

## Detecting and correcting mains disturbances with the Fluke 430 Series Power Quality Analyzer

### Application Note

The new Fluke 433 and 434 three-phase power quality analyzers are ideal instruments for solving power supply problems. With advanced features that help test engineers to locate, predict, prevent and correct problems, they're an indispensable tool for maintaining and troubleshooting power distribution systems. Compared with traditional power quality analyzers, the new meters offer exceptional ease of use and portability, with battery power and an integrated display that eliminates the need for a PC monitor or laptop computer. They're therefore ideal for taking measurements at several points along a distribution – providing immediate information on dips, swells, harmonics, unbalance, power, flicker and waveforms with the minimum of setting up.

It was for these reasons that GTI, the Benelux's leading technical services provider, recently took a serious look at expanding its armory of analytical tools with the Fluke 430 series and investigated many areas where these versatile new instruments could provide a valuable supplement to the powerful but less portable Fluke RPM Power Recorders that the company uses at present.

#### The challenges facing a technical services provider

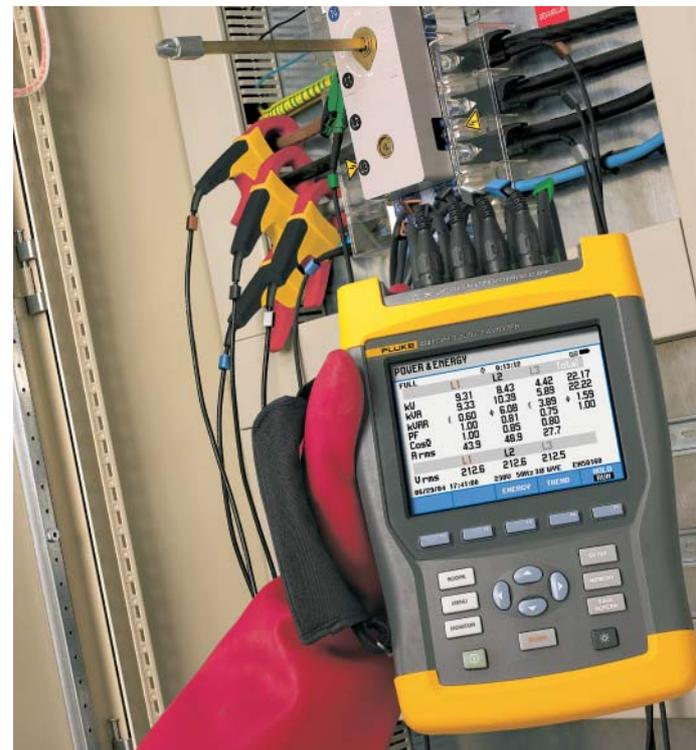
Located in Amsterdam, The Netherlands, GTI Utiliteit Noordwest B.V. is the branch of GTI primarily responsible for providing technical services to the company's customers located in North and South Holland and the Amsterdam region. The company specializes in providing optimal solutions for customers in industry and building services. Its expertise covers industrial air systems, computer-supply systems, processing equipment, heating, ventilating and cooling (HVAC) systems and filtration and separation technology. The company's engineers are also responsible for maintaining installations and for detecting and

correcting problems that may arise during the lifetime of an installation. To carry out the range of tasks for which it is responsible, GTI has expressed interest in supplementing its Fluke RPM meters with smaller, more portable instruments and believes that the recently introduced Fluke 430 series with its range of features and especially its attractive price fits the bill exactly.

#### Troubleshooting for harmonics

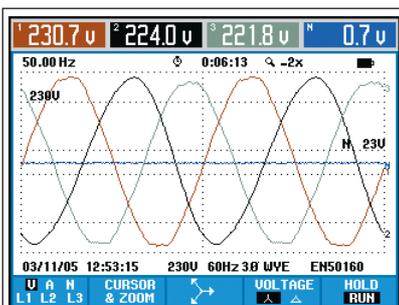
##### Single-phase loads

A perennial problem that confronts technical services companies such as GTI is the presence of higher order harmonics of the mains frequency – especially the third harmonic.

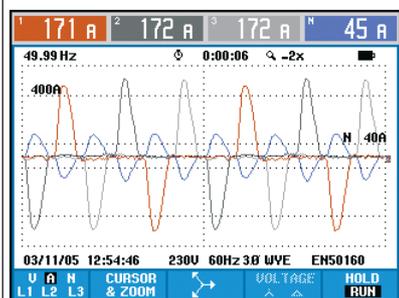


In three-phase, four-wire distribution systems, it's usual to have a common neutral conductor since individual neutral conductors obviously add to the cost of the network. However, when third (and ninth) harmonic components are present on all three phases, the harmonics are in phase. On the neutral conductor where the three phases connect, the harmonics add together, resulting in three times the current of a single-phase harmonic. The problem is particularly acute with unbalanced single-phase, non-linear loads such as those found in office equipment in which the current on the neutral can be as high as 50 A and can lead to overheating or even fire.

