6 simple ways to reduce costs

with a Fluke 434 Power Quality Analyzer

There are hundreds of power quality measurements you can take on electrical systems and equipment. These instructions focus on four predictive maintenance (PdM) measurements and two power consumption measurements that can help you uncover hidden costs, protect equipment from damaging conditions, reduce unscheduled downtime and improve system performance.

PdM Measurement #1: Voltage Unbalance

What is it? In a balanced 3-phase system, the phase voltages should be equal or very close to equal. Unbalance is a measurement of the inequality of the phase voltages.

What does it do? Voltage unbalance can cause 3-phase motors and other 3-phase loads to experience poor performance or premature failure because of the following:

- Mechanical stresses in motors due to lower than normal torque output.
- Higher than normal current in motors and 3-phase rectifiers.
- Unbalance current will flow in neutral conductors in 3-phase wye systems.

How much does an incident cost? The major costs are associated with motor replacement (labor + equipment) and lost income due to circuit protection trips.

Example Calculation

Assume the cost to replace a 50 hp motor each year is €3495 including labor.

Assume 4 hours of downtime per year with income loss of €4195 per hour.

Total Cost: €3495 + (4 x €4195) = €20,275 annually

What to check? Inputs to motors, VFDs, UPSs[1].

How much is ok? The EN50160 power quality standard requires voltage unbalance, as a ratio of negative to positive sequence components, to be less than 2 % at the point of common coupling. NEMA specs call for less than 5 % for motor loads. Consult user manuals for other equipment.

How do I measure it with the Fluke 430 Series Power Quality Analyzer?

1. Connect the voltage leads of the analyzer.
2. Configure the analyzer for the appropriate 3-phase power system: delta or wye.
3. Select "Unbalance" from the main menu.

[1]VFD: Variable Frequency Drive; UPS: Uninterruptible Power Supply

Vneg is the ratio of negative to positive sequence voltage and Vzero is the ratio of zero to positive sequence voltage. They are both indications of voltage unbalance.

PdM Measurement #2: Total Harmonic Distortion

What is it? Total Harmonic Distortion (THD) is the sum of the contributions of all harmonics. Harmonic distortion is a normal consequence of a power system supplying electronic loads such as computers, business machines, electronic lighting ballasts, and control systems.

What does it do? Harmonic distortion can cause:
- High current to flow in neutral conductors.
- Motors and transformers to run hot, shortening their lives.
- Increased susceptibility to voltage sags, potentially causing spurious resets.
- Reduced efficiency of transformer — or, a larger unit is required to accommodate harmonics.
- Audible noise.

How much does an incident cost? The major costs are associated with shortened life of motors and transformers. If the equipment is part of production systems, income may be affected as well.

Example Calculation

Assume the cost to replace a 100 KVA transformer is €4895 including labor each year.

Assume 8 hours of downtime each year with income loss of €4195 per hour.

Total Cost: €3495 + (8 x €4195) = €37,055 annually

What to check? Motors, transformers and neutral conductors serving electronic loads.

How much is ok? Voltage distortion (THD) should be investigated if it is over 5 % on any phase. Some current distortion (THD) is normal on any part of the system serving electronic loads. Monitor current levels and temperature at transformers to be sure that they are not overstressed. Neutral current should not exceed the capacity of the neutral conductor.

How do I measure with the Fluke 430 Series Power Quality Analyzer?
1. Connect the voltage and current leads of the analyzer.
2. Configure the analyzer for the appropriate 3-phase power system: delta or wye.
3. Select "Harmonics" from the main menu.

HARMONICS TABLE

		⏱ 0:04:00		
Volt	A	B	C	N
THD%r	2.5	7.1	3.1	94.8
H3%r	0.5	1.1	1.1	30.7
H5%r	0.8	0.2	1.4	38.7
H7%r	1.9	0.6	1.5	39.7
Amp	A	B	C	N
H3%r	7.7	11.4	2.0	20.1
H5%r	5.2	1.9	4.5	40.7
H7%r	2.8	2.5	3.5	21.0

01/02/03 23:58:06   120V 60Hz 3Ø WYE   EN50160

V&A | | BACK | TREND | HOLD RUN

Voltage THD should be investigated if it is higher than 5 % on any phase.

PdM Measurement #3: Increasing Phase Current

What is it? As insulation deteriorates it begins to leak. Loads will draw slightly higher current as they age and they may send some of this leakage current into the grounding system. Faults within the equipment may also cause high ground current. The best way to check insulation is by periodically checking equipment with an insulation tester. But you can also check equipment while it's in service by monitoring all of the currents (phase, neutral and ground) to make sure none of these is increasing significantly over time.

What does it do?
- Excessive phase currents can further damage insulation and overheat the load, resulting in a shortened life of the load.
- Over-current will cause protection devices to trip, resulting in unscheduled downtime.
- Excessive ground current can create unsafe voltages on metal chassis, cabinets, and conduit.

