HAND-HELD MICROOHMMETER WITH HIGH POWER BATTERIES

Dr. Nijaz Hadžimejlić, dipl.ing.el.
KV-Team, d.o.o.
nijaz.h@kvteam.com

Timur Delić, msc.ing.el
KV-Team, d.o.o.
timur.d@kvteam.com

Branko Planojević,bsc.ing.el
KV-Team, d.o.o.
branko.p@kvteam.com

Sarajevo, Bosnia and Herzegowina

Abstract: This paper describes the system for measuring mainly the contact resistance of power circuit breakers, but also resistance of bar installation, cable splices, welded joints, groundings etc. In order to measure the resistance in range between several microohms up to a few tens of milliohms, it is necessary to generate currents of a couple of hundreds amperes and apply Kelvin's resistance measurement method. High power batteries have been used to generate high currents.
There are various ways to secure resources that enable such high levels of current and power. Usually, for supplying hand-held microohmmeters different batteries are used such as lead-acid batteries [1], NiMH batteries [2], [3] and Li-Ion batteries [4]. In the last 10 years, the application of supercapacitors in the output circuit for generating current impulses of 100 and more amps, has gotten popular, [5], [6], [7].

This paper analyzes the use of high power batteries such as Lithium Polymer (Li-Po) or similar, and current regulators for measuring ohmic resistances. In this way, pulses of current in range 1-600A can be generated in duration from 100 ms to 10 seconds. This current level is sufficient to measure the contact resistance of power circuit breakers, switches and disconnectors, as well as bus resistance. Of course, with this kind of system, it is possible to measure the ohmic resistances of inductive loads such as transformer winding resistance, industrial inductor resistance, motor winding resistance etc. It is important to note that the capacity of the high power battery intended for these uses does not exceed the values which are allowed for the air transport of these devices.

Keywords: microohmmeter, high power battery, battery, linear current regulator, contact resistance measurement, bus resistance measurement, transformer winding resistance measurement, motor winding resistance measurement, industrial inductor winding resistance measurement.

INTRODUCTION

Switchgear elements in power plants are very important elements which enable the connection or disconnection of lines and transformers, both in normal operating conditions and in failure conditions. In these working conditions parts of the power grid must reliably be connected or disconnected. In order for these devices to work reliably, it is necessary to control certain parameters such as, for example, the ohmic resistance of contacts in the closed position and in transition states during open and close operations. The reason for measuring the ohmic resistance is simple; increased ohmic resistance means increased losses and warming up of the contact due to which the device may fall out of operation. In this case, the protective role of circuit breaker and reliable operation of the power system and other components in the system is lost. Increased contact resistance indicates a malfunction, aging of the contact material etc, because of which reparation of such a device is necessary. Similarly, it is necessary to measure the resistance of different windings (transformers, throttles and motors) to determine the condition and the need for possible repairs.

The ohmic resistance measurement is performed standardly by generating a DC current of a certain (high) value and measuring the voltage drop across the contact, respecting the 4-wire Kelvin method. Sources of direct current can be realized in different ways: directly from a network with one or more serial connected power electronic converters [8]. Additionally, non-dissipative energy storages can be used, where an

EDLC-electric double layer capacitor (supercapacitor, ultracapacitor) is used almost as a standard solution. All of these terms refer to capacitors with a capacity of several hundred or thousands of Farad and voltages of 2.3 - 3V for one cell. Most of these supercapacitors have very small internal resistance (milliohm resistance) and therefore it is possible to generate currents of hundreds and even thousands of amps [9] [10]. A supercapacitor can be relatively easily charged from batteries (lead, NiMH, LiIon etc), with charge/discharge currents of several amperes, for a longer period of time (in order of minutes and tens of minutes) and then in seconds discharged with currents of several hundred amperes [5], [6], [7], [11]. In this way, devices become handheld, lightweight with the ability to generate large current pulses (and high power pulses).

1. A NEW METHOD OF GENERING AN IMPULSE OF CURRENT FOR MICROOHMMETERS

The power pulses that are generated by the use of standard batteries and supercapacitors have several shortcomings. The main disadvantage is the long charging time of the supercapacitor. For example, in one of the world's most famous devices in this field, MEGGER'S MOM2 device, the supercapacitor charging time is 10 to 130 seconds depending on the level and duration of the current. In addition, as a disadvantage, it can be taken into account that the supercapacitors are charged to a certain voltage value. When performing the test, supercapacitors are switched into the circuit with the load, where the superccapacitor is discharged by the ohmic load. As this is the standard RC circuit, the load current is not constant but decreases exponentially. Additionally, in order to generate the desired current value, the resistance of the load and cables is estimated, and accordingly to the total resistance the supercapacitor is charged to a certain voltage value. The fact is that the load resistance has essentially different values and therefore the generated current has different values depending on the total loop resistance.

A new system for generating a high level current impulse is proposed in this paper, whereby the current through the load is regulated and maintained constant and independent of the load and the voltage of the source.

