Electrical maintenance and testing guidelines

Introduction

Scope: In industry today, it is common practice for management to overlook electrical equipment, particularly non-rotating machinery, in setting up the facility's preventive maintenance program. Insurance companies routinely pay claims resulting from unplanned electrical outages. While many of these outages are the result of a problem with the electrical utility company, problems that are more serious result when the failure originates within plant owned equipment. The purpose of this article is to summarize some of the most common electrical maintenance and testing procedures.

Note: With the exception of the infrared survey, emergency generators, and motors, all testing listed in this article should be perform by a NETA (National Electrical Testing Association) or NICET (National Institute for Certification in Engineering Technologies) certified electrical testing firm.

Thermo-graphic (infrared) survey – performed annually

1. Inspect physical, electrical, and mechanical condition.
2. Remove all necessary covers prior to thermo-graphic inspection.
3. Equipment inspected should include all current-carrying devices.
4. Provide report including the following:
    a. Discrepancies.
    b. Temperature difference between the area of concern and the reference area.
    c. Cause of temperature difference.
    d. Areas inspected. Identify inaccessible and/or unobservable areas and/or equipment.
    e. Identify load conditions at time of inspection.
    f. Provide photographs and/or thermograms of the deficient area.
5. Inspect distribution systems with imaging equipment capable of detecting a minimum temperature difference of 1 degrees C at 30 degrees C.
6. Equipment should detect emitted radiation and convert detected radiation to visual signal.
7. Thermo-graphic surveys should be performed during periods of maximum possible loading but not less than 40 percent of rated load of the electrical equipment being inspected.

Liquid-filled transformers – performed annually

1. Inspect physical and mechanical condition.
2. Verify that cooling fans and/or pumps operate correctly.
3. Inspect all bolted electrical connections for high resistance using low-resistance ohmmeter.
4. Verify correct liquid level in all tanks and bushings.
5. Verify that positive pressure is maintained on nitrogen-blanketed transformers.
6. Verify correct equipment grounding.
7. Test load tap changer, if applicable.
8. Verify the presence of transformer surge arresters.
9. Remove a sample of insulating liquid in accordance with ASTM D923. The sample should be tested for dielectric breakdown voltage, acid neutralization number, interfacial tension, color, and visual condition.
10. Remove a sample of insulating liquid in accordance with ASTM D3613 and perform dissolved gas analysis.
11. The frequency of insulating liquid sampling should be increased to once per quarter for transformers exposed to severe loading (i.e. arc furnace).

Liquid-filled transformers over 10,000 KVA or those exposed to severe loading (i.e. arc furnace) – performed every 2-3 years

1. Perform insulation-resistance tests, winding-to-winding and each winding-to-ground. Test duration should be for 10 minutes with resistances tabulated at 30 seconds, 1 minute, and 10 minutes. Calculate polarization index.
2. Perform turns-ratio tests at the designated tap position.
3. Perform insulation power-factor/dissipation-factor tests on all windings and correct to 20 degrees C in accordance with test equipment manufacturer's published data.
4. Perform insulation power-factor/dissipation-factor tests (or hot collar watts-loss tests) on bushings and correct to 20 degrees C in accordance with test equipment manufacturer's published data.
5. Measure the resistance of each winding at the designated tap position.

Dry type transformers – greater than 500 KVA or critical to production – performed every 2-3 years

1. Inspect physical, electrical, and mechanical condition including evidence of moisture, corona, or brittleness.
2. Verify that cooling fans operate.
3. Inspect all bolted electrical connections for high resistance by use of low-resistance ohmmeter.
4. Verify that resilient mounts are free and that any shipping brackets have been removed.
5. Verify that the core, frame, and enclosure are grounded.
6. Verify the presence of transformer surge arresters.
7. Thoroughly clean unit prior to testing unless as-found and as-left tests are required.
8. Verify that as-left tap connections are as specified.
9. Perform insulation-resistance tests with winding-to-winding and each winding-to-ground. Calculate polarization index.
10. Perform resistance measurements through all bolted connections with a low-resistance ohmmeter, if applicable.
11. Perform power-factor or dissipation-factor tests in accordance with the test equipment manufacturer's published data.
12. Perform turns-ratio tests at the designated tap position.
13. Measure core insulation-resistance at 500 volts dc if core is insulated and if the core ground strap is removable.
14. Verify correct secondary voltage phase-to-phase and phase-to-neutral after energizing and prior to loading.

