Enhance Power Equipment Reliability with Predictive Maintenance Technologies

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Summary

1.0 The Importance of Electrical Equipment Maintenance

A comprehensive preventive maintenance and testing program should incorporate all electrical power distribution equipment, regardless of the manufacturer, to ensure that all electrical equipment and components operate safely and reliably as originally designed and intended. The ultimate goal is to minimize equipment malfunction, power outages, or interruptions to operations or service.

- An effective and reliable electrical installation is critical to any operation.
- Studies of electrical equipment maintenance show a strong correlation of maintenance level to reliability.
  - > The rate of electrical component failures is three times higher in facilities that do not perform preventive maintenance.
    - Source: Institute of Electrical and Electronics Engineers (IEEE)
- Routine maintenance verifies proper functionality, both electrically and mechanically.
  - > Protective devices are to help ensure safety for people and assets.
  - > The 2012 edition of NFPA 70E references NFPA 70B and now requires an Electrical Preventive Maintenance (EPM) program with documentation.
  - > The Liberty Mutual Research Institute for Safety reports that electrical injuries are the second most costly worker's compensation claim.

Electrical equipment should be installed, operated, serviced, and maintained only by properly trained and qualified personnel. No responsibility is assumed by Schneider Electric for any consequences arising out of the use of this material.

Following are the most common causes of electrical equipment breakdowns:*

> Mechanical Failure

Loose connections, overheating, load changes and/or additions

> Environmental conditions

Humidity, corrosive environments, dirt, or dust may require preventive maintenance more frequently than the OEM's recommended schedule

> Work Improperly performed

OSHA and NFPA® require electrical equipment maintenance to be performed by qualified personnel

* Source: Hartford Steam Boiler Inspection and Insurance Company

2.0 Approaches to Electrical Equipment Maintenance

Depending on the process, operating environment or age of equipment, companies may adopt one or more of the following maintenance strategies:

Reactive Maintenance

- Repair work conducted after a failure or breakdown, often completed as an emergency
- The most costly of all maintenance strategies

Preventive Maintenance

- Routinely performed maintenance, regardless of the condition of the equipment
  - > May be unnecessary, based upon the equipment's condition
- Specified list of inspections, cleaning, testing and part replacement
- Less expensive than reactive maintenance, but more costly than predictive maintenance

Predictive Maintenance (or Periodic Diagnosis)

- Scheduled based on diagnostic evaluations
  - > Factors such as equipment age, environmental stresses, criticality of equipment, utilization, etc. affect decisions concerning maintenance schedule
- Provides significant reduction in equipment-related incidents
- Least expensive maintenance strategy

An efficient maintenance strategy will identify the type and amount of maintenance to be performed as well as the frequency for maintenance activities to be carried out. on each piece of electrical distribution equipment.

The True Cost of Downtime

Every facility should know what the monetary impact of an unplanned outage means to their respective operations. However, when an event happens, the focus is usually on restoring power as fast as possible and at all costs. Often, the tangible and intangible costs are not accounted for during the event. The best way to avoid this financial impact is to reduce the risk of an unplanned outage, which requires time, effort, planning and money.

3.0 What is Predictive Maintenance?

Predictive maintenance technologies enable companies to perform an effective amount of maintenance at an appropriate or practical time. Often referred to as condition-based maintenance, predictive maintenance tools monitor the condition of in-service equipment, either continuously (online) or at periodic intervals. Disruptions to facility operations can be reduced, since many predictive maintenance technologies are performed on in-service equipment. Having regular access to the current state of the equipment provides valuable information to determine when maintenance should be performed. From a cost-effective standpoint, it should take place before the equipment loses optimum performance.

Conditions that can be monitored in electrical equipment include:

• Transformer	>	Temperature, SF_6, insulation breakdown
• Tap Changer	>	Operating time
• Circuit Breaker	>	Opening, closing time, available magnitudes of I^2t energy
• Switchgear	>	Temperature of connections, insulation condition
• Motor	>	Starting time, number of operations, power, insulation breakdown
• Cable Connections	>	Insulation breakdown

Monitoring the condition of equipment provides trending data to help anticipate and plan future maintenance activities.

4.0 Predictive Maintenance Technologies

4.1 Power System Assessments

Power system assessments are often the first inspections performed since equipment was originally installed. Completed by professional electrical engineers trained in power system analyses, power system assessments provide for visual inspections of portions or all of the existing power distribution system. Power system assessments determine the electrical and mechanical 'health' of the electrical equipment and power distribution system and how long they will likely continue to function as originally designed and intended. Defects, deficiencies, deteriorations, hazards, or weaknesses in existing electrical power distribution system installations are also identified as part of a power system assessment.