Innovations related to the proposed system are the following:

- The first, important component of the system is a high power Battery such as Lithium Polymer (Li-Po) or similar, with high current discharge coefficient (NC), where N is the coefficient which multiplies the one-hour capacity C of the battery. For example, for a battery of 5600mAh / 3.7V / 50C the component 50C means that the battery can drain current Imax = 50x5.6 = 280A. Similarly, for a battery of 7000mAh / 7.4V / 90C, 90C means that the battery can be discharged with continuous current Imax = 90x7 = 630A, (short-term, up to 10 seconds this battery can be discharged with a current of 180C or 1260A).
The 100% charged high power cell is 4.2V, 30-35% of the charged cell is 3.7V, and the minimum voltage is 3.2V, so that the battery voltage is not constant. In addition, at different loads, because of the voltage drop on battery's internal resistance and voltage drop on cables etc. the voltage on the load would be variable. Because of this, it is necessary to have current control/regulation so that the current through the load is constant.
- Because of the variable voltage source and the different loads, current regulation has been stated as another important component. In essence it is an implementation with a MOSFET transistor, where other current regulators are also possible.
- The third important fact in the proposed system is to generate a current impulse with a limited rising and falling speed of the current. By limiting the current change speed, the following is achieved:

A. The lifetime of the high power batteries is extended by the application of a current load with limited content of higher harmonics;

B. Due to the limited current change speed, the induced voltages on the parasitic inductance are limited and thus reliability of the device is increased;

c. Due to the lower content of higher harmonics, the corresponding electromagnetic compatibility of the device (EMC) is achieved.

2. COMPONENT CHARACTERISTICS OF THE SYSTEM

In this paper the characteristic values, essential for a handheld device with currents in the range 1-200A and impulse duration from 100ms to 10 seconds, are given.
On basis of the same principle of work, a handheld device for generating 1-600A current pulses can also be designed. In the first case, a single-cell battery (3.7V) is sufficient, while the other device requires a battery of two, serial-connected (7.4V) batteries.

2.1. Characteristic battery parameters

Battery choice and corresponding calculations in terms of nominal and maximum working conditions are limiting factors for handheld devices.
A set of parameters based on which batteries can be selected are: nominal battery voltage; Nominal capacity in Ah and / or Wh; The discharge current overload coefficient given by the NC coefficient; Nominal battery charging current, weight and battery dimensions.

2.2. Current regulator characteristics

The current regulator should provide constant current under all conditions: battery voltage change; Change of load resistance; Variations in battery internal resistance and transitional resistance of the contacts.

3. RESULTS OF TESTING ON THE SYSTEM MODEL

In order to verify the assumptions of the microohmmeter working principle, a system model has been developed with the following characteristics:

- battery 5600 mAh, 3.7V, 50C, 1S2P HardCase;
- Linear current regulator BLLU500 with MOSFET IXFH320N10T2 transistor;
- Control system based on ATXMega128 microcontroller.

The diagrams below show some of the test results

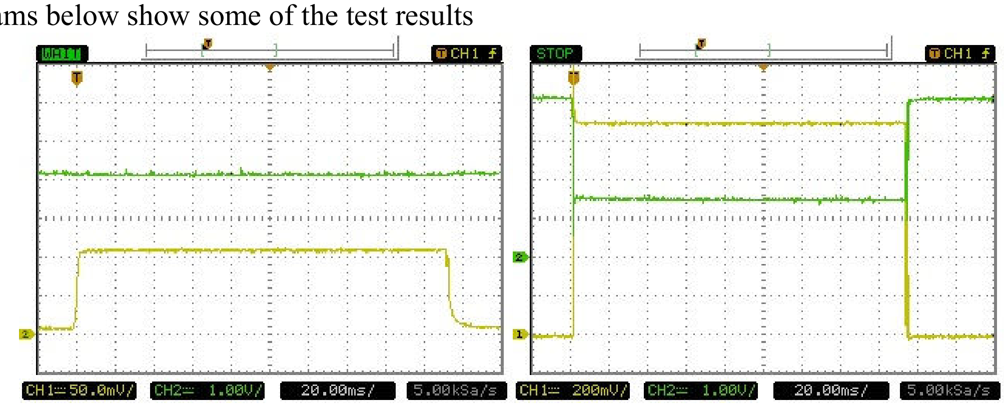

Figure 1. Current pulse diagram of 1.2 A (left) and 125A (right)
CH1- yellow diagram, current; CH2-green diagram, voltage on the current control transistor

In these tests, the load currents were measured simultaneously with voltage on the current regulator transistor to determine power dissipation at the transistor. Also, the load current and voltage at the output terminals of the battery were measured for the purpose of analyzing individual parasitic resistance in the circuit (internal battery resistance, contact transitional resistance, layout etc).

With this model, different shunt resistances were measured to determine the accuracy of the measurement.

The results of the tests are given in Table 1.

Table 1. Results of the measurement of the resistance of various shunts

Shunt value	Measured value	Current	Error
30 [μΩ]	30,1 [μΩ]	200 [A]	0,333 %
100 [μΩ]	100,4 [μΩ]	150 [A]	0,4 %
300 [μΩ]	300,5 [μΩ]	100 [A]	0,167 %
1 [mΩ]	1,003 [mΩ]	50 [A]	0,3 %
10 [mΩ]	10,04 [mΩ]	20 [A]	0,4 %
120 [mΩ]	120,4 [mΩ]	10 [A]	0,333 %

4. CONCLUSION

By analyzing the measurement results on the system model, the following conclusions can be drawn:

- The use of a high power battery and a linear current regulator provide current pulses in wide ranges. In this model currents of 1 - 200A were achieved, which allows the measurement of load resistance within the range of 1 μΩ - 1 Ω;
- Current injection starts immediately, while supercapacitors require some charging time, and recharging between tests. This charging/recharging time may last several minutes, while Li-Po batteries do not need the “warming” sequence – they are ready for immediate measurement;
- Limiting the rate of increase and decrease of current, favorably affects the battery life, while reducing the level of electromagnetic interference and the level of overvoltages caused by the parasitic inductance in the circuit.
- Measuring the battery voltage after some tests and calculating the battery's capacity, it shows that with a single battery charge, more than 500 tests can be performed.
- Analyzing possible solutions based on the principle of this paper outlined above, it is possible to design devices with a current range 1-600A where the 7.4V voltage batteries would be implemented.

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