Metering And Testing With Advanced Instruments

In discussion with technical colleagues, the topic of "dirty" electricity came up. As I reviewed the easily accessible literature, it became obvious that the various presentations were either erroneous by ignorance, or erroneous by deception in order to achieve some business goal. I decided to try my hand at assessing what I could, and present it for review by others who might find it relevant.

Basic pre-test requirements and foundational facts:

1) The environment assessed does not have any wiring errors that can produce Magnetic fields in free space (*without wiring errors, the supply and return currents' respective magnetic fields overlap, and being of opposite orientation, cancel, except in the immediate vicinity of the cable*).

2) The environment assessed does not have shared / redundant / parallel Neutral return current paths, that can create a Magnetic field in free space (*any pre-existing externally-sourced magnetic fields needed to be accounted for, to determine if any internal contribution interacted with them*).

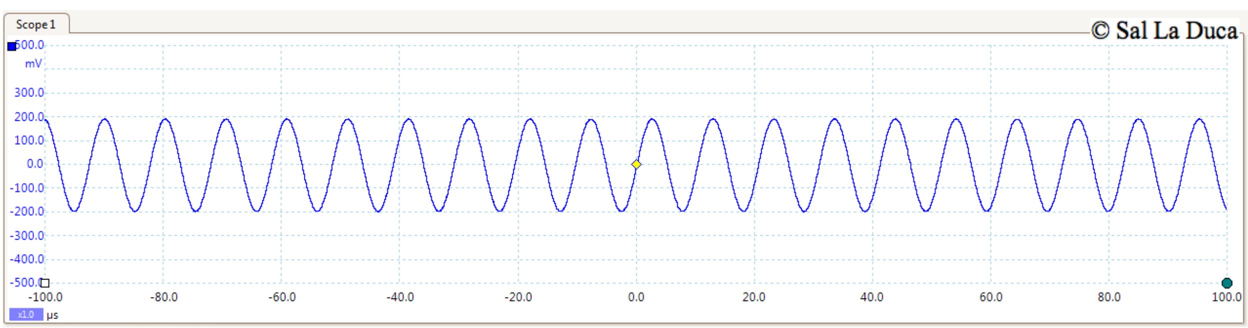
3) The monitoring / assessing equipment needs to be operated on batteries.

4) The monitoring / assessing equipment needs to be qualified as for flatlining without an input, and properly rendering known inputs.

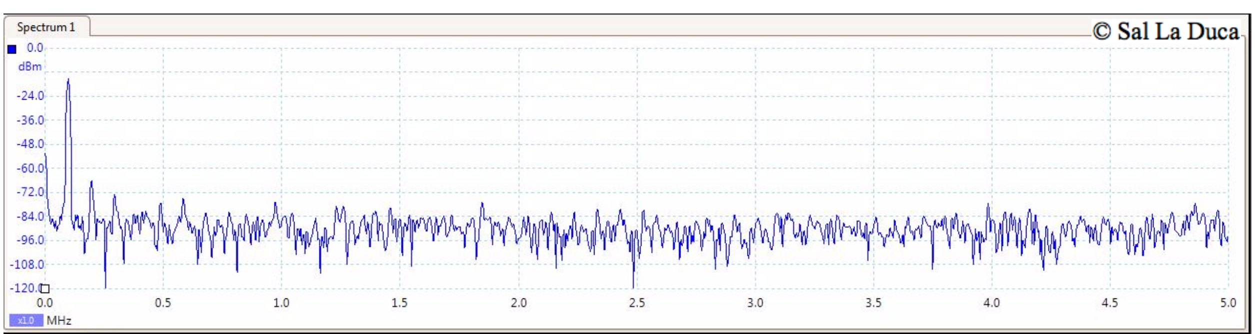
5) The monitoring / assessing equipment needs to be operated in a fashion that is unambiguous.

6) The voltage baseline had to be as expected in North America, being 120V +/- 4%, 60 Hz.

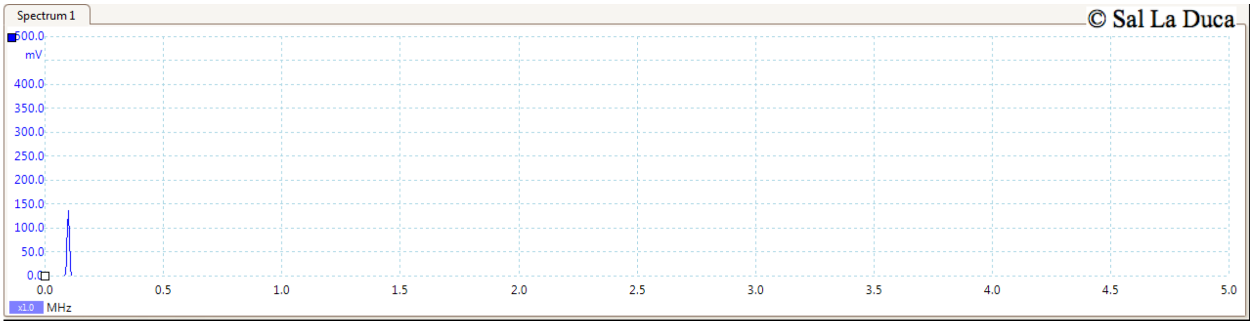
7) **Within the engineering design of the system observed, everything can be turned on, without affecting the supply voltage of 120V by more than about 2%.**



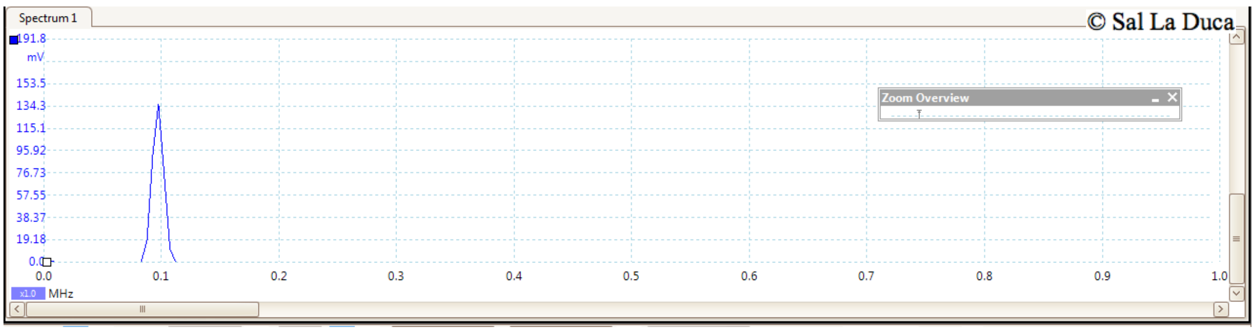
I began with a Picoscope (*a computer-driven oscilloscope / spectrum analyzer*) capable to 5 MHz, and used an external signal generator to feed it a 100kHz sine wave at about 100 mV. The <u>time base per cycle</u> would be 1/100,000 = 10 microseconds, or 10μs, as shown above, which is a satisfactory display.



