Theory and instructions on how to use the phasor tool

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Summary

Part 1.0 explains the fundamentals of how an ION meter will measure voltage and current angles. Part 2.0 explains how to use the phasor tool, what values are required and to provide insight as to what actions need to be taken to correct the faulty diagram. Finally, there are three examples near the end of the document.

Information

Part 1.0 – Understanding phasors in wye and delta mode

1.1 When the ION meter measures voltage on phase A, the angle used will start at zero degrees. Phase B will take on a -120° (from 0° where phase a is located) and phase C will take on a +120° angle from 0°. This corresponds to an ABC rotation where as time goes on, one will see Phase A voltage pass by the 0° point, then phase B voltage and finally phase C voltage in that order. Figure 1.0 illustrates this:

![Figure 1.0: (WYE) In ABC rotation, the eye at the right side of the diagram will see phase a, b, then c in that order](image)

1.2 When a delta system is considered, the phase-to-phase voltages are now used and the Vllab is 30° phase shifted. This is a property of vector addition. Notice, however that Ia is still sitting at zero degrees.
1.3 After connecting the tips of each per-phase (line-to-neutral) voltages, a new reference is made at the phase B point. Now, in the middle image of Figure 3.0, it is clear to see how $V_{llab}$ is now $30^\circ$ from the zero. However, the currents do not change angle.

Now, instead of have all line-to-neutral phases $120^\circ$ from each other, the delta line-to-line phases are $60^\circ$ from each other. Note, an inversion of $V_{llcb}$ to $V_{llbc}$ is required.

Q. Where are $I_b$ and $V_{llca}$?
A. In delta mode, the ION meter will measure phase A in reference to phase B, hence $V_{llab}$. The meter will also measure phase C in reference to phase B, hence $V_{llcb}$. Below in Figure 4.0 one will see how the meter measures these phases.

Q. What about $V_{llca}$?
A. Blondel’s theorem indicates that if a power system is comprised of n wires, then only (n-1) values are required to provide a full description of system.
"If this common point is on one of the N wires, the measurement may be made with N-1 wattmeters" (Andre E. Blondel, 1893)

Therefore, the meter measures only Phase A and C using one wattmeter for each. Phase B is the reference point. This can be seen by a typical 2-element, two wattmeter, 3-wire Delta, or simply a Delta wiring diagram below in Figure 5.0.

3-Wire Delta, 2-Element 2 PTs & 2 CTs

![Diagram](7550_7650_Installation_guide.pdf, Schneider Electric (Sept 6, 2005), available: [www.pwrm.com](http://www.pwrm.com))

In Figure 5.0, only 2 PTs are required as indicated by Blondel, that is only (n-1) or (3-1) measurements. Notice that V2 (or phase B) is grounded. This is why all phase-to-phase voltages start out as Vllxb, or in other words, the voltage line-to-line measuring x with reference b.

1.4 Below, in Figure 6.0, is an illustration of lagging and leading.

![Diagram](current_in_unity_pf.png)

Figure 6.0: (delta) Current in unity Power Factor (PF) is shows at 30° below the voltage at the zero crossing. When current lags, the eye will see the current waveform later in time than when the voltage was first seen. The eye will see the zero-crossing of a leading current before that of the voltage. However, this is not obvious when looking at a delta phasor diagram as the one in Figure 6.0
1.5 As an example, Figure 7.0 was created in the Schneider Electric phasor tool. The values were taken from a live field meter.

![Figure 7.0](image)

**Figure 7.0:** (Delta) Live field meter in Schneider Electric phasor tool.

Figure 8.0 below shows the comparison of Figure 7.0 with the right most diagram from figure 3.0.

![Figure 8.0](image)

**Figure 8.0:** (Delta) Live meter is showing an inductive power factor because both the Ic and Ia currents are lagging their respective voltages by approximately 45°.

1.6 Finally, Ib (or I2) appears in the phasor tool even though it is not measured. In the phasor tool, the angle of I2 is optional. This can be entered directly onto the tool if needed. In balanced loads, I2 will be 120° apart from the other currents as seen in Figure 8.0.
PART 2 - Using the phasor tool:

This section is split into two sections. One for how to use the wye mode and one for the delta mode.

2.1 **Wye mode**

If the meter is in ION volts mode ‘4-wire wye’, then one simply needs to take the values from the front panel of the meter and input them into the phasor tool. This can be done as follows:

**Figure 9.0: (Wye) mode sheet in the phasor tool.**

Use the following steps to retrieve the information required from the front panel:

**75xx, 76xx:**
1. Find the menu 'Summary 2/*
2. Write down kWa, kWb, kWc, PFa, PFb, PFc
3. Find the menu ‘phasors’
4. Write down the voltage phase-to-neutral angles
5. Enter these values into the phasor tool

**73xx:**
For these meters, per phase kW and PF are not given in the default screens. Below are the instructions on how to change the display to see these values:
1. Press the round button to enter Setup*
2. Scroll down to 'Screen Setup' (press the round button to enter)
3. V-THD (round button)
4. Values
5. Choose the first value (under ‘---- RETURN ----’)
6. “Feature manager” will show all the modules types. Choose power meter modules.
7. Choose power meter
8. Choose kWa.
9. Repeat steps 3-9, for the three values kWa, kWb, kWc.
10. Repeat steps 1-9. This time choose I-THD in step 3. Also choose the values PFa, PFb, PFc in step 8.
11. Enter these values into the phasor tool

Next, once the phasor diagram is displayed, the green diagram below is used to make any corrections if needed.

