Use of High Power Batteries as Power Source for DRM and BSG Methods

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Abstract

The arcing contacts are the most important parts of a high voltage circuit breaker (CB). One of the most elegant methods used to detect the condition of the arcing contacts is the Dynamic Resistance Measurement (DRM). It consists of injecting high direct current (DC), order of 100-200 A or even with 500A as reported by Mrdic in [1], through the circuit breaker main circuit and measuring the voltage drop (using Kelvin's four-point method) during the breaker operation. This principle is also used for measurement of the main contact resistance. Additionally, it is used during timing tests to detect the instant of the arcing contacts separation and touch, in conditions when both sides of CB are grounded (BSG – Both Sides Grounded).

DV Power researched the power source that provides high impulse DC current in the form of the High Power batteries. These batteries have higher capacity than supercapacitors (whose usage was already reported for this purpose) and low demand for recharging, while at the same time are suitable for the installation in a portable test instrument. In addition, these batteries are approved for air transportation. The solution applying the current regulator, including use of the High Power batteries as power source for DRM and BSG methods is described in this paper. Also, test results of DRM and BSG methods using this particular power source by DV Power instruments will be presented and discussed.

Introduction

Dynamic resistance measurement

The arcing contact is the first to make contact during a closing operation, and the last to break contact during opening. Therefore, circuit breaker arcing contact wear occurs during normal operation as well as when interrupting fault currents. If the arcing contacts are damaged, the breaker becomes unreliable very soon. Arcing contacts' condition cannot be assessed by conventional timing tests, so a new method had to be introduced.

One of the methods to detect the condition of the arcing contacts without dismantling the breaker is to inject a high DC current (a couple of hundreds of Amperes) and measure a voltage drop as well as the contact motion during the breaker operation – the so called Dynamic Resistance Measurement (DRM). The DRM method records variations in contact resistance (contact voltage drop) during the breaker operation. When the breaker contact motion is measured simultaneously with resistance, the results can be used to assess the wear or reduced length of the arcing contact.

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Very important diagnostic parameter is also main circuit resistance of the circuit breaker. This parameter is measured while breaker main contacts are in closed position. For that reason measuring procedure can be performed just before or after the DRM procedure, which reduces testing time, since both measurements can be performed in one test sequence.

Safe and fast testing of circuit breakers with both sides grounded (BSG)

Safety in high-voltage substations is the highest priority for all personnel involved. Recent regulations and laws (IEEE Standard 510-1983 "IEEE Recommended Practices for Safety in High-Voltage and High-Power Testing") require all objects to be grounded on both sides before any maintenance work is performed on the object. If the breaker is not grounded on both sides there is a risk of induced high voltages (as shown in the Figure 1. left). Eliminating this risk improves safety of the test personnel and the instrument itself. This leads to a requirement for the modern circuit breaker analyzer to detect a main arcing contact's state and to measure the operation time of the contacts when both circuit breaker terminals are grounded (as shown in the Figure 1. right). [2]

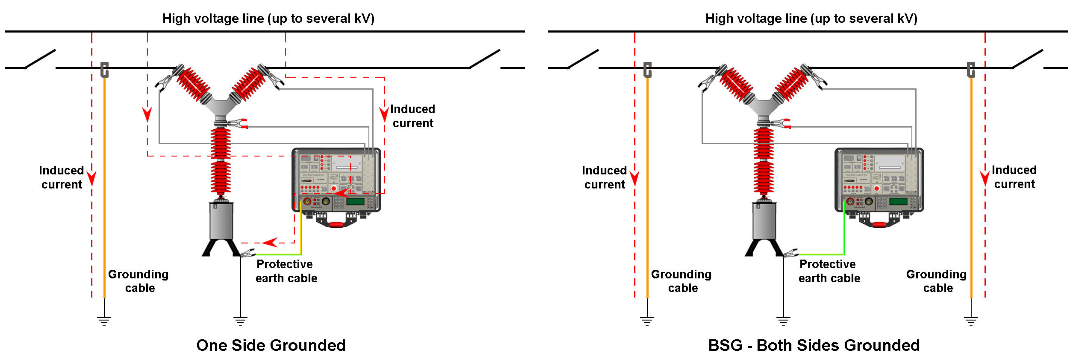

Figure 1. Testing of circuit breaker with one side (left) and both sides grounded (right)

