

## Applying power quality measurements to predictive maintenance

### Application Note

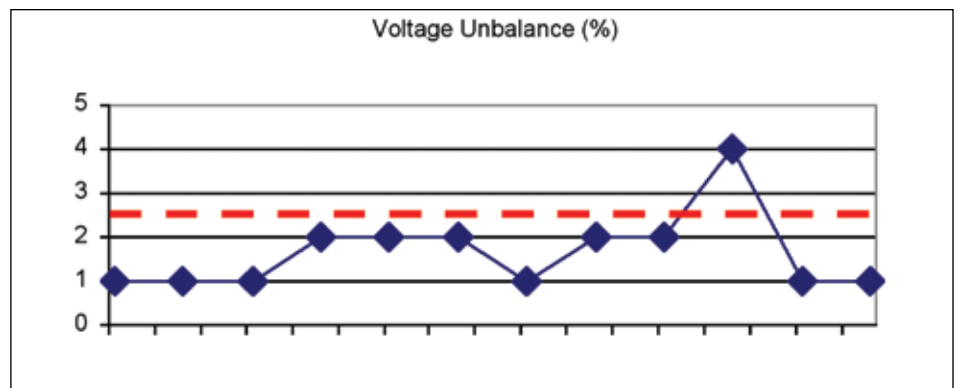
You may already be using predictive maintenance (PdM) techniques on your motors and drives. But how often do you inspect the power to your equipment? By adding basic power quality measurements to production equipment maintenance procedures you can head off unexpected failures in both production equipment and your power system.

#### Cost savings

Insurance claims data in the NFPA 70B maintenance standard shows that roughly half of the cost associated with electrical failures could be prevented by regular maintenance. A study published in IEEE 493-1997 says that a poorly maintained system can attribute 49 % of its failures to lack of maintenance.

To determine the cost of a failure, it helps to consider three key categories:

- Lost income (gross margin) due to downtime
- Cost of labor to troubleshoot, patch, clean up, repair and restart
- Cost of damaged equipment and materials, including repairs, replacements and scrapped material



**Figure 1.** This maintenance control chart tracking voltage unbalance shows a Nov-03 reading above the 2.5 % limit and then the effect of the corrective action.

## Integrating power quality into PdM

Unlike a comprehensive electrical system survey, predictive maintenance power quality focuses on a small set of measurements that can predict power distribution or critical load failures. By checking the power quality at critical loads, you see the effect of the electrical system up to the load. Your predictive maintenance inspection route probably already includes any motors, generators, pumps, A/C units, fans, gearboxes, or chillers on site.

Voltage stability, harmonic distortion, and unbalance are good indicators of load and distribution system health and can be taken and recorded quickly with little incremental labor. Current measurements can identify changes in the way the load is drawing. All of these measurements can be taken without halting operations and generate numbers that can easily be entered into maintenance software and plotted over time.

For each measurement point or piece of equipment, determine what limit should trigger corrective action. Limits should be set well below the point of failure,

and as time goes on limits may be “tightened” or “loosened” by analyzing historical data. The appropriate limits depend somewhat on the ability of your loads to deal with power variation. But for most equipment, your maintenance team can devise a set of default, “house limits” based on industry standards and experience.

The cost of three-phase power analyzers is lower now than ever and it should only take roughly 15 minutes to take the readings discussed in this article. (Storing voltage sag data will add more time, since it requires picking up the data after a day or so.)

## Measurement Guidelines

Voltage Measurements	Phase-to-Neutral Voltages
	Neutral-to-Ground Voltages
Voltage Sags	Phase to Neutral Sag Count
Voltage Harmonics	Phase Voltage THD
Current Measurements	Phase Currents
Voltage Unbalance	Negative Sequence, Zero Sequence

Table 1. Basic power measurements for 3-phase Wye equipment

### Voltage

Good voltage level and stability are fundamental requirements for reliable equipment operation.

- Running loads at overly high or low voltages causes reliability problems and failures. Verify that line voltage is within 10 % of the nameplate rating.
- As connections in your system deteriorate, the rising impedance will cause “insulation resistance drops” in voltage.

Added loads, especially those with high inrush, will also cause voltage decline over time. The loads farthest from the service entrance or transformer will show the lowest voltage.

