XL Risk Consulting

Property Risk Consulting Guidelines

A Publication of AXA XL Risk Consulting

PRC.5.9.1

TRANSFORMERS - MAINTENANCE

INTRODUCTION

Preventive maintenance (PM), which includes operational, planned and predictive maintenance, protects property and safeguards production. PM is a crucial part of loss control activities. PM of electrical equipment monitors the deterioration of equipment and components and detects or predicts insulation, equipment, and system flaws. PM reduces the frequency of losses. As with other loss control techniques, varying degrees of control are possible. A practical approach to PM based on unique conditions at each facility must be found.

Breakdown maintenance has a place in maintenance programs. This means that **no maintenance** is performed on specified equipment until a breakdown occurs. Breakdown maintenance is suited to small, easily replaceable equipment that can sustain breakdown with negligible consequences. Few transformers fall into this category.

Typically, a transformer maintenance program is satisfactory if it covers essential transformer testing and servicing. This guideline identifies the minimum transformer maintenance that should be performed on all transformers rated over 75 kVA.

However, hard and fast rules need not be applied to transformer maintenance schedules. Unique arrangements, locations, uses, designs, and auxiliary protective and control equipment, and test histories all influence maintenance scheduling. Establishing increased or decreased frequencies, or accepting established "recommended frequencies" depends on unique conditions and judgement.

PRC.5.9.0.1 describes a method for evaluating transformer importance and may be used to identify a need for an expanded transformer maintenance program. Additional tests and servicing activities should be included in a maintenance program where the importance of the unit warrants such security. A comprehensive preventive and predictive maintenance program is necessary for important equipment, where breakdown can have disastrous results leading to an unsafe condition or a severe loss.

POSITION

Transformer maintenance programs should:

- Document all INSPECTION AND SERVICING REQUIREMENTS. Actions and frequencies should be no less than those shown by Table 1.
- Thoroughly document TESTING REQUIREMENTS. Actions and frequencies should be no less than those shown by Table 2 and PRC.5.4.5. Where applicable, the program should define acceptable test results and should guide subsequent actions upon test failures.

- Be comprehensive. Document manufacturers' guidelines. Include specific activities similar to those shown in Tables 3 and 4 as appropriate for the transformer type, use, and location. The use of a customized checklist which also documents the "As Found and As Left" condition and required frequency for each activity can be an effective means of administering a comprehensive maintenance program.

TABLE 1
Transformer And Associated Equipment
Inspection And Servicing Activity

Transformer Type	Inspection Frequency	Inspection And Servicing Activity
Oil ≥ 1000 kVA <1000kVA All Others	 Twice per week Weekly Weekly	Look for outward signs of overheating, corrosion, leaks, and deterioration; check the unit and surrounding area for cleanliness; document readings from available instrumentation and compare to past results and manufacturer's specifications. Refer to Table 3 for specific analysis features.
Askarel	Annual for clean environment; more frequently for others	Qualified transformer servicing company to perform deenergized inspection to check for leaks and bushing damage; and to clean external surfaces following 40 CFR 761 and EN 50195 guidelines .Replace transformers containing more than 50 ppm PCBs.
All	Yearly	Thermographic survey on the transformer, power cables, and associated switchgear.
All	2 Yrs	Retorque bolted connections.
Dry	2 Yrs for clean dry areas; more frequently for others	Thoroughly clean and inspect. For units not totally encapsulated or hermetically sealed, vacuum out dirt and blow down with a maximum of 25 psi (1.7 bar) compressed air.

TABLE 2
Transformer And Associated Equipment
Routine Testing Activity

Transformer Type Size/Use	Frequency	Test Activity Perform the following tests:
All Types (Dry & Liquid) >1000 kVA	 3 Yrs	Power(or Dissipation) Factor Test Insulation Resistance Test (optional)
Oil & High Molecular Weight Hydrocarbons 1000 kVA and less > 1000 kVA Arc Furnace Load Tap Changer Rectifier	 2 Yrs Annual 3 Mo-1 Yr 3 Mo-1 Yr 3 Mo-1 Yr	Dielectric Strength Acidity Interfacial Tension Gas - In - Oil Analysis (for units 2500 kVA) Moisture Content (optional) Power (or Dissipation) Factor Test
All Askarel	Annual	Dielectric Strength Acidity Moisture Content (optional)
Silicone 1000 kVA and less > 1000 kVA	 2 Yrs Annual	Dielectric Strength Acidity Gas - In - Oil Analysis (for units 2500 kVA) Moisture Content (optional)
Nonflammable	2 Yrs	Dielectric ~ Strength Acidity

TABLE 3
Transformer And Associated Equipment
Inspection Activity
(Look for the effects of heat, contamination, and deterioration)

