Circuit breaker maintenance in easy steps

Information supplied by Megger

Circuit breakers (CBs) sit quietly for months or even years, apparently doing nothing. Eventually, the time comes, however, when the breaker is required to operate and then it must respond – instantly. If it doesn’t, supply disturbances can cascade, people could be injured, equipment can be damaged and the supply network may be vulnerable.

So what can be done to ensure that CBs respond when they are supposed to? The best solution is proper testing which means using the right test equipment and employing proven test methods alongside more recent developments so that all eventualities are covered. There are 27 steps to keep in mind for your reliability-based maintenance (RBM) or condition-based maintenance (CBM) CB testing programme.

Prepare for testing
Preparation is essential. It is important for the person performing the tests to understand how breakers facilitate the flow of current during normal operation and how they interrupt current flow in the event of a fault. The person needs to understand just how important those CBs really are, because knowing the importance of the equipment will result in a regard for the job in hand that cannot be conveyed through simple orders. Someone who understands the process will be better prepared for the execution of testing and maintenance.

Plan your schedule
Maintenance intervals differ. Your utility may focus on when the CB was last tested. Some utilities develop maintenance plans based on CB use or the severity of fault currents. Others look at details like environment, such as humidity, temperature, geography, and topography. While all of these maintenance-planning options are important, the best option is to base your plan on trending. Know the wear and tear on your CBs, how things are deteriorating, keep an eye on them, compare information to factory thresholds, and plan from there. Time-of-year and temperature should take a backseat to real maintenance data and facts.

Know the standards
CBs, especially high-voltage types, are covered by a variety of international standards. Staying up to date with these standards can help with general maintenance planning and upkeep. A few standards to keep in mind are:

- **ANSI/IEEE C37.** Guides and standards for circuit breakers, switchgear, relays, substations and fuses.
- **IEC 62271-SER, ed 1.0.** High-voltage switchgear and control-gear.
- **IEC/TR 62063 ed 1.0 (1999-08).** TC/SC 17A, high-voltage switchgear and control-gear; the use of electronic and associated technologies in auxiliary equipment of switchgear and control-gear.

Know your breaker
These days, many types of CB are in use. Knowing what you are dealing with will help you understand the testing procedures more completely. Mainly you’ll be facing the four most common types of CBs: disconnecting circuit breakers (DCBs), which are also called circuit switchers; SF6 (live tank or dead tank) CBs; oil circuit breakers (OCBs); and low voltage CBs. A DCB or circuit switcher replaces the conventional combination of a circuit breaker and a separate disconnectator. On live-tank circuit breakers, the interrupter chamber is at high potential and is isolated from the ground by an insulator, which can be either porcelain or a composite material. The distinguishing feature of dead-tank technology is that the interrupter chamber is accommodated in an earthed metal housing. This housing is closer to the ground than in live tank breakers, which is an advantage in case of earthquakes. Low-voltage circuit breakers are common in domestic, commercial and industrial applications up to 1000 V AC.

Be aware of the contact arrangement
SF6 CBs break fault currents using two contact systems: the main contact system and the arcing contact system. (The main contacts conduct the normal operating currents, and the arcing contacts are used to take the load off the main contacts when the CB opens and closes.) Although arcing contacts are made to withstand the heat created during switching, they are exposed to high stress. Understanding the arcing contact arrangement of your CBs will be very helpful with troubleshooting.

Know the insulating medium
Knowing your CB type and its contact arrangement is a good start. But you also need to know about that insulating medium. Is it air, gas, vacuum or oil? For oil circuit breakers, the oil quality must be monitored in order to ensure proper insulation. Tests such as dielectric breakdown and dielectric power factor may be applied to test the insulation. For SF6 circuit breakers, gas purity and moisture tests may be used to determine the insulation quality. For vacuum CBs, a hi-pot test can verify the vacuum integrity.

Consider the contacts
The main contact in a circuit breaker is the current carrying element between the stationary and the moving part of the interrupter. The arcing contact is in parallel with the main contact and takes care of the arcing during separation. If the arcing contact is too short or in poor condition, the breaker becomes unreliable. The main contact surfaces can be degraded by arcing, resulting in increased resistance, excessive heating, and, in the worst case scenario, explosion.

SF6 needs different procedures
Be careful! When severe arcing occurs in an SF6 breaker, the SF6 decomposes and by-products (such as sulphur dioxide and various fluorides of sulphur) are created. Some of these by-products combine with any moisture in the gas, to produce sulphuric acid, which is highly corrosive and can damage the inside of the breaker. The by-products are also highly toxic to humans, so minimise their production by ensuring the gas in the circuit breaker is as dry as possible. Whenever you open an SF6 breaker, take care to avoid these by-products, which may be present in significant quantities after severe faults.

Inspect the operating mechanism
CBs are designed to operate at a moment’s notice; usually, however, they don’t operate frequently. They may remain closed for days, weeks or even years on end, virtually eliminating lubrication and creating friction. Greases and oils can solidify over time. So, watch for lubrication issues when testing.

Define failures
A basic failure means, "not performing the function." But there are major and minor failures. Major failures mean a fundamental switchgear function is lost and things are going to instantly change...
within the system's operating conditions. Minor failures usually don't cause instant changes to condition. According to Cigé, most major failures are mechanical in origin, and operating mechanisms are responsible for the highest number of failures. Knowing the type of failure can help you trace its cause.

Minor issues
Most of the minor failures of operating mechanisms are down to the leakage of either hydraulic oil or air. It's worth keeping this in mind. In case of doubt, check the operating mechanism. The operating mechanism is the principal cause of major and minor failures. It is the most unreliable part of the breaker. "Does not close/open on command" and "locked in open or closed position" remain the most frequently occurring failure modes.