- Neutral to ground voltage tells you how heavily your system is loaded and helps you track harmonic current. Neutral to ground voltage higher than 3 % should trigger further investigation.

Volt/Amps/Hertz				
	A	B	C	N
U <sub>rms</sub>	116.7	112.9	112.6	1.5
U <sub>pk</sub>	167	163	158	4
CF	1.4	1.4	1.4	2.4
Hz	60.16			
	A	B	C	N
I <sub>rms</sub>	288	277	285	1
I <sub>pk</sub>	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

Figure 2. Recording all phase voltages and neutral to ground voltage is a good start for a PQ analysis of critical equipment and overall distribution system health.

### Voltage sag count

Taking a single voltage reading tells only part of the story. How is the voltage changing during an hour? During a day? Sags, swells and transients are short-term variations in voltage. The voltage sag (or dip) is the most common and troublesome variety.

Sags indicate that a system is having trouble responding to load requirements and significant sags can interrupt production. Voltage sags can cause spurious resets on electronic equipment such as computers or controllers, and a sag on one phase can cause the other two to overcompensate, potentially tripping the circuit.

Sags have several dimensions: depth, duration, and time of day. Utilities use a special index to track the number of sags that occur over a period of time. To gauge the depth of the sags, they count how often voltage drops below various thresholds.

The longer and larger the voltage variations, the more likely equipment is to malfunction. For example, the Information Technology Industry Council (ITIC) curve specifies that 120 V computer equipment should be able to run as long as voltage does not drop below 96 V for more than 10 seconds or below 84 V for more than 0.5 seconds.

### Current

Current measurements that trend upward are a key indicator of a problem or degradation in your load. While equipment is running, monitor phase, neutral and ground current over time. Make sure none of the currents are increasing significantly, verify that they're less than the nameplate rating, and keep an eye out for high neutral current, which can indicate harmonics and unbalance.

### Voltage unbalance

In a three-phase system, significant differences in phase voltage indicate a problem with the system or a defect in a load.

- High voltage unbalance causes three-phase loads to draw excessive current and causes motors to deliver lower torque.

- Unbalance is tracked in percentages (see Figure 3). The negative sequence voltage (Vneg) and zero sequence voltage (Vzero) together identify any voltage asymmetry between phases.
- Using a power quality analyzer to do the math, high percentages indicate high unbalance. EN 50160 requires Vneg to be less than two percent.

### Voltage harmonic distortion

Harmonic distortion is a normal consequence of a power system supplying electronic loads such as computers, business machines, electronic lighting ballasts, and control systems. Adding or removing loads from the system changes the amount of distortion, so it's a good idea to regularly check harmonics.

Harmonics cause heating and reduced life in motor windings and transformers, excessive neutral current, increased susceptibility to voltage sags, and reduced transformer efficiency.

As current harmonics interact with impedance, they're converted into voltage harmonics. Total Harmonic Distortion (THD) is a sum of the contributions of all harmonics. By tracking Voltage THD over time you can determine if distortion is changing. For voltage harmonics, IEEE 519 recommends less than 5 % THD.

Unbalance				
DEMO 0:00:58				
	Vneg.	Vzero	Rneg.	Rzero
Unbal.(%)	1.6	0.9	8.7	6.5
	A	B	C	N
Vfund	116.6	112.6	112.5	0.4
Hz	60.16			
∑U(°)	-360	-121	-240	-95
∑A-U(°)	-8	-15	-1	0
	A	B	C	N
Rfund	286	274	283	0
09/16/04 04:44:38 120V 60Hz 3Ø WYE EN50160				
				TREND
				HOLD RUN

Figure 3. This unbalance display shows the voltage unbalance parameters (Vneg and Vzero) as well as current unbalance.

### International safety standards for test tools

Overvoltage Category	Summary Description
CAT IV*	Three-phase at utility connection, any outdoors conductors (under 1000 V)
CAT III	Three-phase distribution (under 1000 V), including single-phase commercial lighting and distribution panels
CAT II	Single-phase receptacle connected loads
CAT I	Electronic

\*CAT IV product specifications are not yet defined in the standard.

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				
U&A		BACK	TREND	HOLD RUN

Figure 4. This Harmonics table shows the voltage THD for each phase. Note that it's normal for the voltage THD on the neutral to run close to 100 %.

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