How much does an incident cost? Costs come from premature motor failure and lost income due to over-current protection devices tripping.

Example Calculation

Assuming the failure of a pump motor each year costs €4895 to replace and causes a €1,747,765 per year continuous process to be shut down for 10 hours. Assume it takes two people 6 hours to clean and restart the process at €50 per hour each.

Lost income = 10 hours*(€1,747,765 / (365 days/year * 24 hrs/ day)) = €1995

Motor replacement = €4895

Clean and restart = €420

Total Cost €7310 annually

What to check? Any critical load, but especially motors, VFDs and transformers.

How much is ok? The nameplate rating of the load should never be exceeded. If you track the phase current being drawn by a load over the months or years, you should be able to get a sense whether the current is changing.

How do I measure with the Fluke 430 Series Power Quality Analyzer?
1. Connect the voltage and current leads of the analyzer.
2. Configure the analyzer for the appropriate 3-phase power system: delta or wye.
3. Select "Volt/Amp/Hertz" from the main menu.
4. Press "Save Screen" to record measurements for comparison with future readings.
5. Monitor phase current regularly for changes.

Volt/Amps/Hertz			
	⏱ 0:01:24		🔋 ⎓
	A	**B**	**C**	**N**
V rms	116.7	112.9	112.6	1.5
V pk	167	163	158	4
CF	1.4	1.4	1.4	2.4
Hz	60.16			
	A	**B**	**C**	**N**
A rms	288	277	285	1
A pk	420	410	430	0
CF	1.5	1.5	1.5	1.9
09/16/04 04:35:06	120V 60Hz 3Ø WYE		EN50160
		TREND	HOLD RUN

Troubleshoot further if amps rms readings increase dramatically, or show an increasing trend, between maintenance intervals.

PdM Measurement #4: Voltage Sags

What are they? Voltage sags are momentary reductions in rms voltage for 1 cycle to 2 minutes. Loads may be added without notifying plant management, and these loads may draw down system voltage, especially if they draw high inrush currents. Also, as electrical systems age, the impedance of the system may increase, making the system more prone to voltage sags.

What do they do? Voltage sags can cause:
- Spurious resets on electronic equipment such as computers or controllers.
- Sags on one or two phases of 3-phase loads causing the other phase(s) to draw higher current in an attempt to compensate. This may trip overcurrent protection.

How much does an incident cost? The main cost factors are lost income due to computer reset, control system reset, VFD trip, and shortened life of backup power system's UPS due to frequent cycling.

Example Calculation

Assume a voltage sag causes a VFD on a conveyor system to trip offline at least once a year. No income is permanently lost, but 10 hourly workers have to work 4 hours to make shipments at €21/hour, which includes overtime.

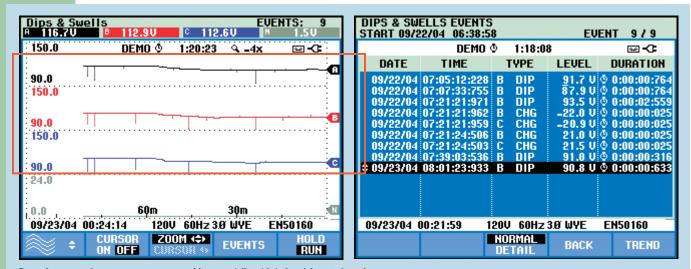*Added Labor = 10 people * 4 hours * €21/hr = €840 annually*

What to check? Motors, VFDs, UPSs, panels or PDUs* serving computer equipment or industrial controls.

How much is ok? Most loads will operate at 90 % of nominal voltage. The ITIC curve suggests that single-phase computer equipment loads should be able to ride through drops to 80 % of nominal for 10 s and 70 % of nominal for 0.5 s.

How do I measure with the Fluke 430 Series Power Quality Analyzer?

1. Connect the voltage and current leads of the analyzer.
2. Configure the analyzer for the appropriate 3-phase power system: delta or wye.
3. Select "Dips and Swells" from the main menu.
4. Monitor power over time.
5. View either as a trend display or event list.

*PDU: Power Distribution Unit

Deep, frequent voltage sags can cause trouble, especially with industrial controls and computers.
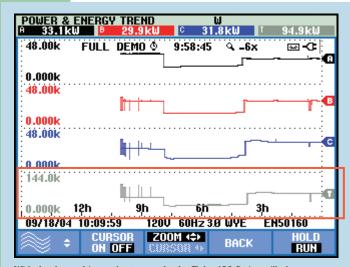
Power Consumption

Commercial and industrial power consumers are charged for power consumption based on multiple variables including energy (kWh), peak demand (kW), and power factor. Power quality analyzers can help manage utility bills by determining which loads have a significant effect on peak demand and power factor.

Power Measurement #1: Peak Demand

What is it? Utilities monitor the amount of power a facility consumes and several times an hour they calculate the average demand for that interval. Peak demand is the highest average demand during all of the intervals in a billing cycle.

