Power quality recording and analysis: Techniques and applications

Application Note

Hooking up a power quality recorder and taking days' worth of data can give you a rich picture of your power. In this article we'll talk about the various recording techniques available in power loggers and recorders—understanding the tools and techniques you have available will be key to your strategy. What should you be looking for? And when does recording make sense?

Setting up a Fluke 1735 Power Logger at the service entrance for a 30-day load study.

Recording techniques

To really know your power, ideally, you'd want to look at every line cycle to see even the smallest changes. However, since our power swings through more than four million cycles per day, it's impractical to look at tiny changes—and often unnecessary. Few loads even notice occasional voltage dips of one or two cycles.

How long you record depends somewhat on the rhythm of your building. If you are working on a typical commercial or light industrial building, then a week is long enough for a building to go through its normal cycle. If you are working in a plant that runs special equipment only periodically (say a furnace that runs only monthly), you'll need to be sensitive to the timing of these loads.

Different recording techniques have been developed to look at small changes over relatively long time periods. Many instruments combine several techniques to improve their coverage. We'll describe the common techniques and some of their pros and cons.

By understanding the different techniques. you'll be better able to choose an appropriate tool for the job at hand.

Techniques for tracking trends

Trending tracks power quality parameters over hours or days. Power loggers measure parameters like voltage, current, or power and log them over time. Trend recording is good for tracking normal power, subtle changes, and exceptional conditions but may have a limited ability to catch fast events. However, instrument makers have come up with some creative ways of showing faster events while allowing recording lengths of weeks or even months.

Fixed interval logging

This is the simplest form of digital recording. To set it up, you choose a time period, or interval, between readings—usually in seconds or minutes. The instrument calculates an average of the rms values during each interval and stores it in memory. This technique is useful for tracking changes longer than the logging interval. Unfortunately, a very short measurement interval will catch fast events, but will also use memory quickly. So even though fixed interval logging is easy to set up, it can't capture fast events over hours or days.

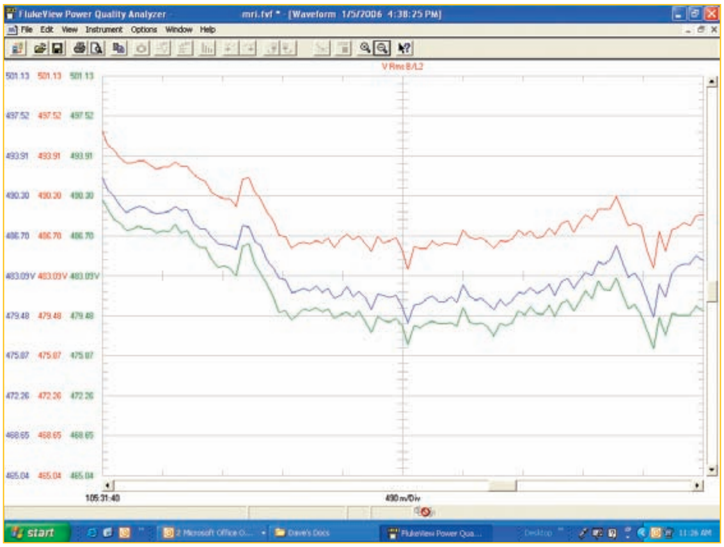

Figure 2. Min/Max/Avg trendplot.

Min/Max/Avg logging

This technique is similar to fixed interval logging since it uses a preset interval. But instead of taking just one reading per interval, the instrument takes many high-speed measurements over each interval. Processors within the instrument crunch through the measurements and log three numbers for each interval: a minimum, a maximum and an average. The min and max indicate the worst-case, short-duration events, in some instruments as short as a single power cycle. The average tracks the overall trend. Graphs from these instruments will often plot min, average and max on the same graph.

Automatic time compression, TrendPlot

TrendPlot is a logging technique in some Fluke instruments. It is a form of min/max/avg recording in which the timescale automatically compresses whenever the trend approaches the end of memory. When the recorder starts to run out of memory, signal processors quickly go to work. They combine adjacent intervals into a new min, max, and average. You still get to see the worst-case measurements and the overall trend. And because you choose when to stop the measurement, you automatically get the best time resolution with the available memory.