If both sides are grounded, applying conventional main arcing contact state detection methods is not possible because there is a parallel circuit through ground cables and the ground network. In conditions when both sides of CB are grounded, modern test methods use a main circuit resistance measurement for the main arcing contact state detection during a circuit breaker operation, what is actually very similar procedure to the DRM method. When the circuit breaker is open, there is closed circuit through the grounding cables and grounding system. Commonly, the resistance of this circuit amounts from few mΩ to tens of mΩ. Arcing contacts are first to close and last to open the main circuit, so actually they define closing and opening time of the circuit breaker. The resistance of arcing contacts is in a range from a couple of hundreds μΩ to a couple of mΩ; thus, it is possible to detect changes in the recorded resistance curve at instances of arcing contact separation or making. Based on the above, breaker timing can be measured in BSG conditions. Unlike conventional methods using only the low power DC voltage sources, BSG method requires additional DC voltage source with ampacity of a few tens to a few hundreds Amperes.

Power source for DRM and BSG methods

Portable equipment used for the resistance measurement, DRM, and BSG methods has to have an integrated power source that will provide high current for the testing purposes.

High DC current power source can be realized in the different ways. Lead-acid batteries were used as a power source for this method, but, transportation, difficult installation in the portable instrument and other technical reasons prevented wide use of lead and similar rechargeable batteries. Other way is use energy directly from the mains supply, based on high frequency DC/DC power converters. This solution provides continuous high DC current, but it constantly depends on the mains supply and power converters require more space in the instrument than some non-dispersible energy storages. One such typically used energy storage is a supercapacitor (ultracapacitor, EDLC-electric double layer capacitor). Supercapacitor refers to a capacitor which have capacitance from a few hundreds or thousands Farads and voltage of a single cell from 2.3 to 3 V. Most of these components have very low internal resistance, order of milliohms, and it is therefore possible to generate currents in order of hundreds and thousands of Amperes [Maxwell]. Supercapacitor can be charged from low power electronic source or from batteries (Lead-acid, NiMH, Li-Ion and similar) with the lower current (around 1 Ampere) which requires longer charging time (up to one minute). Capacitor discharging can be performed with the currents of up to hundreds of Amperes in intervals up to one second.

In this paper, DV Power proposes the power source providing also high impulse DC current, but which overcomes these shortcomings. Those are the High Power batteries such as Lithium Polymer (Li-Po) or similar.

High Power battery vs. supercapacitors

Described solutions applying standard batteries and supercapacitors have a few shortcomings. The main shortcoming for supercapacitor is long charging or recharging time.

Recharging time of supercapacitor ranges from 10 -130 s which depends of the current level and time duration of the test. Supercapacitor DC voltage is significantly reduced with the capacitor discharging, so accordingly, they have a need for constant recharging, to provide voltage level necessary for desired current (e.g. >100 A.)

High Power batteries have higher capacity than supercapacitors and low demand for recharging, while at the same time are suitable for the installation in a portable test instrument.

Once charged, this battery with the capacity of 5600 mAh is capable of generating around one thousand 100A current pulses, with the length of 100 ms and with used lightweight current cables whose length is 10 m to 20 m. Voltage level of the 100 % charged this battery is 4.2 V (single cell 4.2 V, two serial connected cells 8.4 V etc.), while 30-35% charged battery cell has voltage level 3.7 V (7.4V for serial connected cells). That means voltage is reduced only for 0.5 V when battery is about 70% discharged.

These battery cells connected in series can be charged from universal 100-250 V, 50-60 Hz mains supply adapter, but also from the standard car supply outlet (12 V).

Current regulator can be used for setting the desired test current during the resistance measurement of the main circuit.

