Revised Delta Metrics for the RD-3X beginning with RD firmware 07.10.27

By
Shannon Edwards
Steve Ziuchkovski
David Bobick

February 3, 2012

In a continual effort to improve product design and remove inconsistency Radian found it necessary to implement and report the following firmware change. While the impact is not major this document helps explain why the change was necessary. Should you have any questions relating to this or any other Radian product please do not hesitate to contact us.

It was discovered that in the presence of an unbalanced three phase system, an RD-3X using firmware released prior to and including 07.10.22 outputs the VA Delta metric for phase 3 in an inconsistent manner depending upon how the metrics are being reported. Two different formulae were used in calculating VA for phase 3 in Delta metrics. The first method reports through the communications port. The second method reports through the pulse output. Under an unbalanced load, these two formulas can result in different answers though the communications port and pulse output port. The calculations being used for the Delta measurements in RD firmware released prior to and including 07.10.22 are as found in table 1.

Table 1: Delta Metric definition for firmware released prior to and including 07.10.22

Function	phase-1	phase-2	phase-3
A	$\sqrt{\frac{1}{kT}\int_{\tau}^{\tau+kT} I_A(t)^2 dt}$	$\sqrt{\frac{1}{kT}\int_{\tau}^{\tau+kT} I_B(t)^2 dt}$	$\sqrt{\frac{1}{kT}\int_{\tau}^{\tau+kT} I_C(t)^2 dt}$
V Delta	$\sqrt{\frac{1}{kT}\int_{\tau}^{\tau+kT} \left[V_A(t)-V_B(t)\right]^2 dt}$	$\sqrt{\frac{1}{kT}\int_{\tau}^{\tau+kT} \left[V_B(t)-V_C(t)\right]^2 dt}$	$\sqrt{\frac{1}{kT}\int_{\tau}^{\tau+kT} \left[V_C(t)-V_A(t)\right]^2 dt}$
W Delta	$\frac{1}{kT}\int_{\tau}^{\tau+kT} \left[V_A(t)-V_B(t)\right] I_A(t) dt$	0.000000	$\frac{1}{kT}\int_{\tau}^{\tau+kT} \left[V_C(t)-V_A(t)\right] I_C(t) dt$
VA Delta(Com)	$V\_Delta\_1 \times A\_1$	0.000000	$V\_Delta\_3 \times A\_3$
VA Delta(Pulse)	$\sqrt{\left(\frac{1}{kT}\int_{\tau}^{\tau+kT} \left[V_A(t)-V_B(t)\right] I_A(t) dt\right)^2 + \left(\frac{1}{kT}\int_{\tau}^{\tau+kT} \left[V_A\left(t-\frac{k}{4}\right)-V_B\left(t-\frac{k}{4}\right)\right] I_A(t) dt\right)^2}$	0.000000	$\sqrt{\left(\frac{1}{kT}\int_{\tau}^{\tau+kT} \left[V_B(t)-V_C(t)\right] I_C(t) dt\right)^2 + \left(\frac{1}{kT}\int_{\tau}^{\tau+kT} \left[V_B\left(t-\frac{k}{4}\right)-V_C\left(t-\frac{k}{4}\right)\right] I_C(t) dt\right)^2}$
VAR Delta	$\frac{1}{kT}\int_{\tau}^{\tau+kT} \left[V_A\left(t-\frac{k}{4}\right)-V_B\left(t-\frac{k}{4}\right)\right] I_A(t) dt$	0.000000	$\frac{1}{kT}\int_{\tau}^{\tau+kT} \left[V_C\left(t-\frac{k}{4}\right)-V_A\left(t-\frac{k}{4}\right)\right] I_C(t) dt$

As can be seen in table 1 the communications interface output for phase 3 VA Delta is just the scalar Voltage, V Delta, times the scalar current, A. The pulse output for phase 3 VA Delta is a vector determination of the VA by using Watts and VARs. To complicate the matter further, this vector approach uses a different definition for the Watts and VARs than is being reported for phase 3 W Delta and VAR Delta. This gives rise to the difference in answers between com and pulse outputs for VA under balanced and unbalanced 3 phase conditions. The question thus becomes, which one if either is correct?

