USE OF MICRO OHM METER AS A POWER SOURCE FOR DRM TESTING ON DEAD TANK CIRCUIT BREAKERS

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ABSTRACT

The arcing contacts are the most important part of the high voltage circuit breaker. One of the methods to detect the condition of arcing contacts is to inject high direct current (DC) and measure the voltage drop during a breaker operation, a process called Dynamic Resistance Measurement (DRM). Lead batteries were used as a power source to produce pure DC current. Transportation and other technical reasons prevented wide use of lead and other rechargeable batteries for DRM testing. As an alternative, the micro ohm meter was used as a 200 A direct current source. The high DC current magnetizes the current transformers (CTs) in dead tank circuit breakers and a demagnetization circuit is added to the micro ohmmeter. Test results of DRM and use of a micro ohm meter as a power source are presented and discussed.

INTRODUCTION

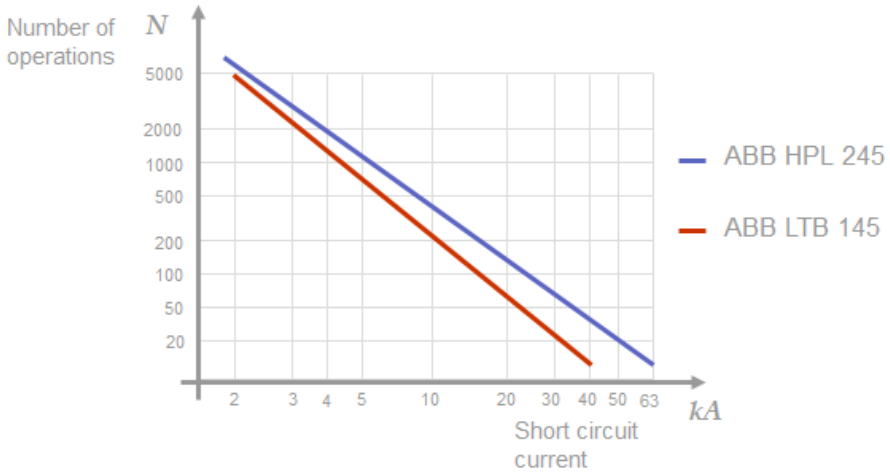
The SF6 circuit breaker contact system consists of main and arcing contacts. During the trip operation the main contacts open first and arcing contacts open after a few milliseconds. The electrical arc starts after the separation of the arcing contacts, and is cleared at the next zero – crossing.

CONTACT OVERLAP TIME

During each opening and closing operation, a fraction of the arcing contact material burns away. According to literature, temperature at the center of the arc is around 25,000° C. This temperature is four times higher than the temperature of the surface of the sun, there is no material which can withstand such a high temperature. The standard operation for circuit breakers requires a test in a high power laboratory under rated short circuit current condition and there are three opening operations O – t1 – CO – t2 – CO. The standard operation practically represents the life span of a circuit breaker and is directly connected to the shape of the arcing contact. The life span of a circuit breaker, and at the same time of the arcing contacts, is represented graphically.
Each circuit breaker type has its own permissible electrical wear curve. In most designs, a minimal number of circuit breaker operations under rated short circuit conditions are from 3 to 10.

Figure 1 shows the number of interruptions versus short-circuit current that the arcing contacts in a circuit-breaker can withstand before they must be replaced.

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Service Life of Arcing Contacts with Short-Circuit Interruption
Figure 1

One of the consequences of material lost at the arcing contacts is that the time difference between separation of the main contacts and the separation of arcing contacts is shorter. This time difference is called the contact overlapping time. Other characteristics of material lost are that the surface of the arcing contacts is changed and that changing shape will change the dielectric strength of space between the arcing contacts.



