EC&M

CONDITION-BASED MAINTENANCE FOR SHUTDOWNS, TURNAROUNDS AND OUTAGES (STOs)

Predictive Maintenance is the Best Maintenance

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INTRODUCTION

The proper operation and reliability of a plant's electrical equipment is directly related to the application and quality of maintenance of the equipment. During large shutdowns, turnarounds and outages (STOs), executing proper maintenance tasks is required. It is imperative that the right maintenance is prioritized and implemented to minimize plant downtime and maximize production uptime. One way to determine and accommodate the right maintenance is through a conditioned-based maintenance program.

Condition-Based Maintenance means evaluating the condition of the equipment by performing:

1. **Periodic or continuous (online) equipment condition monitoring.**
2. **Scheduling maintenance during STOs based on the actual condition of equipment rather than some pre-set schedule.**

A condition-based maintenance program will utilize the results of predictive maintenance to determine the level and frequency of preventive maintenance that is to be implemented during an STO. The focus of this paper is using predictive maintenance techniques to determine equipment condition.

PREDICTIVE MAINTENANCE

The Predictive Maintenance activities and results are the basis for implementing a condition-based maintenance program. These activities are performed while the facility is operating. Further, to obtain maximum benefit from the associated inspections, samples and surveys, and diagnostic tests, knowledge of the equipment, systems, and indications of potential failure modes is required. Since the associated equipment is on-line and operating, the importance of utilizing qualified people perform these tasks is mandatory. They are aware of the safety implications and applicable safety precautions that should be implemented while performing these activities.

Periodic walkthroughs are performed to inspect and evaluate general equipment condition and changes to operating parameters. In environments where there is an extreme exposure to adverse conditions, the frequency of inspections should be increased as conditions warrant. For critical equipment, a periodic "maintenance route" should be developed to ensure that adequate predictive maintenance is performed.

PHYSICAL INSPECTIONS

Physical Inspections should be performed on electrical equipment for the visual evidence associated with installation errors, equipment subassembly failures, poor equipment condition, overheating, and corona. On outdoor, metal-enclosed switchgear, inspections should be performed to ensure proper structural integrity and weatherization.

1. PHYSICAL AND MECHANICAL CONDITION

Evaluate the paint condition and cleanliness of the outside of equipment compartments. Inspect for conditions that could result in a leak, reduced ventilation and cooling, or potential exposure to an energized circuit. Conditions should be recorded and brought to the attention of appropriate management for corrective action during the STO, if necessary.

Transformers – Evaluate the transformer's radiator cooling fins and make a determination that there is no hindrance to getting air to the radiator cooling fins.

Capacitors – Inspect capacitor cans for swelling, leaking, or a pressure pop out.

Batteries – Inspect batteries under normal float conditions. For flooded batteries, inspect the electrolyte level, the positive plates, the negative plates, and the internal sediment.

Emergency Generators – Ensure the engine-generator area is free of debris to ensure sufficient ventilation during operation. Further, inspect the exhaust system, including the manifold, muffler, and exhaust pipe with all connecting gaskets, joints, and welds being checked for potential leaks. This includes checking fittings and connections; tighten them as needed. Where applicable, examine charge-air piping, and supply hoses for leaks, holes, and damaged seals. The fuel system and charge-air cooler should also be free of dirt and debris.

Physical Inspections should be performed on electrical equipment for the visual evidence associated with installation errors, equipment subassembly failures, poor equipment condition, overheating, and corona.

2. PROPER ANCHORAGE AND GROUNDING

Inspect for proper anchorage and bonding. Evaluate the condition and connections of the grounding straps from the equipment case to the grounding system connection. The straps should be continuous and free of defects. The connections should be tight and show no discoloration.

3. FLUID LEAKS AND SPILLS

Evaluate electrical equipment rooms, vaults and enclosures for evidence of water or fluid seepage. If observed, the source of the water or fluid should be immediately identified and corrective measures taken to permanently correct the condition.