Three key issues for breaker maintenance
Briefly, the single most important factor in breaker maintenance is grease. All breakers use grease as a lubricant, and grease tends to dry out over time. The three most important issues for breaker maintenance:
- Lubrication
- Contact adjustment
- Neglect or lack of maintenance

Attend to the connecting cables and clamps – every time
Since breaker testing is often based on comparison and trend analysis, it is important to have the same conditions from test to test. High precision signal acquisition is also necessary, together with high measurement accuracy and a reliable means of data storage. If the setup work required can be minimised and the connection from the test instrument to the apparatus can be simplified, faster testing and evaluation of results can be achieved.

Test throughout the life of the breaker
Testing can be done at various stages in the life of a CB including:
- Development
- Production
- Commissioning
- Maintenance/fault tracing
- After service (re-commissioning)

It's unsatisfactory to test a breaker just once and think that's good enough.

Consider testing with the CB still in service
Some tests are possible with the CB still online. And, having it online gives the technician information quickly. Tests available for online consideration include:
- First trip test with analysis of coil currents
- Vibration test
- Main contact timing through sensing of CT secondary current
- Auxiliary contact timing
- Control voltage measurement

Caution: When performing online tests, the CB can operate at any moment, so proper care must be taken to prevent personal injury.

Observe local standards
While international standards should be considered one must always test according to applicable local standards, regulations and best practices. The instruction manual and the nameplate for the circuit breaker can also be useful aids to testing.

Work safely
Safety is of highest importance when testing CBs. Be careful to follow all safety instructions and regulations. Before testing, make a visual inspection to see if there are any signs of damage. Make sure the breaker is in the open position and the mechanism is de-energised before performing any work inside the cabinet or attaching any transducers to the circuit breaker. The best way to improve safety when working in a substation is to increase the distance between personnel and devices with voltage. Regulations and laws require all objects to be grounded on both sides before any maintenance work. For circuit breaker maintenance, the most basic and important test, main contact timing, is often performed without observing this basic safety prerequisite. Modern dual-ground testing means that it's no longer necessary to compromise safety during timing tests.

Observe the correct sequence
Before connecting the instrument to power, connect the separate ground lead to test/work ground, and, when disconnecting the instrument, disconnect the instrument from mains outlet and, last of all, disconnect the test/work ground. Most substations have a common ground system and no additional actions need to be taken. In substations having separate ground systems, two alternatives are possible: a temporary connection between the two ground systems or the use of an isolating transformer to power the test instrument.

First trip
A proven way to check the condition of a circuit breaker is to document its behaviour at the first open operation after it's gone for a long time without tripping. The connections to the circuit breaker and the measurements are carried out while it is still in service. All of the connections are made inside the control cabinet. (Caution: There can be up to 480 V inside the control cabinet, and the circuit breaker can operate at any moment, so observe appropriate safety procedures). The biggest benefit of using first trip testing is that it tests the CB under real-world operating conditions. If the circuit breaker has not operated for years, first trip testing will reveal if it is slower due to problems in the mechanism linkages or coil armatures caused by corrosion or dried grease. With other methods, testing is carried out after the circuit breaker has been taken out of service and has been operated once or even twice.

Pay attention to timing
Time and travel are two of the most important tests you can perform on a
circuit breaker. They assure that the CB is operating within the correct parameters to clear a fault. If the timing of the CB is too slow, it will fail to protect the equipment it is assigned to guard; if the velocity is too slow or too fast, it won’t interrupt the arc correctly and severe damage can occur to the CB. Traditionally timing could only be performed with just one side of the breaker grounded, but with dual ground techniques, you can time a breaker with both sides grounded, which is much safer. You can also time CBs with graphite nozzles using a dynamic resistance measurement (DRM) method.

Don’t neglect damping
Damping is an important parameter to monitor and test, as the stored energy the operating mechanism uses to open and close a circuit breaker is considerable. The powerful mechanical stress can easily damage the breaker and/or reduce its useful life. The damping of opening operations is usually measured as a second speed, but it can also be based on the time that elapses between two points just above the breaker’s open position.

The value of vibration testing
Vibration testing is based on the premise that all mechanical movements in equipment produce sounds and/or vibrations and, by measuring the vibrations and comparing the result with the results of previous tests (known data), the condition of the equipment in question can be determined. Vibration analysis is a non-invasive method using an acceleration sensor. The breaker can stay in service during the test. The industry has used this testing method for 15 years with all kinds of transmission breakers.

Use the right test equipment
The following equipment is required for thorough CB-testing: A micro-ohm meter, breaker analyser, power supply, vacuum tester, high-current source. Ideally, one should also have access to software that can set user-defined parameters, create databases, generate reports, analyse data, and create graphical presentations for record-keeping purposes.

Measure the control voltage
It’s vital to measure the control voltage for every test since both timing results and coil current traces are dependent on the voltage that is applied. In order to make a fair comparison between tests, it is crucial to verify that the control voltages are equal. Excluding the control voltage parameter could make it difficult to determine the reason for an outlying result when making trend analyses.

Check the contact resistance
Timing, travel and contact resistance are your most important tests with CBs. Time and travel have been discussed, but contact resistance offers a look at how well the CB conducts current. A lower contact resistance means less loss of energy. If the resistance is too high, the contacts can heat up, and damage may occur.

Compare the results
The ability to accurately compare circuit breaker tests with previous test results is essential. Comprehensive, accurate testing also requires analytical tools and efficient reporting. It must be possible to validate test results in detail and then easily compare them with other test results. The test data is valuable information that must be safely stored, as it will be needed many times in the future.

Regular and thorough testing of CBs will ensure that when the breaker is required to operate it will respond instantly.

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