The V Delta results are consistent with the voltages we would expect for a 3 element three phase meter. For sinusoidal voltages and currents the results are consistent with the phasor diagram shown in figure 1. The phase A voltage reported would be the RMS value of vector voltage V_{BA}, the phase 2 voltage would be the RMS value of vector voltage V_{CB}, and the phase 3 voltage would be the RMS value of vector voltage V_{AC}.

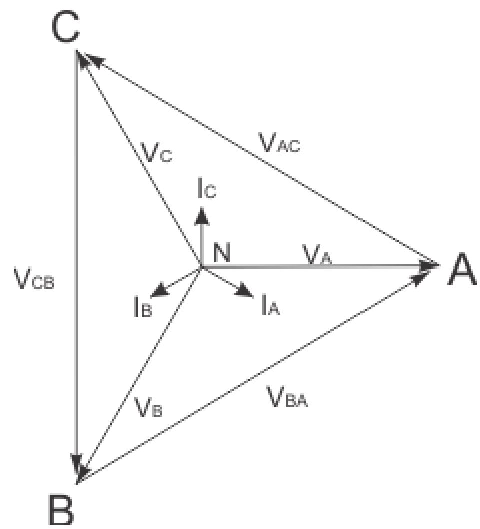

Figure 1. Three element three phase meter voltages and currents

We then reviewed the format for the rest of the Delta outputs we notice that W Delta, VA Delta (Com), VA Delta (Pulse) and VAR Delta all have phase 2 results that are 0.000000. This is characteristic of a Delta measurement using Blondel's Theorem and a two element meter. For sinusoidal voltages and currents the results are somewhat consistent with the phasor diagram shown in figure 2.

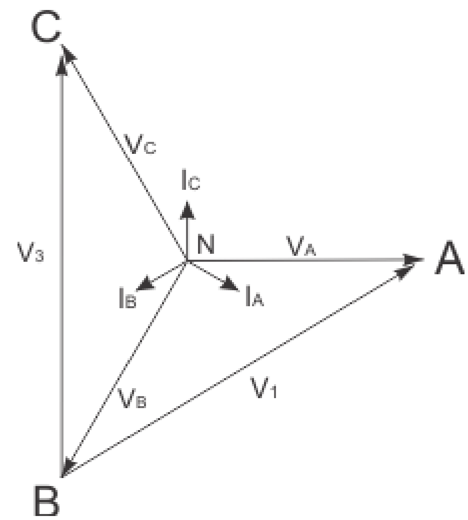

Figure 2 Two element three phase meter voltages and currents

The only inconsistency is that in phase 3, the W Delta, VA Delta (Com) and VAR Delta use the vector voltage V_{AC} in figure 1 instead of the vector voltage V3 in figure 2 that one would expect from Blondel's Theorem. Interestingly, the VAR Delta (Pulse) does a correct vector calculation for VA as one would expect from a two element meter using Blondel's theorem.

From the above we conclude that we have a mixed reporting system. In order to be consistent we will use the two element meter system using Blondel's theorem. This means that the voltage reported for phase 3 will change to the voltage that a two element meter would see and the W Delta and VAR Delta will be calculated using this voltage. The phase 3 VA Delta will be calculated by using the phase 3 voltage V Delta times the phase 3 current A and will be the same for communication and pulse output.