Protective relays – performed every 2-3 years

1. Inspect relays and cases for physical damage
2. Tighten case connections. Inspect cover for correct gasket seal. Clean cover glass. Inspect shorting hardware, connection paddles, and/or knife switches. Remove any foreign material from the case. Verify target reset.
3. Inspect relay for foreign material, particularly in disc slots of the damping and electromagnets. Verify disk clearance. Verify contact clearance and spring bias. Inspect spiral spring convolutions. Inspect disk and contacts for freedom of movement and correct travel. Verify tightness of mounting hardware and connections. Inspect bearings and/or pivots.
4. Verify that all settings are in accordance with coordination study or setting sheet supplied by owner.
5. Perform insulation-resistance test on each circuit-to-frame.
6. Inspect targets and indicators.
7. Verify that each of the relay contacts performs its intended function in the control scheme including breaker trip tests, close inhibit tests, and alarm functions.

Switchgear and switchboard assemblies – performed every 2-3 years

1. Compare equipment nameplate data with latest one-line diagram when available.
2. Inspect physical, electrical, and mechanical condition including evidence of moisture or corona.
3. Verify appropriate anchorage, required area clearances, physical damage, and correct alignment.
4. Verify that fuse and/or circuit breaker sizes and types correspond to drawings and coordination studies as well as to the circuit breaker's address for microprocessor-communication packages.
5. Verify that current and voltage (potential) transformer ratios correspond to drawings.
6. Inspect all bus connections for high resistance.
7. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data.
8. Confirm correct operation and sequencing of electrical of electrical and mechanical interlock systems. Attempt closure on locked-open devices. Attempt to open locked-closed devices. Make key exchange with devices operated in off-normal positions.
9. Thoroughly clean unit prior to testing unless as-found and as-left tests are required.
10. Inspect insulators for evidence of physical damage or contaminated surfaces.
11. Verify appropriate contact lubricant on moving current-carrying parts. Verify appropriate lubrication on moving and sliding surfaces.
12. Verify correct barrier and shutter installation and operation.
13. Exercise all active components.
14. Inspect all mechanical indicating devices for correct operation.
15. Verify that filters are in place and/or vents are clear.
16. Test operation, alignment, and penetration of instrument transformer withdrawal disconnects, current carrying, and grounding.
17. Perform electrical tests on all instrument transformers.
18. Perform resistance measurements through all bus joints with a low-resistance ohmmeter, if applicable.
19. Perform insulation resistance tests on each bus section, phase-to-phase, and phase-to-ground for one minute.
20. Verify operation of switchgear/switchboard heaters.

Metal-enclosed busways – performed every 2-3 years

1. Inspect busway for physical damage and evidence of corona.
2. Inspect for appropriate bracing, suspension, alignment, and enclosure ground.
3. Inspect all bolted electrical connections for high resistance using a low-resistance ohmmeter.
4. Verify tightness of accessible bolted electrical connections and bus joints by calibrated torque-wrench method in accordance with manufacturer's published data.
5. Confirm physical orientation in accordance with manufacturer's labels to ensure adequate cooling.
6. Examine outdoor busway for removal of "weep-hole" plugs, if applicable, and the correct installation of joint shield.
7. Inspect and clean all ventilating openings.
8. Measure insulation resistance of each busway, phase-to-phase, and phase-to-ground for 1 minute.
9. Perform an overpotential test on each busway, phase-to-ground with phases not under test grounded. Examine outdoor busway for removal of "weep-hole" plugs, if applicable, and the correct installation of joint shield.
10. Inspect and clean all ventilating openings.
11. Measure insulation resistance of each busway, phase-to-phase, and phase-to-ground for 1 minute.
12. Perform an overpotential test on each busway, phase-to-ground with phases not under test grounded