Transformers – Around bushings and penetrations associated with a liquid-filled transformers and oil-filled breakers, oil seepage from within the transformer typically appears as a discoloration of the painted surface around the bushing or penetration.

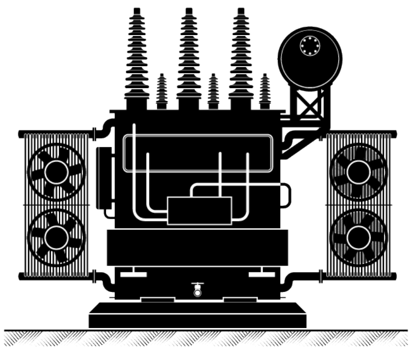
Capacitors – Inspect capacitor cans for swelling, leaking, or a pressure pop out.

Batteries – Inspect the outside of the jar. A crusty trail or accumulation is evidence of electrolyte leakage. Signs of corrosion on the terminal connections, inter-cell connections, and racks are also indicative of electrolyte leakage. To support proper battery health, battery posts and connections should be cleaned, when necessary.

Emergency Generators – Inspect engine-generator systems to ensure fluids, such as oil and coolant, are not leaking. Also inspect the fuel delivery system periodically for leaks. A fuel sample, taken from the bottom of the fuel tank and from the supply line, should be visually examined monthly. Engine-generator fluids, such as oil and coolant, should be at the proper mix and levels.holes, and damaged seals. The fuel system and charge-air cooler should also be free of dirt and debris.

4. PROPER VENTILATION AND TEMPERATURE CONTROL

For applicable ventilation and air conditioning, clean and examine for signs of wear and deterioration. Clean fan blades and vent openings of all dust and dirt accumulations. Filters should be cleaned and/or changed as recommended by the manufacturer or more often if conditions warrant. Bearings should be properly lubricated. For outdoor electrical switchgear and enclosures, accessible heater circuits should be checked for proper operation.



Transformers – Check transformer cooling fans for proper operation. If the system does not operate, this condition should be recorded and brought to the attention of appropriate management for a repair of the system.

Batteries - If applicable, verify the presence and condition of flame arrestors. Additionally, verify battery area ventilation is operable and that suitable eyewash equipment is present.

Emergency Generators – Inspect and clean the area around the engine-generator to ensure it is kept free of debris to ensure sufficient ventilation during operation. Clean the radiator, when applicable, to remove any dust and/or debris, taking care not to damage the fins. The fuel system and charge-air cooler should also be free of dirt and debris. Also, verify proper operation of the engine jacket water heater.

5. PERFORMANCE INDICATORS

Monitor electrical equipment indicators periodically to ensure that the equipment is operating within acceptable parameters.

Transformers – Monitor liquid level, temperature, and pressure indicators, as applicable, to ensure that the transformer is operating within acceptable parameters. For larger transformers, oil-filled bushing levels should be verified as acceptable for continued service. Further in free-breathing transformers, verify that the desiccant is satisfactory for continued service.

Capacitors – Verify proper operation of battery charge method, voltage, and current.

Batteries – Monitor SF6 breakers alarms or metering for temperature-corrected pressure and density.

6. PROPER PROTECTIVE CONTROLS AND SETTINGS

Monitor voltage and current meters periodically to ensure proper voltage, voltage balance, voltage stability, and operating current. In addition to simple meters, power meters may be available that are very useful in determining electrical system health. Additionally, these devices may have a communication capability such that the information within the relay can be accessed through a system control and data acquisition system (SCADA system).

Power Meters – Where applicable, interrogate power meters regularly to monitor electrical system parameters and possible power quality disturbances.

MV Breakers – Interrogate protective relays for detailed event files and operational information and settings. Protective relays also have many of the attributes of power monitors. Interfacing with protective relays can typically be accomplished by connecting a computer to the relay.

LV Breakers – For larger LV breakers, inspect trip units for alarm “flags” and appropriate settings.

SAMPLES AND SURVEYS

There are some samples and surveys that can be performed while equipment is on-line and operating.