In the RD firmware release, 07.10.27 and later, the Delta information for phases 1, 2 and 3 will be calculated from input voltage vectors V_A, V_B, and V_C and current vectors I_A, I_B, and I_C on the rear panel of the RD-3X as follows:

Table 2: Delta Metric definition for firmware release 07.10.27

Function	phase-1	phase-2	phase-3
A	$\sqrt{\frac{1}{kT}\int_{\tau}^{\tau+kT} I_A(t)^2 dt}$	$\sqrt{\frac{1}{kT}\int_{\tau}^{\tau+kT} I_B(t)^2 dt}$	$\sqrt{\frac{1}{kT}\int_{\tau}^{\tau+kT} I_C(t)^2 dt}$
V Delta	$\sqrt{\frac{1}{kT}\int_{\tau}^{\tau+kT} \left[V_A(t)-V_B(t)\right]^2 dt}$	0.000000	$\sqrt{\frac{1}{kT}\int_{\tau}^{\tau+kT} \left[V_C(t)-V_B(t)\right]^2 dt}$
W Delta	$\frac{1}{kT}\int_{\tau}^{\tau+kT} \left[V_A(t)-V_B(t)\right] I_A(t) dt$	0.000000	$\frac{1}{kT}\int_{\tau}^{\tau+kT} \left[V_C(t)-V_B(t)\right] I_C(t) dt$
VA Delta	$V\_Delta\_1 \times A\_1$	0.000000	$V\_Delta\_3 \times A\_3$
VAR Delta	$\frac{1}{kT}\int_{\tau}^{\tau+kT} \left[V_A\left(t-\frac{k}{4}\right)-V_B\left(t-\frac{k}{4}\right)\right] I_A(t) dt$	0.000000	$\frac{1}{kT}\int_{\tau}^{\tau+kT} \left[V_C\left(t-\frac{k}{4}\right)-V_B\left(t-\frac{k}{4}\right)\right] I_C(t) dt$

Appendix A

For the case where the input voltage and currents are pure sinusoids the equations in tables 1 and 2 can be reduced to simple vectors. This vector representation in alternate tables 1 and 2 is only valid for pure sine wave. In the presence of harmonic it will not give the same answer as the integrals shown in the original tables 1 and 2. They are presented only as an alternate method communicating the nature of the change that is occurring.

Alternate Table 1: Pure sine wave vector interpretation of Delta Metric definition for firmware release prior to and including 07.10.22

Function	phase-1	phase-2	phase-3
------------	------------	------------	------------
A	$\left\Vert \overrightarrow{I_{NA}} \right\Vert$	$\left\Vert \overrightarrow{I_{NB}} \right\Vert$	$\left\Vert \overrightarrow{I_{NC}} \right\Vert$
V Delta	$\left\Vert \overrightarrow{V_{BA}} \right\Vert = \left\Vert \overrightarrow{V_{NA}} - \overrightarrow{V_{NB}} \right\Vert$	$\left\Vert \overrightarrow{V_{CB}} \right\Vert = \left\Vert \overrightarrow{V_{NB}} - \overrightarrow{V_{NC}} \right\Vert$	$\left\Vert \overrightarrow{V_{AC}} \right\Vert = \left\Vert \overrightarrow{V_{NC}} - \overrightarrow{V_{NA}} \right\Vert$
W Delta	$\left\Vert \overrightarrow{V_{BA}} \right\Vert \times \left\Vert \overrightarrow{I_{NA}} \right\Vert \times \cos(\angle \overrightarrow{V_{BA}}, \overrightarrow{I_{NA}})$	0.000000	$\left\Vert \overrightarrow{V_{AC}} \right\Vert \times \left\Vert \overrightarrow{I_{NC}} \right\Vert \times \cos(\angle \overrightarrow{V_{AC}}, \overrightarrow{I_{NC}})$
VA Delta(Com)	$\left\Vert \overrightarrow{V_{BA}} \right\Vert \times \left\Vert \overrightarrow{I_{NA}} \right\Vert$	0.000000	$\left\Vert \overrightarrow{V_{AC}} \right\Vert \times \left\Vert \overrightarrow{I_{NC}} \right\Vert$
VA Delta(Pulse)	$\sqrt{\left(\left\Vert \overrightarrow{V_{NA}} - \overrightarrow{V_{NB}} \right\Vert \times \left\Vert \overrightarrow{I_{NA}} \right\Vert \times \cos(\angle \overrightarrow{V_{NA}} - \overrightarrow{V_{NB}}, \overrightarrow{I_{NA}})\right)^2 + \left(\left\Vert \overrightarrow{V_{NA}} - \overrightarrow{V_{NB}} \right\Vert \times \left\Vert \overrightarrow{I_{NA}} \right\Vert \times \sin(\angle \overrightarrow{V_{NA}} - \overrightarrow{V_{NB}}, \overrightarrow{I_{NA}})\right)^2}$	0.000000	$\sqrt{\left(\left\Vert \overrightarrow{V_{NC}} - \overrightarrow{V_{NB}} \right\Vert \times \left\Vert \overrightarrow{I_{NC}} \right\Vert \times \cos(\angle \overrightarrow{V_{NC}} - \overrightarrow{V_{NB}}, \overrightarrow{I_{NC}})\right)^2 + \left(\left\Vert \overrightarrow{V_{NC}} - \overrightarrow{V_{NB}} \right\Vert \times \left\Vert \overrightarrow{I_{NC}} \right\Vert \times \sin(\angle \overrightarrow{V_{NC}} - \overrightarrow{V_{NB}}, \overrightarrow{I_{NC}})\right)^2}$
VAR Delta	$\left\Vert \overrightarrow{V_{BA}} \right\Vert \times \left\Vert \overrightarrow{I_{NA}} \right\Vert \times \sin(\angle \overrightarrow{V_{BA}}, \overrightarrow{I_{NA}})$	0.000000	$\left\Vert \overrightarrow{V_{AC}} \right\Vert \times \left\Vert \overrightarrow{I_{NC}} \right\Vert \times \sin(\angle \overrightarrow{V_{AC}}, \overrightarrow{I_{NC}})$

