ELECTRONOTES

WEBNOTE 27 9/03/2015

ENWN-27

FUN WITH "POWER FACTOR CORRECTION"

INTRODUCTION:

Early in her teaching career, a young colleague of mine was teaching a DSP course and the subject was filter banks. (I was running the lab, so was generally in the classroom.) Appropriately, she suggested to the students that the DFT, which they already knew, was an example of a filter bank. The students did not seem to get the idea, so she asked me if I had any idea about how to explain the issue further. I said that I thought that looking at Gertzel's algorithm for the DFT would be useful. [The simplest form of Gertzel's algorithm just takes a finite length-N sequence x(n) and shoves it through what looks exactly like a single-pole feedback (a filter - coefficient $e^{-j2\pi k/N}$), for each k, iteratively converging on X(k).] Largely historical even then. Her response was that she had never understood Gertzel's algorithm very well. True enough, as after class she popped into my doorway saying "Bernie – what the HELL is Gertzel's algorithm!) Well handled.

Of course, as engineers we generally have specific knowledge of (happenstance exposure to) material that is not at the "tip of the tongue" of all other engineers. These are the moments when we ask "tell me more" or just run for cover. I myself cringe and hide if someone (like my younger colleague) mentions Kalman filtering. Is there anything that most of us EEs cringe at? Perhaps the issue of "POWER FACTOR" in AC circuits, particularly as we are confronted with an advertized power-saving device displayed (usually with alarming anecdotes - about **"someone"** who does not want you to know the truth!) on the side of web pages.

So what the HELL is POWER FACTOR CORRECTION all about?

Well, first of all, energy can be stored and used later. Arriving at Cornell in Fall 1963 many of us first-term engineers of course had at least one well-equipped tool box (a metal box with tools and parts in those days!) My roommate had one that included a curious device – the biggest metal-can non-polarized capacitor I had ever seen, and it was attached to a standard AC line cord. You could plug it in and unplug it. I knew all about charging a capacitor with DC. Plugged into an AC line, what would happen? Well the capacitor took on the instantaneous AC line voltage of course. When you pull the plug, the capacitor holds the last voltage it sees, which could be anything between something like ±150 volts. The plug could then be touched to a foil chewing gum wrapper and burn in an impressive hole (or perhaps only a tiny spark or none at all). Sparks are disconcerting enough to many people even when anticipated. When even the perpetrator did not know what was coming, that metal can was additionally useful to torment those nearby. But clearly, the capacitor could hold energy (charge) for later use.

Most freshman engineers (in those days) knew a reasonable deal about practical electronics. We understood Chuck's intimidating metal can. We had not yet appreciated any duality of capacitors and inductors, although we knew that a magnetic field was induced when a current was passed through a conductor, and that when the field collapsed, a current could then flow. Somehow, none of us wound a coil of ordinary wire across the AC plug and attempted to plug it in. We knew the result would be a search for the janitor to replace a fuse. Still, we had acceptable inductors – the primaries of metal-core transformers. We could power them up. But when we pulled the plug, we couldn't carry them to the gum wrapper to discharge. Whatever happened seemed to happen very quickly well behind the plug. The lack of magnetic monopoles was not part of our worldview.

Eventually the theories associated with AC circuits would become part of our "electrical science" curriculum with the additional annoyances that these things did not seem particularly real, even to the extent that we enjoyed electronics back in high school. Somehow, the notion of "power factor" got by, perhaps because it may have been uncomfortable even to the instructors.