Insulated case/molded case circuit breakers – performed every 2-3 years

1. Inspect circuit breaker for correct mounting.
2. Operate circuit breaker to ensure smooth operation.
3. Inspect case for cracks or other defects.
4. Inspect all bolted electrical connections for high resistance using a low-resistance ohmmeter.
5. Inspect mechanism contacts and arc shuts in unsealed units.
6. Perform a contact resistance test.
7. Perform an insulation-resistance test at 1000 volts dc from pole-to-pole and from each pole-to-ground with breaker closed and across open contacts of each phase.
8. Perform long-time delay time-current characteristic tests by passing 300 percent rated current through each pole separately unless series testing is required to defeat ground fault functions.
9. Determine short-time pickup and delay by primary current injection.
10. Determine instantaneous pickup current by primary injection using run-up or pulse method.
11. Verify correct operation of any auxiliary features such as trip and pickup indicators, zone interlocking, electrical close and trip operation, trip-free, and antipump function

Oil circuit breakers – performed every 2-3 years

1. Inspect physical and mechanical condition.
2. Verify correct oil level in all tanks and bushings.
3. Inspect anchorage, alignment, and grounding.
4. Verify that breather vents are clear.
5. Perform all mechanical operation tests on the operating mechanism in accordance with manufacturer's published data.
6. If performing internal inspection:
    a. Remove oil. Lower tanks or remove manhole covers as necessary. Inspect bottom of tank for broken parts and debris and clean carbon residue from tank.
    b. Inspect lift rod and toggle assemblies, contacts, interrupters, bumpers, dashpots, bushing current transformers, tank liners, and gaskets.

   c. Slow-close breaker and check for binding, friction, contact alignment, penetration, and overtravel. Check that all phases make contact simultaneously.
   d. Refill tank(s) with filtered oil to correct levels
7. Inspect all bolted electrical connections for high resistance using a low-resistance ohmmeter.
8. Test alarms and lockouts for pneumatic and/or hydraulic operators as recommended by the manufacturer.
9. Thoroughly clean unit prior to testing unless as-found and as-left tests are required.
10. Verify appropriate contact lubricant on moving current-carrying parts. Verify appropriate lubrication on moving and sliding surfaces.
11. Record as-found and as-left operation counter readings.
12. Perform a contact-resistance test.
13. Remove a sample of insulating liquid in accordance with ASTM D923 and test for the following: electric breakdown voltage, color, interfacial tension, and visual condition.
14. Perform tripping of circuit breaker by operation of each protective device.
15. Perform insulation-resistance tests pole-to-pole, pole-to-ground, and across open poles at 2500 volts minimum.
16. Verify trip, close, trip-free, and anti-pump functions.
17. Perform dissipation factor/power-factor tests on each pole with breaker open and each phase with breaker closed. Determine tank loss index.
18. Perform dissipation factor/power-factor tests on each bushing. Use conductive straps and hot collar procedures if bushings are not equipped with a power factor tap.

Power circuit breakers – performed every 2-3 years

1. Inspect physical and mechanical condition.
2. Inspect anchorage, alignment, and grounding. Inspect arc chutes. Inspect moving and stationary contacts for condition, wear, and alignment.
3. Verify that all maintenance devices are available for servicing and operating the breaker.
4. Verify that primary and secondary contact wipe and other dimensions vital to satisfactory operation of the breaker are correct.
5. Perform all mechanical operator and contact alignment tests on both the breaker and its operating mechanism.
6. Inspect all bolted electrical connections for high resistance using a low-resistance ohmmeter.
7. Verify cell fit and element alignment.
8. Verify racking mechanism.
9. Thoroughly clean unit prior to testing unless as-found and as-left tests are required.
10. Verify appropriate contact lubricant on moving current-carrying parts. Verify appropriate lubrication on moving and sliding surfaces.
11. Perform a contact-resistance test.
12. Perform an insulation-resistance test at 1000 volts dc from pole-to-pole and from each pole-to-ground with breaker closed and across open contacts of each phase.
13. Inspect all bolted electrical connections for high resistance.
14. Make adjustments for the final settings in accordance with the coordination study supplied by owner.
15. Determine minimum pickup current, long-time delay, short-time pickup and delay, ground-fault pickup and delay, and instantaneous pickup values by primary current injection.
16. Activate auxiliary protective devices to insure operation of shunt trip devices. Check the operation of electrically operated breakers in their cubicles.
17. Verify correct operation of any auxiliary features such as trip and pickup indicators, zone interlocking, electrical close and trip operation, trip-free, and anti-pump function.

