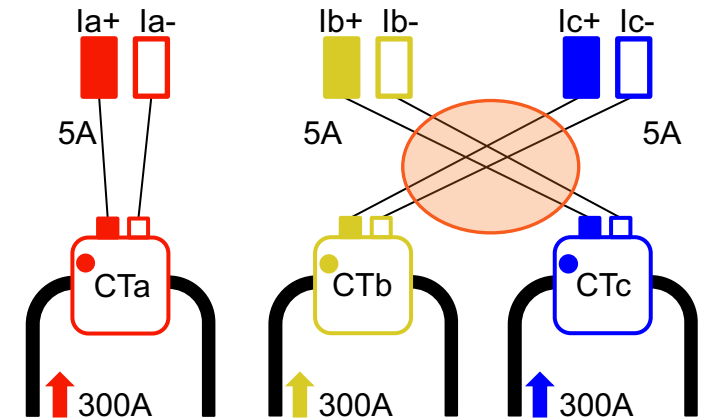
EXAMPLE #7
WHAT IS GOING ON?

Secondary Current Signals to Test Switch

Ia+ Ia-   Ib+ Ib-   Ic+ Ic-

5A   5A   5A

CTa   CTb   CTc

↑300A   ↑300A   ↑300A
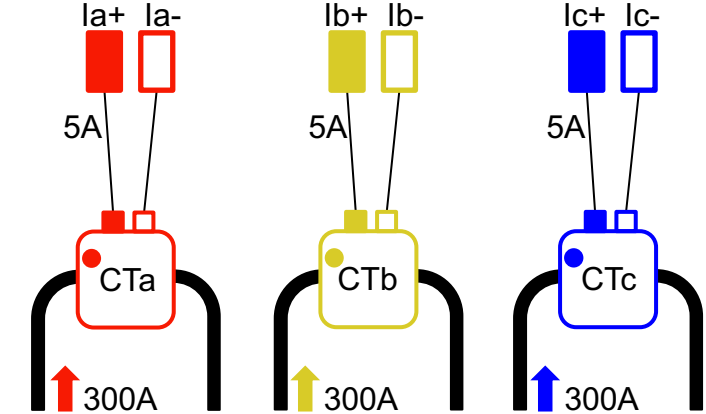
Primary Signals from Utility

Vector Diagram looks OK
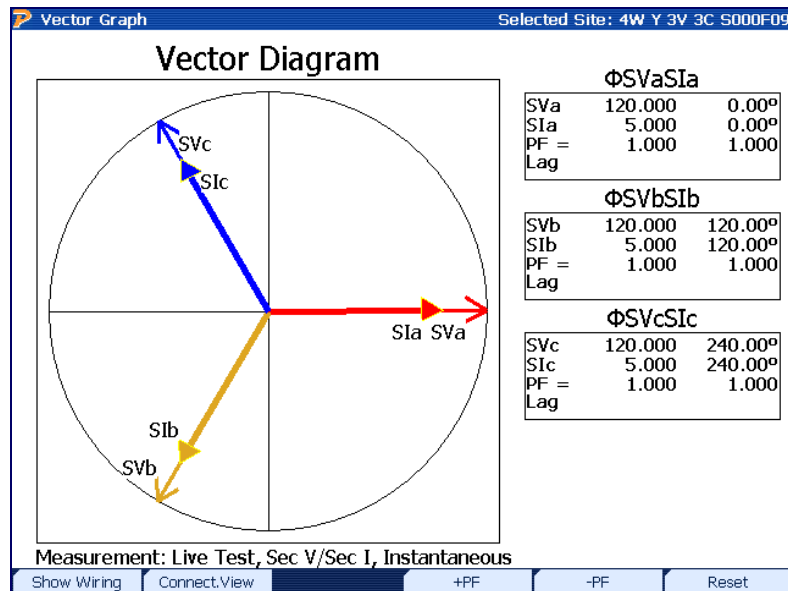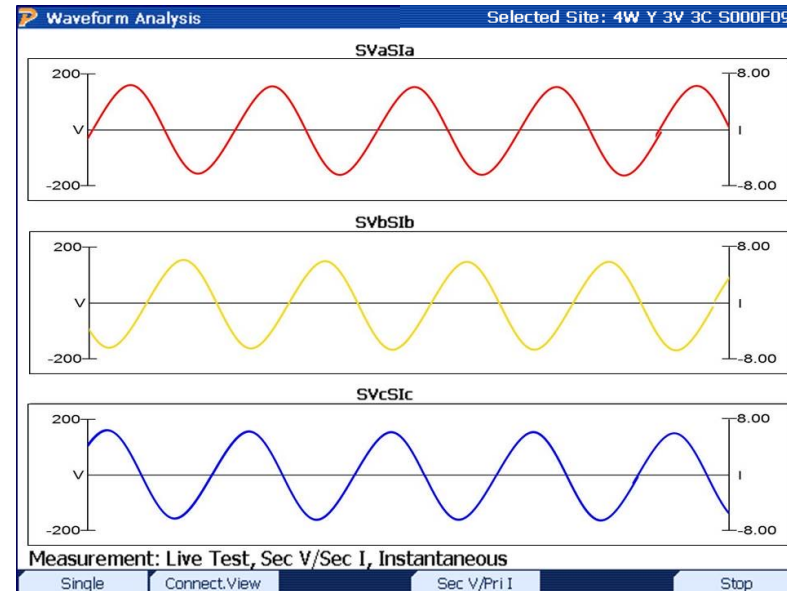
Vector Graph — Selected Site: 4W Y 3V 3C S000F09