I think that today "power factor" is enjoying a revival because the term (like quantum elixir, entropy, vacuum-energy, etc?) has become a fixture of so many sidebars of web pages. These are far from being uniform, but most offer a miracle cure or "free energy" or just a plug-in that saves you 1/3 on your energy bill. A gamut of possible motives seem not only apparent, but plausible. Many are ordinary scams – the "originators" know better. But sometimes the proponents are apparently just hapless dupes in a pyramid. Then there are the debunkers – some of whom have the right conclusions, but not all explain it well enough. In Essence: THERE IS NO SUCH THING AS A FREE LUNCH. If you run into YouTube, you will get a mess to sort out. Here are two excellent (correct) explanations:

https://www.youtube.com/watch?v=b7-TFJZTMeA

which is a whiteboard and lab-demo presentation (several parts – well worth the time)

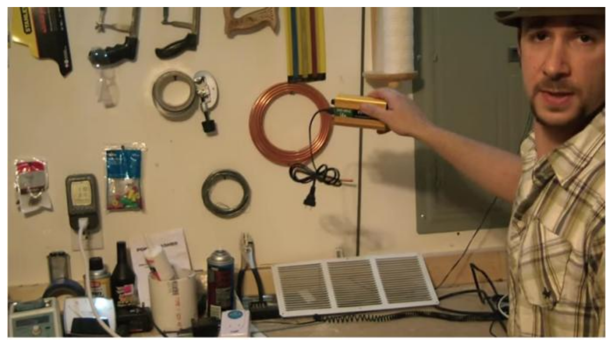
and:

http://www.allaboutcircuits.com/textbook/alternating-current/chpt-11/calculating-power-factor/

which is a good text presentation (also see various parts).

For an excellent presentation that the little boxes don't work, see the link with the guy in the Robin Hood hat. This is a hoot because he thought (apparently) he was showing that it DID work.

https://www.youtube.com/watch?v=Y9ly8tfI7GA



At right "Pete" who has been showing the current decreasing from 1.87 amps to 1.52 amps discovers that when he pushes the meter button for watts (power – which is what you actually pay for) **remains** the same at 110 watts. **NOT A CLUE!** He says *"Still the same. That's kind of interesting."* REALLY – Just Interesting?

IN A NUTSHELL

(1) If your household electric service were a purely resistive load (incandescent bulbs, electric stove, etc) you would have a Power Factor (PF) or 1.0. Your current would be exactly in phase with the voltage.

(2) But you have non-resistive loads (like inductive refrigerator motors) and non-linear loads (like CFL bulbs) and just about everything else (including the power supplies like we have been building for 40 years), so you have a PF less than 1 – almost certainly an inductive lag. BUT YOU DON'T REALLY CARE.

(3) Very careful measurements and calculations (including the variable times appliances are actually on) might allow you to "correct" each and every assault on a unity PF within your household. Mostly, these would be capacitors added across the mains reasonably close to the appliance. In some cases, this would involve L-C filtering for harmonics.

(4) A typical “power-saver box” is just a fixed capacitor (one time guess) with some LEDs to show it is on (and hopefully, “bleeder” resistors – remember Chuck’s toolbox). You plug it in about anywhere (sometimes fixed wired to you breaker panel). Likely it will, to a degree, “correct” (or overcorrect) an inductive load. The gadget will cost you money. Your power bill will not change (perhaps go up 1% or so).

(5) What is happening is that you may reduce some “reactive power” which is the VA (volt-amps) manifestation depending on phase angle, NOT THE WATTS. This reactive component (in and out of the power company grid) involves actual currents which may cause minor excess heating in cables (or require larger cables). Mainly, the currents are borrowed and paid back (not dissipated as heat).

(6) Note that for fixed watts, an out-of-phase current will need to be higher. If you correct the phase angle, the current will be lower. [Signal processing engineers: note the similarity of computing VA and in calculating a Fourier Series coefficient.] This lower current is exactly what the believers will demonstrate (and confuse amps with power). See Pete above!

(7) Next suppose you are not a household but rather a large commercial user with relatively fixed loading (perhaps with water-supply pumps running 24/7/365). The power company looks at you and says – hey – your PF is 0.6, you are costing us money. We couldn’t be bothered with the 0.9 PF in your little house, but your commercial operation is big. Note that the issue is not “stolen power” (both household and businesses pay fully for watts which remain the same) or even an issue of the low value of the PF, but the totality of the reactive power, AND the fact that remediation is practical. So it is easy for the power company to incentivize by a surcharge for a low PF.