Generator power quality and furnaces:

The effects of harmonic distortion

Application Note

Power Quality **Case Study**

Measuring tool: 43B Power Quality Analyzer

Operator: Bill Dove, HVAC technician and trainer

Features used: Harmonics/THD, logging, voltage waveform analysis (flat-topping), volts/amps/hertz analysis

When bad power supply affects equipment performance, the first thing most people do is blame the utility. For better or worse, they're usually wrong. Utility power is actually remarkably consistent, according to highly regulated standards of voltage, frequency and total harmonic distortion (THD).

So what's corrupting your power? Probably a non-linear electronic device, such as an air handler VFD or ECM (electronically commutated motor), florescent lights, dimmer switches, etc. Electronic devices can actually feed distortion back into their own power supply, where it comes back around to affect them and everything else.

DC power supplies are another common culprit. Their filter capacitors gulp power only from the peaks of the electrical sine waves they receive, causing a flat-topping effect. The more power demanded by dc power supplies on a circuit, the more extreme the flat-topping effect may become, and the less useable that power becomes for anything else on the circuit.

Sometimes poor power quality will cause delayed failures that go undiagnosed. For instance, harmonics and flat-topping can cause electronic power supplies and induction motors to overheat, leading to premature failures. And sometimes, if distortion is severe, the unit may not even work.

Power requirements for furnaces

Furnaces, unlike consumer electronics, do not have a built-in regulated power supply (which would add about $1500 to the cost). They rely on a clean, consistent sine wave to power an IFC (integrated furnace control) and establish clock timing and synchronization of integrated circuits.

A simple IFC may only control furnace functions such as turning line or low voltage switches on and off, controlling fan-timing circuits, and monitoring flame rectification circuits. More advanced IFCs also control voltage to igniters, ECM and VFD motors, and variable frequency drives.

Even the simplest IFC may not operate when supplied with poor quality power.

Furnaces have a minimum basic electrical requirement for voltage, frequency and power quality. The accepted standard is:

- 120 V ± 10 % (108 V to 132 V)
- 60 Hz frequency ± 3 % (57 Hz to 63 Hz)
- Harmonic distortion <5 % THD

Furnaces supplied with voltages that have harmonic distortion greater than 8 % THD may not operate or will operate with possible damaging consequences for the electronic circuitry and components.

Case in point

One such case involved a sophisticated furnace installed in a residence that also had a standby generator with a combination transfer switch and essential loads sub-panel. The furnace operated reliably throughout an unseasonably cold winter until the power failed and the standby generator was called into action. Under generator power, the furnace locked out on a communications error failure code.

One could assume that either the furnace or the generator was substandard. The electrician who installed the generator said he had never had an installation where a furnace would not operate on generator power, so the problem had to be with the furnace.

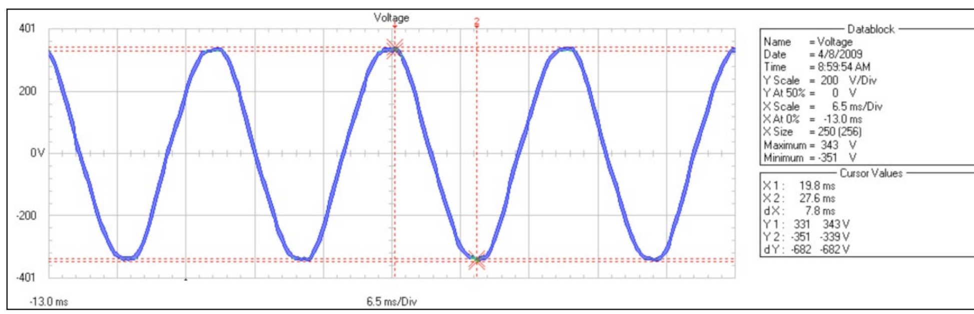
The HVAC contractor had only seen this problem with portable generators, not with standby generator installations. He also knew that no other furnace did so much to provide the greatest comfort at the greatest efficiency. It had a variable frequency/variable voltage CAI (cold air intake) and an ECM blower motor. Both motor circuits converted single phase to three phase power and used multiple "power gulping, sine wave flat-topping" 500 µf and 1000 µf filter capacitors. The IFC included the power supply and the program for the VFD and the program for the 20 kHz PWM signal to drive the blower motor. It also had a circuit that regulated voltage to the hot surface ignitor. But still, the generator worked, why wouldn't the furnace?