1. OIL SAMPLE ANALYSIS

Monitor voltage and current meters periodically to ensure proper voltage, voltage balance, voltage stability, and operating current. In addition to simple meters, power meters may be available that are very useful in determining electrical system health. Additionally, these devices may have a communication capability such that the information within the relay can be accessed through a system control and data acquisition system.

2. INFRARED INSPECTION

Perform infrared (IR) Inspections, or Thermographic Surveys, on high and low voltage equipment where accessibility is not an issue. It should be noted that this survey requires a direct line-of-sight to the area being surveyed to ensure acceptable results. This type of survey is very useful in identifying loose or bad connections and terminations and overloading conditions and should be applied to electrical equipment (i.e., breakers, transformers, buses, surge arresters, and cables terminations.

3. ULTRASONIC EMISSION (UE) SURVEYS

Perform UE Surveys on high voltage equipment, only. It should be noted that this survey requires a direct line-of-sight to the area being surveyed to ensure acceptable results. A UE survey is highly recommended when evaluating outdoor substation equipment with connections that are visible.

4. SF6 GAS ANALYSIS

For some higher voltage devices, perform SF6 gas analysis for contamination, including moisture or air in leakage. It should be noted that many SF6 chambers are not provided with the capability for sampling. When sampling is not provided for, do not break the seal or distort sealed-for-life interrupters.

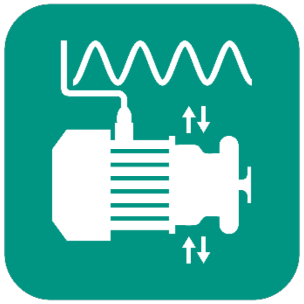
5. PARTIAL DISCHARGE (PD) TESTING (ON-LINE).

Perform a partial discharge survey on high voltage insulation systems. PD surveys are typically performed with a hand-held device with various sensors for different types of analysis (i.e., ultrasonic, capacitive-coupled, or High frequency current transformers (HVCTs)). For critical buses, switchgear, and cable terminations, consideration should be given to installing permanent sensors to accommodate PD surveys and trending. Additionally, capacitive couplers can also be installed in critical medium voltage buses and motors to accommodate continuous on-line surveys and trending.

IN SUMMARY, the profitability of a chemical plant or refinery is based on the number of reliable, uninterrupted days of operation. Due to this, these plants typically schedule large shutdowns, outages and turnarounds (STOs) with minimal down time to perform needed maintenance. Prior to these STOs, a condition-based maintenance program should be implemented to minimize plant downtime and maximize production uptime. This program should include predictive maintenance techniques that are utilized while the facility is operating. This predictive maintenance includes inspections, samples and surveys, and diagnostic tests and should be performed by qualified people, who are aware of the safety implications and applicable safety precautions required to perform this work safely.

DIAGNOSTIC TESTS

There are some diagnostic tests that can be performed while equipment is on-line and operating.



1. VIBRATION TESTING

With proper knowledge and diagnostic procedures, it is normally possible to quickly identify and pinpoint the cause of destructive vibration for a motor. By utilizing the proper data collection and analysis techniques, the true source of the vibration can be discovered. This includes, but is not limited to:

- Electrical imbalance
- Mechanical unbalance – motor, coupling, or driven equipment
- Mechanical effects – looseness, rubbing, bearings, etc.
- External effects - base, driven equipment, misalignment, etc.
- Resonance, critical speeds, etc.

Once the electrical and mechanical interactions in a motor are understood, and the influence external components have on the apparent motor vibration, identification of the offending component is usually straightforward.

2. BATTERY TESTS

Battery systems are unique in that most electrical tests can be performed while the system is on-line and operating. The following annual tests should be performed for both vented and sealed battery systems. In some cases as with UPS systems, a cabinet is utilized to house sealed batteries. As such, accessibility for tests may be an issue.

Cell-to-cell and terminal connection resistance.

Cell voltage and total battery voltage.

Appropriate charger float and equalizing voltage levels

Cell temperature.

Internal ohmic tests on battery cells with DC and/or AC voltage.

