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# Instrument Transformer Wiring Troubleshooting Guide Three Phase Meters

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## **I. HOW TO USE THIS GUIDE**

1. Symptoms listed are "ideal"; some judgment must be exercised. For example, if KW reading is 25 but you know that it should be about 300 KW, go to where this guide lists "KW=0" as one of the symptoms.
2. Section II "Common Problems for 3-Wire and 4-Wire Systems" addresses symptoms and possible causes which occur regardless of system type; this section should be checked first. If the symptoms are more complicated, proceed to Section III for 3-wire systems or Section IV for 4-wire systems as appropriate.
3. Always assume that the problem is in the wiring to the Circuit Monitor; do not assume a defective Circuit Monitor. Experience has shown that this is almost always a good assumption.
4. This guide addresses mostly only a single wiring problem at a time. It is nearly impossible to address all combinations of multiple wiring mistakes or other problems which can occur such as blown PT fuses, missing PT neutral ground connection, etc.
5. When calling in for troubleshooting assistance, it is imperative that all instantaneous Circuit Monitor readings be provided. Specifically, this includes line-to-line voltages, line-to-neutral voltages, phase currents, phase power factors, KW, KVAR, and KVA. Printouts of logged readings or waveform capture data, if available, can be extremely useful as well.

**What is "Normal"?** See the next page.



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## **What is "Normal"?**

Most power systems have a lagging (inductive) power factor. The Circuit Monitor and PowerLogic software displays lagging power factor as negative, leading (capacitive) power factor as positive. The only time a leading power factor would be expected would be if the customer had power factor correction capacitors switched in or over-excited synchronous motors with enough capacitive KVARs on-line to overcorrect the power factor to leading.

"Normal" lagging power system readings are as follows:

$$\text{Positive KW} = (\sqrt{3} * V_{AB} * I_{3\text{fAvg}} * PF_{3\text{fAvg}}) / 1000$$

$$\text{Negative KVAR} = (\sqrt{(KVA)^2 - (KW)^2}) / 1000$$

$$\text{KVA (always positive)} = (\sqrt{3} * V_{AB} * I_{3\text{fAvg}}) / 1000$$

$PF_{3\text{fAvg}}$  = lagging (negative) in the range -0.70 to 1.00 (for 4W systems, all phase PF's about the same)

Phase currents approximately equal

Phase voltages approximately equal

## **Quick Check**

A quick check for proper Circuit Monitor readings consists of KW comparison (calculated per equation above and compared to the Circuit Monitor reading) and a reasonable lagging 3-phase average power factor reading. If these checks are OK, there is no reason to do anything more.

If your calculations indicate that Circuit Monitor readings are correct but the customer disagrees, check CT ratio, PT ratio, and system type (3-wire or 4-wire) programmed into Circuit Monitor versus what is actually installed. If this is not the problem, ask customer what he based his estimate of the "correct" reading on. Be aware that there is a surprisingly high percentage of mis-wired watt-hour and power factor meters installed which make the Circuit Monitor appear wrong. Many times old meters that "never have worked right" have been in reality mis-wired from the start and the new Circuit Monitor is using the same instrument transformers.

## **Updates to this Guide**

This guide will be updated as new types of problems and/or fixes are uncovered.

Updates will also be incorporated if features of subsequent Circuit Monitor or software versions facilitate simpler or more detailed troubleshooting.

For example, the Series 2000 Circuit Monitor has two 4-wire mode metering functions which were not available in original Circuit Monitor design that may be very helpful in troubleshooting. These are per phase power readings and neutral current reading (neutral current may be calculated or measured from a neutral CT).

## II. Common Problems for 3-Wire and 4-Wire Systems

### Case A

Symptoms : 3-Wire and 4-Wire	Possible Causes
Zero amps Zero KW, KVAR, KVA	<ol style="list-style-type: none"> <li>1. CT secondaries shorted</li> <li>2. Less than 2% load on Circuit Monitor based on CT ratio (example: with 100/5 CT's, at least 2 amps must flow through CT window for Circuit Monitor to "wake up")</li> </ol>