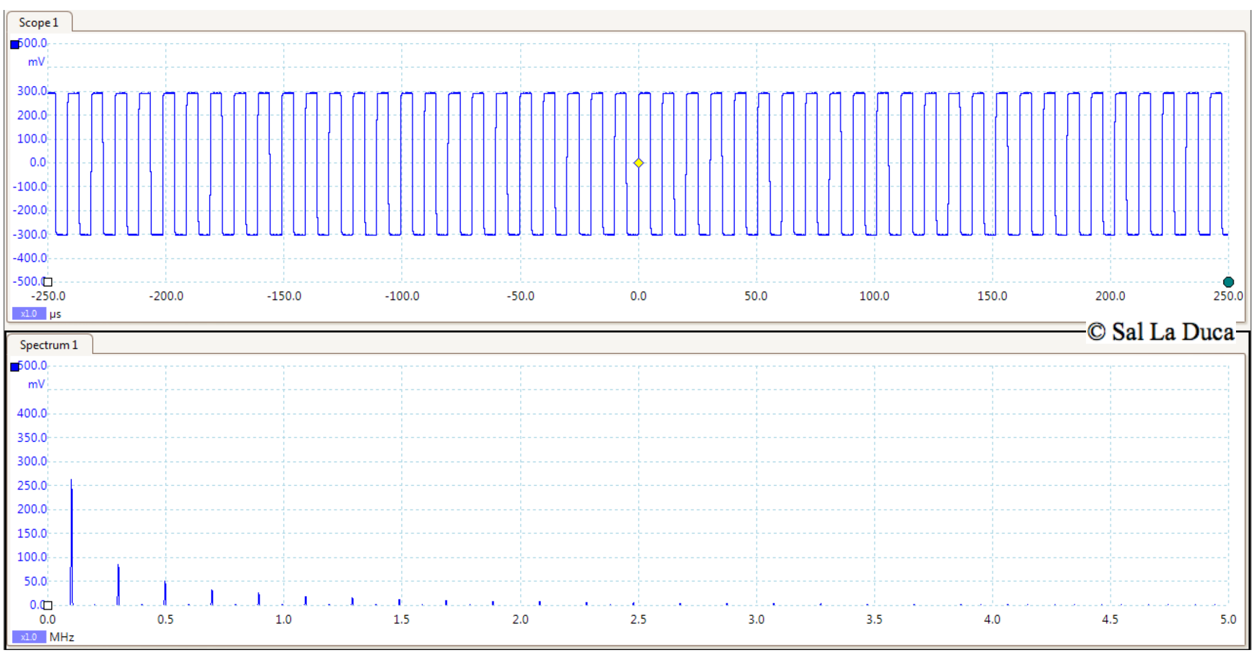
However the spectrum analyzer vertical setting was Logarithmic as above, revealing the device's internal noise, which was not desirable. So I set the spectrum analyzer to Linear, which removed the internal noise and cleanly provided the signal being generated by my previous setting, as shown below.



As shown, the 100 KHz was located where I expected it, so I almost deemed that acceptable. But wanting to verify I was actually seeing the injected 100 kHz, I zoomed in frequency-wise, and seeing nothing but the intended signal (*0.1 MHz = 100 kHz*) I deemed that acceptable.



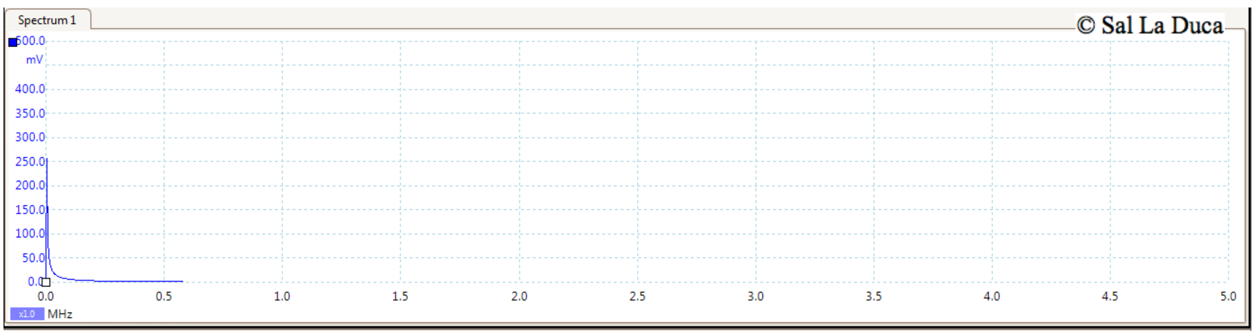
I then switched the external signal to a Square wave, bumped up the amplitude to about 300 mV, and acquired the graphs below. The waveform and spectrum displays were acceptable as the square wave was clean.



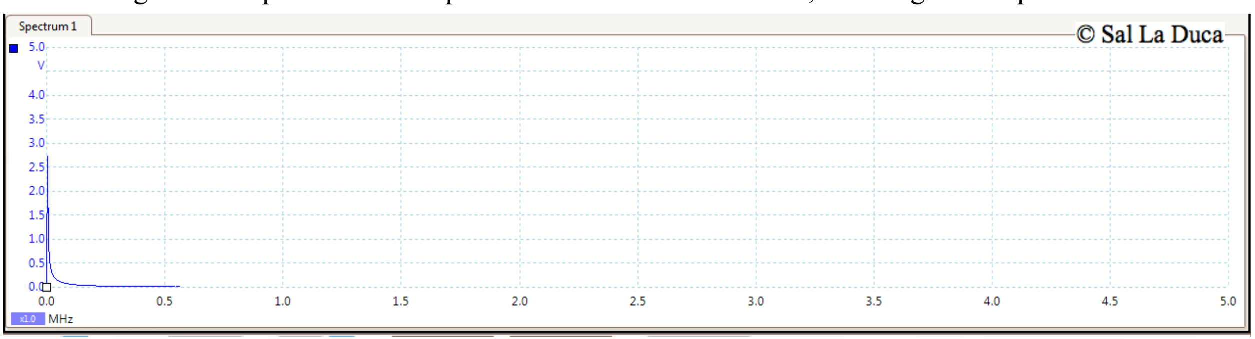
I zoomed in vertically on the spectrum display to verify Harmonic frequencies, and only the Odd Harmonic multiples of the Fundamental (100 kHz) were displayed, as should be expected of a wave that is symmetrical about its midline. That is, equal distance traveled above the zero reference, as below it.

When symmetry is lacking Odd <u>and</u> Even Harmonics are displayed. The harmonics shown are 100kHz, 300 kHz, 500 kHz, 700 kHz, shown as 0.1 MHz, 0.3 MHz, 0.5 MHz, 0.7 MHz, etc.

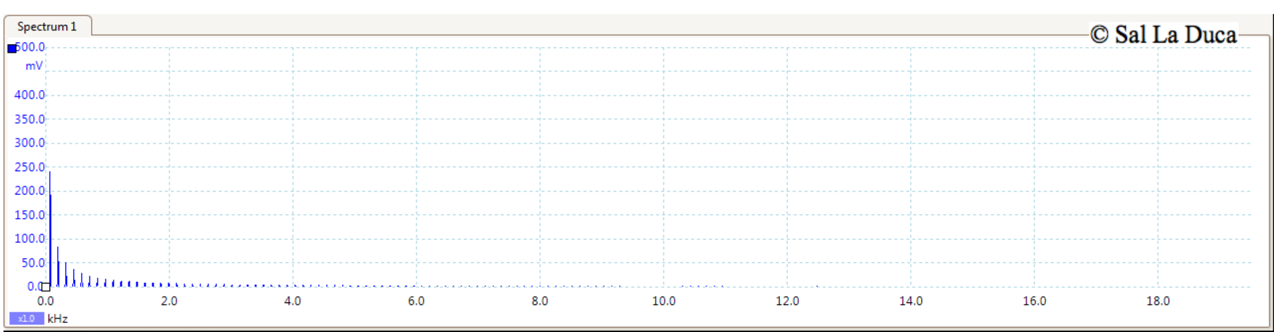
I then changed the external oscillator to 64 Hz, and kept the square wave, resulting in the spectrum below.