- **CABLES & CONNECTIONS**: No heat distress, corrosion, dirt; check for hot spots during operation by means of an Infrared Scanning Device (ISD)
- **BUSHINGS**: No cracks, chips, tracks, dirt, leaking compound or oil; should be cleaned and coated with a silicone elastomer, wax or other material appropriate for the environment
- **TANK & RADIATORS/FINS**: No rust, peeling paint, corrosion, physical damage, dirt, leaks; check for obstructions during operation with an ISD
- **TANK GASKETS**: No leakage, dirt
- **PUMPS**: No leaks, noise
- **GROUNDS**: No corrosion; check tightness
- **ARRESTERS**: No cracks, chips, tracks, dirt, leaking compound or oil
- **RELIEF DEVICE**: No leakage; look inside openings for obstructions
- **VAPOR SPACE**: Verify positive pressure
- **INTERNAL BLOCKS & BRACING**: Check condition (listen for unusual sounds)
- **TAP CHANGERS**: Alignment, freedom of movement; condition of contacts (no significant burning, pitting, wear); condition of the Load Tap Changer motors and bearings; refer to manufacturer's guidelines
- **FANS**: Quiet, cool, bearings; clean blades; clean maintained motor; automatic start
- **GAUGES, INDICATORS, ALARMS, PROTECTIVE DEVICES**: Good condition and showing appropriate liquid level, temperature, pressure, voltage, current, "ready" condition, etc.
- **EXPOSURE**: Area free of trash, weeds, leaves, combustible storage, unsecured (wind susceptible) items
- **TRANSFORMER YARD**: Check fencing, locks, drains (clear), gravel (turned and free of silt), pad, structures
- **ENVIRONMENT**: Evaluate conditions (adverse conditions include dust, fibers, vapors, gases, extreme high or low temperature)

TABLE 4
Transformer And Associated Equipment
Test Activity

- **BUSHINGS**: Power (or Dissipation) Factor Test
- **GROUNDS**: Measure ground resistance
- **WINDINGS**: Transformer Power (or Dissipation) Factor Test, Transformer Turns Ratio Test, Insulation Resistance Test (optional); these tests are done on the complete transformer assembly
- **VAPOR SPACE**: Total Combustible Gas Analysis
- **DIELECTRIC**: Dielectric Strength Test, Acidity (Neutralization Number) Test, Interfacial Tension Test, Gas Chromatography Test (Dissolved Gas or Gas-In-Oil Analysis), Color Test, Moisture Content (Karl Fischer) Test, Oil Power (or Dissipation) Factor Test. Also refer to Property Risk Consulting Guidelines PRC.5.4.5.

Conduct transformer, Power (or Dissipation) Factor (PF) and Transformer Turns Ratio (TTR) tests before reenergizing any unit that was:

- Shut down and relocated.
- Deenergized by the operation of an overcurrent protective device which interrupted a fault or surge current.

- Shut down for major repair or overhaul.
- Moved on its foundation or severely shaken by an earthquake or other ground movement.

Conduct transformer PF test before and after any transformer servicing.

Follow testing recommendations of the test equipment supplier and implement appropriate pretest precautions, such as:

- A visual inspection of the equipment being tested.
- The use of barricades and appropriate safety measures.
- The deenergization and isolation of necessary equipment according to written plans.

Consider on-line monitoring for large and/or critical transformers. The software-based monitoring systems are equipped with smart sensors and analysis tools that permit on-line measure and analysis of the gas-in-oil and the relative humidity in the oil and its changes with load variations. The benefits of on-line monitoring includes:

- Can be arranged to detect most prevalent failure modes of transformers including fault gases and moisture in oil
- Can provide early warning of potential failure, allowing maintenance to schedule proper corrective action
- Can reduce the likelihood of catastrophic failures that can result in costly repairs and long term outages

Carry out the inspections by qualified personnel who is knowledgeable of the electrical systems and equipment being maintained and safe work practices. Use contractors specialized in electrical preventive maintenance. Consider employing contractors that are certified by accredited organizations in areas of thermography, ultrasonic and oils analysis.

DISCUSSION

Aging

Electrical equipment begins to wear out as soon as it is put into service. It will have to be replaced at some time, and is likely to require repairs or maintenance one or more times over its useful service life. If a transformer is not replaced or renovated before reaching the end of its service life, it may fail catastrophically.

As transformers age, insulation gradually deteriorates. Deterioration usually proceeds “slowly.” The service life is influenced primarily by the manufacturer’s attempts to design for the maximum economically feasible operating life. However, aging can be accelerated and the service life of the equipment shortened by imperfections in the manufacturing process, substandard methods of installation and handling, and severe equipment use (loading, environment, maintenance, exposures). No manufacturer can guarantee a product free of all imperfections, and no two units will experience identical handling and use, so the service life can be only estimated.

When a group of identical transformers is operating, units with a 5°C – 10°C (9°F – 18°F) higher operating temperature will deteriorate twice as fast as the other units. The hotter units may have a rate of failure twice that of cooler ones, and a service life only half as long. Even this deterioration is gradual and it can be considered part of the aging process if the temperature is within operating design parameters.

