Safety Improvements when Testing High and Medium Voltage Circuit Breakers with Both Sides Grounded

A. Secic, DV Power – Sweden
N. Hadzimejlic - Faculty of Electrical Engineering, Sarajevo

ABSTRACT

Testing circuit breaker main contacts is an important phase in production, commissioning and maintenance. During the test a simultaneous *timing measurements* on the circuit breaker main contacts are performed to determine displacements of the CB moving parts. These measurements can also provide information on synchronization between the circuit breaker poles.

Time differences between phases with a common operating mechanism could indicate internal faults on the main contacts on a particular phase. On the other hand, increased *static resistance* causes heating of circuit breaker contacts during operation, which can lead to melting of the main contacts, or in the worst case, explosion of the breaker chamber. Also, *Dynamic Resistance Measurement* (DRM), although not described in standards, is one of the relatively new methods for testing the SF6 circuit breaker with separated main and arcing contacts.

There are many regulations and laws that require all objects to be grounded before any maintenance work is performed on the object. Testing a high voltage circuit breaker that is not grounded on both sides can be hazardous due to the high electric potential.

The paper presents the principles of performing timing tests, static and dynamic resistance measurements on the circuit breakers with both sides grounded. This paper discusses specifics of testing circuit breakers in this way and presents the results in comparison with the results obtained on the circuit breaker that is not grounded on both sides.

Keywords: *HV Circuit Breaker testing, diagnostic, maintenance, safety, both sides grounded*

1. INTRODUCTION

In recent years, considerable research has been done towards the development of on-line monitoring systems for continuous monitoring of the components of the power system (transformers, circuit breakers, disconnectors, etc). Regardless of the obvious advantages of such solutions (for example their ability to follow sequences of events and the on-line decision-making process) [1], these methods have not yet become common practice.

The reasons vary - from economic constraints, to reasons of a technical nature and above all the achieved satisfactory and efficiency level in the maintenance process based on the conventional testing methods.

Therefore, in the most cases, the diagnostics of power system components are still done through regular maintenance procedures that are performed on-site by the trained personnel.

The diagnostic processes on these elements are performed through the implementation of different types of tests (usually defined by various standards - such as IEC 62271-100, IEC 56, ANSI C37.09, etc.), by which data is collected on different parameters of the tested object, arranging them in a mosaic in order to come to certain conclusions about the state of the equipment and its reliability.

Although such tests are performed on the test objects that have been taken out of service, they are carried out directly in the field where the testing itself can be potentially life threatening.

There are many different laws and regulations that prescribe all test objects to be properly grounded before any testing is done in order to minimize the number of unwanted situations and to increase the safety and protection of personnel.

Testing itself has to be done in the shortest possible time which, besides the obvious reasons of economic nature (excluding the test object from the power grid), is also dictated by the safety of the personnel, since reducing the time spent in a dangerous environment also reduces the risk of the unwanted situations.

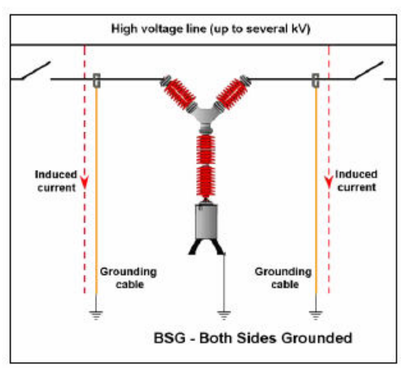

Figure 1.1 *Circuit breaker grounded on both sides*

For high and medium voltage circuit breakers, one of the basic rules required by the laws and the regulations is to ground the test object on both sides before performing any tests. There are some exceptions, however, for when this is not possible to do. For example, the conventional method of conducting timing tests on the power circuit breakers does not require both sides of the breaker to be grounded but only one side.

In practice, the power circuit breaker proper grounding refers to the grounding of its main contacts on both sides (as shown in the Figure 1.1).

In this way potentially dangerous situations are avoided. Such situations can be caused by various factors, such as [2]:

- A fault occurs and unwanted electrical potential reaches this object;
- Lightning strikes somewhere on de-energized lines connected to the object;
- Capacitive coupling from nearby HV conductors causing a dangerous potential on the object in question;
- The high voltages are induced on the apparatus under the test from adjacent energized objects.

Common practice when conducting conventional resistance measurement on the circuit breaker implies that one side of the circuit breaker is grounded

Since resistance measurement does not require opening of the circuit breaker and considering the low electrical resistance of the main contact one can argue that this procedure should be completely safe.

Although this is not totally incorrect, such a failure may occur on the main contact which causes its resistance to increase substantially.