New and Used Arcing Contacts
Figure 2

TESTING

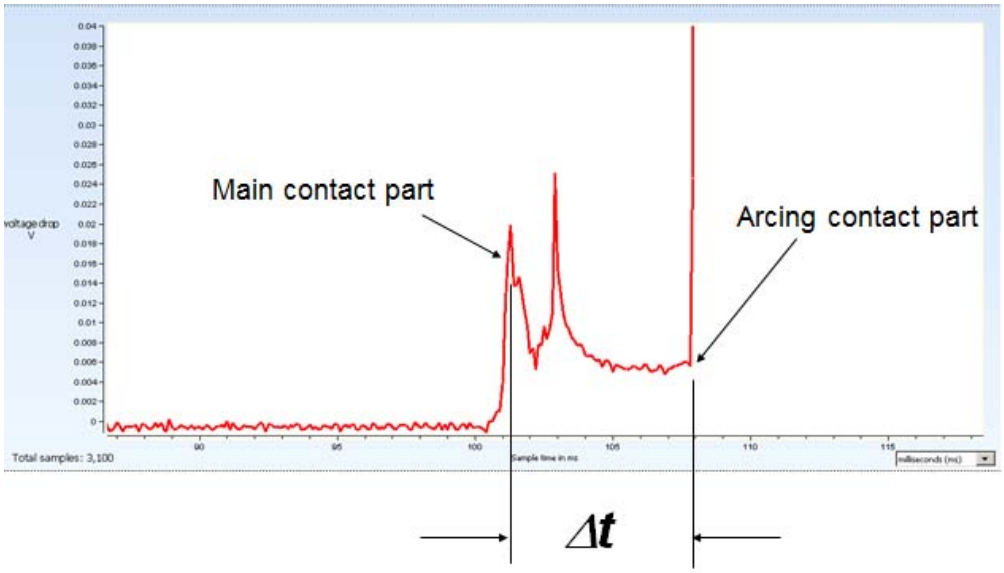
Measuring principle

High DC current is injected during circuit breaker operation. Voltage drop is measured across the terminals of the circuit breaker.

During an opening operation, sudden resistance change coincides with the separation of the main contacts and the separation of the arcing contacts. The resistance change results in sudden changes of the voltage drop measured across the breaking element.

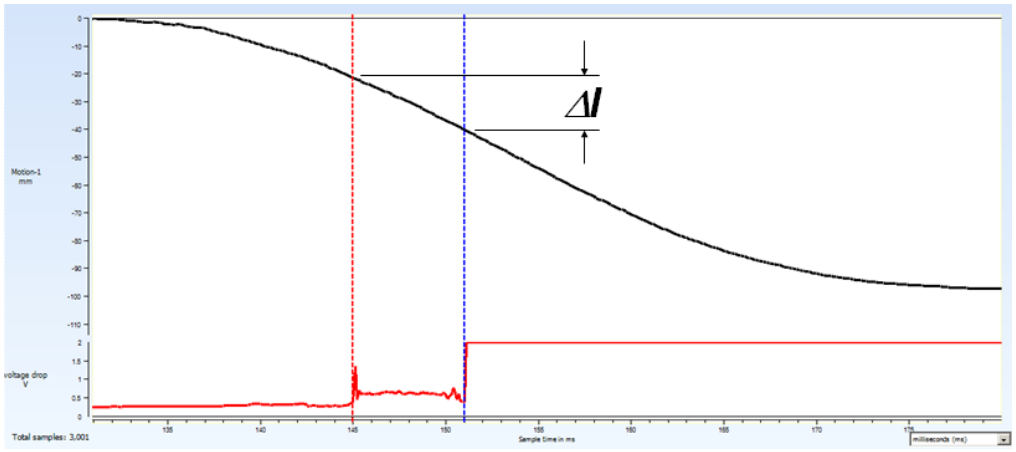
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Time difference between the main contact and the arcing contact separation represents the overlaping time. (Figure 3)



Δt = Overlapping Time
Figure 3

When motion is measured, the difference between the moment of main and arcing contacts parting can be presented in distance unit, for example milimeter. (Figure 4)



Δl = Overlapping Length
Figure 4

The best source for a DRM test is a DC battery. The reason is, the battery will supply real direct current and measurement of voltage drop across the breaker terminal will give traces without any imperfections.

