

Applying handheld test tools to predictive maintenance

Application Note

Unplanned downtime due to equipment failure costs manufacturers up to 3 % of their revenue each year. For a \$1 billion manufacturer, that's \$30 million of potential savings, directly to the bottom line. If a company has a net income of \$100 million, that's a 30 % reduction in profitability.

In an era of extreme competitiveness, no one can afford to let this kind of money slip through their hands.

Scheduling downtime for maintenance is much more cost effective and efficient. Planned downtime allows maintenance managers to determine:

1. How to utilize their personnel,
2. If the correct spare parts are in stock to make repairs, and
3. How to minimize the amount of time a facility is out of operation.

The trick is figuring out what equipment needs repair when — otherwise downtime, technician's time and part costs can still get out of hand.

Predictive maintenance (PdM) programs regularly measure key indicators on critical equipment and track that information over time, helping technicians predict when repairs are necessary.

This application note describes the PdM measurements you can gather and track with DMMs, clamp meters, digital infrared thermometers and insulation resistance testers. Other application notes in this series discuss PdM applications for thermal imagers and power quality analyzers.

Predictive maintenance cost savings

Predictive maintenance programs improve performance, increase productivity, reduce downtime hours, and lower maintenance and inventory costs. Studies by the Federal Energy Management Program (FEMP), estimate predictive maintenance can save 8 % to 12 % over routine maintenance and 30 % to 40 % over unplanned downtime.

Independent surveys report the following average savings from industrial predictive maintenance programs:

- Return on investment: 10 times
- Reduction in maintenance costs: 25 % to 30 %
- Elimination of breakdowns: 70 % to 75 %
- Reduction in downtime: 35 % to 45 %
- Increase in production: 20 % to 25 %

Integrating tools and programs

PdM programs vary from the highly sophisticated, with continuous online monitoring and automated alerts, to more traditional offline programs that rely on inspection routes and manual measurements.

PdM monitoring tools also vary in complexity, from digital spot infrared thermometers to thermal imagers, vibration analyzers and power quality tools, to permanently mounted and networked sensors. Investigative tools vary from handheld DMMs, clamp meters, and insulation resistance testers to specialized motor circuit testers.

Many facilities mix and match, depending on their equipment and scale of operations. What's different is that these technicians are repurposing tools traditionally used for troubleshooting for predictive maintenance measurement programs.



Digital multimeter

PdM measurements with handheld test tools

Equipment	Key Indicators	Measurement	Test Tool
UPS/PDU	<ul style="list-style-type: none"> – Intermittent tripping – Process interrupts 	RMS voltage, rms current, frequency (Hz), connection resistance, data log readings over time for anomalies.	IR, DMM
Transformer	<ul style="list-style-type: none"> – Heat – Buzzing 	Temperature, impedance at neutral-ground bond, voltage balance, current balance, loose connections.	IR, DMM, CM
Panels/switchboards	<ul style="list-style-type: none"> – Intermittent tripping – Hot circuit breakers 	Voltage balance, current balance, data log readings over time for anomalies, loose connections, temperature.	IR, DMM, CM
Controls (ASDs Disconnects)	<ul style="list-style-type: none"> – Process anomalies – Change in system performance 	Voltage balance, current balance, inrush current, voltage sags, connection resistance, data log readings over time for anomalies.	IR, DMM, CM
Lighting panels	<ul style="list-style-type: none"> – Flickering lights – Buzzing 	Voltage balance, current balance, inrush current, voltage sags, connection resistance, data log readings over time for anomalies.	IR, DMM, CM
Motors and other equipment (gearboxes, pumps, fans, chillers, A/C units, generators)	<ul style="list-style-type: none"> – Heat – Intermittent tripping 	Inrush current, insulation resistance to ground, temperature, nameplate rating, overloading, voltage balance, current balance, resistance, connection motor start capacitor.	IR, IRT, DMM, CM

Key: Infrared thermometer (IR), digital multimeter (DMM), insulation resistance tester (IRT), clamp meter (CM).
Note: These recommendations are not a complete set of PdM measurements.

Measurement Guidelines

Predictive maintenance measurements aren't that different from troubleshooting tests. You're looking for signs of potential failures, so you take measurements related to failure modes.

1. For each type of equipment, identify the potential failures and related key indicators.
2. Determine what measurements can reduce the likelihood of problems.
3. Determine how often equipment needs to be measured.
4. Collect and track the results, watch for trends, and instigate repairs as needed.

Temperature

Infrared thermometers are a low-cost monitoring option for quick, frequent measurements of specific components while equipment is operational. Use your knowledge of your equipment to identify key hot spots to track, compare those temperature readings to operational limits, and watch for upward trends.

For example, scan the bearing housings on motors, the switches in circuit breaker panels, and the wiring connections at all equipment. For the best measurements, get as close as is *safely* possible to your target, make sure you're not measuring a reflective surface, and compensate for emissivity.

Insulation resistance to ground

Caution: Before testing cabling and motors, disconnect any electronic controls — misapplication of high voltage test-equipment can destroy them.

Regularly conducting the following insulation resistance tests on loads and connections can help detect imminent equipment failure.

- Ground testing line and load circuits at the starter will identify the resistance to ground of the starter, line circuits to the disconnect, and load lines to the motor and starter windings.