Vector Diagram

ΦSVaSIa		
SVa	120.000	0.00°
SIa	5.000	0.00°
PF =	1.000	1.000
Lag		

ΦSVbSIb		
SVb	120.000	120.00°
SIb	5.000	120.00°
PF =	1.000	1.000
Lag		

ΦSVcSIc		
SVc	120.000	240.00°
SIc	5.000	240.00°
PF =	1.000	1.000
Lag		

Measurement: Live Test, Sec V/Sec I, Instantaneous

| Show Wiring | Connect.View | | +PF | -PF | Reset |

Waveforms look OK

Waveform Analysis — Selected Site: 4W Y 3V 3C S000F09)

SVaSIa

SVbSIb

SVcSIc

Measurement: Live Test, Sec V/Sec I, Instantaneous

| Single | Connect.View | | Sec V/Pri I | Stop |

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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

Ia+ Ia-   Ib+ Ib-   Ic+ Ic-

5A   5A   5A

CTa   CTb   CTc

300A   300A   300A
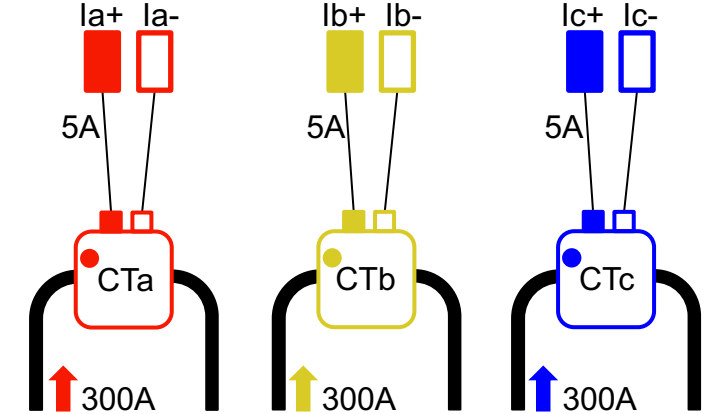
Primary Signals from Utility

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

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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

Ia+ Ia-   Ib+ Ib-   Ic+ Ic-

5A   5A   5A

CTa   CTb   CTc

300A   300A   300A

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

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Retest   Retest All   Done

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EXAMPLE #7

WHAT IS GOING ON?

Wrong Kh?
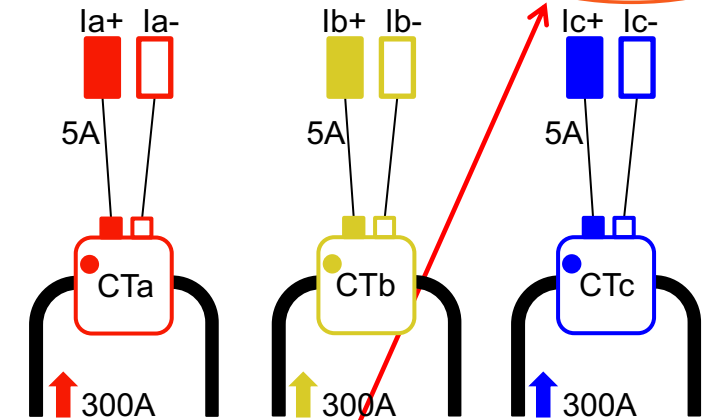
Bad Meter?

Bad element on the meter?

Something else?

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

Ia+ Ia-	Ib+ Ib-	Ic+ Ic-
5A	5A	5A
CTa	CTb	CTc
300A	300A	300A

Primary Signals from Utility

SAME RESULTS

Customer Load Meter Test — Wh Test

Selected Site: *NONE*

% 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

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.

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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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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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