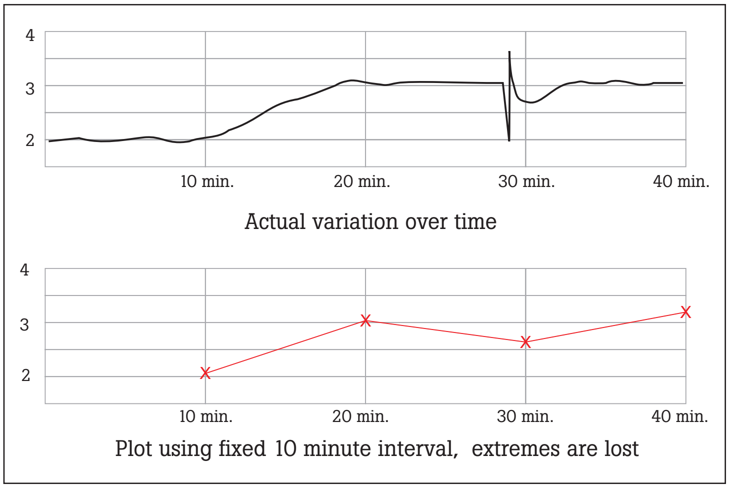

Figure 1. Fixed interval voltage trend.

Event recording

Dips, swells, interruptions, and transients are all voltage events. Power quality events are characterized by the time and date they occur, severity, and duration. User-defined thresholds or triggers determine what qualifies as an event. Event recording is great for ensuring your voltage stays within tolerances, say ± 10 %. Data is usually presented as a list, making it easy to see all of the extraordinary conditions on the power system. Whether or not an event causes problems depends on both severity and duration. For example, a 20 % dip that lasts for 5 seconds is more likely to cause problems than a 20 % dip that lasts for 1 line cycle. So event data is sometimes compared to standard tolerance curves, like the CBEMA curve, that give limits for severity and duration. The need to specify multiple limits can make event recording tricky to set up. If you set the tolerances too tightly, you'll capture lots of events and if you set the tolerance too loosely, you may not see anything at all.

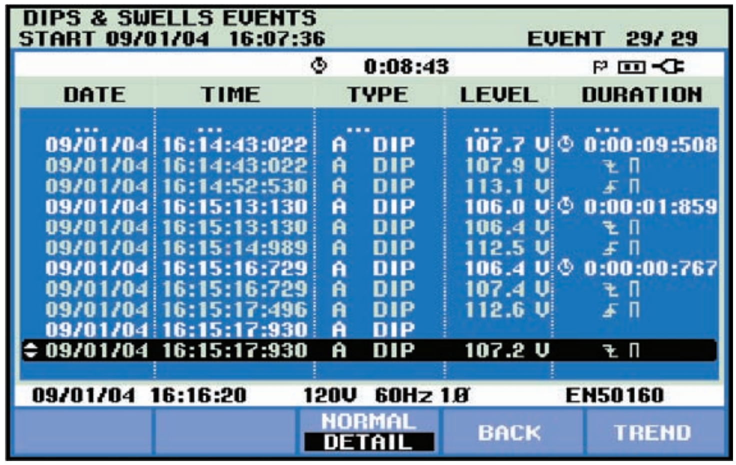

Figure 3. This event table lists multiple small dips captured within seconds of each other.

Transient waveform capture

This technique records the actual sine wave of the voltage or current, allowing you to see any event shorter than one line cycle. The capture is initiated by a trigger and uses a high speed digitizer. Various triggers can start the capture but most instruments use an "envelope trigger".

An envelope trigger finds deviations from a clean sine wave. It builds an envelope around the sinusoidal voltage waveform, based on a user-specified tolerance. If the waveform goes outside the envelope then the instrument captures and stores. Some instruments, like the Fluke 430 Series, can also take a snapshot of the waveform based on other criteria like rms events or current increases.

Full disclosure recording

This technique combines min/max/avg recording, transient, and event capture all at the same time. So you don't have to decide whether to look for dips or transients—you can capture both.

These instruments can determine event thresholds automatically and adjust the threshold on the fly. This eliminates the difficulty in setting event thresholds. Full disclosure recording is very useful for performing comprehensive studies over days, weeks or even months.

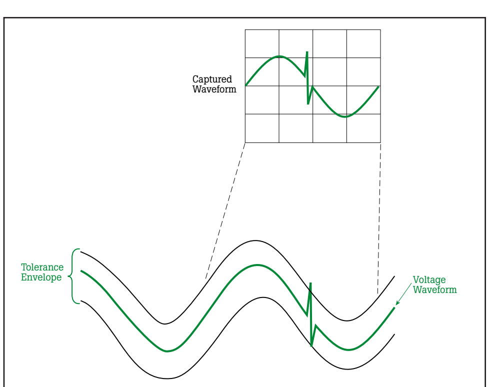

Figure 4. Envelope trigger example.