But even an event not usually considered a part of the aging process, such as a voltage surge, severe overheating, abrasion, or contamination, may lead to a failure due to the degree of aging that the transformer has experienced. Loss control measures should include a close monitoring of the condition of the transformer to help minimize the likelihood of failures.

Maintenance

A good maintenance program minimizes shutdowns, operating costs, and losses. It monitors the condition of equipment and responds in a cost-effective manner. It does not try to prevent every failure. By specifying maintenance requirements for each piece of equipment, a good program detects and slows down or corrects problems. Good maintenance repairs or replaces important equipment before electrical breakdown is likely to occur. Evaluating the degree of deterioration facilitates orderly, budgeted, planned repairs to correct unsatisfactory conditions. A good maintenance program can be predictive and can minimize the chances of unexpected failure and catastrophic loss.

Close monitoring can reduce transformer maintenance costs. One utility company, reportedly, continuously senses oil temperatures in load tap changers (LTCs) on selected units. Oil in the main tanks and contactor compartments is monitored. The system alarms when temperatures or temperature differentials exceed set limits. In some cases, where there is a good inspection and oil testing program, a temperature monitoring system may allow extending the period between routinely scheduled overhauls. The program appears to adequately identify when LTC contacts are worn and require replacement.

A good electrical maintenance program **lists all equipment** included in the program, **documents the activities** needed for each piece or category of equipment, and **specifies the frequency** appropriate for those activities. Documentation of the activities should include: INSPECTION, what to look for and what to listen for; TESTING, the test equipment and testing procedures that should be used; and SERVICING, the cleaning, lubricating, adjusting, repairing, and parts replacement requirements.

The testing frequency may be fixed-interval or event-dictated. The fixed-interval frequency may be set by considering the use, type, and size of the equipment. The frequency for an event-dictated test is the frequency of experiencing a loss-associated event. Examples include:

- Finding unsatisfactory results during fixed-interval testing.
- Determining that specified electrical or mechanical disturbances occurred.

A good electrical maintenance program requires the **resources** of administration, equipment, and maintenance personnel to work effectively as designed. Preventative maintenance typically costs less than breakdown maintenance, which requires repairs to be made following unexpected losses. In reality, breakdown maintenance is a lack of maintenance. For supplemental background information and an action plan for Maintenance, refer to Section 3 in AXA XL Risk Consulting's *OVERVIEW* manual. (See PRC.1.3.0.)

Severe and costly losses have been **initiated** by the restoration of power following the operation of a fuse or relay. Had the cause and consequences of the blown fuse or tripped relay been fully examined and appropriate testing and response provided, these losses could have been avoided. Knowledge of the causes and effects of electrical faults is vital to an effective program. Some background information is provided in PRC.5.9.0.2.

Testing

Generally, the variety of acceptance, warranty period, and maintenance tests conducted and the procedures for those tests will be influenced by: the manufacturer's recommendations; the use, type, size, and importance of the transformer; the availability of test equipment, testing services, and time for testing; the results of earlier tests; and the abilities of those responsible for testing. Typically, acceptance tests establish benchmarks. When subsequent transformer tests use newer test equipment or different test procedures, the comparison of the new test results with past results may not be meaningful; but benchmarks can be reset regardless of the age of the transformer. By comparing results of identical test procedures and identical test equipment, trends can be used to analyze maintenance needs. Sometimes the most recent test results alone will determine these needs.

Where a transformer dielectric contains polychlorinated biphenyls (PCBs), maintenance tests and the disposal of waste fluids following the tests require special precautions. Individuals responsible for directing and implementing the program should keep abreast of current laws pertaining to the handling of PCBs.

PRC.5.4.5 discusses dielectric fluids and testing. PRC.5.4.5.1 discusses the PCB problem.

Some tests, like Hi-Pot Tests, are go/no-go tests, and may **cause** a failure of weak insulation. However, insulation breakdown occurring during such testing is less likely to be catastrophic than insulation breakdown occurring while operating and when personnel are unprepared. High stress tests can be of great value and are sometimes necessary.

Test methods should follow accepted practices and should be fully documented, including descriptions of equipment, connections, settings, times, and conditions, to allow duplication of efforts with later tests. Test results influenced by temperature should be corrected to 20°C (68°F) to simplify comparisons. Certain tests should not be made in high humidity environments or the results will not be meaningful.

Test records should provide a history of performance from acceptance tests, through warranty period tests, to and including periodic maintenance tests over the lifetime of the unit. Test results should be compared to recognized criteria for an evaluation of needed action. In some cases, analysis of test results should be the responsibility of independent testing labs or services.

The AXA XL Risk Consulting position is a minimum guideline. It does not list every test and inspection nor does it prescribe test equipment and procedures. Where a comparable test procedure is substituted for that specified by the AXA XL Risk Consulting position, the specified test need not be done. (For instance, an Excitation Current Test may be done in lieu of a Transformer Turns Ratio test.) Supplemental information concerning transformer inspections and tests is in NFPA 70B.