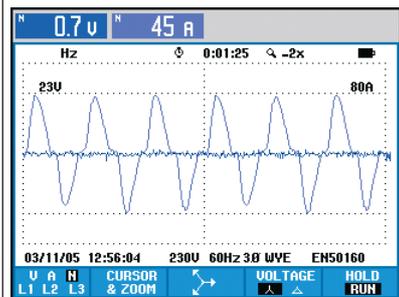
Using a Fluke 434 Power Quality Analyzer, the magnitude of the third-harmonic components can easily be measured (see Figure 1). In Figure 1, note the significant current flowing in the neutral wire (blue on the screen). The instrument can also display the voltage and current on the neutral on a single screen (as shown in Figure 1(c)).



(a)



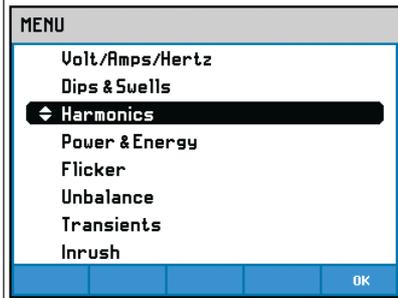
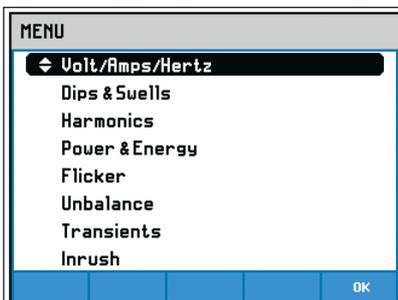
(b)



(c)

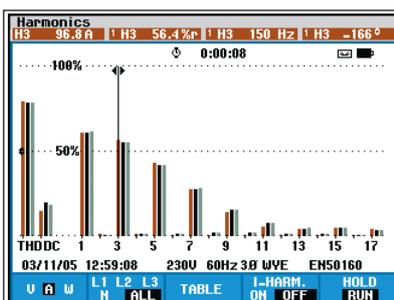
**Fig 1** - Voltage (a) and current (b) generated in the supply to a single-phase load measured on a Fluke 434 Power Quality Analyzer in Scope Waveform mode. The instrument can also be set to display both current and voltage on the neutral alone (c)

To identify the source of the excessive current in the neutral wire, it's only necessary to switch the meter to the Bar Graph screen by selecting the Harmonics display from the Menu (Figure 2).

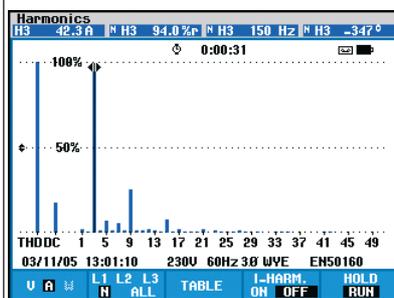


**Fig 2** - Accessing the Harmonics Bar Graph screen

The Harmonic display (Figure 3) shows conclusively that the third harmonic is here indeed the major odd-harmonic component responsible for the excessive neutral current.



(a)



(b)

**Fig 3** - Total harmonic distortion (THD) on the three phases of the supply to a single-phase load showing the high third-harmonic content. The 434 analyzer can also display THD on the neutral (b). Here the fundamental (50 Hz) component is not present and the third harmonic (150 Hz) is clearly the largest component

Reducing the third harmonic component, for example by filtering, would lengthen the lifetime of the network components but this solution is not always suitable, especially for installations with constantly changing equipment in which a filter network designed for one configuration may prove ineffective when this configuration changes. A typical example of this can be found in casinos, in which the gaming machines are mainly capacitive which can cause significant disturbance to the whole network. The gaming machines are also supplied by many different vendors and are regularly changed. For such configurations, a more appropriate solution is simply to increase the size of the neutral wire and in casinos it's now common practice to over-specify the neutral cables by 100% to accommodate the excess current.

### Three-phase loads

In typical three-phase loads such as a UPS or variable-frequency motor drive, usually the largest harmonic component generated is not the 3rd harmonic (or multiples of the 3rd) but the 5th. Figure 4a shows the current drawn by a six-pulse inverter of a three phase variable frequency motor drive (such as those used by GTI in its HVAC installations). Figure 4b shows that although a 3rd harmonic component is present, it is much smaller than the 5th harmonic. In contrast to the 3rd harmonic, the 5th does not cause current to accumulate in the common neutral wire.

