

## 5.0 CIRCUIT BREAKER MAINTENANCE

### Learning Objectives

Circuit breaker maintenance is an important component in assuring breaker reliability. As a result of this lesson you will be able to:

1. Understand the difference between preventive maintenance (PM) and overhauls
2. Understand the elements of a good preventive maintenance process
3. Explain the three elements of a preventive maintenance inspection
4. Understand differences in overhaul levels
5. Have a general understanding of the lubrications used by breaker manufacturers
6. Understand the uses for penetrating oils in the preventive maintenance process
7. State the three common potential breaker failure causes
8. Understand the use of breaker timing analysis and the potential failures it can uncover
9. Understand the benefits and potential misinterpretation of contact resistance testing

## 5.1 MAINTENANCE RULE

The Code of Federal Regulations, Part 10, Section 50.65, "Requirements for monitoring the effectiveness of maintenance at nuclear power plants," states the following regarding maintenance at nuclear power plants:

Each holder of a license to operate a nuclear power plant shall monitor the performance or condition of structures, systems, or components (SSCs), against licensee-established goals, in a manner sufficient to provide reasonable assurance that such structures, systems, and components are capable of fulfilling their intended functions. Such goals shall be established commensurate with safety and, where practical, take into account industry-wide operating experience. When the performance or condition of a structure, system, or component does not meet established goals, appropriate corrective action shall be taken.

Medium voltage circuit breakers meet the maintenance rule criteria and qualify for monitoring under the Maintenance Rule program.

## 5.2 WHY BREAKERS FAIL

The cause of most breaker failures can be attributed to one or more of the following areas: lubrication failure, improper maintenance process, and component failure.

- **Lubrication:** The lubrication (Grease) consists of oil, a thickener and fillers plus other additives. The grease used in the 60's and 70's were nearly all petroleum base lubricant, and as the lubrication aged the petroleum would seep out or evaporate. What remained was the thickener and fillers. Since the bearings could not move the breakers would fail. As breakers are overhauled older lubrication is being replaced with synthetic lubrication, which is showing a longer operational life.
- **Maintenance Practice:** These failures have two components, lack of maintenance and maintenance performed incorrectly.
  - Many plants were not performing maintenance of overhauling breakers at reasonable intervals. With any mechanical device inspections, adjustments, and lubrication renewal is required for proper operation.
  - Improper maintenance can cause failures such as not following the manufacturer's tech manual instructions, and misinterpretation of specifications. Also breakers are complicated devices that require specialized knowledge, and maintenance personnel that need proper training.
- **Component failures:** The majority of component failures are in plastic components and electrical devices; both of these components are especially susceptible to aging and wear.

### 5.3 MEDIUM-VOLTAGE CIRCUIT BREAKER MAINTENANCE

Breakers were ignored for many years but as with any mechanical equipment if not properly maintained they will develop problems.

Routine inspection, testing, and maintenance ensures that:

- a circuit breaker is operating properly.
- the breaker adjustments are within specification.
- potential component failure can be detected.

- data is available to better evaluate the condition of the breaker.

### 5.3.1 Preventive Maintenance (PM):

Nuclear power plants generally perform their own circuit breaker preventive maintenance and have developed plant procedures specific to their breaker type. A plant preventive maintenance (PM) schedule is performed on an established cycle between overhauls.

The PM schedule should also take into consideration other conditions that may affect a breakers operation, such as its operating environment and the breaker application. Breakers in a high operation cycle application may also require more frequent maintenance. Also, if a breaker remains in a static position from refueling to refueling it should be cycled periodically to redistribute the lubrication.

A good preventive maintenance inspection should consist of:

- good visual inspection
- adjustment verification
- electrical and mechanical testing

During a PM, corrective actions (repairs) and minor lubrication will be required to assure continued reliable service of the circuit breaker. It is also important to collect all the data from the PM process and compare and evaluate it to past inspections.

5.3.2 **Overhaul:** Breaker overhauls were traditionally only performed by the Original Equipment Manufacturers (OEM's) at nuclear power plants. This has changed over the years and today plants could be using OEM's, non-OEM breaker overhaul companies, or may have an in house overhaul program.