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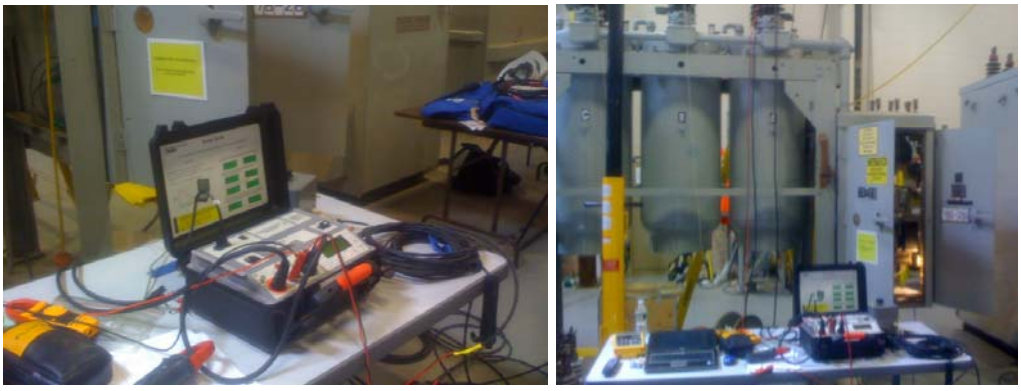
The use of lead acid or other rechargeable batteries as a source presents technical problems that will prevent their use as a practical source.

A micro ohm meter has a power source for resistance calculation and that source has to be with relatively small voltage and current imperfection to satisfy Ohm's law for resistance calculation. The micro ohm meter type RMO200 was used as a DC power source for DRM tests.

DRM tests with micro ohmmeter RMO200D as the power source

Technical characteristics of micro ohm meter RMO200D used as a power source where output current ranges from 5 A to 200 A DC with load voltage of up to 7 V and when used as a micro ohm meter measuring accuracy of ± (0.1 % reading + 0.1 % full scale).

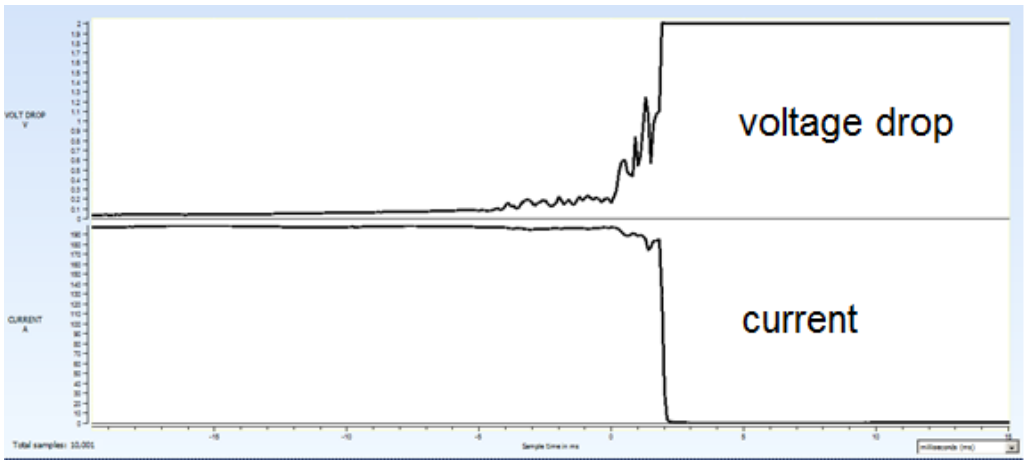
The TDR900 test instrument was used for current and voltage drop measurement across dead tank circuit breakers terminals. A calculation of resistance and so called dynamic resistance during the breaker operation is done inside T-Doble software using virtual channel and is graphically represented.
Micro ohm meter RMO200 was in continuous mode for 30 s. During that time, the circuit breaker was operated manually and change of stage at auxiliary contact was used as a trigger to start recording. Testing was performed only on trip operation. The reasoning behind this is that micro ohm meter will report error when breaker is closed and micro ohm meter is in circuit. Change in firmware of micro ohm meter is required to allow current flow from power source when the circuit is closed.
The overlapping time and length are best calculated when trip operation is performed. For example, closing operation can be good to detect misalignment of arcing and main contacts. Such problems can be also detected during regular timing and motion testing observing the velocity diagram during the first period of arcing contact engagement.