In this case one side of the closed circuit breaker would not be properly grounded and unwanted situation may occur.

2. Resistance measurement of the main contacts with both sides grounded (BSG)

Standards are prescribing the measurement of the circuit breaker main contacts should be conducted with DC currents of a least 50A (IEC 60694) or even 100A (ANSI C37.09).

Although resistance measurement could be conducted with lower currents, there are several reasons why such guidelines are prescribed.

Experience has shown that real resistance values are obtained at high test currents while low test currents might give false results in some cases (resistance values slightly higer than the real ones). For example, at some contact finger's surface the insulating layer is built from decomposition products or dry lubricant, and then only a few contact fingers carry current, and the contact reistance is much higher than its real value[3].

Therefore, precision micro-ohmmeters, capable of generating high DC currents are used to perform field measurements of the circuit breaker main contacts resistance.

Today, commercially available micro-ohmmeters are devices capable of generating up to 800A DC (ripple free) current and measuring the resistance with very high precision (resolution up to 0.1 μΩ).

The method is based on the Kelvin measurement principle, so the device generates DC current and simultaneously measures the voltage drop across the circuit breaker main contact and the current value through the precision shunt resistor (or some other current measurement principle) in order to calculate the corresponding resistance value.

Measuring the resistance of the main contact is usually done along with other tests, such as the timing measurement. Because of this, today, on the market are very popular devices that combine all of these features together. Such devices are called Circuit Breaker Analyzers and Timers with built-in micro-ohmmeters.

Cables for connecting the high current DC source to the test object are required in order to perform the measurement. Cable length, due to the different structure of high and medium voltage circuit breakers, can be quite large (up to 20m). This means that even cables with very high cross-section (tens of mm2) can still have high resistance. Voltage drop on current cables plays an important role in design of high current DC source for this purpose. That is the reason why this current source should be very powerful.

There are two basic principles for generating high DC current in order to perform resistance measurement:

First principle requires energy storage element, such as super-capacitor. These high energy capacitors, based on the double-layer technology, can have capacitance up to few hundred Farads. Due to its very low internal resistance, this type of capacitor appears to be the best choice for situations where it is necessary to frequently perform charging and discharging at high currents and in short periods of time.

The second principle is based on rectifying mains voltage and usage of high frequency switching type DC/DC converter in order to achieve the desired current.

Measurement of the resistance of the circuit breaker that is grounded on both sides requires some modifications for this method. In this case, the generated current has two paths, one consisting of the circuit breaker main contact and the other one consisting of the resistance of the grounding cables and the ground resistance.

There are two test methods that allow resistance measurement of the CB's main contact in this case:

a) Additional measurement of the current that flows through the grounding cables. This method requires external current clamps and enables generating adjusted current by taking into consideration the measured current value from the current clamps. An obvious advantage of this method is that the given current will flow through the main contact since a feedback controller can now use the $I_r=I_t-I_g$ signal, where the I_t represents total current and I_g current that flows through the ground wires. The result will also be obtained immediately after one measurement. A disadvantage is that the precision of the measurement is influenced by the precision of the used current clamps.

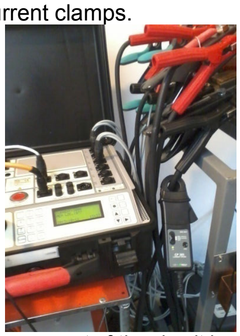

Figure 2.1 *Measurement of the circuit breaker resistance with BSG using test device with the external current clamps*

b) The other method consists of two consecutive measurements and tripping off the circuit breaker. In the first measurement, the circuit breaker is in a closed position and R_p (parallel resistance of both main contacts and grounding cables) is measured. After that the device issues a command to the Trip coil of the circuit breaker and after the breaker is closed another measurement is obtained. Based on these two results resistance of the main contact of the circuit breaker can be calculated. In this case, measurement is more precise, since there is no need for usage of the external current clamps. The disadvantage of this method is that there is a need for performing two measurements and opening of the circuit breaker, and that the given current value will not flow through the main contact because some of the current will flow through the grounding cables. The percentage of the current that flows through the grounding cable is very low because of its resistance.

No.	Curr.	100 uΩ	300 uΩ	1 mΩ
1	100A	97.5 uΩ	297.4 uΩ	978.0 uΩ
2	150A	97.8 uΩ	297.5 uΩ	1.02 mΩ
3	200A	101.5 uΩ	302.5 uΩ	1.01 mΩ

Table 2.1 Shunt resistance measurement results obtained by method based on CC

Ph.	Curr.	Rg	Rp	Rc	Rm
A	200A	12,6772m	352,80u	362,899u	367.4u
B	200A	12,3636m	338,90u	348,451u	349.4u
C	200A	13,3558m	485,20u	503,491u	504.0u

Table 2.2 CB resistance measurement results obtained by two consecutive measurements method

3. Circuit breaker timing with BSG

The main function of the power circuit breaker could be defined through the following:

- To act as close as possible to a perfect conductor in a closed position
- To act as close as possible to a perfect insulator in open position
- To have adequate transition speed between these two stages.