18. Verify operation of charging mechanism.

Network protectors – 600 volt class – performed every 2-3 years

1. Open the protector and rack it out of the enclosure. Note that the network bus and transformer generally will be energized. Exercise extreme caution. Observe clearances and check for smoothness of operation with racking.
2. Inspect physical and mechanical condition.
3. Inspect the enclosure door gasket and sight glass for damage.
4. Inspect the interior of the enclosure for debris or damaged components. Inspect insulating components, current carrying parts, and secondary disconnecting devices. Exercise extreme caution when working around the network bus conductors.
5. Check for missing parts on the protector. Check tightness of electrical and mechanical connections. Tighten as necessary according to manufacturer's published data.
6. Inspect insulating barriers for damage and correct mounting.
7. Inspect network protector fuse covers, fuses, and blown fuse indicators for damage.
8. Inspect closing motor brushes and commutator surface for wear or damage. Replace brushes or disassemble motor for cleaning as necessary. Inspect and clean motor brake mechanism, as applicable.
9. Remove and inspect arc shutes for damage.
10. Inspect main and arcing contacts. Clean surfaces and align contacts as necessary.
11. Verify sequence of main and arcing contacts by slow-closing the protector. Adjust as necessary according to manufacturer's published data.
12. Manually open and close the protector and verify that the mechanism latches correctly in each position. Verify correct operation of the position indicator.
13. Verify electrical connections to network and auxiliary relays. Clean relay contacts if necessary. Inspect electromechanical relays for freedom of movement of internal parts.
14. Verify electrical connections to auxiliary switches, secondary disconnects, current transformers, voltage transformers, control power transformers, closing motors, contactors, trip coils, loading resistors, and any other auxiliary devices.
15. Thoroughly clean unit prior to testing unless as-found and as-left tests are required.
16. Verify appropriate contact lubricant on moving current-carrying parts. Verify appropriate lubrication on moving and sliding surfaces.
17. Record the as-found and as-left operations counter readings.
18. Perform a leak test on submersible enclosure in accordance with manufacturer's published data.
19. Perform insulation-resistance tests at 1000 volts dc for 1 minute across the contacts of each pole with the protector open and from pole-to-pole and each pole-to-ground with the protector closed.
20. Perform a contact-resistance test.
21. Measure minimum pickup voltage of motor control relay.
22. Measure minimum pickup voltage of the trip actuator. Verify that the actuator resets correctly.
23. Perform operational tests:
    a. Verify correct operation of all mechanical and electrical interlocks.
    b. Verify trip-free operation.
    c. Verify correct operation of the auto-open-close control handle.
    d. Verify the protector will close with voltage on the transformer side only.
    e. Verify the protector will open when the source feeder breaker is opened.

Grounding systems – performed every 2-3 years

1. Perform fall-of-potential test or alternative in accordance with IEEE Standard 81 on the main grounding electrode or system.
2. Perform point-to-point tests to determine the resistance between the main grounding system and all major electrical equipment frames, system neutral, and/or derived neutral points.
3. The resistance between the main grounding electrode and ground should be no greater then 5 ohms for commercial or industrial systems and 1 ohm or less for generating or transmission station grounds.
4. Investigate point-to-point resistance values that exceed 0.5 ohm.

Cables – Low voltage (600 volt maximum) – performed as needed

1. Inspect exposed sections of cables for physical damage and evidence of overheating.
2. Inspect all bolted electrical connections for high resistance using low-resistance ohmmeter.
3. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data.
4. Inspect compression-applied connectors for correct cable match and indentation.
5. Perform insulation resistance tests on each cable phase-to-phase and phase-to-ground. Applied potential should be 1000 volts dc for 1 minute.
6. Perform resistance measurements through all bolted connections with a low-resistance ohmmeter, if applicable.

Metering – perform every 1-2 years

1. Inspect physical and mechanical condition.
2. Verify tightness of electrical connections.
3. Inspect cover gasket, cover glass, condition of spiral spring, disc clearance, contacts, and case-shorting contacts, as applicable.
4. Verify freedom of movement, end play, and alignment of rotating disk(s).
5. Thoroughly clean unit prior to testing unless as-found and as-left tests are required.
6. Check calibration of meters at all cardinal points.
7. Calibrate meters in accordance with manufacturer's published data.