Recording applications

Power quality is recorded in several general situations. This section describes the most common applications.

Troubleshooting with long-term analysis

Troubleshooting intermittent failures is challenging. When a piece of equipment fails or resets itself mysteriously, it's tempting to just swap gear out or reset a circuit breaker and hope for the best. For equipment with a high cost of downtime, the risk of a repeat failure is too great to rely on a quick fix. Monitoring the power after getting your equipment running again will reduce the number of repeat failures and rule out power problems if a failure does recur.

The first decision you'll have to make is where to connect the monitor or analyzer. In general you should start with the recorder close to the "victim load" (the equipment that's having problems). This way the monitor will "see" what the load "sees". If you have multiple tools available it can help to record at different points in the power system.

Before recording, start by taking some spot measurements to answer some basic questions. Is the voltage level right? Is the voltage waveform a clean sine wave or is it noisy or distorted? If the victim is a 3-phase load, are the phases balanced? Is the current being drawn by the load too high?

The next question is: what should I record? Unless you are lucky enough to have a sophisticated power analyzer, you're probably going to have to decide whether to start by tracking trends or hunting for transients.

Checking data during recording with the wireless PDA feature of the FLuke 1750 Power Recorder.

Trends will uncover more problems so try trend recording first (use fixed interval logging or min/max/avg). Recording rms voltage trends on all relevant phases is the most basic approach. This will determine if the supply is subject to voltage dips or outages which can cause load dropouts or resets. Recording voltage will also uncover swells or unbalance which can cause overheating.

Current trends can also help in troubleshooting. Excessive current draw will cause overheating. If the voltage is stable, clean and balanced, high current indicates a problem with the load itself. By comparing the voltage and current recordings you can tell whether the voltage drop is being caused by high current being drawn by the victim load or is being caused by some other load upstream.

Voltage distortion can also cause overheating and should be recorded if possible. The most basic way to track voltage distortion is by recording total harmonic distortion (THD). Some analyzers can also track individual harmonics which can help point to the source of high THD.

If the victim load shows evidence of arcing or blown input circuitry transients may be to blame, but don't jump to this conclusion too quickly. After you've performed some trending, or if the evidence strongly suggests transient damage, then it's time to try transient capture and look at waveforms.

Tools from Fluke

Fluke offers a number of power recording tools for almost any application. In some cases a combination of tools is best. For example, you could use the Fluke 434 for quick troubleshooting and short term monitoring or for longer term monitoring you might select a Power Recorder.