Method verification on the real test object

In order to verify the ability of this battery as power source for DRM and BSG methods, the measurement module is constructed and tests have been carried on the real test objects.

Measurements are performed simultaneously recording the voltage drop across CB main circuit and the test current. Tested CB was low-voltage 600 V, manufactured by ASEA. Current is recorded by measuring voltage drop across the resistor shunt 0.5 mΩ. Used current cables are 2x15 m length and 16 mm^2 cross-section. Equivalent resistance R_Σ of the circuit was around 50 mΩ, so expected current was about 80 A for battery (single cell) charged to voltage level around 4 V, that is enough for experimental proof of the solution.

First tests were performed with one side of CB grounded. Figure 2 shows voltage drop (blue trace) and current (red trace) for the opening operation. Looking into the voltage drop graph, it is clear where the main and arcing contact separation instants are. Based on these instants, parameter overlapping time can be determined, which is used for assessment the arcing contact condition. Peak on the voltage drop graph appearing during arcing contact engagement indicates bouncing of the arcing contact during opening operation that is confirmed by the current drop at the same instant. Voltage drop across shunt (0.5 mΩ) for the current measurement was 40 mV, meaning that current was about 80 A.

Figure 2. Voltage drop (blue) and current (red) during opening operation

In the Figure 3 below the voltage drop and current graphs during closing operation are shown. In the voltage graph, there are two voltage peaks, followed by the two current drops, indicating that there are two bounces during closing operation. If voltage drop and current are considered in the interval of the arcing contact engagement, when both voltage drop and current are constant, arcing contact resistance can be assessed. For example, the voltage drop is about 820 mV and the current is 64 A, meaning that arcing contact resistance is about 12-13 mΩ. This is unusually high resistance for the arcing contact and can be encountered only for low voltage circuit breakers.

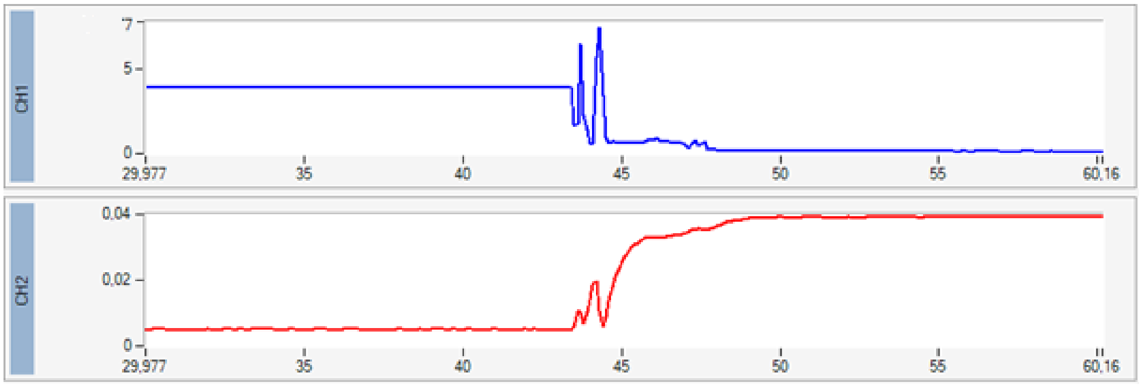

Figure 3. Voltage drop (blue) and current (red) during closing operation

Further tests were performed on the CB with both sides grounded (BSG). Breaker was grounded on both sides. Measured grounding resistance loop was around 10mΩ. Current ranged from 80 A in closed position of CB to 66 A in the open position. If we look into voltage drop graph, in the Figure 4, instants of the main and arcing contacts separation can be detected, even in this worst case, when arcing contact resistance is higher that grounding loop resistance. Detection of the arcing contact separation further provides timing measurement of the CB operations in BSG conditions. During the test, in open position, current and voltage drop across grounding loop circuit was pretty constant regardless of high discharging current, meaning that battery voltage was constant too.

