Circuit breaker diagnostic testing

Introduction

The objective of all circuit breaker diagnostic testing is to detect defects before they cause damage and system outages. Many test techniques are used to achieve this, but one that receives less attention than it deserves is vibration testing.

A recent CIGRÉ study on circuit breakers in active use revealed that 70% of malfunctions were caused by mechanical rather than electrical faults. What better basis could there be for diagnostic tests, therefore, than looking directly at the mechanical behaviour of the breaker? And this is exactly what vibration testing and more accurately an acoustic signature does.

The test method employed is easy to under-stand. Accelerometers, which behave in much the same way as microphones, are attached to the circuit breaker under test. As the breaker opens and closes, the vibrations they pick up are recorded in much the same way as an MP3 file might be captured for a voice or music recording. The recordings can subsequently be replayed and analysed at will.

The results are easiest to interpret if a reference recording – often referred to as a reference signature or "footprint" – is available. This is simply a recording made when the breaker was known to be in good condition and operating correctly. The reference signature can be readily compared with subsequent recordings, with any significant changes indicating potential problems. If no reference signature is available for the specific breaker under test, the comparisons can instead be made with the reference signature of another breaker of the same type. This is however a compromise, not least because it is very different to be certain that the parameters for tests on two individual breakers – such as the exact placement of the accelerometers – are identical.

While it is possible for experienced users of vibration analysis to display the recordings on a computer screen and compare them by eye, dedicated software will always provide more detailed and more reliable results. The analysis looks in particular at two aspects of the comparison, which are usually referred to as time shift and deviation (magnitude).

Particular vibration patterns are associated with specific mechanical events, such as the closing of the breaker's arcing contacts or main contacts. The time shift analysis looks for differences in the timing of these vibration patterns between the reference signature and the test recording. Deviation analysis looks for differences in the amplitude and frequency spectrum of the events.

While experience is undoubtedly the best guide to the interpretation of the results, it is possible to provide some rules of thumb. While these illustrate the usefulness of vibration testing however, it must be understood that they are neither absolute nor universal criteria and they must not be used without careful consideration of the specific application.

According to these rules of thumb, if the time shift is less than 4 ms, and the deviation curves never diverge by more than 10 dB, it is reasonable to assume that the circuit breaker is in the same mechanical condition as it was when the reference signature was generated. Note that successive tests on the same breaker will typically show differences of between 5 to 7 dB, and this should be regarded as normal. In cases where the time shift is greater than 4 ms but less than 8 ms, but the deviation curves still never diverge by more than 10 dB, this is likely to mean that the breaker is in the same mechanical condition, but that it is operating more slowly.

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This may be due to inadequate lubrication but, if the test is the first operation of the breaker for some considerable time, it is worth repeating it. If the second test gives normal results, it is very probable that the slow operation was caused by poor lubrication and/or corrosion friction. Note that a difference in ambient temperature can also produce a time shift as, in general, the colder the mechanism the slower the operating speed. This is particularly noticeable with hydraulic operating mechanisms.

Finally, in cases where the deviation curves diverge by more than 10 dB or the time shift is greater than 8 ms, this is a strong indication that the breaker is no longer in the same mechanical condition, and that there is a severe risk of it malfunctioning if it is put back into service. At this point, the vibration data can be further analysed to provide a guide to which part of the breaker's mechanical system is behaving differently. This is a good starting point for further diagnostic and remedial work.

This article has, until now, concentrated on offering a simple explanation of vibration testing and the type of diagnostic information it can produce. Care must be taken in setting up and carrying out the tests if accurate and dependable results are to be obtained. In particular, the positioning of the accelerometers that pick up vibrations from the breaker is critical - changes in position of just a centimetre or two can make a big difference to the results. This also means that the positions used for the reference test must be clearly and indelibly marked, so that the accelerometers can be mounted in exactly the same positions for subsequent tests.

Another issue that often needs to be addressed is that of electrical interference such as induction, which is always present in electrical substations. The best instruments, such as the TM1600 and TM1800 from Megger, are well protected against interference but, nevertheless, it is still important to inspect the recordings for evidence of its influence. Fortunately, this is in most cases straightforward, as genuine vibration signals are always symmetrical around the zero line, whereas interference signals are not. Other factors that affect the quality of the results obtained from vibration testing include the method of attachment of the accelerometers to the circuit breaker, the level of signal pre-amplification used, and the time window used for the result comparisons. Manufacturers of test sets that support vibration analysis can be expected, however, to provide practical and reliable advice in all these areas.

Nothing in this article should be interpreted as meaning that vibration analysis is the only type of testing needed for circuit breakers – it should always be used in conjunction with more conventional motion, timing, DRM (Dynamic Resistance Measurement), and coil current tests to give an overall picture of breaker operation and condition. Vibration analysis is, however, a very useful weapon in the circuit breaker testing armoury – it is convenient to apply and it can often uncover incipient problems that other test techniques would miss until they had become far more serious.

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ABSTRACT: The paper provides a simple explanation of vibration testing and the type of diagnostic information it can produce. Care must be taken in setting up and carrying out the tests if accurate and dependable results are to be obtained. Users should also be aware of electrical interference such as induction, which is always present in electrical substations.

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