By definition, a circuit breaker timing test is the process of measuring the mechanical operating times. These tests are also used to determine sinchronisation between phases, or within one phase for circuit breakers having more then one break unit per phase.

Timing measurement is triggered by the instant of energising the opening release or a closing circuit of the circuit breaker.

There are several methods that can be used in order to determine timing on the main contacts.

These methods are based on tracking changes either on resistance or capacitance of main contacts during operation.

First method consists on using a voltage source (with a current limiter) and measurment of a voltage drop accros the contacts. Based on measurement and pre-defined thresholds circuit breaker state can now be easily detereminated in any position (closed / preinsertion-resistor / open).

Second method is based on the variable capacitance in the circuit breaker chamber formed by the two separated connectors. The capacitance is used as a part of a resonant circuit. This method consist on using high frequency generator in order to detect impedance changes of the circuit on resonant frequency during operation.[4]

Either way, a timing test requires the opening or closing of the main contacts.

Conventional testing methods cannot be used to perform timing measurements on the circuit breaker grounded on both sides.

That's because grounding is usually achieved through low resistance cables (in most cases over 70mm sq) and earth resistance is also very low.

Field experiments have shown that grounding resistance in some extreme cases can even go below 20 mΩ.

In that case, the overall change of the resistance during closing or opening of the main contacts is too low for conventional test methods to determine the comparator threshold in the time measurement process.

Modification of the mentioned conventional resistance testing method in terms of increasing current, paying particular attention to the signal filtration and development of special state detection algorithms will define a test method that can be used to perform timing measurement on a breaker grounded on both sides – BSG measurement

In order to demonstrate the efficiency of this method, tests were performed on the same circuit breaker in both cases – with and without grounding on both sides.

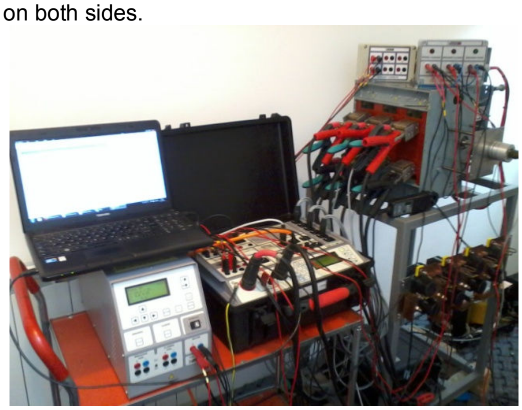

Figure 3.1 *Timing tests on a circuit breaker*

For this purpose, low resistance cables were used to simulate grounding. Circuit Breaker Analyzer and Timer with built in Micro-Ohmmeter has been used to determine the resistance of these cables and the obtained values are:

PhaseA: 12.68 mΩ | PhaseB: 12.36 mΩ | PhaseC: 12.36 mΩ

Now, standard O-03s-C test has been performed on a circuit breaker with and without grounding.

The next figures show comparison of obtained graphical and numerical results in both cases:

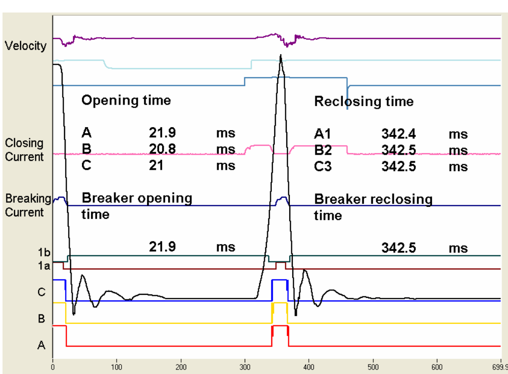

Figure 3.2a *O-0.3s-C test without both sides grounded*

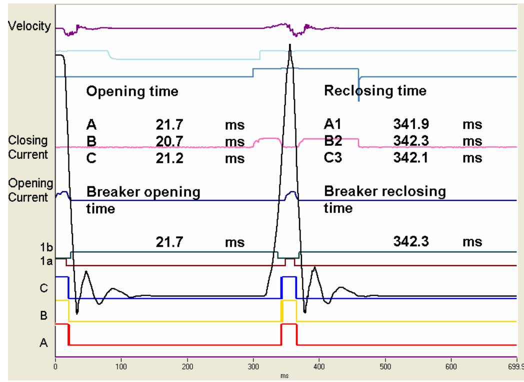

Figure 3.2b *O-0.3s-C test with BSG (grounding resistance 12mΩ)*

4. Dynamic resistance measurement and BSG

The design of modern high-voltage puffer- type SF6 gas circuit breakers is based on the switching of two parallel contact sets. First, the low-resistance silver-plated contacts, or the main contacts, are specifically designed to carry the load current without any excessive temperature rise. Second, tungsten-copper arcing contacts operate at breaker opening following the main contact part. [5]