Ground fault protection systems – perform every 2-5 years

1. Visually inspect the components for damage and errors in polarity or conductor routing.
    a. Verify that ground connection is made ahead of neutral disconnect link and on the line side of any ground fault sensor. Verify that neutral sensors are connected with correct polarity on both primary and secondary.
    b. Verify that all phase conductors and the neutral pass through the sensor in the same direction for zero sequence systems.
    c. Verify that grounding conductors do not pass through zero sequence sensors.
    d. Verify that the grounded conductor is solidly grounded.
2. Inspect all bolted electrical connections for high resistance using a low-resistance ohmmeter.
3. Verify correct operation of all functions of the self-test panel.
4. Verify pickup and time-delay settings.
5. Measure the system neutral-to-ground insulation resistance with the neutral disconnect link temporarily removed. Replace neutral disconnect link after testing.

6. Perform the following pickup tests using primary injection:
    a. Verify that the relay does not operate at 90 percent of the pickup setting.
    b. Verify pickup is less than 125 percent of setting or 1200 amperes, whichever is smaller.
7. For summation type systems utilizing phase and neutral current transformers, verify correct polarities by applying current to each phase-neutral current transformer pair. This test also applies to molded-case breakers utilizing an external neutral current transformer.
    a. Relay should operate when current direction is the same relative to polarity marks in the two current transformers.
    b. Relay should not operate when current direction is opposite relative to polarity marks in the two current transformers.
8. Measure time delay of the relay at 150 percent or greater of pickup.
9. Verify reduced control voltage tripping capability: 55 percent for AC systems and 80 percent for DC systems.
10. Verify blocking capability of zone interlock systems.

AC motors – visual and mechanical inspection – performed every 1-3 years

1. Inspect for physical and mechanical condition.
2. Inspect for correct anchorage, mounting, grounding, and connection.
3. Inspect all bolted electrical connections for high resistance using a low-resistance ohmmeter.
4. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data.
5. Perform special tests such as air gap spacing and pedestal alignment, if applicable.

AC induction motors – electrical tests – performed every 1-3 years

1. Perform insulation-resistance tests in accordance with ANSI/IEEE Standard 43.
    a. Motors larger than 200 HP: Test duration should be for 10 minutes. Calculate polarization index.
    b. Motors 200 HP and less: Test duration should be for 1 minute. Calculate the dielectric absorption ratio.
2. Perform DC over-potential tests on motors rated at 1000 HP and greater and at 4000 volts and greater in accordance with ANSI/IEEE Standard 95.
3. Perform insulation-resistance test on pedestal in accordance with manufacturer's published data.
4. Test surge protection devices.
5. Test motor starter.
6. Verify that resistance temperature detector (RTD) circuits conform to drawings. Verify that metering or relaying devices using the RTD's have the correct rating.
7. Verify the motor space heater is functional.
8. Perform a rotation test to insure correct shaft direction if the motor has been electrically disconnected.
9. Measure running current and evaluate relative to load conditions and nameplate full-load amperes.

AC synchronous motors – electrical tests – performed every 1-3 years

1. Perform all tests as indicated above for induction motors.
2. Perform insulation-resistance tests on the main rotating field winding, the exciter-field winding, and the exciter-armature winding in accordance with ANSI/IEEE Standard 43.
3. Measure and record resistance of motor field winding, exciter-stator winding, exciter-rotor windings, and field discharge resistors.
4. Prior to re-energizing, apply voltage to the exciter supply and adjust exciter-field current to nameplate value.

5. Verify that the field application timer and the enable timer for the power factor relay have been tested and set to the motor drive manufacturer's recommended values.

Note: All critical motors regardless of size should be included in a comprehensive vibration analysis program, with reading taken based upon need (a minimum of every 6 months). Most electrical problems on motors begin as mechanical problems.