All overhauls should include some level of disassembly, component reconditioning, and part replacements. At a minimum, an overhaul will include complete disassembly, cleaning, and lubrication of the operating mechanism and contact pivots.

The following are three examples of potential overhaul levels:

- Disassembly, cleaning, and lubrication of operating mechanism, and contact pivots. Evaluate breaker components for wear and damage, and replace as required. Replace industry recommended components.

- Complete disassembly of the breaker, replate mechanism metal components, evaluate contact and bus silver plating and replate as required. Evaluate all components for wear and replace as required. Replace industry recommended components.
- Complete disassembly of the breaker, replate mechanism metal components, silver plate all copper bus and contacts, evaluate all components for wear and replace as required. Replace all potential high wear items. Replace industry recommended components.

All of these overhaul processes are effective programs if performed properly; all these plans take in to consideration lubrication, component evaluation, and industry recommended replacement parts.

### 5.3.3 How frequently should breaker overhauls be performed?

After several failures attributed to lubrication the nuclear industry is sensitive to potential breaker failures because of lubrication. Most plants have completed or are in the process of performing overhauls of their breaker population. EPRI, circuit breaker user groups, and breaker manufacturers have been evaluating and comparing information to provide a reasonable overhaul interval for breakers, but there is not an industry standard.

## 5.4 BREAKER INSPECTION PROCESS

Breaker assessment performed during preventive maintenance will provide information on its' condition. Doing this allows the user to prioritize and define a reasonable corrective action plan for any deficiencies identified.

Medium voltage circuit breaker assessment includes:

- evaluating the circuit breaker's overall condition (visual inspection)
- measuring and comparing adjustments to the manufacturer's specifications
- electrical and mechanical testing
  - measuring and comparing contact resistance to the manufacturer's specifications or industry criteria
  - measuring insulation resistance
  - contact timing test
- assessing the operating mechanism condition (visual inspection)

### 5.4.1 Visual inspection

The following are components checked during visual assessment:

- exterior and interior appearance
- racking mechanism if applicable
- ground stab and interlock
- arc chutes and insulation barriers (after removal)
- main and arcing contacts and arc puffer
- primary Bushings
- primary Contacts (Used to connect to the cubicle)
- secondary Contacts (Used to connect the control contacts to the cubicle)
- wiring, relays, coils, switches and charging motor
- operating mechanism

### 5.4.2 Breaker adjustments

All breaker manufacturers' technical manuals provide the adjustments required for proper operation of their breaker. These adjustments should be checked and verified to be within the technical manuals specifications. Adjustment checks have two main areas operating mechanism and contacts.

#### 5.4.2.1 Mechanism adjustments

Mechanism adjustments will ensure all latches and switches are within a set operating range. Future chapters will discuss specific checks for each breaker manufacturer.

#### 5.4.2.2 Contact adjustments

All breaker types, Air, Vacuum, and, SF6 have contact adjustment requirements. The process for performed adjustment for each style and manufacturer will differ, but you are checking for similar conditions, pressure simultaneous make and erosion or wear. Future chapters will discuss specific checks for each breaker manufacturer.

### 5.4.3 Breaker electrical and mechanical testing

In addition to checking breaker adjustments and inspecting breaker component parts for defects there are several tests that can be performed to provide additional information to evaluate the breakers condition.

#### 5.4.3.1 Breaker timing

The main function of a circuit breaker is to open under a fault condition. The speed of the contact opening is critical to minimizing the damage to the breaker and the equipment it feeds. The time between the impulse to actuate the trip coil and the actual opening of the circuit breaker indicates how quickly the circuit breaker operates.

For example, if the breaker design requires the contacts to break at 65ms and it opens in 450ms, there is a strong probability it will fail during a fault condition.

The above example is the reaction time from the coil receiving the signal to trip the breaker arc contact opening. Most plants use these times to assess the breakers operating speed.