### Case B

Symptoms : 3-Wire and 4-Wire	Possible Causes
Negative KW of expected magnitude Positive KVAR Normal lagging power factor	<ol style="list-style-type: none"> <li>1. All three CT polarities backwards; could be CT's physically mounted with primary polarity mark (H1) toward the load instead of toward source <u>or</u> secondary leads (X1 and X2) swapped</li> <li>2. All three PT polarities backwards; again, could be on primary <u>or</u> secondary</li> </ol> <p><b>Note:</b> Experience shows CT's are usually the problem.</p>

### Case C

Symptoms : 3-Wire and 4-Wire	Possible Causes
Frequency is some ridiculous value; may or may not be a multiple of 60 Hz	<ol style="list-style-type: none"> <li>1. PT's primary and/or secondary neutral common not grounded (values as high as 275 Hz and as low as 10 Hz have been seen)</li> <li>2. System grounding problem at the power distribution transformer (such as utility transformer); this is not likely</li> </ol>

### III. 3-Wire System Troubleshooting

#### Case A

Symptoms : 3-Wire	Possible Causes
Currents and voltages approximately balanced KW = near 0 KVAR = near 0 PF can be any value, probably fluctuating	1. CT secondary leads are swapped (A phase lead on C phase terminal and vice versa)  2. PT secondary leads are swapped (A phase lead on C phase terminal and vice versa)

#### Case B

Symptoms : 3-Wire	Possible Causes
Phase B current is $\sqrt{3}$ higher than A and C KVA = about half of the expected magnitude KW and KVAR can be positive or negative, less than about half of the expected magnitude PF can be any value, probably a low leading value	1. One CT polarity is backwards

#### Case C

Symptoms : 3-Wire	Possible Causes
$V_{CA}$ is $\sqrt{3}$ higher than $V_{AB}$ and $V_{BC}$ KVA = about half of the expected magnitude KW and KVAR can be positive or negative, less than about half of the expected magnitude PF can be any value, probably a low leading value	1. One PT polarity is backwards

#### Case D

Symptoms : 3-Wire	Possible Causes
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<p>KW = 0 or low, with magnitude less than KVAR  KVAR = positive or negative with magnitude of close to what is expected for KW  KVA = expected magnitude  PF = near 0 up to about 0.7 lead</p>	<ol style="list-style-type: none"> <li>1. Either the two voltage leads are swapped <u>or</u> the two current leads are swapped  <p style="text-align: center;"><u>AND</u></p> one instrument transformer has backwards polarity (look for <math>V_{CA} = \sqrt{3}</math> high or phase B current <math>= \sqrt{3}</math> high)</li> <li>2. The Circuit Monitor is metering a purely capacitive load (this is unusual); in this case KW and KVAR will be positive and PF will be near 0 lead</li> </ol>
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**Case E**

Symptoms : 3-Wire	Possible Causes
<p>One phase current reads 0  KVA = about 1/2 of the expected value  KW, KVAR, and power factor can be positive or negative of any value</p>	<ol style="list-style-type: none"> <li>1. The CT on the phase that reads 0 is short-circuited.</li> <li>2. Less than 2% current (based on CT ratio) flowing thru the CT on the phase that reads 0</li> </ol>

## IV. 4-Wire System Troubleshooting

### Case A

Symptoms : 4-Wire	Possible Causes
KW = 1/3 of the expected value KVAR = 1/3 of the expected value KVA = 1/3 of the expected value All else is normal	1. One CT polarity is backwards <b>Note:</b> the only way this problem will usually be detected is by the Quick Check procedure. It is very important to always <u>calculate KW</u> . In this case, it is the only symptom and will go unnoticed unless the calculation is done or someone notices backwards CT on a waveform capture.

### Case B

Symptoms : 4-Wire	Possible Causes
KW = 1/3 of the expected value KVAR = 1/3 of the expected value KVA = 1/3 of the expected value 2 of the 3 line-to-line voltages are $\sqrt{3}$ low All else is normal	1. One PT polarity is backwards <b>Note:</b> the line-to-line voltage reading that does not reference the PT with backwards polarity will be the only correct reading. Example: $V_{AB}=277$ , $V_{BC}=480$ , $V_{CA}=277$ In this case, the A-phase PT polarity is backwards. $V_{BC}$ is correct because it does not reference $V_A$ .

