Understanding Delta Conversion Online™ "Input Power Factor Correction" - Part 6

Introduction

This application note is the sixth in a series on delta conversion theory of operation. For complete understanding of the engineering benefits of this technology we recommend that you read all the series in order and any of the supplemental white papers found on the APC web site.

What is Power Factor?

The answer is not as simple as it seems, because the term "Power Factor" is very generic. Power factor is a way of describing the relationship between real power (P), apparent power (S), and reactive power (Q). Traditionally the term has been applied to many different loads with out consideration of the load reactive harmonic power characteristic. Today we now understand that this term is to broad, and we apply different formula's to calculate power factor for specific load reactive power characteristics. The traditional power factor is what we now call Displacement Power Factor (DPF). This is used for loads that exhibit sinusoidal current waveforms, a.k.a. linear loads, such as electric motors, etc. (1)(2)(3)

Eq. 1: $DPF = \cos \theta_1$

Where: θ_1 = the angle between the apparent power (S) and the real power (P)

Because of this we can say the power factor for a sinusoidal load can be calculated with either of the following:

Eq. 2: $$PF = \frac{P}{S} = \frac{P}{VI} = \cos \theta_1$$

Where power factor is the real power (P= watts) divided by the apparent power (S= volt-amperes)

For example: A load that requires 500kVA/325kW has a power factor of .65 (325/500 =.65).
We can also determine power factor using the first equation, if we know the phase displacement (θ_1) between the voltage waveform and load current waveform.

With the advent of electronic nonlinear loads, i.e., capacitor input switched-mode power supplies (SMPS), 6-pulse rectifier/chargers, variable speed drives (VSD) & variable frequency drives (VFD), and the like, it became apparent that traditional DPF calculations did not accurately describe the relationship between the watts consumed and the harmonic reactive currents drawn by the electronic load.

This new power factor equation includes these harmonic components and the linear component (DPF). (1)

Eq. 3: $$PF = \frac{1}{\sqrt{1 + THD_i^2}} DPF$$

Power factor is the percentage of electricity that is being used to do useful work. It is expressed as a ratio. For example, a power factor of 0.72 would mean only 72% of your power was being used to do useful work. Perfect power factor is 1.0,(unity), meaning 100% of the power is being used for useful work. Power factor correction, then, is the method(s) used to fix the problems that cause power to be wasted. Energy is saved, and penalties levied by power companies are reduced or eliminated.

Comparing UPS Input Power Factors

The input to a 160kVA APC Delta Conversion Online™ UPS is shown in figure 1. As you can see both input and load power factor are ideal, i.e., ~1.0. Meaning neither the UPS nor its load is drawing any reactive current components. The same 160kVA unit is shown in figure 2, powering a non-linear 6-pulse rectifier load. Actually a competitor's 225kVA double conversion UPS.