The time travel analysis can provide information on malfunctions such as:

- worn or sticky latching mechanism
- defective coils
- mechanical wear and hardened grease
- defective shock absorbers
- contacts not opening/closing at the same time

#### 5.4.3.2 Time Travel Analysis

The breaker can also have a more detailed timing analysis with the use of a travel transducer attached to the contacts. This is a “Time Travel Analysis” and provides a graphical trace of the movement of contacts during the closing and opening travel.

The time travel curve yields a thorough analysis of circuit breaker

operation during the opening and closing. Curve of the contact motion is captured from a travel sensor (transducer) attached to the arcing contact of the breaker.

The following example is for the closing cycle; the trip cycle would be the same process with contacts opening.

Timing Process (Close):

- Phase 1: is the initial step of the closing operation. The breaker hasn't started to close, but the close or trip coil has been energized and has activated the close latch, and the operating mechanism is free to move the contacts to the closed position.
- Phase 2: is the actual closing. The poles are now moving to the closed position.
- Phase 3: is when the moving contacts connect with the stationary contacts and the mechanism is latched closed.

The energy involved in the close and trip operation creates energy especially at the end of an opening operation. Performing timing with a transducer, the bounce at the end of the opening action can be analyzed and compared to previous data to provide additional evaluation information.

#### 5.4.3.3 Contact resistance measurement (micro-ohm)

Contact resistance measurement is an indicator of the overall condition of the conducting path, which includes the main contacts, contact pivots and other connection points.

Contact resistance measurement test generally specifies a 100A outputs to ensure an accurate test result but 10A outputs can give a fair evaluation for most breakers.

The measured values and acceptance criteria is usually presented in micro-ohms and is compared with values specified by the equipment manufacturer. If a manufacturer's acceptance criterion is not provided, values can be compared to industry-established values for the breaker or from previous inspections.

Any deviation greater than 50% should be evaluated even if within an acceptable range.

The test process is:

- two probes are placed across the primary contact points of a closed breaker
- the micro ohmmeter will provide a digital reading in Micro ohms

The contact resistance can be within acceptable values, but contacts may still require replacement. Also, the contact resistance only provides the main contact resistance. Therefore, the contact resistance measurement should be used in conjunction with the contact adjustment check and a contact visual evaluation to determine the overall condition of conducting path components.

#### 5.4.3.4 Insulation testing (meggering)

This test evaluates the condition of the breaker insulation. The test is performed with an insulation tester commonly referred to as a megger.

Insulation resistance testing is applying a voltage across an insulator, measuring the amount of current flowing through that insulator, and calculating (using Ohm's Law) a resistance measurement. The term "current" is referring to leakage current. The resistance measurement is in megohms. Current flow through an insulator may seem somewhat contradictory, but remember, no electrical insulation is perfect. So, some current will flow.

No calculation is required as the test instrument provides the results in megohms.

The test process is:

- two leads (positive and negative) are connected across an insulator
- a test voltage is applied for 1 min.; during this interval, the resistance reading should drop or remain relatively steady
- after 1 min. you should read and record the resistance value

Insulation resistance is temperature and humidity-sensitive. When temperature increases, insulation resistance decreases. Some plants do use correction factors to insulation results for humidity.



#### 5.4.3.5 Over potential (hipot) testing

Hipot is an abbreviation for high potential. Traditionally, Hipot is a term given to a class of electrical safety testing instruments used to verify electrical insulation.

This test is not normally performed to air breakers because of the potential for damage to the insulating material. It is a required test for vacuum breakers; the hipot test is used to test the integrity of the vacuum bottles.

Dielectric Withstand Test is when a standard test voltage is applied (below the established Breakdown Voltage) and the resulting leakage current is monitored. The leakage current must be below a pre-set limit or the test is considered to have failed.

#### 5.4.3.6 Vacuum bottle Interrupter integrity test

The only way to determine the vacuum integrity of a vacuum bottle is the Hipot test. This is a pass or fail test.

The test process is:

- two Hipot test leads are connected across the vacuum bottle
- a test voltage of 36kV AC is applied to the vacuum bottle
- voltage should hold for a minimum of 5 seconds and maximum of 10 seconds

If the voltage holds the bottle is good.