The heating contractor knew he was in over his head. Both the furnace manufacturer and the generator manufacturer were contacted. Each blamed the other. The generator manufacturer did not know why the furnace would not operate on one of their generators. The furnace manufacturer said it had to be a power quality issue and recommended using a power quality analyzer to verify the power supply. Presented with this, the electrician had the power quality checked and reported that it was fine, but had no actual documentation to back it up.

The HVAC contractor knew it would be up to him to resolve this issue. He had several options.

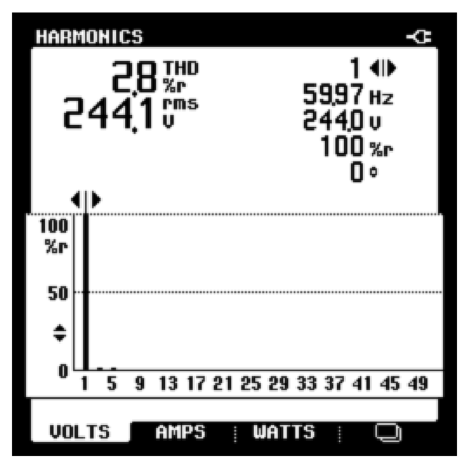
1. Install a furnace with fewer high-tech functions and hope it would work.
2. Refund the customer's money and pass it off to another HVAC contractor.
3. Install a 2200 kVA UPS (uninterruptible power supply) to condition the power to the furnace.
4. Replace the generator with one he knew had low THD.
5. Acquire a power quality analyzer to learn the truth and be able to document it.

Options one and two were immediately dismissed by the home owners. This was the most comfortable heating system they had ever lived with and were not about to give it up. Option three was not assured to solve the problem. If the power quality

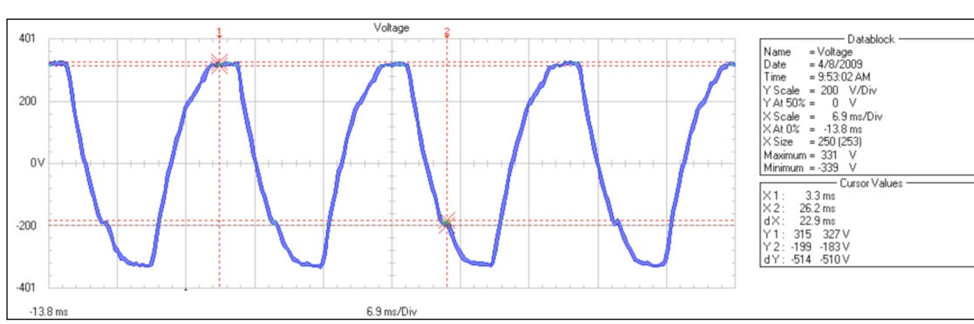


Site utility voltage waveform, showing clean power.

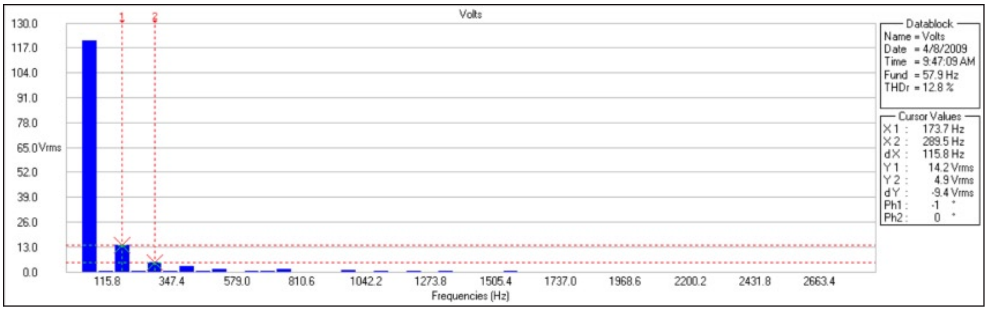
Site utility voltage, hertz, amperage meter screen shot.