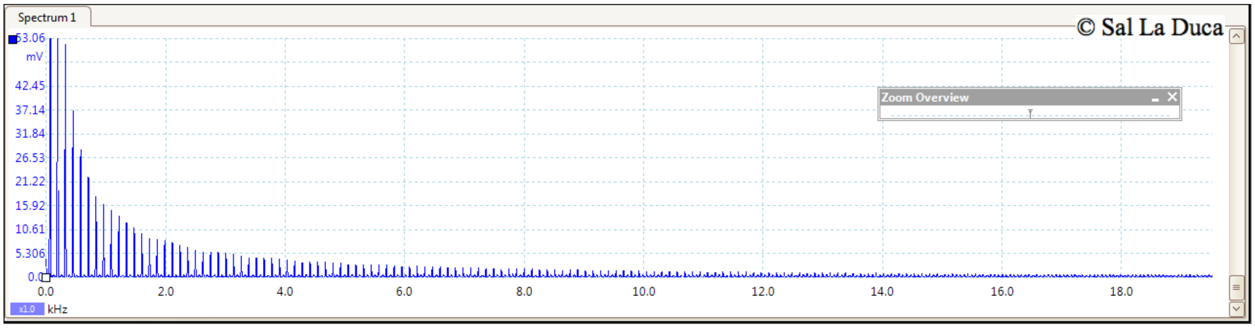
I then changed the amplitude of the square wave from 300 mV to 3V, resulting in the spectrum below.



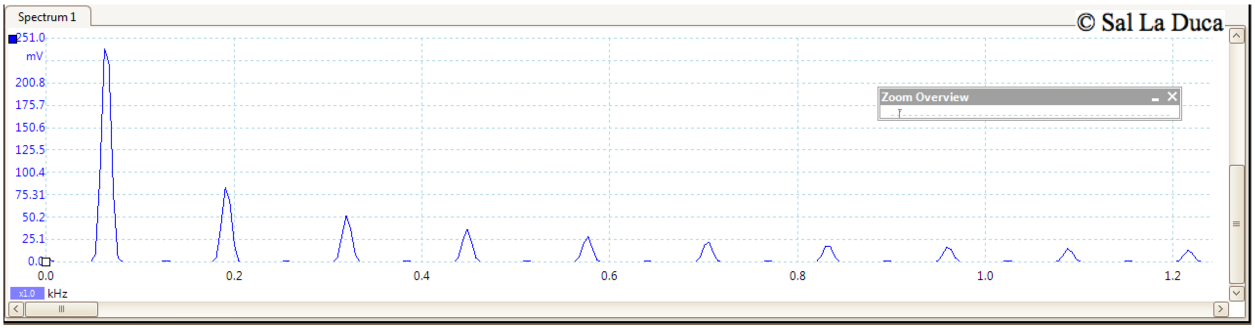
It might appear that all relevant activity is happening exclusively below about 0.5 MHz / 500 kHz, regardless of amplitude. I reset the input to 300 mV. I progressively zoomed in for detail, and as I did, the detail remained about the same until I zoomed down to 20 kHz, achieving the spectrum display below.



I then zoomed in vertically to get a "clearer" view of the strongest harmonics.

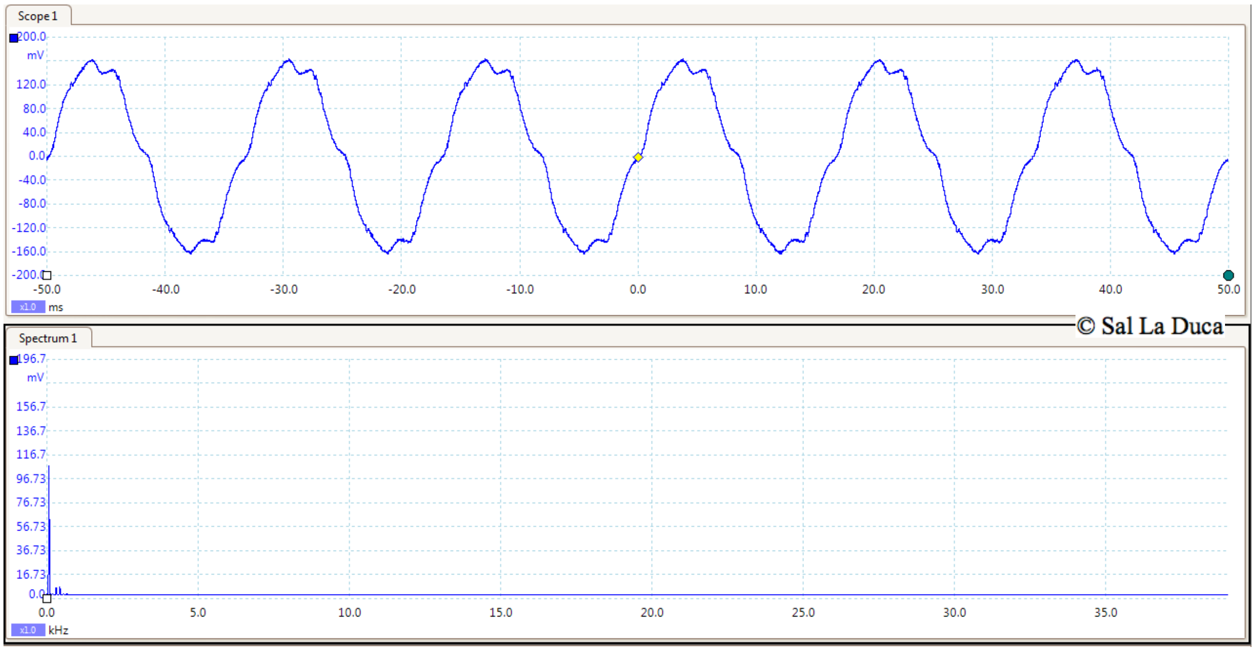


To verify the injected signal frequency of 64 Hz, the Fundamental, and the first bunch of harmonics, I zoomed in horizontally. As shown below, they would 64 Hz, 64x3 (192), 64x5 (320), 64x7, 64x9, etc.

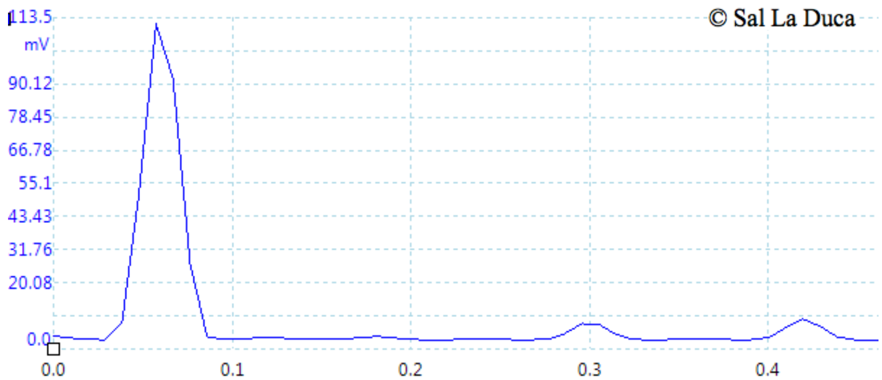


I now felt I could use the instrument to look at the power system.

I connected to the 120V by wrapping a sensing wire around the energized wire, and the reference wire around the neutral, acquiring the graphic below.

