The Inefficiency of PQ

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The other day I received a phone call from a colleague from the NFPA 70B Electrical Equipment Maintenance Committee concerning any statistics that I had relative to energy efficiency and power quality. There are plenty of statistics about the financial impacts of power quality phenomena on productivity. A typical textile mill will experience a $10K loss when a sag causes a difference in torque on the drums, resulting in the fiber breaking. Or there are the financial institutions, such as the stock markets, where losses are measured in millions of dollars or more per minute of downtime. But efficiency and PQ, that was a new question for me.

It turns out that there are a number of factors where the two are related. One of the most significant is in the mitigation devices used to minimize the effects of transients, sags, swells, interruptions and harmonics. Obviously, unless we can disprove the conservation of energy laws, anything device put in the circuit between two points will result in losses, hence lower efficiency than just a plain wire. Transient voltage surge surpressors or TVSS devices are used today in distribution panels as well as within most electronic equipment. These devices '"eat" up transients above a specified voltage level. However, in systems with significant voltage distortion resulting in high crest factors or peaks of the voltage waves, these devices can be forced to clamp the voltage on each cycle. This results in efficiency losses, as that energy doesn't make it to the load.

There are devices that can use the electricity more efficiently than is presently being used, though these also can have impacts when lightly loaded, such as the decrease in power factor of rectified input-switching power supplies in adjustable speed drives when lightly loaded. Many of these devices may actually introduce potential power quality related problems, such as increased harmonic currents. Harmonic currents result in higher losses in transformers, especially with higher order harmonics.

A typical six-pulse converter (full wave, three phase) will produce significant harmonics of the 5, 7, 11, 13, 17 and 19th, and so on. A more energy efficient and lower harmonic distortion 12 pulse converter will produce harmonics of the 23, 25, 35, 37, ... The eddy current and other frequency-dependent losses are a function of the square of the harmonic number (or frequency). Hence, the losses at the 3rd harmonic would be a factor of 9, compared to the 13th, which would have a factor of 169, or 19 times greater losses than the 3rd harmonic if the current levels were the same. The transformer must be derated, which may mean adding an additional or larger size transformer to maintain the load. Transformers can also experience higher losses when there are half-wave rectifiers drawing unsymmetrical current, which is an effective DC offset on the transformer's magnetic curves. Harmonic currents can also resulting in fluting of the bearings of grounded motor shafts. This can result in increased drag, hence higher losses in the motor and lower efficiency.

Voltage unbalance, often considered in the PQ realm of things, is an enemy of electric motors also. The NEMA MG-1 book can provide information as the significant impact of just a 3% unbalance. Some people considered sustained low voltage levels or interruptions to be a power quality phenomena. These are more likely to be considered "reliability" issues from an electric utility stand point, rather that power quality. Depending on the type of load, they can result in efficiency changes.

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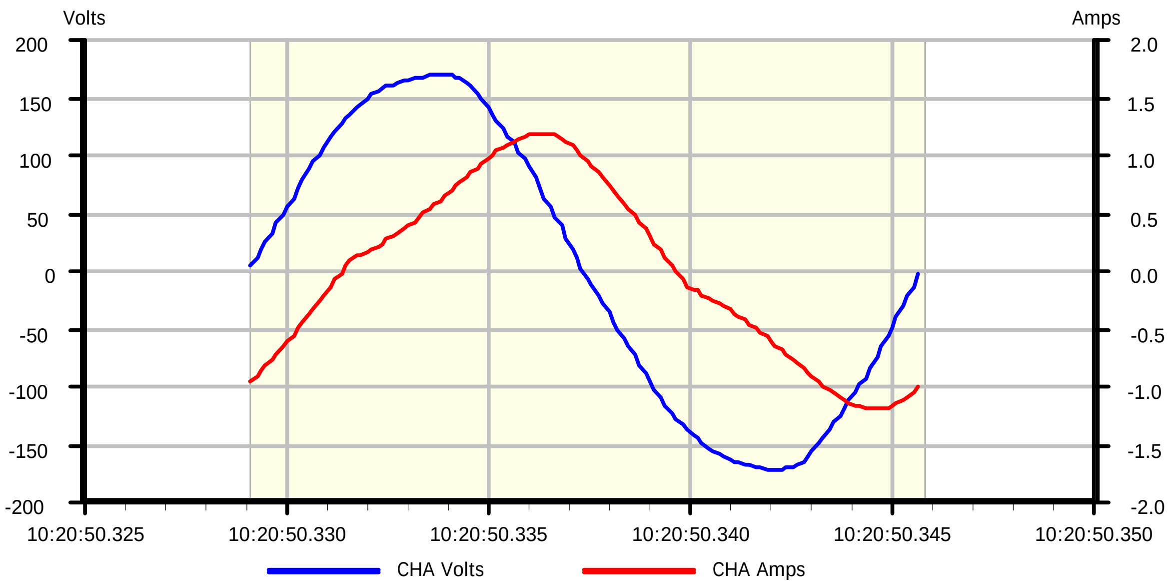
There are even some people who consider power factor to be a power quality problem, and sell devices under the power quality banner that correct for power factor. Most of us PQ traditionalists don't see it that way, but everyone is entitled to their opinion. However, some energy efficient devices do effect power quality, as well as power factor. For example, some of the compact fluorescent lamps that are used to replace incandescents can consume less energy, but at the expense of decreased power factors and even introducing transients during start-up. The figures below show the significant phase difference between the voltage and current, with a resulting PF of 0.8, as well as some 400V transients produced by the lamp during start-up.