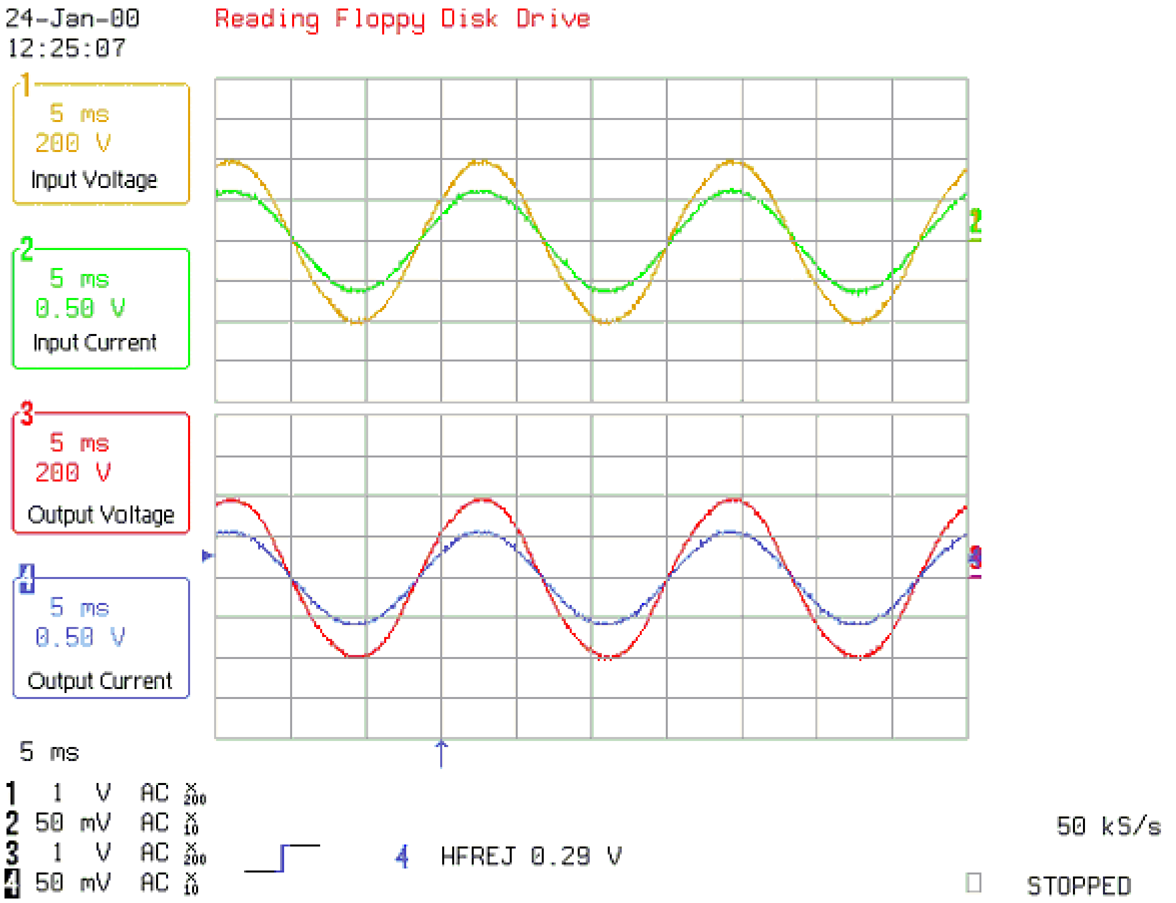

Figure 1 - *160kVA Delta Conversion Online™ @ 100% kW load*

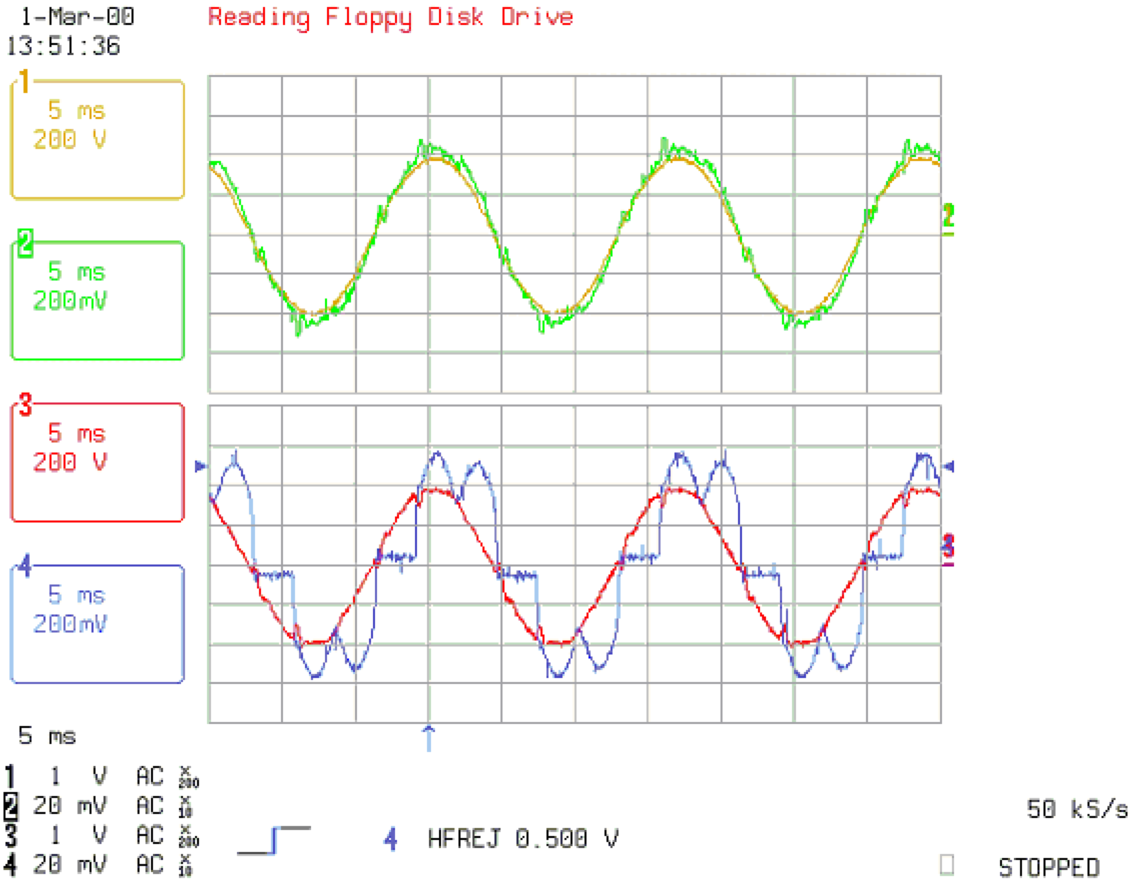

Figure 2 - *160kVA Delta Conversion Online™ @ 100% kVA Nonlinear Load*

As we can see in figure 2, this is a horrible load for any power source. The notching in the output voltage waveform is caused by the load, i.e., the commutation of the SCR's in the rectifier/charger of the double conversion UPS. This same current waveform is very common for other three phase electronic loads like adjustable speed drive (ASD) or variable frequency drives (VFD). (4)

As shown above the input current waveform to the 6-pulse rectifier/charger exhibits both displacement power factor (DPF) and harmonic reactive currents, i.e., because of the distortion of the waveform. However, there's no phase shift and very little effect on the Delta Conversion Online^{TM} input current THD. This means there is virtually no effect on the input power factor waveform (PF =.996- actual measured with Voltek PM 3000 Three-Phase Power Analyzer). This proves the APC Delta Conversion Online™ provides load harmonic & power factor correction so the utility or generator source feeding it sees a linear load w/ low harmonics and high power factor. It also proves the unit is not line interactive, as a line interactive UPS cannot inherently do what's presented above. Calculating the power factor of the load waveform can be done using equation # 3 above:

Eq. 3: $$PF = \frac{1}{\sqrt{1+ THD_i^2}} DPF$$

Where

θ_1 = The phase shift between the voltage waveform and the current waveform. This can be tricky because of the nonlinear nature of the current waveform. The easiest way to do this is to visually superimpose a sinusoidal waveform over top of the nonlinear current waveform. If we say the phase shift is ~ 1.5 milliseconds (time div = 5 mSec/div). One complete cycle of 60 Hertz AC voltage is 16.666 mSec. This means each mSec represents ~21.6 degrees, i.e., 360°/16.666 mSec = 21.6°/mSec.

Then: 1.5 mSec * 21.6° = 32.4° phase shift.

DPF = $\cos \theta_1 = \cos 32.4° = .8443$

THDi = Actual measured using Voltek PM3000 Power Analyzer was: 32% = .32

Now if we put our numbers above into the equation:

Eq. 3: $$PF = \frac{1}{\sqrt{1+THD_i^2}} DPF = \frac{1}{\sqrt{1+.32^2}} .8443 = \frac{1}{\sqrt{1.10224}} .8443 = .952441 * .8443 = .804$$

Therefore calculated PF = .804

Our Voltek PM3000 measured actual PF at: .808

In figure 3. is the same double conversion UPS powered from utility power. As you can see the input harmonic distortion and power factor are unaffected by the actual load. Which in this case was PF 1.0 resistor load. This means it can create PF and harmonic problems where none existed prior to its installation, i.e., data centers where dominant load is power factor corrected computer loads, servers, etc.