Motor starters – low voltage – performed every 1-3 years

1. Inspect physical and mechanical condition.
2. Inspect contactors: 1) Verify mechanical operation. 2) Inspect and adjust contact gap, wipe, alignment, and pressure in accordance with manufacturer's published data.
3. Inspect all bolted electrical connections for high resistance using low-resistance ohmmeter.
4. Thoroughly clean unit prior to testing unless as-found and as-left tests are required.
5. Verify appropriate contact lubricant on moving current-carrying parts. Verify appropriate lubrication on moving and sliding surfaces.
6. Measure insulation resistance of each combination starter, phase-to-phase and phase-to-ground, with the starter contacts closed and the protective device open.
7. Test the motor overload relay elements by injecting primary current through the overload circuit and monitoring trip time of the overload element. Note: Test times for thermal trip units will, in general, be longer than manufacturer's curve if single-pole testing is performed.
8. Test circuit breakers as discussed above.
9. Perform operational tests by initiating control devices.

Batteries – perform annually

1. Inspect physical and mechanical condition.
2. Inspect all bolted electrical connections for high resistance using a low-resistance ohmmeter.
3. Clean corroded/oxidized terminals and apply an oxide inhibitor.
4. Verify electrolyte level.
5. Verify presence of flame arresters.
6. Verify adequacy of battery support racks, mounting, anchorage, and clearances.
7. Verify ventilation of battery room or enclosure.
8. Verify existence of suitable eyewash equipment.
9. Measure electrolyte specific gravity and temperature.
10. Measure charger float and equalizing voltage levels.
11. Verify all charger functions and alarms.
12. Measure each cell voltage and total battery voltage with charger energized and in float mode of operation.
13. Measure intercell connection resistances.

Chargers – perform annually

1. Inspect for damage and moisture contamination.
2. Inspect all bolted electrical connections for high resistance using a low-resistance ohmmeter.
3. Verify float voltage and equalized voltage settings.
4. Verify operation of ammeter.
5. Verify operation of alarms.

Low-voltage surge protection devices – perform annually

1. Inspect physical and mechanical condition.
2. Inspect for correct mounting and adequate clearances.
3. Inspect all bolted electrical connections for high resistance using low-resistance ohmmeter.
4. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data.
5. Verify that the ground lead on each device is individually attached to a ground bus or ground electrode.
6. Perform insulation-resistance tests. Use manufacturer's recommended values.
7. Test grounding connection as described above.

Capacitors – perform every 1-3 years

1. Inspect physical and mechanical condition.
2. Inspect capacitors for correct mounting and required clearances.
3. Verify that capacitors are electrically connected in their specified configuration.
4. Inspect all bolted electrical connections for high resistance using low-resistance ohmmeter.
5. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data.
6. Perform insulation-resistance tests from terminal(s) to case for 1 minute on capacitors with more than one bushing. Test voltage and minimum resistance should be in accordance with manufacturer's published data.
7. Measure the capacitance of all terminal combinations.
8. Measure resistance of internal discharge resistors.

Emergency generators – annually

Note: The prime mover is not addressed in this article.

1. Inspect physical and mechanical condition.
2. Inspect correct anchorage and grounding.
3. Perform an insulation-resistance test on generator winding with respect to ground in accordance with
4. ANSI/IEEE Standard 43. Calculate polarization index.
5. Test protective relay devices as described above.
6. Functionally test engine shutdown for low oil pressure, over-temperature, over-speed, and other features
7. as applicable.
8. Perform vibration test for each main bearing cap.
9. Conduct performance test in accordance with NFPA Standard 110.
10. Verify correct functioning of governor and regulator.

Automatic transfer switches – every 2-3 years

1. Inspect physical and mechanical condition.
2. Verify appropriate contact lubricant on moving current-carrying parts. Verify appropriate lubrication on moving and sliding surfaces.
3. Verify that manual transfer warnings are attached and visible.
4. Verify tightness of all control connections.
5. Inspect all bolted electrical connections for high resistance using low-resistance ohmmeter.