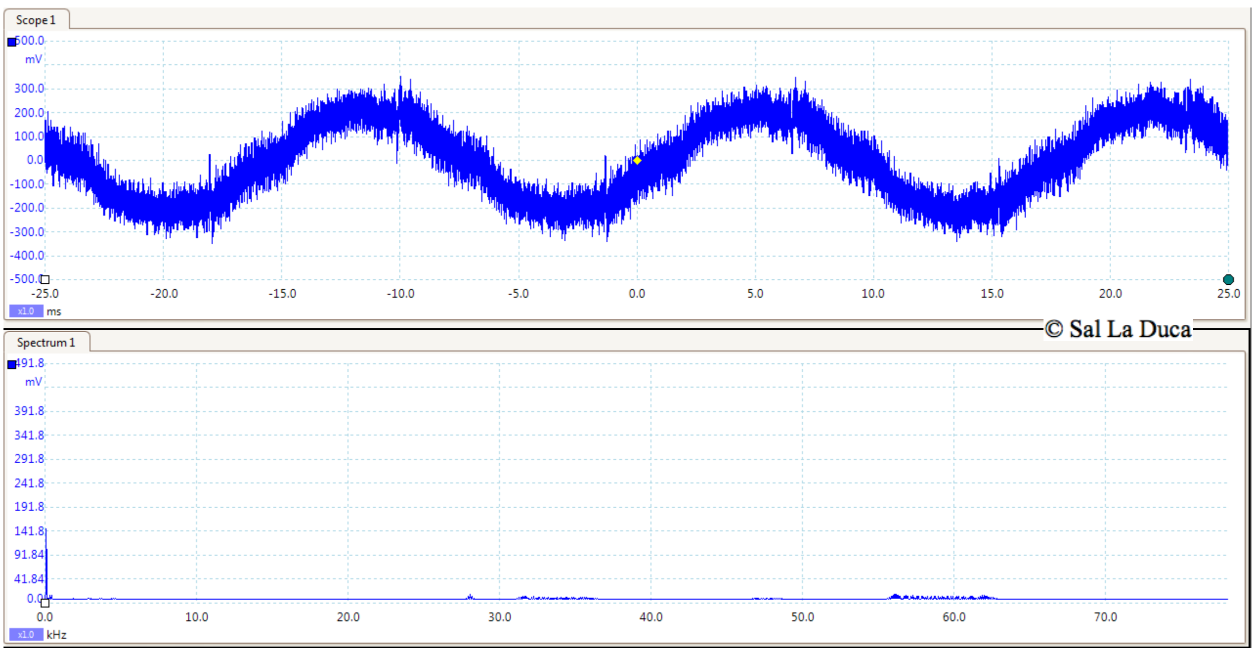


With insulation around the wires, this was capacitive coupling. There were no loads "downstream" of where I connected, although there might have been loads on the circuit "upstream." That is, toward the breaker panel.

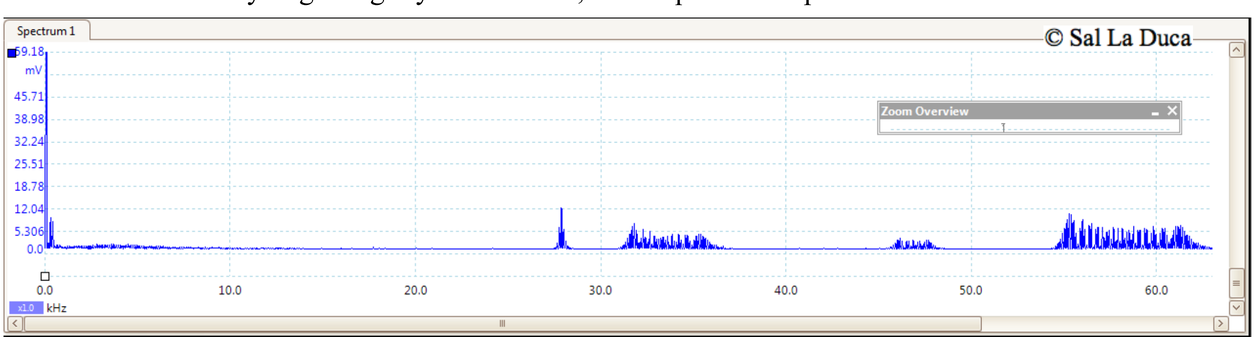


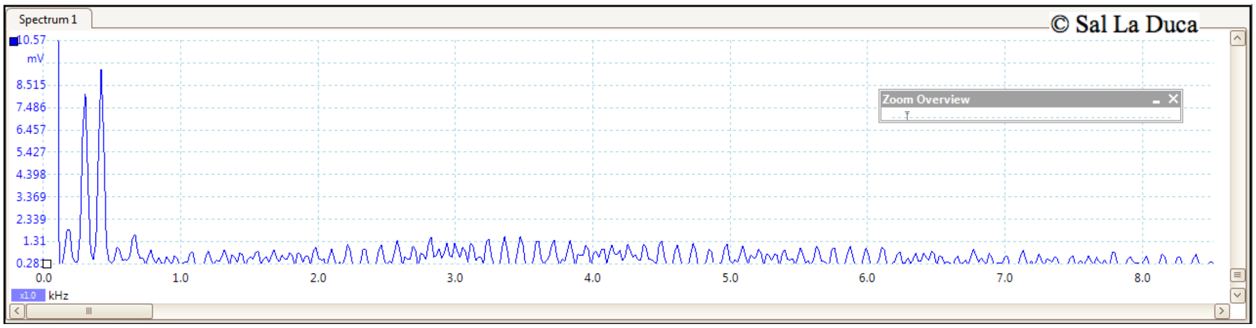
In the above display I was interested in a little more detail of the harmonics. I zoomed in to get detail (*perhaps excessively*) and noted 60 Hz, 300 Hz, and 420 Hz, shown as 0.06, 0.3, and 0.42 kHz respectively. I also noted the 300 and 420 Hz harmonics a bit short of 10 mV, while the fundamental is about 110 mV, so the waveform distortion is below 10%.

I powered up several CFLs from different vendors totaling about 860 mA, and captured the graph below.



I zoomed in vertically to get slightly better detail, and acquired the spectrum below.





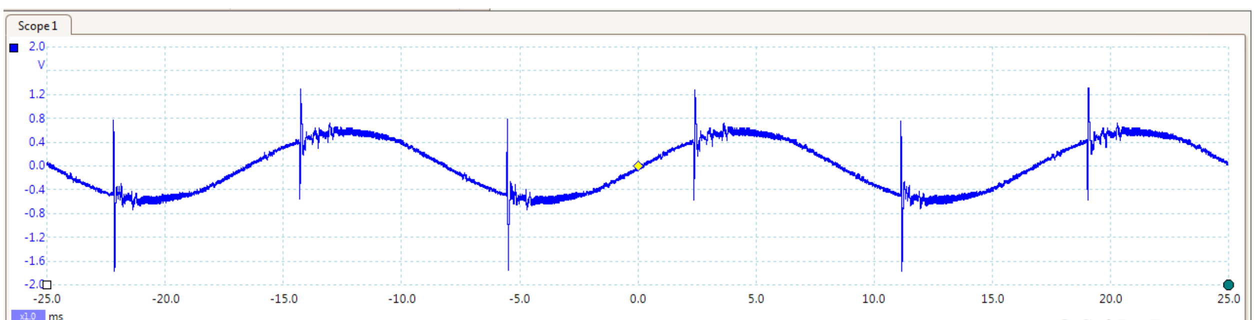
While lower in the audio range, I saw the above. The lowest peak to the extreme left, extending beyond the top of the graph is the 60 Hz, then 180, 300, 420, 540, 660, etc.

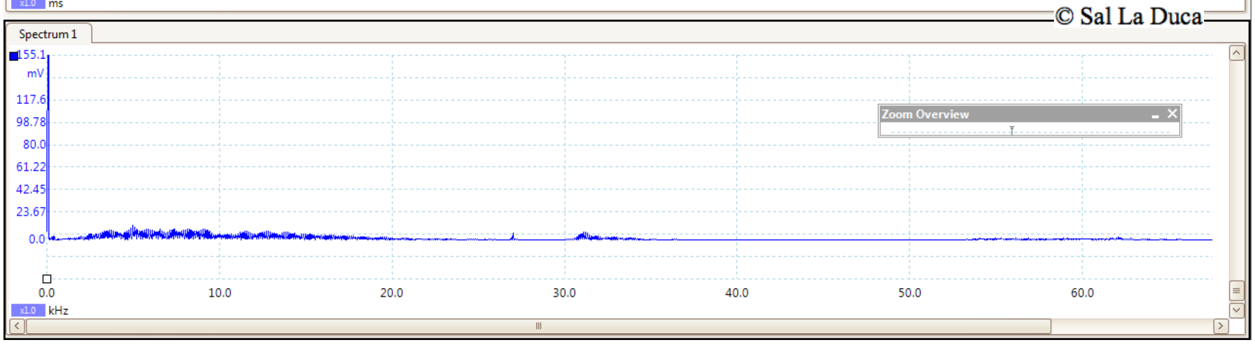
I powered down the CFLs, and plugged in a DE meter that read about 70. I turned on the CFLs once more. The DE meter now read 570. I plugged in a DE filter. The DE meter dropped to about 50.
The display showing harmonic content remained unchanged.