What does it do? Utilities charge based on peak demand because they have to maintain infrastructure large enough to supply power at peak levels. Commercial and industrial customers can manage the high cost of peak demand rates by staggering load cycles to reduce total draw at any one time.

How much does an incident cost? This depends on the rate schedule of the utility. It may be higher during summer months and certain times of day.

Example Calculation

Assume your normal demand is about 600 kW, but three HVAC chillers come on at once and your demand hits 750 kW at 4 p.m. on a Wednesday in July.

Assume the utility demand charge is €70 per kW.

*(750 kW – 600 kW) * €100 = €10,485 in potential savings for July*

What to check?
- Find out what demand interval the utility uses — 15 minutes is common.
- Measure demand over time at the service entrance.
- Look for significant loads operating concurrently and use demand measurement to verify readings for the individual loads.

How much is OK?
There are no safety or regulatory limits other than what the facility can afford.

How do I measure it with the 430 Series Power Quality Analyzer?
1. Connect the voltage and current leads of the analyzer.
2. Configure the analyzer for the appropriate 3-phase power system: delta or wye.
3. Set the demand interval to correspond to the one specified by your power utility. Press Setup, Function Pref (F3). Select "Power & Energy" from the Select Function menu. Arrow down past the bottom of the screen until "Demand int" is highlighted.
4. Select "Power & Energy" from the main menu and monitor the power for as long as necessary.
5. Use the trend display to see the peak demand. The cursor will help you see the demand at any time during the recording.

With the demand interval set correctly, the Fluke 430 Series will plot one average demand reading for each demand interval. Your peak demand will be the highest of these readings.

Power Measurement #2: Power Factor or Reactive Demand

What is it? Power factor compares the real power (watts) being consumed to the apparent power (Volts–Amps) of the load. A purely resistive load would have a power factor of 1.0.

What does it do?

The power available to perform work is called real power (kW). Inductive loads such as motors, transformers, and high–intensity lighting introduce reactive power (kVARs) into a power system. The system capacity is rated by the apparent power (kVA) which must be large enough to accommodate both the real power (kW) and reactive power (kVAR). Since reactive power requires system capacity, but performs no work, utilities and plants try to keep net kVARs low. High reactive power translates to low power factor.

- Utilities may charge higher rates or penalties for low power factor or high VARs.
- System capacity restrictions cause voltage drops and overheating.
- Inductive VARs can be corrected by applying capacitors or active conditioners.

What to check?

- See if your utility rate plan imposes a charge for reactive demand or power factor.
- Find out how the utility measures power factor or VARs. For example, are they looking at peak intervals or averages?
- Identify loads that are causing lagging reactive power and develop a strategy for power factor correction.

How much is OK?

To avoid paying higher utility fees, power factor should be higher than .97. Capacitors may be applied on individual loads, at a confluence of several, or at the service entrance to improve power factor.

Note: This varies. Some utilities charge a rate for every percentage point between .85 and .97. Some charge a rate based on the number of VARs you use. Some don't charge at all.

How much does an incident cost?

Example Calculation

Assume the utility adds 1% of demand charge for each 0.01 below PF of 0.97.

Assume your PF averages 0.86 each month and your demand charge is €4895.

$(0.97{-}0.86) * 100\% = 11\%$

(11% x €4895) x 12 months = €6460 avoidable annual cost

How do I measure it with the 430 Series Power Quality Analyzer?
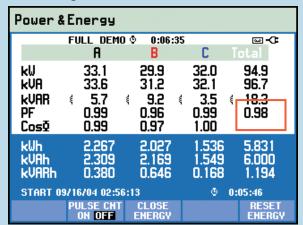
Start at the service entrance, where the utility takes its data, and then check individual loads or transformers.

1. Connect the voltage and current leads of the analyzer.
2. Configure the analyzer for the appropriate 3–phase power system: delta or wye.
3. Set the demand interval to correspond to the one specified by your power utility. Press Setup, Function Pref (F3). Select "Power & Energy" from the Select Function menu. Arrow down past the bottom of the screen until "Demand int" is highlighted.
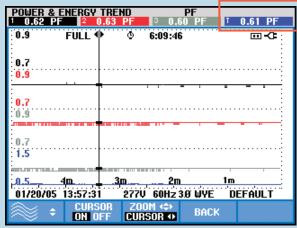4. Select "Power & Energy" from the main menu and monitor the power.

Measuring the lowest power factor for a demand interval: Press F4 Trend and then press F1 to toggle through the parameters until PF is displayed.

Measuring average power factor: Take the ratio of kWh/kVAh to get the average PF over the recording period. In the example shown below, $2.267/2.309 = 0.9818$.

Measuring kVARh:

Whether your utility charges on total power factor(PF) or total kVARh you can see it on this screen.

Cursors can help you record the lowest (PF) over a recording session.