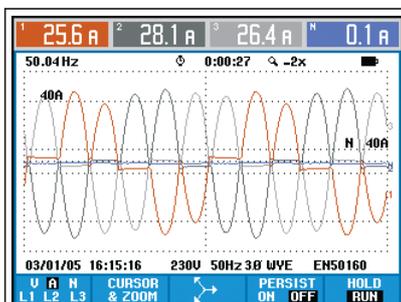


Fig 4a - Current waveforms of a six-pulse inverter

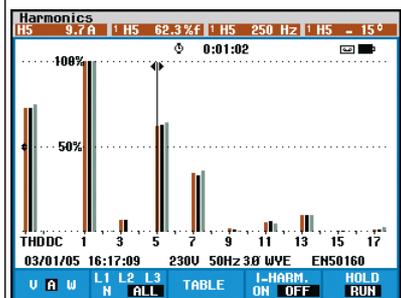


Fig 4b - The display of the 434 in Harmonic mode clearly shows the high content in the 5th harmonic

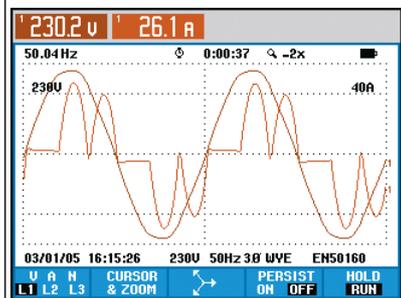


Fig 4c - Voltage and current of phase L1 clearly show the distorted 'double pulse' current which causes high 5th and 7th harmonic currents

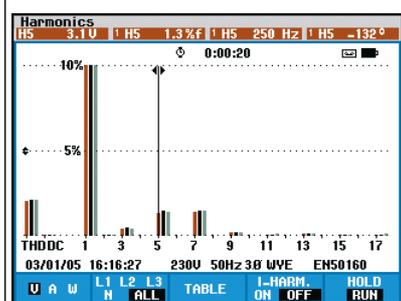


Fig 4d - Harmonic currents cause Voltage harmonics as well

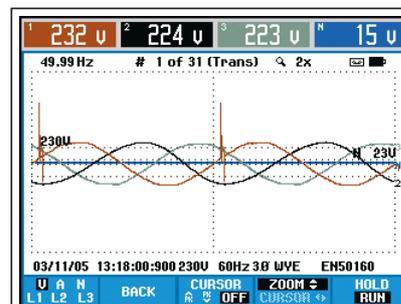
However, if the content of the 5th harmonic current is high, it can cause a 5th harmonic component in the voltage as well. The magnitude of the voltage harmonic component depends on the impedance of the mains system.

In conventional electric motors, these 5th harmonics voltage components act as a brake on the rotational motion induced by the 50 Hz mains signal. The 5th harmonic is a negative sequence harmonic, and when supplied to an induction motor it produces a negative torque. In other words, it attempts to drive the motor in a reverse direction and slows down its rotation, limiting the amount of power it can efficiently use to generate torque. This will result in build-up of heat and possibly to vibration in the motor. This problem, once identified, can not be solved by filtering since harmonic content will change with the load of the drive producing the 5th harmonic. The solution is to use thicker wires to reduce the impedance of the electrical system so current harmonics generate less voltage harmonics. Alternatively the drive could be powered via a separate transformer to isolate it from the rest of the system.

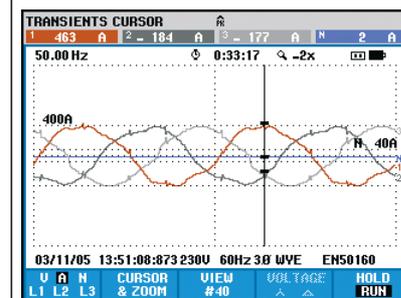
### Measuring voltage and current transients

Transients are fast spikes on the voltage (or current) waveform. The energy generated in a transient may be sufficient to affect or even damage sensitive electronic equipment, and according to present estimates, voltage transients are believed to account for around 80% of all electrically-related downtime. The most common internal causes of voltage transients encountered by technical services providers like GTI are HVAC systems, elevator motors, electronic ballasts in lighting installations, photocopiers, laser printers and, in fact, any inductive load. Since an electrical distribution system is designed to transmit electricity with the least impedance possible to maintain maximum efficiency, these internally generated voltage transients can propagate throughout a facility with minimal obstruction.

Measuring and diagnosing the cause of transients within an installation is therefore a crucial element of good maintenance. The Fluke 434 Power Quality Analyzer captures waveforms at high resolution during a variety of disturbances, the instrument being capable of giving a snapshot of the voltage and current including transients at the precise time of the disturbance. The Transients screen looks similar to that of Scope Waveform, but its vertical span is enlarged to make voltage spikes visible that are superimposed on the 50 or 60 Hz sine wave (Figure 5).