So, yes, Virginia, I guess there is a bit of correlation between efficiency and power quality phenomena, though it would be a challenge to produce meaningful statistics on it.

Event waveform/detail



Meter mode snapshot at 10:20:52.000

Unit	A	B	C	D	ABC
V	122.1	0.2	0.1	0.4	122.1
I	0.8	0.0	0.0	0.0	0.8
kW	0.1	0.0	0.0	0.0	0.1
kVA	0.1	0.0	0.0	0.0	0.1
kVAR	0.1	0.0	0.0	0.0	0.1
PF	0.555	0.000	0.000	0.000	0.555
Vunbal					0.0
HZ	60.0	0.0	0.0	0.0	

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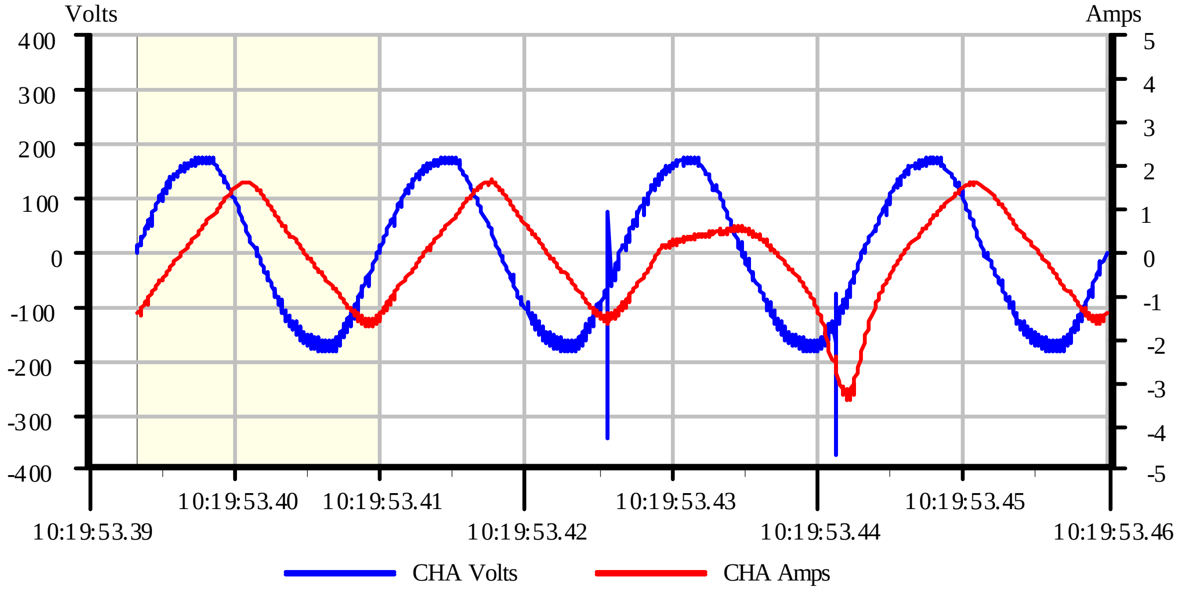

Pre/Post-trigger at 10:19:53.393

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