* If meter is a tran model (no display), one will need to connect via ION Setup to make changes
In figure 10.0, one will see the options “Invert V1” or “Move I1 to”. These will help in constructing the correct diagram.

![Diagram of options in figure 10.0](image)

**Figure 10.0:** (Wye) mode sheet in phasor tool. Corrected diagram in green.

In the case above, no corrections need to be made.

## 2.2 Delta mode

If the meter is in Delta mode, additional steps need to be taken to get the present phasor diagram.

Notice the small print on the first part of the phasor tool that reads, “In delta mode, the meter only displays total power. Set the meter to 4-wire Wye mode – ignore b-phase” in figure 11.0.

![Diagram of delta mode steps](image)

**Figure 11.0:** (Delta) Enter values as given by 4-wire wye mode.

Here are the required Steps:

1. Put the meter into 4-Wire-Wye mode: Press the round button on the front panel > Basic Setup > Volts mode > 4 wire wye.* Follow the remaining steps in Section 2.1.
2.3 **WYE Example 1:** Here, a faulty diagram is presented in Figure 12.0 and the corrections are resulting diagram are shown in Figure 13.0.

![Original Incorrect Diagram](image1)

![Corrected Diagram](image2)

The changes that the wiring diagram reflects can be as simple as inverting the polarity of some of the phases or it can be as difficult as doing a complete rewiring of the meter. In this case, no inversions are required, however each voltage and current phase leads require swapping with each other. This means the meter will need to come out of service.

2.4 **WYE Example 2:** Figure 14.0 shows a faulty diagram. Recall that one cannot use the tool with the values given alone, they must also discuss with the customer what type of load they expect.

![Faulty Diagram Similar to One Seen in the Phasor Tool](image3)

In discussions with the customer, they have indicated they should have a lagging PF and that the majority of the energy is delivered to the load. There is no internal generation of power, as such, there should be no energy received (flowing from the load back to the meter).
In the above image, it is expected that the phase A current would either lag or lead the phase A voltage (Va) in the range of +/- 90 degrees. However, Ia appears at approximately 160° from the zero crossing (Va). With the information given, and that Ia is expected to be closer to Va, if one inverts Ia, it appears in the correct position showing a lagging PF.

The final solution involves inverting all three currents through the front panel of the meter. No rewiring is required.

2.5 **DELTA Example 3**: (Author GRS)

In Delta mode the meter does not provide individual phase information for the power parameters.

**Therefore to correct meter wiring for a Delta wired meter - you would need to “temporarily” set the Volts mode on the meter to 4W-Wye Mode. Obtain Power parameters. Ignore b-phase.**

\[
\begin{align*}
KW_a &= -2640 \text{ kW} & \text{PF}_a &= 70 \text{ LG} \\
KW_c &= 3882 \text{ kW} & \text{PF}_c &= 98 \text{ LD}
\end{align*}
\]

Then use the Phasor tool to obtain a phasor diagram and make modifications to correct the wiring.

**Step1:**
Begin by selecting the correct excel sheet. The Phasor tool has 2 sheets - select either WYE Mode or Delta Mode. In this example Delta Mode is selected. (see example on next page)

Enter Power parameters or Voltage and Current angles in the appropriate cells. A Phasor diagram is plotted based on the parameters entered.

Note: The Phasor Diagram plotted in step1 of our example does not look correct.

**Step2:**
Make the necessary modifications to correct the phasor diagram plotted in Step1.

In this example: Inverting I1 would fix the phasors.

So using the check boxes:
- Invert the I1 phasor

The Corrected Phasor Diagram in step2 is plotted based on the changes made.

**Step3:**
Provides summary information of the wiring changes required
**DELTA MODE (Meter Wiring: Troubleshooting Tool)**

### Figure 15.0: (DELTA) phasor tool

#### Step 1: Selecting Use of the Two Phases Calculation Mode

- **L1A**: 240
- **L1**: 3082
- **V1**: (L1) 69
- **V3**: (L1) 69
- **PF**: 90
- **P2 option**: 240

#### Step 2: Correct Phasor Diagram with the Insert Option

**Corrected Phasor Diagram (from step 2)**

After completing steps 1 and 2, exercise caution during wire connections to avoid errors. Always verify connections carefully for accuracy.
2.6 **Additional Information:**
The phasor diagrams in the back of the 7550_7650_Installation_Guide.pdf can help to determine what situation the present wiring is doing. Again, after discussions with the customer the type of load is understood and hence the resolution becomes apparent.

2.7 **Phase-to-phase voltages referenced to zero degrees:**
Some diagrams use the zero crossing to place the Vllab, see Figure 16.0.

![Figure 16.0: Using Vllab as the zero degree reference](image)

2.8 **Related Knowledge Base Articles:**

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