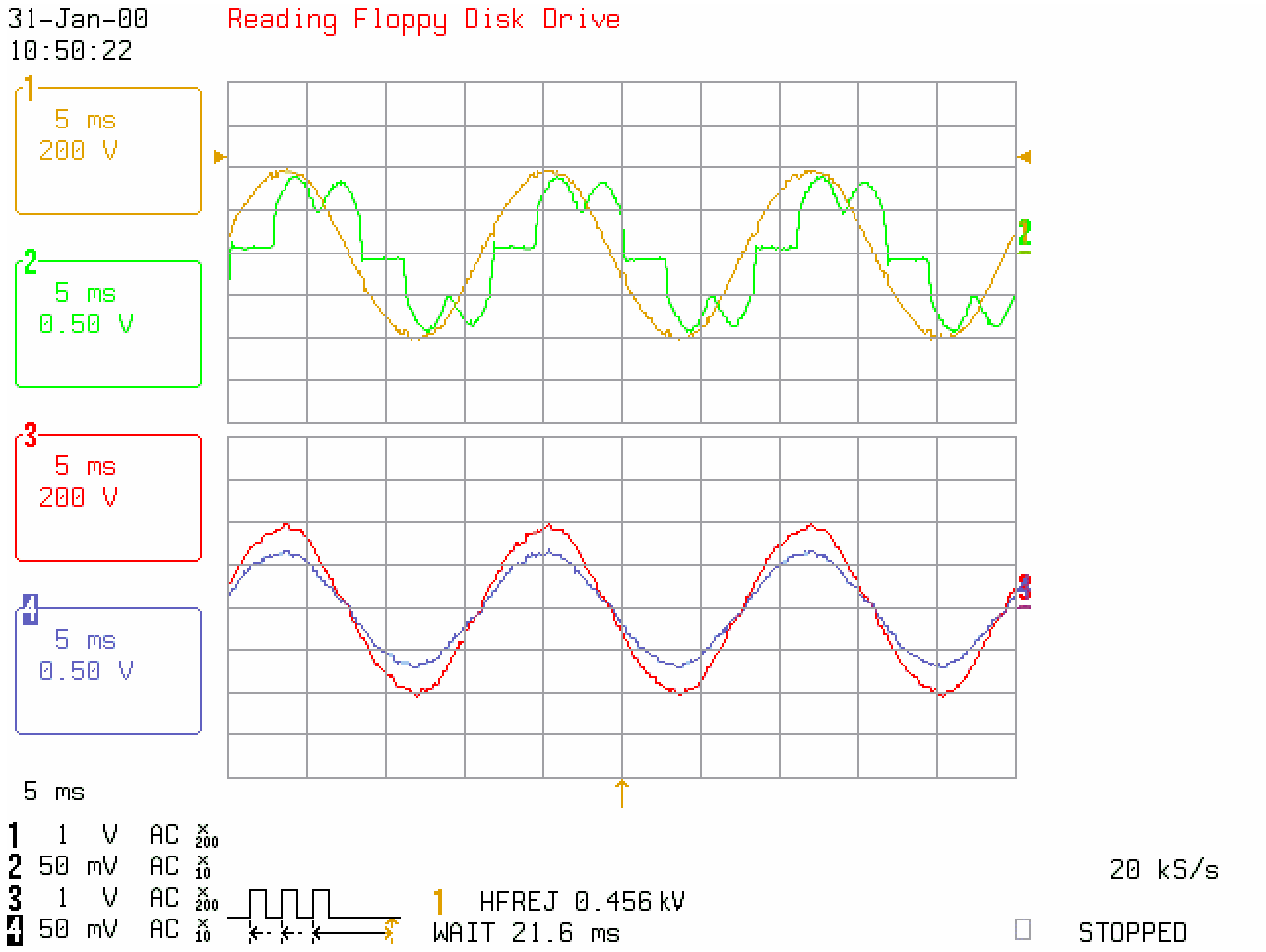

Figure 3 - *225kVA Double Conversion @ 100% kW Load*

The Delta Conversion Online™ Advantage

Power factor is the percentage of electricity that is being used to do useful work. It is expressed as a ratio. For example, a double conversion input power factor of 0.808 would mean only 80.8% of your power was being used to do useful work.

Perfect power factor is 1.0,(unity), i.e., like the Delta Conversion Online™ , meaning 100% of the power is being used for useful work. Power factor correction, then, is the method(s) used to fix the problems that cause power to be wasted. Energy is saved, and penalties levied by power companies are reduced or eliminated. The benefits of power factor correction also include reduced capital costs for installations, smaller generators, transformers, circuit breakers, cabling , etc.

Advantages of Power Factor Correction

- Eliminate Power Factor Penalties
- Increase System Capacity
- Reduce Line Losses in distribution systems
- Conserve Energy
- Improve voltage stability
- Increase equipment life
- Save on utility cost
- Less total plant KVA for the same KW working power
- Improved voltage regulation due to reduced line voltage drop
- Reduction in size of generators, transformers, cables and switchgear in new installations"

This concludes part 6 of our series. We encourage you to review the Bibliography links below. Particularly those cited in the text above (x).

Bibliography

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