Issues discovered as a result of the assessment are prioritized based upon one of four factors:

1. The safety hazard to electrical workers
2. The impact of the occurrence to key process elements
3. The probability of an occurrence
4. The ability to respond quickly to correct the negative effects of the occurrence (vulnerability)

Power system assessments can be customized based upon the need to reduce risk to your facility from reliability issues, process disruptions, code violations and/or outdated workplace safety requirements.

4.2 Infrared (Thermographic) Inspections

Infrared inspections use an infrared camera to detect anomalies not noticeable to the naked eye. In an electrical setting, infrared inspections identify hot spots, which can be a precursor to equipment malfunction, which leads to unplanned downtime. Heat rise in electrical equipment can be the result of:

1. Poor or loose electrical contacts or connections
2. Unbalanced electrical loads
3. Defective components

Having infrared inspections routinely performed may qualify a company for reduced insurance premiums.

> Infrared Windows Enhance Safety

Since infrared inspections are performed while equipment is on-line, equipment covers typically need to be removed. Having infrared windows installed in equipment panels enables permanent access for inspection of electrical components without disturbing operations. The window is made of a glass-like material that is transparent to infrared rays and allows hot spots to be registered by a thermographic camera.

4.3 Online Temperature Monitoring

Online temperature monitoring technology provides 24/7 access to critical connection points where traditional thermography cannot be used. Continuous monitoring provides the means to evaluate the equipment's current condition and detect abnormalities at an early stage. Conduction problems caused by loose connections or deterioration of contact surfaces result in a local temperature rise, which contributes to the reduction of the contact quality. Thermal runaways induced by conduction problems deteriorate the insulating material and cause disruptive dielectric discharges resulting in arcing faults.

How it Works: During a planned outage, wireless temperature sensors are installed in low-voltage and medium-voltage equipment* in areas usually not accessible with an infrared camera. Utilizing wireless technology eliminates the need for special cables and provides lower installation costs than other types of online condition monitoring equipment.

Temperature data is transmitted from the sensors to a nearby receiver via radio frequency signals. The receiver is connected to a computer via serial or Ethernet. The data can be alarmed on, compiled, analyzed and reported by a dedicated software package or via a SCADA program with Modbus TCP connectivity.

* Sensors can also be installed on equipment with high arc flash ratings, allowing equipment condition to be monitored without a risk of danger to personnel or equipment.

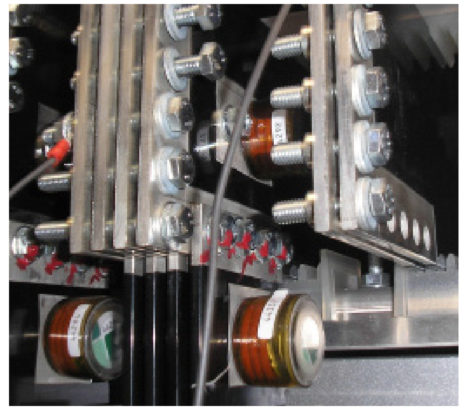

Photo shows the placement of temperature monitor sensors attached to service entrance bussing.

4.4 Insulating Fluid Analysis

This predictive maintenance technology measures the physical and chemical properties of oil in an oil-filled transformer. Since transformers represent a substantial investment in a company's electrical distribution system, they must be maintained properly to maximize their reliability. An oil analysis can detect the breakdown of the oil paper insulating system along with a variety of other potential issues. Common tests performed on electrical insulating oils include:

> Moisture Content
> Increased moisture content can negatively affect the insulating properties of the oil and cause dielectric breakdown.

> Acid Number
> As oil degrades, it produces charged by-products – including acids and hydroperoxides – that adversely affect the oil's insulating properties.

> Dielectric Strength
> This is the maximum voltage that can be applied across the fluid without electrical breakdown. A significant reduction in the dielectric strength may indicate the oil can no longer perform as intended.

> Power Factor
> In transformers, a high power factor is an indicator that the insulating oil has a significant power loss, usually caused by contaminants (water, oxidized oil or degrading cellulose paper).

> Dissolved Gas Analysis (DGA)
> Concentrations and ratios of certain gases in the oil may be indicators of operational problems with the transformer. Two examples are shown below:
> - High levels of carbon monoxide in relation to other gases may be a symptom of thermal breakdown of cellulose paper.
> - High hydrogen levels, in conjunction with methane, may point to a corona discharge within the transformer.

Possible issues can be discovered in time and outages can potentially be avoided. In addition, an efficient approach to maintenance can be adopted and the optimum intervals determined for oil processing, repairs or replacement.

4.5 Partial Discharge Monitoring

Partial discharge is a leading indicator of insulation breakdown and occurs in electrical equipment under high voltage stress, usually greater than 2,000 V. The higher the voltage, the higher the potential for damage or downtime. Specifically, partial discharge is a localized electrical discharge in an insulation system that does not completely bridge the electrodes. As insulation systems age, they become more susceptible to breakdown. Continuous monitoring provides early warning alarms to help prevent equipment damage or downtime.