(a)



(b)

Fig 5 - The Fluke 434's Transient display is similar to the Scope Waveform display with the vertical span enlarged to make spikes more visible; (a) voltage transients caused by transformers in a halogen lighting system and (b) current transients caused by bad dimmer design

The voltage transients shown in Figure 5, in this instance caused by the transformers in the halogen lighting in the kitchen area of one of GTI's client companies, were responsible for causing substantial damage to other equipment in the building, including TV sets, DVD and CD players.

The original problem was detected and corrected using a Fluke RPM Power Recorder.

The same diagnostic and troubleshooting functionality, however, is now available with the Fluke 434, in a much more compact, portable and easy-to-use package.

## Power and energy measurements

The Fluke 434 also measures power and energy usage, the results being displayed on the instrument's Power & Energy display (Figure 6). All power parameters are displayed in one overview for easy interpretation. The instrument also allows  $\cos \phi$  or DPF (displacement factor) to be compared with the PF (power factor). With linear loads (Figure 6a), the  $\cos \phi$  is equal to the PF indicating the absence of harmonics. When however there is a difference between  $\cos \phi$  and PF (Figure 6b), harmonics are present. For power calculations, it's possible to choose Fundamental or Full. FUNDamental considers voltage and current only at the fundamental frequency (50 or 60 Hz) for power calculations; FULL uses the full frequency spectrum (true rms voltage and current). A trend over time will also be automatically generated for all variables (Figure 6c).

Power & Energy				
FUND	L1	L2	L3	Total
kW	64.6	58.6	62.1	185.2
kVA	65.2	60.5	62.1	187.8
kVAR	8.8	15.1	0.3	30.8
PF	0.98	0.95	0.99	0.97
$\cos \phi$	0.99	0.97	1.00	
A <sub>rms</sub>	286	275	282	
-----				
U <sub>rms</sub>	230.6	223.7	222.2	
03/11/05 14:27:54 230V 60Hz 3Ø WVE ENS0160				
VOLTAGE	ENERGY	TREND	HOLD RUN	

Fig 6a - Power measurements on linear load

Power & Energy				
FUND	L1	L2	L3	Total
kW	23.9	23.5	23.4	70.9
kVA	24.2	23.7	23.6	71.5
kVAR	3.3	3.1	2.9	9.5
PF	0.59	0.58	0.59	0.58
$\cos \phi$	0.99	0.99	0.99	
A <sub>rms</sub>	174	176	175	
-----				
U <sub>rms</sub>	229.9	223.2	221.3	
03/11/05 14:28:23 230V 60Hz 3Ø WVE ENS0160				
VOLTAGE	ENERGY	TREND	HOLD RUN	

Fig 6b - Power measurements on non-linear loads.

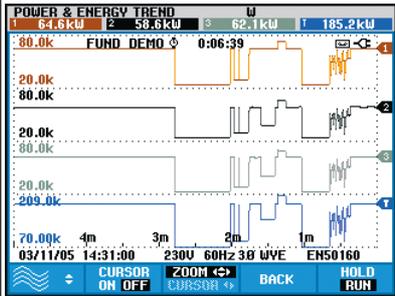


Fig 6c - Trend display automatically shows system behavior over time.

In addition, for power consumption profiles or for checking/calibrating power consumption meters, the power consumption mode can be activated by pressing the meter's Energy button (Fig. 7).

Power & Energy				
FUND	L1	L2	L3	Total
kW	23.9	23.6	23.4	70.9
kVA	24.1	23.8	23.6	71.5
kVAR	3.2	3.1	3.0	9.5
PF	0.59	0.58	0.59	0.58
$\cos \phi$	0.99	0.99	0.99	
-----				
kWh	6.983	6.321	6.652	19.96
kVAh	7.045	6.511	6.656	20.21
kVAh	0.786	1.399	0.054	2.776
START 03/11/05 14:24:20 0:07:23				
PULSE CNT	CLOSE ENERGY	FUNDAMENTAL	RESET ENERGY	

Fig 7 - The energy button activates the power consumption display.

## Conclusion

Today, power quality measurement equipment is essential for technical service providers such as GTI. Whereas in this respect the Fluke RPM Power Recorder is without doubt one of the most advanced instruments available on the market, the need for an easier to use, more portable instrument to work alongside the RPM has long been felt. The new Fluke 430 series fulfils this requirement admirably and companies such as GTI consider it to be the ideal instrument for their day-to-day troubleshooting and maintenance work.

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

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