Micro Ohmmeter RMO200 During DRM Testing
Figure 5

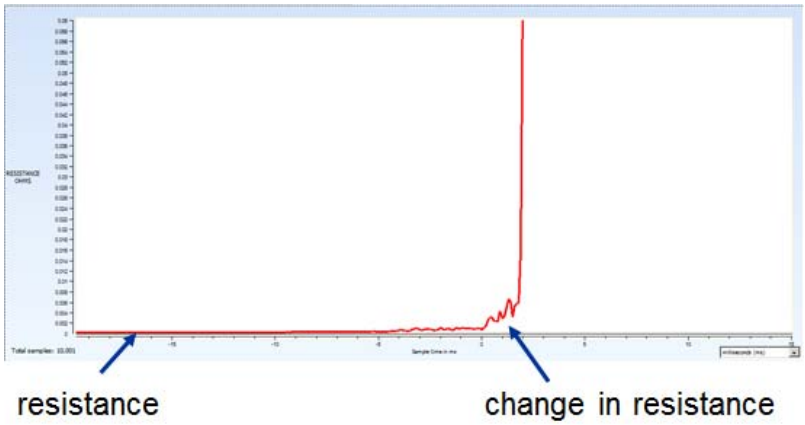
Voltage drop across circuit breaker terminals and current were measured during breaker operation and recorded.

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Voltage Drop and Current Measurement During Breaker Operation
Microohm Meter Used as Power Source
Figure 6

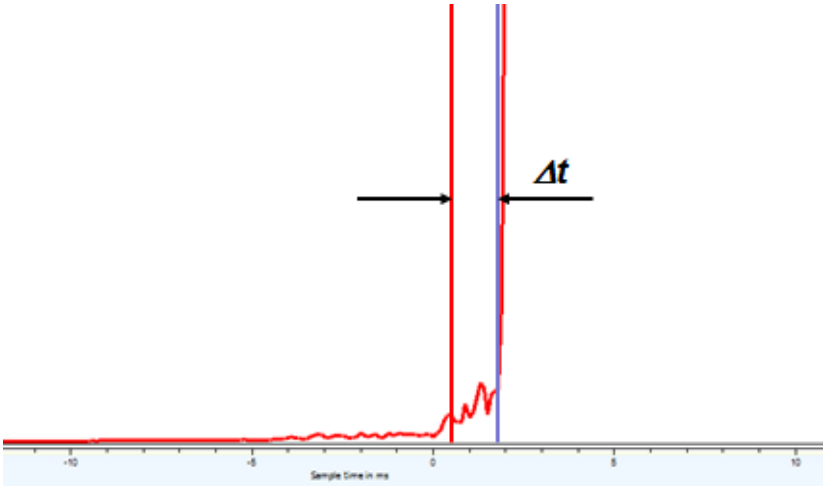
Virtual channel calculation option was used to divide voltage drop and current. This calculation represents resistance in the area when both voltage drop and current where constant. For area after main contact open voltage drop and current are not constant and calculation does not represent resistance, rather impedance. Industry practice is to name this calculation dynamic resistance when voltage drop and current are not constant. Overlapping length of main and arcing contact is calculated manually, positioning the cursor at the moment when main contact part is the starting point and moment when arcing contact part is the ending point.