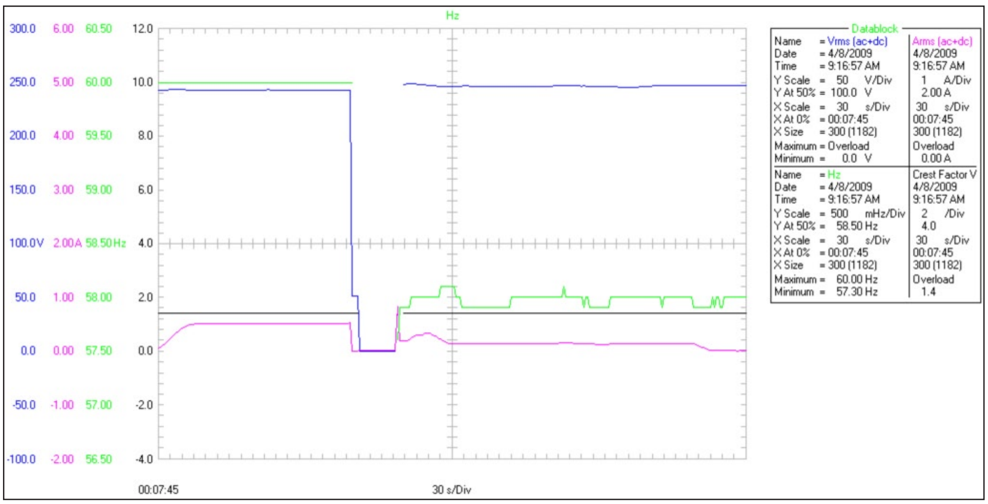
Site utility harmonic distortion meter screen shot.



Site generator voltage waveform showing distortion.



Generator voltage harmonic distortion graph.



Data log of utility to generator power changeover.

is poor, the UPS may want to operate in battery backup mode. Option four would solve the problem, but was expensive and would not really prove anything. Nothing would be learned except to be very afraid to install a furnace when a particular brand of stand-by generator is installed. Option five was a gamble. If it didn't produce the desired results, option four would be the only acceptable way out.

A decision was made. A power quality analyzer would not only document the needed facts on this job, but would be available to verify generator power quality on future jobs before a sales contract was signed.

He chose the Fluke 43B Power Quality Analyzer/logger because of its built-in waveform view, just like an oscilloscope. Presented with a visual representation of voltage and amperage waveforms, anyone (including homeowners) can see distinct differences between clean and distorted power.

In addition to measuring detailed electrical data, the analyzer can also store screens, graphs and waveforms in meter memory and/or transfer those files to a computer for subsequent analysis and reports. The analyzer was expensive, but not nearly as expensive as a replacement stand-by generator.

It worked!

The analyzer measured utility power at 2.8 % THD under normal loads…but measured the generator power at 12.8 % THD without any loads. The data was saved and sent to the generator manufacturer. Since the generator was less than one year old, and its marketing literature promised a harmonic distortion rate of less than 5 % THD, the manufacturer offered to supply a newer model generator with less harmonic distortion.

Anyone who's spoken with engineers knows that they respond to documented, accurate data and facts, not anecdotes or heresay. When we think about it, most HVAC techs are pretty similar. Without the necessary meters, gauges, thermometers, manometers, anemometers, etc., we are nothing more than parts changers who hope to get lucky. Work smarter. I'm learning to.

What's distortion?

Deviation of the expected voltage (or amperage) at any point on a sine wave is distortion. A harmonic is a regularly occurring distortion of a pure sine wave. If we have ac voltage supplied at 60 Hz, 60 Hz is the fundamental and harmonics are measurements at frequency integer multiples of the fundamental. The fundamental is considered the 1st harmonic (60 Hz). The 2nd harmonic would be twice the fundamental, or 120 Hz. The 3rd harmonic would be three times the fundamental, or 180 Hz. A power quality meter may be able to measure, say, up to the 51st harmonic. This means that the meter would measure the sine wave at 51 evenly spaced points and report the voltage (or amperage) deviation at each of the 51 harmonic frequencies. Total Harmonic Distortion (THD) is derived from the sum of all of the individual harmonic voltage (or amperage) deviations. Transients are isolated events and are not harmonic distortions since they do not occur regularly in each cycle.

Common acronyms:

VFD	=	Variable Frequency Drive
THD	=	Total Harmonic Distortion
IFC	=	Integrated Furnace Control
UPS	=	Uninterruptible Power Supply
ECM	=	Electronically Commutated Motor (formerly by GE, bought by Regal-Beloit and branded Genteq)

Fluke. *Keeping your world up and running.®*

Fluke Corporation
PO Box 9090, Everett, WA 98206 U.S.A.

Fluke Europe B.V.
PO Box 1186, 5602 BD
Eindhoven, The Netherlands

For more information call:
In the U.S.A. (800) 443-5853 or
Fax (425) 446-5116
In Europe/M-East/Africa +31 (0) 40 2675 200 or
Fax +31 (0) 40 2675 222
In Canada (800)-36-FLUKE or
Fax (905) 890-6866
From other countries +1 (425) 446-5500 or
Fax +1 (425) 446-5116
Web access: http://www.fluke.com

Printed in U.S.A. 6/2009 3497420A AW-EN-N