#### 5.4.3.7 Power factor testing (doble)

Power factor tests are used to measure dielectric losses, which relate the wetness, dryness, or deterioration of insulation. Power factor testing or Doble testing is popular in some areas of the country it is commonly used to test transformer insulation but has also been used on circuit breakers.

The acceptance criterion is not based on a specific calculation and is generally provided by the test instrument company. The acceptance criteria was developed by performing testing on many breakers and using this data to establish an acceptable value for the breaker power factor results. It can provide an indication of a potential defect, but normally meggering will provide the same indication.

## 5.5 LUBRICATION

Circuit breakers need to operate quickly and reliably; this requires moving parts to have friction-free movement of their mechanical components. If the lubrication is not in good condition it limits a circuit breakers ability to operate properly.

The 1998 INPO SOER 98-2 on Circuit Breaker Reliability sites degraded lubrication as the largest single contributor to breaker failures.

Over the past 20 plus years lubrication has been the biggest contributor to circuit breaker failures. The cause of the majority of the failures has been old, dry lubrication. Most nuclear power plants were started in the 1960's and 1970's. During this time the lubrication used in many circuit breakers was petroleum type grease, which had a soap base. When the oil in the grease evaporated, the soap solidified and stopped the bearings from moving.

ITE/ABB and GE low voltage breakers experienced lubrication related failures because of soap based grease, but Westinghouse breakers lubrication did not experience the same grease hardening failures. Siemens breakers did not have a presence in the nuclear industry until the 1970's, so there is not any documentation to suggest they had lubrication issues.

### 5.5.1 Lubrications used by breaker manufacturers:

- General Electric uses Mobil 28 on all breaker mechanism and contact structure pivots and sliding surfaces.
- ABB recommends Anderol for operating mechanism sliding and pivot points. NO-OX-ID is used on contact structure. Mobile 28 has recently been approved for operating mechanisms, but only after all traces of other lubrication has been removed.
- Westinghouse/Cutler Hammer use several different types of lubrication and are location specific.

BR2 Plus, Graphite/Alcohol mixture (Normally only in low voltage application), Lubriplate 130A, and Poxylube for operating mechanism sliding and pivot points. For contact slides and pivots they use special formulation graphite grease.

- Siemens/Allis: Siemens uses different grease on each breaker type. Contacts have a Siemens formula. For mechanism sliding surface; Beacon P290, 325 or Anderol 732.

### 5.5.2 Penetrating oils and spray lubrications.

It is not recommended to use penetrating oils and spray penetrating formulas as a lubricant on circuit breakers. These are intended only for short-term freeing-up of a corroded or "frozen" assembly prior to disassembly or when troubleshooting a potential friction problem. Penetrants contain solvents that evaporate quickly and can leave behind a viscous deposit. Also, it will eventually leach out and dissolve the original lubrications propellants, leaving conditions worse than before and possibly freezing up the bearings.

### 5.5.3 Lubrication considerations:

- With the possible exception of Westinghouse /Cutler Hammer breakers, any breaker manufactured before 1975 that has never been overhauled, should be overhauled immediately.
- Breaker function and operation cycles are important considerations for when maintenance and overhaul need to be performed.
- If a breaker is in a high cycle function, wear and loss of lubrication become an issue. These breakers need to be constantly evaluated and should be on an aggressive overhaul cycle.
- If a breaker sits in a static position for a long period it should be cycled at least every 18 months. Breakers even with good lubrication can be sluggish when called on to operate, if the lubrication has not been redistributed on the pivots.
- Most Synthetic greases have a longer operational life than t petroleum greases but can still deteriorate over time. That is why it is important to evaluate the breaker preventive maintenance information.

## 5.6 RELAY TESTING

Relay testing is a specialized skill and normally not done by the department in charge of breaker maintenance. Most utilities have a dedicated department who is in the utility but not necessarily working at the plant. Relay testing should be performed on a regular periodicity to assure proper function of the device.