Resistance and so Called Dynamic Resistance Calculated in T-Doble Software
Figure 7

Overlapping time is calculated from the moment when the main contact part and the moment when arcing contact part. (Figure 8)

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Overlapping Time
Fig 8

CONCLUSION

Use of micro ohm meter as a power source for the DRM test, shows very good results for detecting the moment of main contact separation. A micro ohm meter with 200 A current was sufficient to detect main and arcing contacts' overlapping time and distance. The demagnetization option on the micro ohm meter allows it to inject relatively high DC current into the main current circuit of dead tank circuit breakers without worries about saturation of current transformers. After current injection test, demagnetization of the CT is required.
Next step will be to make a change in firmware to allow micro ohm meter to be used also in closing operation without reporting error message.

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BIOGRAPHY

Jozef Levi has been employed at Doble Engineering since 1999, and currently works as technical application engineer for TDR instruments and circuit breaker testing. His special field of interest is electrical contacts systems of circuit breakers and disconnects switches. Levi received his Bachelor of Science in Electrical Engineering from University of Sarajevo Bosnia and Herzegovina.



Radenko Ostojic is a test engineer at DV Power, Sweden, working on the improvement of the circuit breaker testing equipment and development of the new methods for circuit breaker testing. He graduated at University of East Sarajevo with Bachelor's degree in Electrical Engineering.



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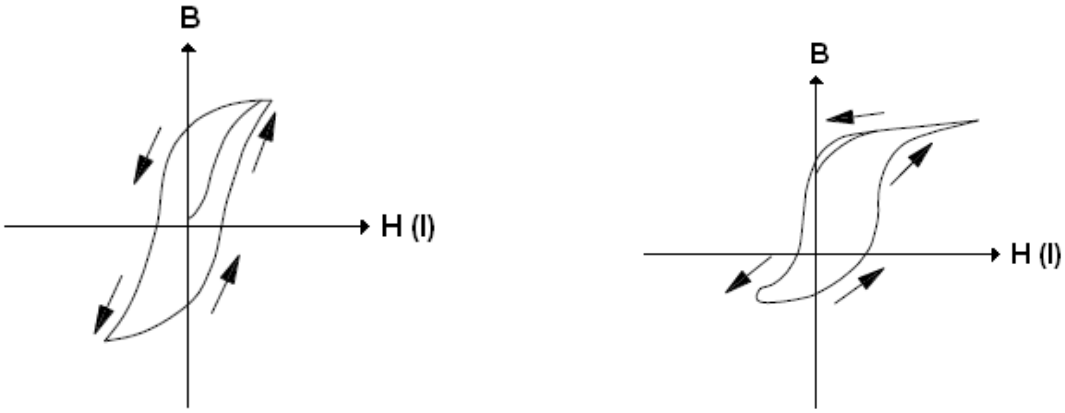
APPENDIX

Magnetization and demagnetization of the current transformer's core

Dead tank circuit breakers have current transformers (CTs) mounted externally on the circuit breaker bushings. Current Transformers (CTs) are instrument transformers that are used to supply a reduced value of current to meters, protective relays, and other instruments. These are dead tank current transformers since the core and secondary winding of the CT is housed in the toroid enclosure which is grounded. The primary is conductor at high voltage which passes through the bushing and center of the wound toroid core.

Current transformers can become magnetized by DC current applied during resistance measurement of the main circuit or DRM testing of the circuit breaker. When the main circuit resistance is measured, the standard test current (according to IEC 62271-100 and ANSI C 37.09 standards minimum test currents are 50 A and 100 A, respectively) which flows through the main circuit can magnetize the current transformer. Also, after DRM testing with the DC test current of 200 A, the residual magnetism can remain in the core of the current transformer.
To avoid magnetization of current transformers, direct currents up to 20 A are used for resistance measurement. However, this current is not enough to accurately measure a resistance. Thus, standardized test currents need to be used.