Alternate Table 2: Pure sine wave vector interpretation of Delta Metric definition for firmware release 07.10.27 and later.

Function	phase-1	phase-2	phase-3
------------	------------	------------	------------
A	$\left\Vert \overrightarrow{I_{NA}} \right\Vert$	$\left\Vert \overrightarrow{I_{NB}} \right\Vert$	$\left\Vert \overrightarrow{I_{NC}} \right\Vert$
V Delta	$\left\Vert \overrightarrow{V_1} \right\Vert = \left\Vert \overrightarrow{V_{NA}} - \overrightarrow{V_{NB}} \right\Vert$	$\left\Vert \overrightarrow{V_2} \right\Vert = \left\Vert \overrightarrow{V_{NB}} - \overrightarrow{V_{NB}} \right\Vert = 0$	$\left\Vert \overrightarrow{V_3} \right\Vert = \left\Vert \overrightarrow{V_{NC}} - \overrightarrow{V_{NB}} \right\Vert$
W Delta	$\left\Vert \overrightarrow{V_1} \right\Vert \times \left\Vert \overrightarrow{I_{NA}} \right\Vert \times \cos(\angle \overrightarrow{V_1}, \overrightarrow{I_{NA}})$	0.000000	$\left\Vert \overrightarrow{V_3} \right\Vert \times \left\Vert \overrightarrow{I_{NC}} \right\Vert \times \cos(\angle \overrightarrow{V_3}, \overrightarrow{I_{NC}})$
VA Delta	$\left\Vert \overrightarrow{V_1} \right\Vert \times \left\Vert \overrightarrow{I_{NA}} \right\Vert$	0.000000	$\left\Vert \overrightarrow{V_3} \right\Vert \times \left\Vert \overrightarrow{I_{NC}} \right\Vert$
VAR Delta	$\left\Vert \overrightarrow{V_1} \right\Vert \times \left\Vert \overrightarrow{I_{NA}} \right\Vert \times \sin(\angle \overrightarrow{V_{BA}}, \overrightarrow{I_{NA}})$	0.000000	$\left\Vert \overrightarrow{V_3} \right\Vert \times \left\Vert \overrightarrow{I_{NC}} \right\Vert \times \sin(\angle \overrightarrow{V_{AC}}, \overrightarrow{I_{NC}})$