Test device is used to inject a high DC current through the breaker contact and simultaneously monitor the voltage drop across the main contact during the trip operation.

An analog or digital (linear or rotary) transducer is used to record the motion of the main contacts.

DRM measurement can also be performed on a circuit breaker grounded on both sides. The main goal of this test is finding out the overlapping time and overlapping length of a main and arcing contact.[6]

The same circuit breaker as in the previous tests has been used for DRM measurements with the BSG and without the BSG option. Grounding resistance is measured after opening the main contact and the obtained value was around 12 mΩ.

Figures 4.1 and 4.2 show the obtained DRM results with an injected current of 200A.

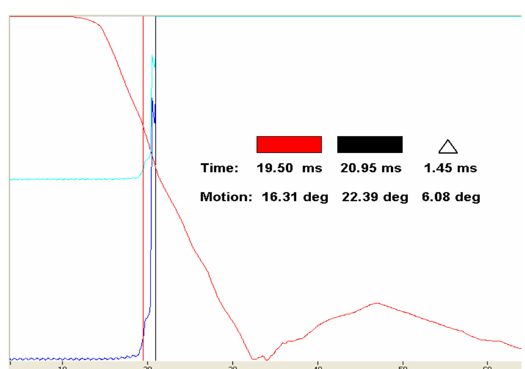

Figure 4.1 DRM results without BSG

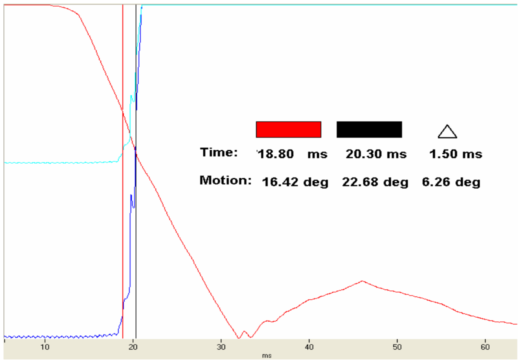

Figure 4.2 DRM results with BSG

Test is performed with a constant current source (in this case with a current of 200A).

The voltage drop across the arcing contacts, in case of a circuit breaker grounded on a both sides, will be lower due to the presence of a parallel resistance that comes from the grounding cables and a ground resistance.

Even with decreased total resistance in cases when both sides of the circuit breaker are grounded, the overlapping time does not change as can be seen on the diagrams. Considering the overlapping length is determined by the motion diagram based on overlapping time one can conclude that grounding does not affect the DRM results.

5. Conclusion

In the most cases, the diagnostics of power system components are still done through regular maintenance procedures that are performed on-site by the trained personnel.

The above mentioned conventional testing methods are also one of the most common testing methods applied as part of testing procedures in regular maintenance processes of MV and HV circuit breakers in the field.

Conventional tests are performed on a circuit breaker that is grounded only on one side.

Testing a high voltage circuit breaker that is not grounded on both sides can be hazardous due to the high electric potential.

Development of new technologies has made it possible to modify conventional methods in order to perform BSG measurements.

In this way a higher level of personal safety and protection is achieved.

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BIOGRAPHY

Adnan Secic is a developer at DV Power, Sweden. As a project leader he is currently responsible for the development of Circuit Breaker Analyzer and Timer series - CAT device series.
Secic received his Bachelor of Science degree in Electrical Engineering from University of Sarajevo Bosnia and Herzegovina in 2008 and is currently preparing his M. Sc. in EEA (Electronics, Electrotechnics and Automation).

Nijaz Hadzimejlic is currently Associate Professor at the Department Of Electrical Engineering, University of Sarajevo. He also works as a consultant for DV Power from company's foundation in 2000. He received his B.S., M.S. and Ph.D. degrees in Electrical Engineering in 1977, 1987 and 1997, from University of Sarajevo. Hadzimejlic's research interests are in power electronics converters, motor drive control for electrical cars and robotics. He is the author and co-author of over fifty technical papers.