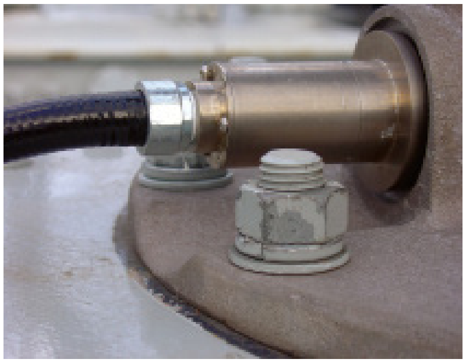

Photo shows connection of a partial discharge sensor into the capacitive coupler port of a high voltage transformer bushing.

Technology is available to detect and notify facility engineers of impending insulation breakdown. Partial discharge monitoring is applicable on equipment rated 5 kV to 500 kV where the age of the insulation could be cause for concern. Specific equipment applications include:

- Metalclad switchgear and switches: 5kV and 15kV
- Motors and generators > 2.4kV
- Large power transformers and bushings
- Substation yard structure-mounted voltage transformers and current transformers
- Generator step-up transformers and bushings

Photo shows clear indications of corona tracking due to damaged insulation laminate on bussing and long term electron tracking prior to a phase-to-ground fault condition.

How it Works: Sensors are installed to equipment during a planned outage. They are wired to a monitoring unit, which can be tied into an existing SCADA system via open protocol (web hosting is also available). The sensors monitor:

- Magnitude (mV or pC) - Size or volume of the deficiency
- Pulse Count (PS) - Number or growth of deficiency
- Intensity / Power (mW) - Destructive power of the partial discharge events
- Signature - Includes phase of deficiency as well as type of deficiency

Monitored results are evaluated and compared against an existing database. Trending data helps anticipate and plan future maintenance activities.

4.6 Circuit Monitor Analysis

Circuit monitors record data relating to voltage, current, and power. They also offer a full-range of power quality features to help facility managers and engineers understand where and when dangerous and destructive transients, sags and swells occur. These include:

- Wave form capture and wave shape analysis
- Disturbance recording
- Disturbance direction detection
- Transient Analysis

Some circuit monitor models can provide data on other utilities, including gas, compressed air, water, and steam to help management control operating costs. Whether addressing operational or power quality, circuit monitors have the capacity to diagnose potential problems to minimize downtime.

4.7 Intelligent Protective Devices

Circuit Breakers

- Electronic trip units or separate monitors can provide intelligent information regarding the circuit breaker's status, which include:
  - > General Condition: Identification, position, number of operations, cumulative interrupted currents, integrity of interrupting medium for medium-voltage (SF_6 or vacuum)
  - > Mechanical Condition: Operating times, charging time, travel-time curve, excess closing energy, wear of contacts
  - > Control Circuit / Auxiliaries: Supply voltage; supervision of trip coil circuit, of sensors circuit
- Provides advanced planning ability as "condition-based" activity instead of routine maintenance

Motor Control Centers

- Intelligent motor starters allow cost-effective monitoring of motor current and power.
  - > Motor control centers are upgraded and networked into a centralized or distributed control scheme
  - > Digital display can be mounted on the door to minimize the need to open/close
  - > Motor run time can be easily tracked
- Intelligent monitoring functions include:
  - > Current: Thermal capacity, line currents, average current, ground current, motor temperature (sensor) and current phase imbalance
  - > Voltage: Frequency, line to line voltage, line voltage imbalance
  - > Power: Active and reactive power, power factor, active and reactive energy
- Electrical signature analysis can detect:
  - > Rotor bar damage
  - > Stator electrical faults
  - > Defective bearings
- Maintenance can be scheduled on an as-needed basis.

Motor control center outages can typically be attributed to:

> Power Quality
> Voltage and Current Waveforms
> Harmonic Voltage Factor
> Voltage THD

5.0 Benefits of a Predictive Maintenance Program

Industry trends point to reduced maintenance staffs and budgets as well as aging electrical equipment. Predictive maintenance provides cost-efficient solutions to maximize reliability and enhance workplace safety. Benefits of incorporating predictive maintenance technologies into a company's maintenance strategy include:

1. Determines the operational status of equipment
2. Evaluates present condition of equipment
3. Detects abnormal conditions in a timely manner
4. Initiates actions to prevent possible forced outages

Monitoring the condition of equipment provides trending data to help anticipate and plan future maintenance activities, which saves time and money.

According to the U.S. Department of Energy, independent surveys indicate the following average industrial savings or improvements when a functional predictive maintenance program is implemented:

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

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