Infrared thermometer

- General thresholds: ac devices can safely operate at not less than two megohms to ground and dc devices can safely operate at not less than one megohm to ground.
- When measuring the resistance of a three phase motor between the load legs of the starter, you should see high resistance and roughly equivalent measurements between phases.

Note: Insulation resistance to ground tests conducted with an insulation resistance tester require disconnecting the components or cabling to be tested from the power system –incorporate this into planned downtime.

Power quality

DC and AC supply voltage

It pays to regularly measure voltage at critical equipment, to verify the load is receiving stable supply voltage within the name-plate rating tolerances. Too much or too little voltage causes reliability problems and equipment failures.

A true-rms DMM is necessary to accurately measure ac voltage affected by harmonics, and a low-bandwidth filter is necessary to accurately measure adjustable speed drive (ASD) voltage. A DMM can also be used to check for proper voltage balance in the supply system. Logging DMMs can be used to monitor changes in performance over time and can give you warning of impending failure.

Resistance

Caution: Resistance measurements must be made with the circuit power off. Otherwise, the meter or circuit could be damaged.

A DMM can check the resistance across most connections. The higher the resistance, the more degraded the connection, a flag for reduced voltage supply, nuisance tripping and potential equipment failure.

- High resolution DMMs can also measure the resistance across relay and circuit breaker contacts - resistance goes up as the contacts degrade.
- IR thermometers can also identify high resistance connections – they show up as hot spots when compared to a good connection.

DMM Notes: Most DMMs measure down to 0.1 Ω and some measure as high as 300 MΩ. For accurate low-resistance measurements, use the DMM's REL function to eliminate test lead resistance.

DC and AC current

Caution: After measuring current with a DMM, don't forget to move test leads back to voltage before attempting your next voltage measurement.

Loads will draw slightly higher current as they age. Regularly measuring current can help you track equipment reliability. Use either a clamp meter or a DMM combined with a current clamp for measuring current.

Voltage balance

A greater than two percent voltage unbalance can reduce equipment performance and cause premature failure. Use your DMM to check voltage between phases for voltage drops at the protection and switchgear delivering power from the utility and at high priority equipment.

Voltage unbalance can be calculated with this formula.

$$\text{average volts} = (\text{ph1 volts} + \text{ph2 volts} + \text{ph3 volts}) / 3$$

$$\% \text{ voltage unbalance on ph1} = ((\text{ph1 volts} - \text{average volts}) / \text{average volts}) \times 100$$

Note: Voltage drops across the fuses and switches can also show up as unbalance at the motor and excess heat at the root trouble spot. Before you assume you've found the cause, double check with a thermometer.

Current balance

Another root cause for equipment overheating is current unbalance. Use a clampmeter or an ac current clamp with your DMM to check the current draw on each of the three legs. To determine average current, sum the current from all three phases and divide by three. Then, calculate the percent unbalance by subtracting the actual on one leg from the average amps, then divide by the average amps and multiply by 100. More than 10 percent current imbalance can be a problem.

$$\text{average amps} = (\text{ph1 amps} + \text{ph2 amps} + \text{ph3 amps}) / 3$$

$$\% \text{ unbalance on ph1} = ((\text{ph1 amps} - \text{average amps}) / \text{average amps}) \times 100$$



MegOhmMeter insulation resistance tester

Inrush current

If a motor isn't performing correctly or if your circuit is unexpectedly tripping, check inrush current at startup with a clamp meter or a DMM designed to capture inrush current. Inrush current can reach up to twelve times the normal running current – much higher than the circuit breaker rating – without tripping the breaker, as long as the circuit isn't overloaded. Evaluating your inrush current depends on comparisons of inrush measurements over time for that motor.



Clamp meter

Safety and test tool rating requirements

Before you start using your DMM or other test tools for predictive maintenance, make sure you understand the limitations of your tool and the safety precautions that go along with it.

- Choose a DMM rated for 1000 V CAT III / 600 V CAT IV and a clamp meter rated for 600 V CAT III.
- For DMMs, look for true-rms, resistance of 0.1 ohms or less, capacitance test to 9999 microfarads, and frequency. If you're tracking data over time, get a DMM with data/event logging capabilities and fast Min/Max, sufficient memory, extended-life batteries, an optical port, and software for downloading measurement results to your computer.
- For typical industrial and commercial motors, choose an insulation resistance tester with a minimum of 500 V output and resistance measurements to several gigohms.
- Determine how close you can safely stand to your equipment during temperature measurements and use that to determine what distance-to-spot ratio your infrared thermometer must support. A Distance-to-spot size ratio of 50:1 allows accurate measurement within 8 feet, depending on target object emissivity.
- Ensure the voltage rating on your test probes matches your test environment. Insulation resistance testing typically requires high voltage probes, as do some DMM tests.
- If you must make live measurements in a three phase environment, wear the appropriate Personal Protective Equipment (PPE), use the three point test method, and if possible, keep one hand in your pocket to prevent current transfer.

Three-point test method:

1. Test a known live circuit.
2. Test the target circuit.
3. Test the live circuit again.

This verifies that your meter worked properly before and after the measurement, and ensures you know whether a circuit is live.

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