Using the technology makes it possible to perform a circuit breaker timing test with both sides grounded throughout the test. Working with both sides grounded is safe while removal of one ground creates a dangerous environment. Regulations from legal bodies, standardization organizations and trade unions require that all objects in high voltage substations to be grounded at both sides during maintenance. In coming years application of regulations will be stricter. Using the dual grounded method approach makes it easy to comply with the safety regulations. At the same time the tests become easier and faster when some of the safety procedures are omitted. This is illustrated in Fig. 1.

The DRM (Dynamic Resistance Measurement) method was introduced in 1992. This technology enables estimation of the arcing contact length in a non-intrusive measurement. Without this, circuit breaker dismantling was required. Five years later the vibration solution was put on market. Vibration is a direct mechanical method designed to detect mechanical failures that conventional measurements cannot detect. This was a response to the CIGRE study on the installed base showing that 70% of all actual circuit breaker failures are caused by mechanical problems.

In 2007 the methods and equipment making circuit breaker testing in high voltage substations safe were introduced. Today there is no reason to work with only one side grounded. All diagnostic tests available for circuit breakers can, with the right methods and equipment, be made with both sides grounded throughout the test.

Test Methods
Contact resistance: Measure the current through earth and compensate accordingly in the calculation.
Timing: Technology described in this paper. (TM1800, DCM)
Motion: The conventional method can be used.
DRM: The same as contact resistance.
Vibration: The conventional method can be used.

Timing test
For the field engineer the timing test is very similar to conventional timing. The difference in method is to keep the ground connection throughout the measurement. The administration of sanction for test and other safety related paperwork is reduced. Fig. 1 is an overview of how the test sequence is changed. The difference in instrumentation for the timing test is that the TM1800 is complemented with the dynamic capacitive measurement (DCM) module and...
DCM Cables. On the timing leads there is a small box built into the cable with electronics for generation of test signals. The module converts the signal into the equivalent of a conventional timing measurement that is transmitted over to the timing M/R Module. The box on the cable can be seen on Fig. 2 in the lower right corner. The technology that enables the timing test with is described briefly in next section.

DCM timing technology

The DCM technology for enabling two-sided grounded timing is described below. For more in-depth description of this technology papers presented at the IEEE and CIGRE technical conferences is recommended. The fundamental physical property that the DCM timing technique is based is the capacitance that exists when two areas of conductor are separated by an insulation medium. In a circuit breaker, the contacts are the conductors and the insulation media is usually oil, air, vacuum or SF₆. Any circuit breaker, therefore, has capacitance. When the contacts move, i.e., during a close or open operation, the capacitance varies. The capacitance in the circuit breaker is used as a part of a resonant circuit. See Fig. 4 for a theoretical model. The resonant frequency is dependent on the value of the circuit breaker capacitor and the resonant frequency will vary with movement of the main contacts.

The recorded response to a high frequency test signal will be proportional to the capacitance of the circuit breaker. Fig. 5 shows a theoretical diagram for a close operation.

Timing test with DRM

Working with both sides grounded, which is possible with DRM, has long been the preferred practice. The definition of timing according to standards such as IEEE/ANSI C37.100-1981 is:

“The time interval between the initiation of the closing operation and the instant when metallic continuity is established in all poles.”

The DRM equipment is generally considered too clumsy and expensive for a timing test. Also it is a more complicated test demanding more time with the circuit breaker taken out of service. A few initiatives to sidestep these problems have been proposed. There is DRM equipment available that is not capable of a DRM because the current is too low.
It is theoretically possible to make the resistance test with both sides of the test object grounded. The generated current now has two paths and is therefore not equal to the current through the test object. If the current through earth is measured the current through the test object is the generated current minus the earth loop current. The voltage drop is measured as normal. In this way (see Fig. 6), the resistance can be measured with both sides grounded given a test device capable of the theoretically simple calculations. Measuring the ground loop current with a current clamp gives sufficient accuracy. The test object has a low resistance compared to the ground grid and therefore most of the current, typically 90%, takes the path through the test object.

Summary and conclusions

All diagnostic tests required for in-field diagnostic test of high voltage circuit breakers can be performed, including micro-ohm measurement, timing, motion, coil currents as well as DRM and Vibration. The advantages of using the technology and methods are:

- Improved field safety for field engineers.
- A more time efficient workflow is achieved when dangerous steps are omitted and safety arrangements are no longer needed.
- High accuracy is provided with an easier test sequence.

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![Fig. 6: The test hook up. The current through the ground is measured with a current clamp and the resistance calculation is compensated accordingly.](image)