I connected the Picoscope through a "ubiquitous DE filter," hereinafter the "*ubi*,"and detected 0.4VAC with an RMS DMM, 0.8 VAC Peak with the Picoscope, except for the digital spikes.

I momentarily connected the PC to AC power for charging, but the difference between the charger's frame of reference through the Picoscope, and hard contact to the "ubi" filter output, expressed 40 V or more potential difference, causing the Picoscope to display a top-and-bottom-clipped sine wave, and warning of input overload. Not being nice to your instruments can ruin your day . . .

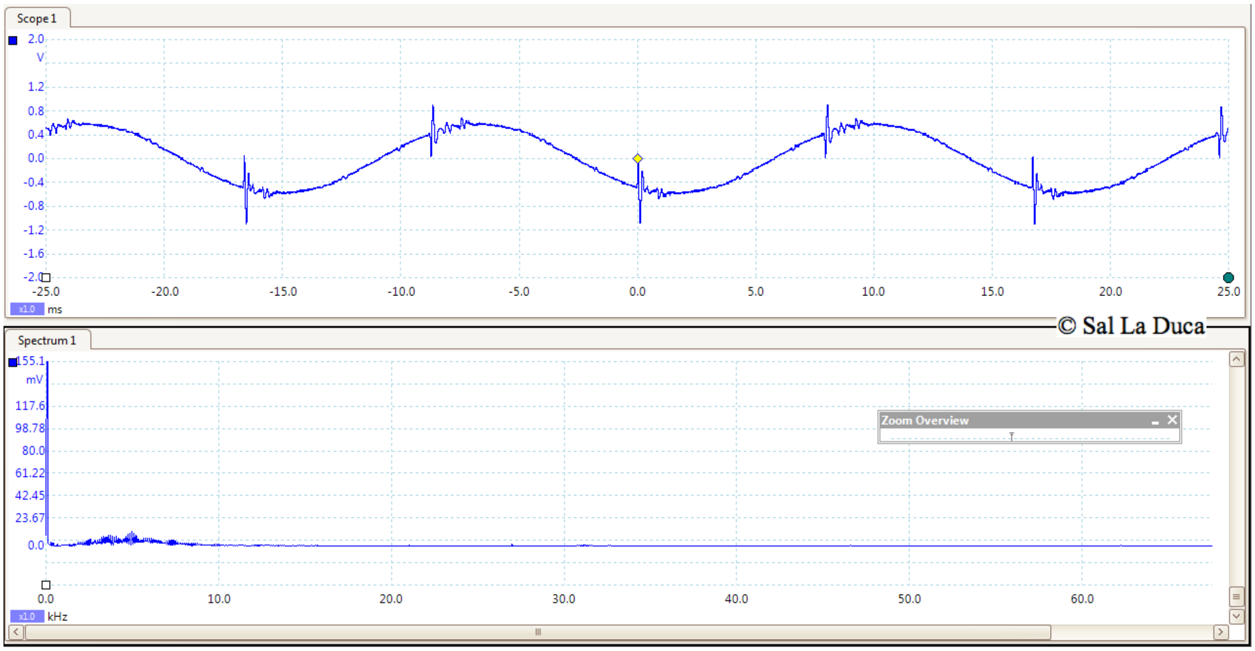
The waveform and spectrum through the "ubi" filter, with the PC on battery, with the CFLs on, is below.





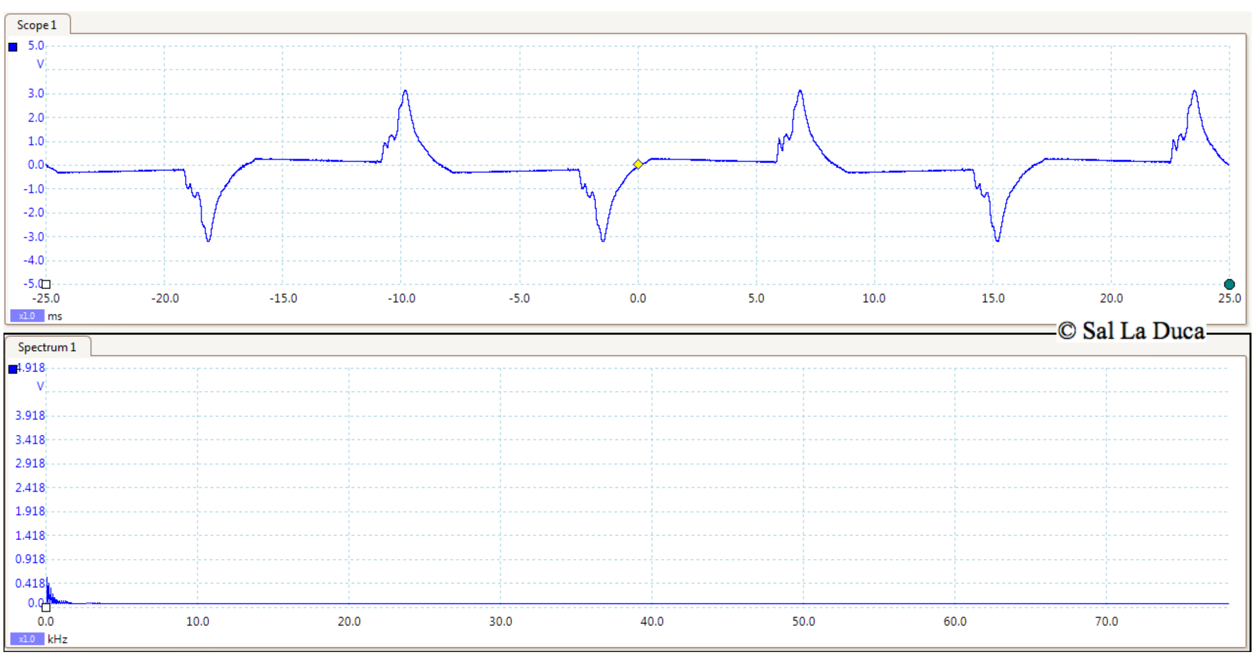
Compare the "ubi" filtered spectrum above, with the unaltered one on the bottom of page 5.
It appears the "ubi" filter provides a different "reality."

The waveform and spectrum, through the “ubi” filter, <u>with the CFLs on, AND a DE filter,</u> is below.