6. Perform manual transfer operation.
7. Verify positive mechanical interlocking between normal and alternative sources.
8. Perform a contact-resistance test.
9. Perform insulation-resistance tests, phase-to-phase and phase-to-ground, with switch in both source positions.
10. Verify settings and operation of control devices.
11. Calibrate and set all relays and timers as described above.
12. Perform automatic transfer tests as follows:
    a. Simulate loss of normal power.
    b. Return to normal power.
    c. Simulate loss of emergency power.
    d. Simulate all forms of single-phase conditions.
13. Verify correct operation and timing of the following functions:
    a. Normal source voltage-sensing relays.
    b. Engine start sequence.
    c. Time delay upon transfer.
    d. Alternate source voltage-sensing relays.
    e. Automatic transfer operation. 6) Interlocks and limit switch function.
    f. Time delay and retransfer upon normal power restoration
    g. Engine cool down and shutdown feature

Air switches – low voltage – every 2-3 years

1. Inspect physical and mechanical condition.
2. Verify appropriate anchorage and required area clearances.
3. Verify appropriate equipment grounding.
4. Verify correct blade alignment, blade penetration, travel stops, and mechanical operation.
5. Verify that fuse sizes and types are in accordance with drawings and short-circuit and coordination studies.
6. Verify that each fuse holder has adequate mechanical support.
7. Inspect all bolted electrical connections for high resistance using a low-resistance ohmmeter.
8. Test all interlocking systems for correct operation and sequencing.
9. Inspect insulating assemblies for evidence of physical damage or contaminated surfaces.
10. Exercise all active components.
11. Verify all indicating and control devices.
12. Verify operation of heaters, if applicable.
13. Thoroughly clean unit prior to testing unless as-found and as-left tests are required.
14. Verify appropriate contact lubricant on moving current-carrying parts. Verify appropriate lubrication on moving and sliding surfaces.
15. Perform insulation-resistance tests on each pole, phase-to-phase, and phase-to-ground with switch closed and across each open pole for 1 minute.
16. Measure contact-resistance across each switchblade and fuse holder.

17. Measure fuse resistance.
18. Perform resistance measurements through all bolted connections with a low-resistance ohmmeter.
19. Perform ground fault test.

Important note: The frequency of the testing in all items listed above as every 2-3 years is variable based upon the environment in which the equipment operates. If the plant is extremely dirty, the frequency can be increased to annually.

Short-circuit (fault) study – usually done as part of modernization/expansion projects

1. The study input data should include the short-circuit single and three phase contributions from all sources, with the X/R ratio, the resistance and reactance components of each branch impedance, motor and generator contributions, base quantities selected, and all other applicable circuit parameters.
2. Short-circuit momentary duties and interrupting duties should be calculated on the basis of maximum available fault current at each switchgear bus, motor control center, distribution panelboard, pertinent branch circuit panelboards, and other significant locations throughout the system.
3. For the portions of a system utilizing medium and high voltage breakers, separate calculations should be made for one-half cycle (close and latch) currents and interrupting currents. Calculations should be for three-phase and phase-to-ground faults at each bus under consideration.
4. For the portions of a system utilizing low voltage breakers (less than 1000 volts), calculations should be made for three-phase and phase-to-ground interrupting currents at each bus under consideration.

Note: This study should be recommended if the plant does not have a one-line electrical distribution diagram.

Protective device coordination study – usually done as part of modernization/expansion projects

1. A protective device coordination study should be performed to select or to verify the selection of power fuse ratings, protective-relay characteristics and settings, ratios, and characteristics of associated transformers and breaker trip characteristics and settings.
2. The coordination study should include all voltage classes of equipment from the source's incoming line protective device down to and including each motor control center and/or panelboard. The phase and ground over-current protection should be included as well as settings for all other adjustable protective devices.
3. Protective device selection and settings should be in accordance with the requirements of the National Electrical Code and the recommendations of the ANSI/IEEE Standard 399, as applicable.

Note: This study should be recommended if the plant does not have a one-line electrical distribution diagram. Summary: Incorporating the practices listed above into a comprehensive preventive/predictive maintenance program will elevate the reliability of plant owned electrical equipment, preventing unplanned outages.

References

Author: Vic Casada, - Risk Engineering Consultant, Zurich Services Corporation

International Electrical Testing Association (NETA) Maintenance Testing Specifications

Technical point of contact - Stuart Jackson, Instel Power Products, NETA President

Zurich Services Corporation
Risk Engineering
1400 American Lane, Schaumburg, Illinois 60196-1056
800 982 5964 www.zurichna.com

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