Specific Gravity.

3. EMERGENCY GENERATOR SYSTEM TESTING

Backup generators should be checked and tested periodically to ensure that they'll function as designed and when required. The engine-generator should be run under a load on a periodic basis. During dynamic testing engine parts become lubricated, oxidation is prevented, old fuel is consumed, and overall functionality is ensured. Therefore, periodic operation of the generator at a load of at least 30% of the nameplate rating for no shorter than 30 minutes should be performed.

If it is not possible or practical to use a site load for the test, a load bank should be used. Sometimes problems only become noticeable during operation. Therefore, it is important to remain attentive for unusual circumstances, e.g. abnormal sights, sounds, vibration, excessive smoke or changes in fuel consumption.

4. GROUND RESISTANCE

Ground resistance should be verified every 5 years. For large industrial complexes, an equipotential ground should be verified for all structures. Over time, corrosive soils with high moisture content, high salt content, and high temperatures can degrade ground rods and their connections. So although the ground system, when initially installed, may have had low earth ground resistance values, the resistance of the grounding system can increase if the ground ods are eroded away or damaged.

5. GROUND CONTINUITY TEST

A continuity test should be performed every 5 years on equipment and building grounding systems to verify proper grounding and bonding of the grounding system. A specialty measuring device, like a digital low resistance ohmmeter (DLRO) should be used to perform this test. In many cases, this will involve establishing a network of reference points throughout the system and making further continuity measurements from those reference points.

6. EMERGENCY OR BACKUP SYSTEM OPERABILITY/LOAD TEST

There is a difference between emergency systems and backup systems. Emergency systems are associated with life safety issues such as lighting for egress and ingress during loss of normal power. In an industrial facility, backup systems are typically associated with minimizing the effects of a normal power loss so that return to production can be facilitated. Both systems are equivalent in design in that they typically involve generators and/or uninterruptible power systems combined with transfer controls to and from the normal power source. If it is not possible or practical to use a site load for the test, a load bank should be used. Sometimes problems only become noticeable during operation. Therefore, it is important maintenance personnel remain attentive for unusual circumstances

Backup Generators – Backup generators should be checked and tested periodically to ensure that they'll function as designed and when required. The engine-generator should be run under a load on a periodic basis. During dynamic testing engine parts become lubricated, oxidation is prevented, old fuel is consumed, and overall functionality is ensured.

UPS Systems – UPS systems are designed to provide primary power to downstream equipment with immedi-ate switching to battery systems with loss of power. Failed or discharged batteries mean the UPS won't be able to supply the temporary backup power needed in the event of a power sag or outage. Even though UPSs are not designed to keep a facility running during a long-term outage, they do provide the carry-over capability that accommodates a seamless transfer to an alternate power source like a backup generator. The battery is by far the most vulnerable and failure-prone part of a UPS system. Because of this, much time and effort is allocated to max-imizing the battery's reliability and life. However, the transfer capabilities of the UPS should also be tested periodically to ensure proper operation.

Battery Systems – For battery systems, load capacity tests should be performed for vented (flooded), station-type, lead acid batteries every five years. Further, for valve-regulated (sealed) lead acid batteries, capacity tests should be performed every two years.

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Lynn graduated with a Bachelor of Science in Nuclear Engineering from the University of Tennessee in 1979. He has worked in the power industry since graduation and is a licensed Professional Engineer. He has 40 years of experience in power plant design, construction, commissioning, and startup testing. Lynn was on the board of the International Electrical Testing Association (NETA). As a board member, he held the following positions: Board Secretary; Safety Committee, Chairman; Technical Library Committee, Chairman; and Membership Committee, member. Lynn is also a NETA Level III technician. He has contributed to NETAWorld magazine by writing over 30 articles on electrical safety and electrical testing. In his role as Senior Consultant in Workforce Development, Lynn has contributed to or developed Shermco Industries' Standard Operating Procedures (SOPs), Safety Work Practices (SWPs), and the Quality Management System (QMS).