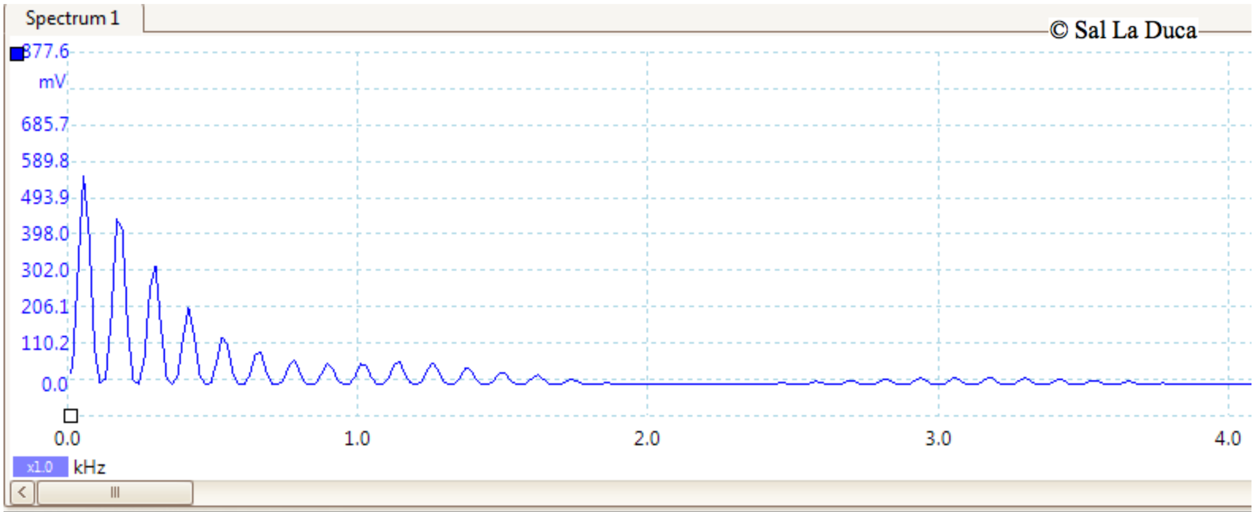


Lots of change, heh? You are left to guess how the “ubi” filter is “massaging” your data. From the little experience I have of safely operating a nuclear power plant, and a bulk power transmission systems, I’ve had the necessity to properly assess electrical signals of various origin, in order to employ any appropriate corrective measures. I fail to appreciate what the “ubi” filter does, other than maybe slick marketing . . .

While all the previous graphs considered Voltage only, I then looked at the Current of the CFLs, as below.

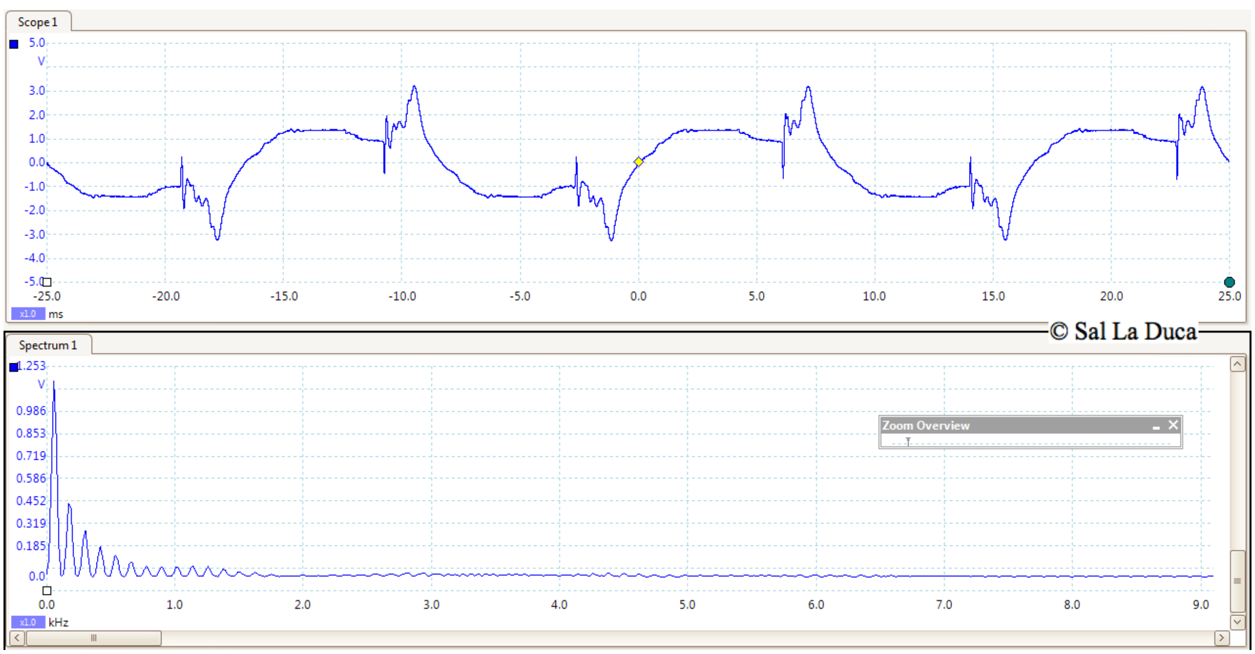


With a slight zoom on the low end of the harmonics below. Shown are 60, 180, 300, 420, etc.



Waveform distortion from 60 Hz sine, about 80%.

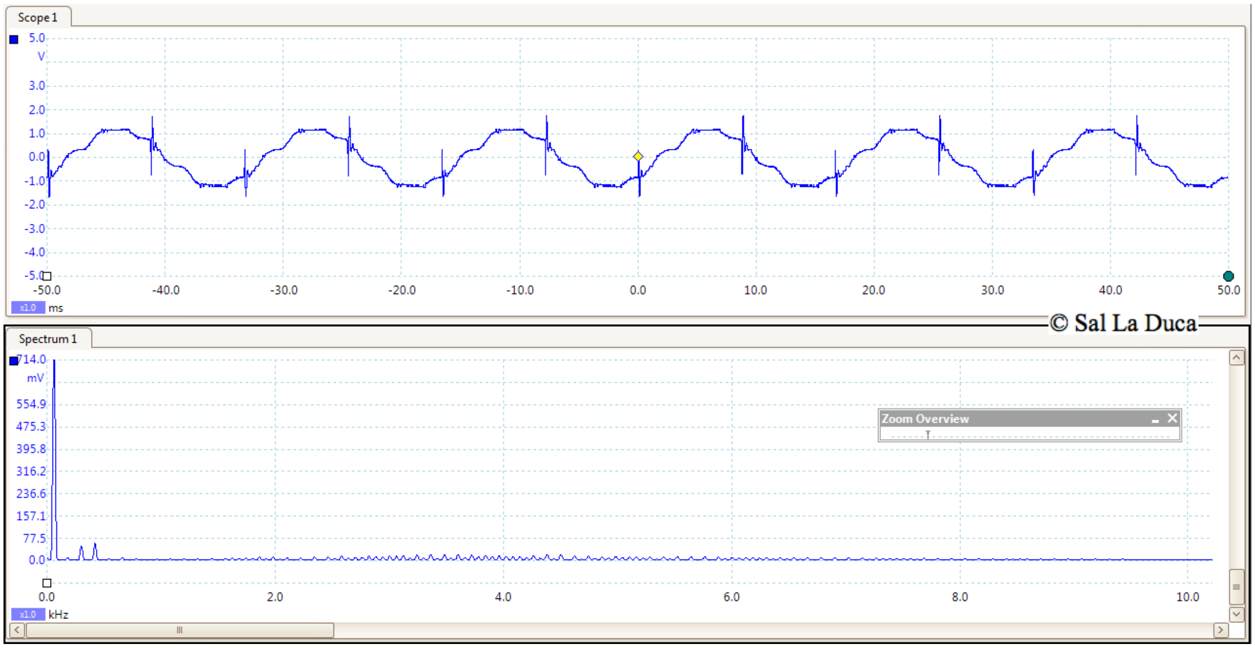
I then plugged in a DE filter, and noted the waveform and spectrum below.