### Case C

Symptoms : 4-Wire	Possible Causes
One line-to-neutral voltage is zero 2 of the 3 line-to-line voltages are $\sqrt{3}$ low KW = 2/3 of the expected value KVAR = 2/3 of the expected value KVA = 2/3 of the expected value One phase power factor may look abnormal	1. PT metering input missing (blown fuse, open phase disconnect, etc.) on the phase that reads zero <b>Note:</b> the line-to-line voltage reading that does not reference the missing PT input will be the only correct reading. Example: $V_{AB}=277$ , $V_{BC}=277$ , $V_{CA}=480$ In this case, the B-phase PT input is missing. $V_{CA}$ is correct because it does not reference $V_B$ .

Case D

Symptoms : 4-Wire	Possible Causes
KW = 2/3 of the expected value KVAR = 2/3 of the expected value KVA = 2/3 of the expected value One phase current reads 0 All else is normal	1. The CT on the phase that reads 0 is short-circuited. 2. Less than 2% current (based on CT ratio) flowing thru the CT on the phase that reads 0.

Case E

Symptoms : 4-Wire	Possible Causes
KW = near 0 KVAR = near 0 KVA = near 0 One phase power factor reads lagging (normal magnitude) One phase power factor reads leading One phase power factor reads very low 3-phase average power factor flip-flopping lead and lag Voltages and currents are normal	1. Two CT secondary leads are swapped (A phase on B phase terminal, for example) 2. Two PT secondary leads are swapped (A phase on B phase terminal, for example) <b>Note:</b> in either case, the phase input that is <u>not</u> swapped will read normal lagging power factor.

Case F

Symptoms : 4-Wire	Possible Causes
KW = negative and less than KVAR KVAR = negative and close to value expected for KW KVA = expected value All power factors low and leading Voltages and currents are normal	1. All three PT lead connections "rotated" counterclockwise: A-phase wire on C-phase terminal, B-phase wire on A-phase terminal, C-phase wire on B-phase terminal. 2. All three CT lead connections "rotated" clockwise: A-phase wire on B-phase terminal, B-phase wire on C-phase terminal, C-phase wire on A-phase terminal.

Case G

Symptoms : 4-Wire	Possible Causes
<p>KW = negative and less than KVAR KVAR = positive and close to the value expected for KW <b>Note:</b> looks like KW and KVAR swapped places KVA = expected value All power factors low and lagging Voltages and currents are normal</p>	<ol style="list-style-type: none"><li data-bbox="805 279 1430 426">1. All three PT lead connections "rotated" clockwise: A-phase wire on B-phase terminal, B-phase wire on C-phase terminal, C-phase wire on A-phase terminal.</li><li data-bbox="805 468 1430 615">2. All three CT lead connections "rotated" counterclockwise: A-phase wire on C-phase terminal, B-phase wire on A-phase terminal, C-phase wire on B-phase terminal.</li></ol>

## V. Actual Field Examples

### A. 4-wire system

$$KW = 25$$

$$KVAR = -15$$

$$KVA = 27$$

$$I_A = 904A$$

$$I_B = 910A$$

$$I_C = 931A$$

$$I_{3\phi Avg} = 908A$$

$$V_{AB} = 495V$$

$$V_{BC} = 491V$$

$$V_{CA} = 491V$$

$$V_{AN} = 287V$$

$$V_{BN} = 287V$$

$$V_{CN} = 284V$$

$$PF_A = -0.75$$

$$PF_B = 0.96$$

$$PF_C = 0.27$$

$$PF_{3\phi Avg} = -0.75 \text{ to } .22 \text{ fluctuating}$$

### Troubleshooting Diagnosis

- Power factors cannot be correct
- None of the Section II symptoms exist so proceed to the 4-wire troubleshooting Section IV
- Cannot calculate KW because 3-phase power factor cannot be right so calculate KVA instead
- Calculated KVA =  $(\sqrt{3} * V_{AB} * I_{3\phi Avg}) / 1000$   
 $= (1.732 * 495 * 908) / 1000$   
 $= 778 \text{ KVA}$
- Circuit Monitor reading is essentially zero compared to this value
- 4-wire Case E looks similar
- Since the PT's were connected to other Circuit Monitors which were reading correctly, suspect two CT leads swapped
- since A-phase power factor is the only one that has a normal looking lagging value, suspect B and C phase CT leads may be swapped
- after swapping B and C phase CT leads, all readings went to the expected values; problem solved