Residual magnetism, or remanence, has a large impact on transient performance. When the current transformer is energized, the flux changes required will start from the remanent value. If the required change is in the direction to add to the remanent flux, a large part of the cycle may find the current transformer saturated [4]. When this occurs, much of the primary current is required for excitation and secondary output is significantly reduced and distorted on alternate half cycles. This phenomenon is illustrated in Figures 9a and 9b [4]. It can cause the serious problems. Protection relay action could be slow or even incorrect during operation. Further, during testing the CT, the ratio reading may be subsequently higher or lower (depending upon the orientation of the molecules in the core) than the rated ratio, causing metering to be significantly inaccurate.



a) Normal hysteresis curve and b) Hysteresis curve with remanence

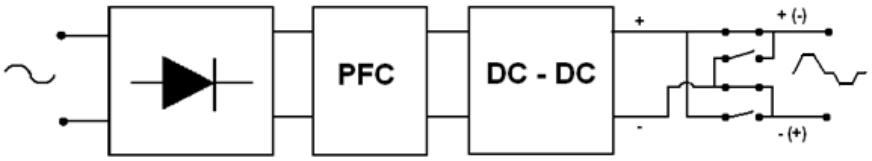
Figure 9

Very little of the remanent flux can dissipate during normal CT operation and it will remain in the core until the CT is de-magnetized [5]. Since magnetized CT can cause a delay or incorrect operation of protective relays due to premature saturation, they should be demagnetized after DRM testing on the Dead tank circuit breaker with the 200 A DC current**.**

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Developed power source with built-in demagnetization circuit

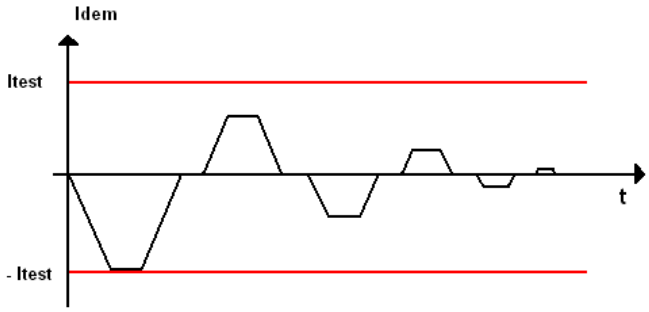
There are a few methods for a demagnetization of the CT core. Method which is employed in the RMO200D uses trapezoid current pulses which are generated by the demagnetization circuit. The demagnetization circuit (Figure 10) is actually the reversible controlled DC current source, since it includes the existing DC supply used for DC current generation and the circuit for changing the polarity of the DC current.



Electric diagram of the demagnetization circuit
Figure 10

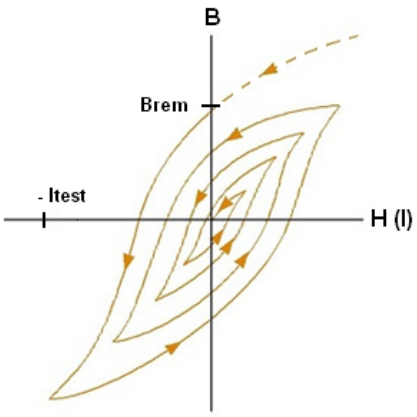
The generated trapezoid current pulses change the polarity and they are reduced in amplitude until the minimum amplitude is reached, as shown in Figure 11. As can be seen, the first generated current pulse has the same amplitude as the value of the DC test current I_{test}, but the opposite direction in order to speed up the demagnetization process. Therefore, the core molecules are driven into positive and negative direction, but with decreasing the total flux in order to get the working point of the current transformer back to the origin, which means no remanent magnetism B_{rem} in the core. This process is illustrated in Figure 12. As can be seen, demagnetization of the CT core is accomplished by carrying it through successive hysteresis loops.

The advantage of the demagnetizer with the reversible DC current source is that it requires relatively little power as compared to the other methods, and that the output voltages are low and therefore safe. The whole demagnetization process does not require any modification of connections (the same cables are used as for DRM testing), it is automatic and very quick.



Trapezoid current pulses
Figure 11

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Successive hysteresis loops
Figure 12

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