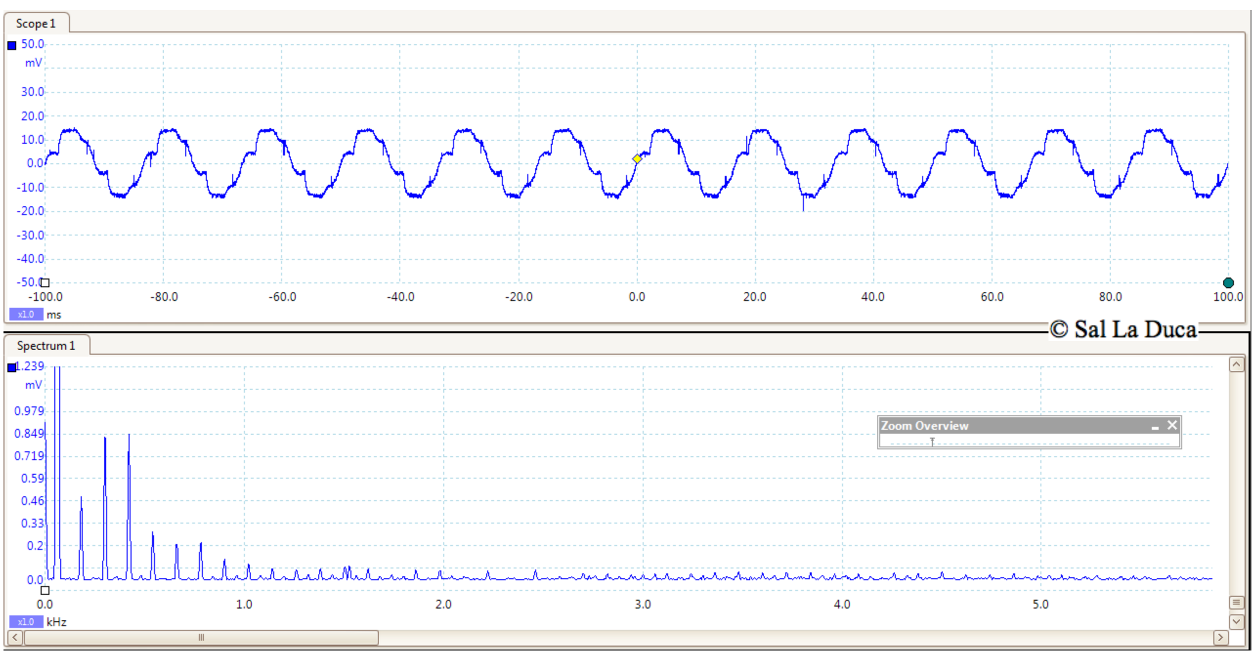
Waveform distortion from 60 Hz sine, about 45%. Note that the harmonic frequencies present in the previous graph are still there, at about the same amplitude (*which should make you wonder*). However, due to the now greater 60 Hz current demand, in perspective they might appear less "relevant."

Electric field measurement in circuit as done here, is little different than electric field measurement in free space, except for emphasis of harmonics due to different polarity buses in the latter. The same sensor can be used for both. Current measurement in circuit as done here, is little different from magnetic field measurement in free space. The same sensor can be used for both.

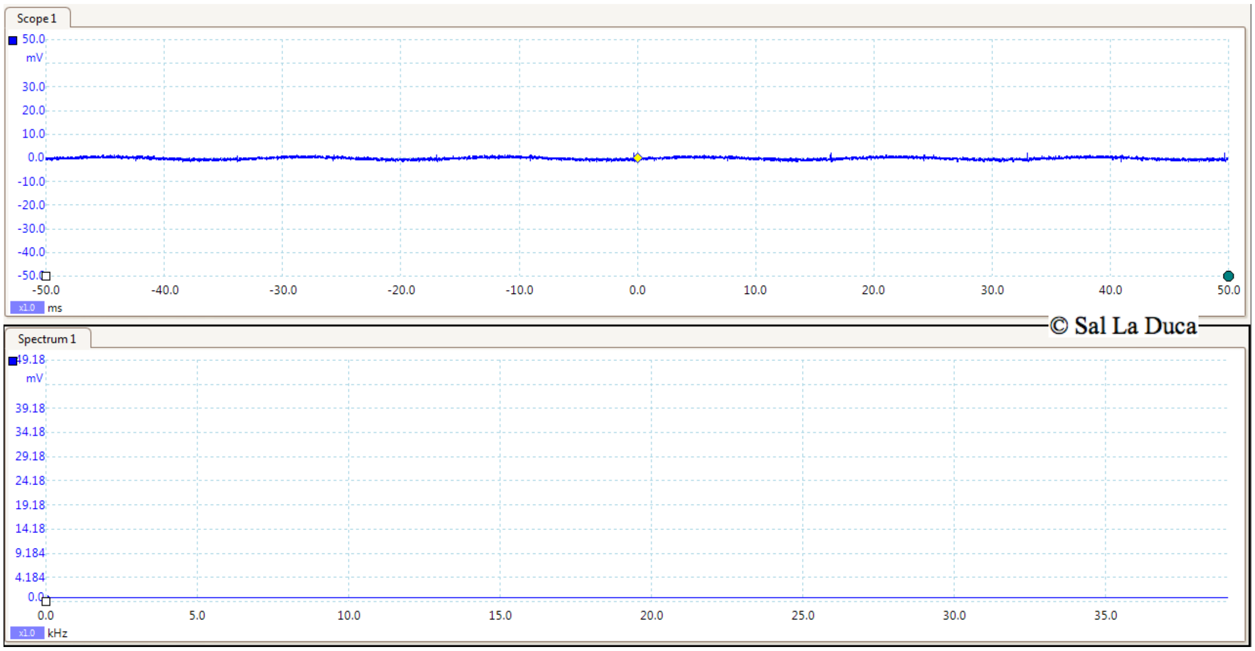
I then turned off the CFLs, and looked at the current used by the DE filter, and DE meter, below.



I then unplugged the DE "filter," and after zooming in a bit, looked at the current used by the DE meter only, below.

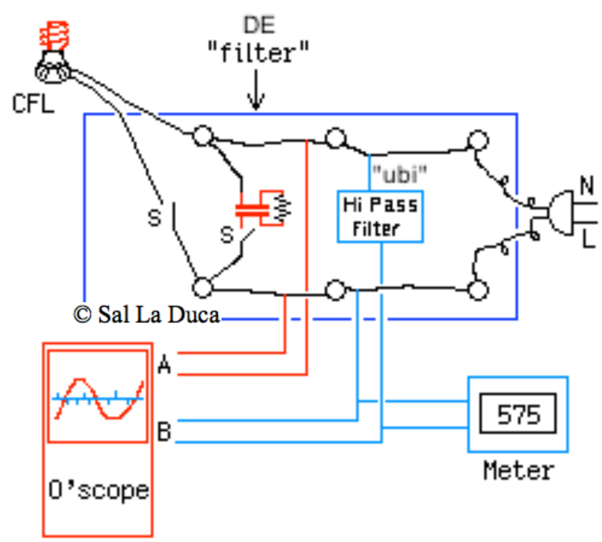


I then unplugged all current users, and was left with the Picoscope flatlining, below.



The Windows PC has a touchpad with a sensing frequency of about 51kHz. Depending on the instrument settings, this can present itself as a phantom noise source around 26 kHz, but only if the touchpad is in use.

The methodology for measuring power system harmonics has long been established. Its constraints are strictly imposed on industry to prevent compromising the power quality for other users at large. While the "dirty electricity" phenomenon is recent, perhaps 20 years, several vendors have joined the money train. Yet the electrical "dirt" has been present on most electric systems to some degree since electricity has been available, more than 100 years. The nonstandard, but popularized, arrangement is shown below.



In this arrangement, an oscilloscope is connected directly to the 120V to acquire the sine waveform (*the red trace on the simulated o-scope screen below*). Another input is connected to the o'scope second channel, this being the output of a "ubi" filter to block most frequencies below about 4 kHz. Somehow, this second channel (*the blue trace*) is supposed to represent an aggregate of the higher frequency content, but gives no specific frequency information.

What I attempt to show here, is that with reasonably inexpensive instruments (*and without the popularized test scheme and tools noted*) you can get an immediate and complete visual display, giving exact frequency information. No guessing involved, and no "ubi" filter to distort measurement needed.