	Loggers							Recorders	
	Fluke 434 Power Quality Analyzer	**Fluke 435** Logging Power Quality Analyzer	**Fluke VR101** Voltage Event Recorder	**Fluke 1735** Power Logger	**Fluke 1743** Power Quality Logger	**Fluke 1744** Power Quality Logger	**Fluke 1745** Power Quality Logger	**Fluke 1750** Power Recorder	**Fluke 1760** Power Quality Recorder
Applications									
1-Phase / 3-Phase	3-Phase	3-Phase	1-Phase	3-Phase	3-Phase	3-Phase	3-Phase	3-Phase	3-Phase
Frontline troubleshooting	•	•	–	–	–	–	–	–	–
Predictive maintenance	•	•	–	–	–	–	–	–	–
Load study/PQ survey	•	•	–	•	•	•	•	•	•
Quality of service compliance (EN50160)	•	•	–	–	•	•	•	•	•
Long-term analysis	–	•	•	•	•	•	•	•	•
Recording capability									
Typical recording period	1 week	1 month	1 month	1 month	3 months	3 months	3 months	1 month	3 months
Memory	8 Mb	16 Mb	32 kB	4 MB	4 MB	4 MB	8 MB	2 GB	1 GB
Min/Max/Avg logging	•	•	•	•	•	•	•	•	•
Event capture	•	•	•	•	•	•	•	•	•
Waveform capture	•	•	–	–	–	–	–	•	•
User defined logging	–	•	–	–	•	•	•	–	•
Full-disclosure	–	–	–	–	–	–	–	•	–
Powered off of measured signals	–	–	–	–	•	•	•	–	–
Sample rate	10 kHz	10 kHz	1/2 cycle integrated	10.24 kHz	10.24 kHz	10.24 kHz	10.24 kHz	12.8 kHz and 15.36 kHz	10.24 kHz
High-speed capture rate	200 kHz	200 kHz	•	•	•	•	•	5 MHz	0.5 or 10 MHz
Peak voltage	6 kV	6 kV	2.5 kV	•	•	•	•	6 kV	6 kV
Features									
Display	Color Graphical	Color Graphical	LED	Color Graphical	LEDs	LEDs	LCD and LEDs	PDA and LEDs	LEDs
Voltage channels	4	4	1	4	4	4	4	4	4 (8 without current)
Current channels	4	4	–	4	4	4	4	5	4 (0)
Included current probes	40 A/400 A Clamps	3000 A Flexis	–	15 A /150 A/ 3000 A Flexis	15 A/150 A /1500 A/ 3000 A Flexis	15 A/150 A /1500 A/ 3000A Flexis	15 A/150 A /1500A/ 3000A Flexis	400 A Clamps	200 A/ 1000 A Flexis
Dust/water resistance	IP51	IP51	–	IP 65 (not including battery housing)	IP65	IP65	IP50	IP50	IP50
Safety rating	600 V CAT IV	600 V CAT IV	300 V CAT III	600 V CAT III	600 V CAT III	600 V CAT III	600 V CAT III	600 V CAT IV	600 V CAT III
Software	Fluke View	Fluke Power Log	Fluke Event View	Fluke Power Log	Fluke PQ Log	Fluke PQ Log	Fluke PQ Log	Fluke Power Analyze	Fluke PQ Analyze
Battery Operation /UPS	7 hours	7 hours	–	24 hours	–	–	5 hours	5 min UPS	40 min
Analysis capability									
Statistical analysis (including EN50160)	•	•	–	•	•	•	•	•	•
Report generator	–	•	–	•	•	•	•	•	•
Root causeanalysis	–	–	–	–	•	•	•	–	•
Accuracy									
IEC 61000-4-30 Class A compliant	–	•	–	–	–	–	–	•	•
Volts rms	0.5 % Vnom	0.1 % Vnom	± 2 V 0 to 200 V ± 4 V 0 to 270 V	± (0.5 % + 10 counts)	0.1 % of range	0.1 % of range	0.1 % of range	0.1 % Vnom	0.1 % Vnom
Amps rms	1 % +-5 counts	0.5 % +-5 counts	–	± (1 % + 10 counts)	2 % of range with flex CT	2 % of range with flex CT	2 % of range with flex CT	1 % with flex CT	1 % with flex CT

Quality of service

In some cases, utilities agree to provide power that complies with predetermined specifications. The specifications may be laid out in contracts or may take the form of regulations, like EN50160. In these agreements, details of the recording techniques, tolerances and recording duration may be spelled out. Standard EN50160, for example, specifies tolerances for a 1-week recording and references standard IEC 61000-4-30 for measurement and recording techniques. If you believe that the power your utility is providing does not meet the agreed upon specifications, test it.

Load studies, power quality studies, and commissioning

These types of recordings are generally done to assess the power prior to installation or operation of equipment.

A load study is performed to determine the existing loads on a system, prior to adding more loads. This may be required by local authorities and local norms or standards dictate the required measurements, intervals and durations. For example, the US National Electrical Code specifies current or power measurements average over 15 minute intervals, taken over 30 days. In addition to satisfying the authorities, taking recordings prior to significant system modifications can help in debugging the system later.

Power quality studies and commissioning studies try to answer the questions: "Is this system healthy?" The strategy in these applications is to cast a wide net and record as much as possible. Ideally we would record voltage, current and power trends, transients, and event logs.

Before you push the RECORD button

- Don't jump right into recording. Gather as much information as you can with spot measurements of voltage level, voltage waveform/distortion, current, unbalance. These may point you to the problem or give you some insight as to where to go next.
- Check your connections. If the instrument has a phasor or scope display, use it to verify that the connections are correct.
- To twist the old saying: set twice, measure once. If you are trending, double check your recording interval. If you are using event or transient capture, recheck your limits.
- Consider doing a short run of an hour or so, before leaving a monitor for a longer period. This will help you work any bugs out of your setup, and you may get lucky and find what you're looking for!

Fluke. *Keeping your world up and running.*

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