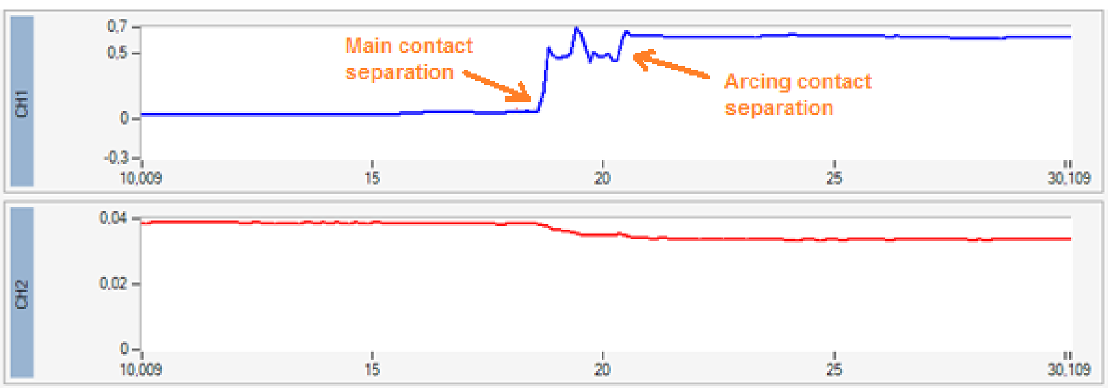

Figure 4. Voltage drop (blue) and current (blue) during opening operation in BSG mode

In the Figure 5 the voltage drop and current graphs during closing operation in BSG conditions are shown. As can be seen, instant of the arcing contact touch can be easily detected, since the voltage drop in that instant is about 200 mV. The current still has value of 80 A in closed position of CB. In all the performed tests during the experiment (about 20) the current was around 80 A, without battery recharging, indicating that these batteries have large capacity.

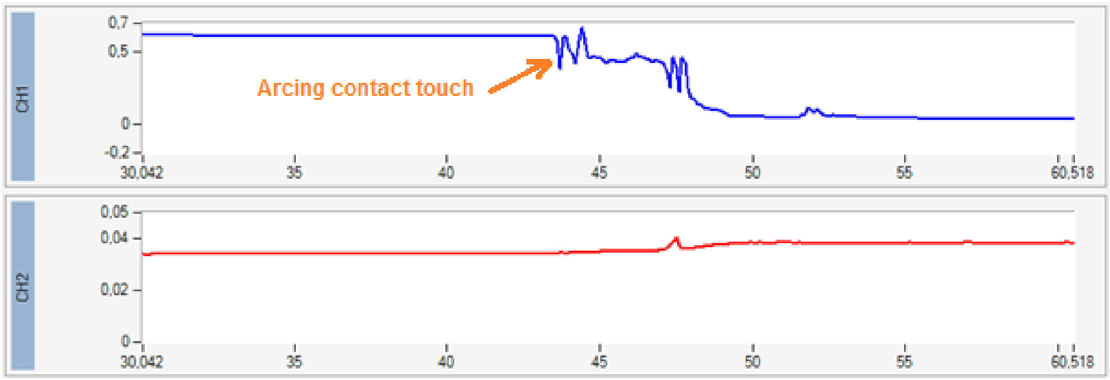

Figure 5. Voltage drop (blue) and current (blue) during closing operation in BSG mode

Conclusion

High Power batteries present a very good solution for generating DC current pulses for Dynamic Resistance Measurement and Timing tests with circuit breaker grounded at both terminals (BSG). Conducted experiments are showing that these batteries can hold a steady voltage regardless of the high discharging test currents. This makes these batteries superior to similar solutions, as handheld devices can be designed which are capable of performing a large number of operations without battery recharging. This reduces testing time and contributes to savings in test personnel working hours.

Reference

[1] V. Mrdic, R. Levi, “Advanced Dynamic Testing of Substation Apparatus”, TechCon USA, Albuquerque, NM, USA, 2016

[2] R. Ostojic, B. Milovic DV-Power, “NEW REQUIREMENTS IN CIRCUIT BREAKER DIAGNOSTICS” NETA World - Feature Article for Spring/Conference Edition, 2014

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