Yet some consultants proceed to measure various outlets with a DE meter, and promote filter installation as a panacea that will make your home electrically "clean."

This could not be further from the truth (*and in many cases it will make conditions worse*).

But, of course, this is only my opinion . . . (*and that of my clients*).

Some conclusions:

1) **If the voltage has harmonic content to begin with, linear current users, such as incandescent lamps, will have the same harmonics in their current.**

2) If pre-conditions # 1 and # 2 listed on page 1 are not met, these will need to be resolved, as free space magnetic field testing will otherwise replicate circuit testing described here.

3) With no a) wiring errors, b) external power line fields, and c) no relevant levels of stray current through systems grounded together, magnetic fields will not exist except immediately near cabling, so ambient magnetic field measurement is unnecessary and irrelevant.

3) If there are magnetic fields *(excluding those from external power lines*) the harmonics content will be a much more significant portion of the field. This has strong implications for Gaussmeters that do not measure the fields with RMS constraints, as they may display a value as much as 50x the real field. These fields can be eliminated.

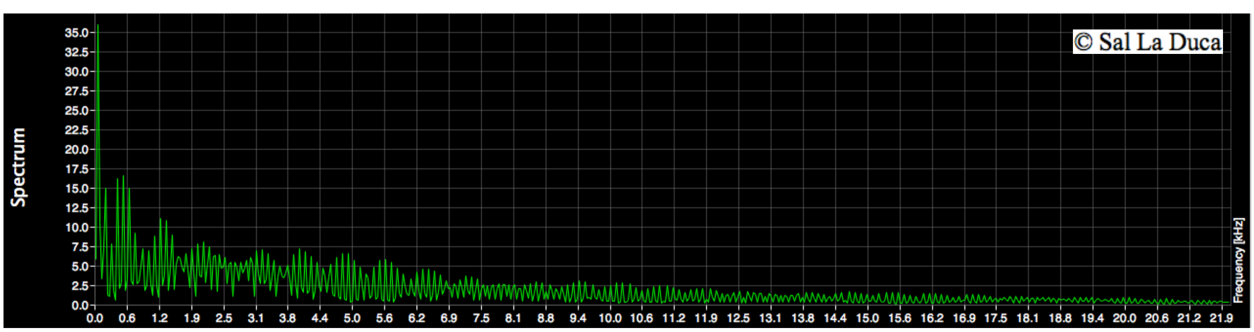
4) The character of harmonics is similar to that on top of page 8. The Fundamental, or source frequency, is always there, and its "echoes" will progressively get smaller as the frequency increases, or should.

5) The use of a "ubi" filter gives a false sense of no relevant harmonics where they are the strongest, and which are the most biologically relevant. But what the "dirty electricity" group are promoting, is those harmonics slower than 4 kHz don't matter. You can decide on your own why this is.

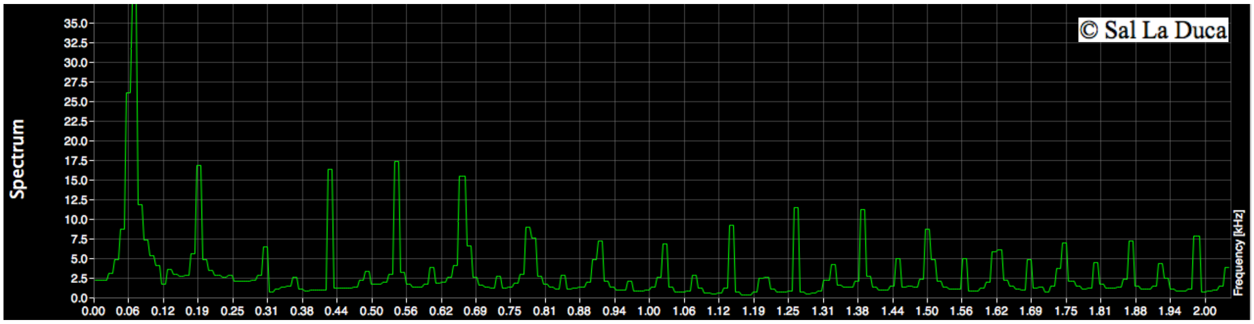
6) While I was amused toying with a Picoscope, there is a much simpler, and less expensive means of screening for harmonic content . . . for another day.

But as a hint of that, due to my generosity, enclosed are:

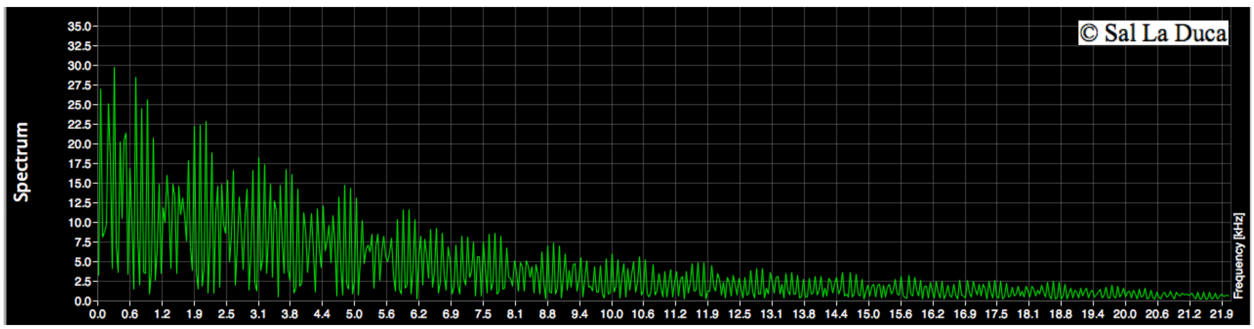
The current spectrum through a dimmer, on maximum intensity. The leftmost peak is 60 Hz.



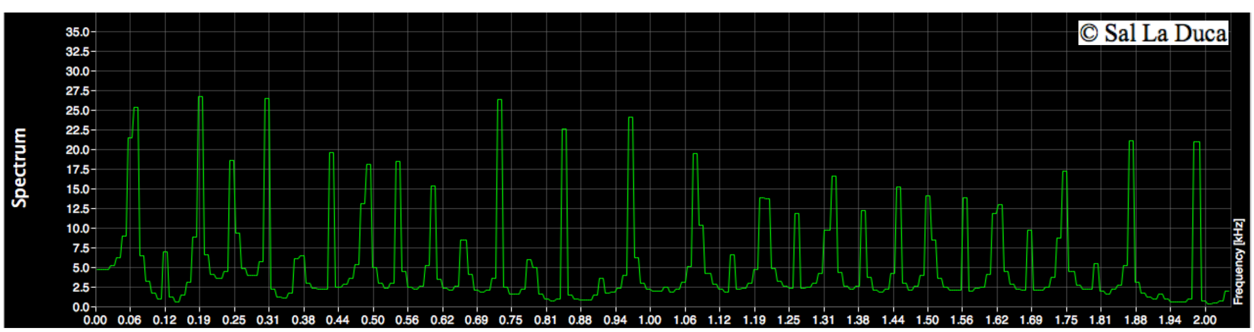
The current spectrum through a dimmer, on maximum intensity, zoomed in. The leftmost peak is 60 Hz.



The current spectrum through a dimmer, on minimum intensity. The leftmost peak is 60 Hz.



The current spectrum through a dimmer, on minimum intensity, zoomed in. The leftmost peak is 60 Hz, and while still present, the harmonics match or exceed the intensity of it. This is "mood" lighting, whose impact on voltage can easily drive some people up the wall. Have enough of these, and you have an "unexplained" RF presence. Current waveform distortion can be > 100%, while Voltage waveform distortion is typically < 4%. "DE" metering looks at the latter albeit with "blinders," not the former, where the problem really resides.



Assessment inquiries welcome.

Measurement tutoring, at the going rate.