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Publisher’s version / Version de l'éditeur:
https://doi.org/10.1109/CPEM.2014.6898535
2014 Conference on Precision Electromagnetic Measurements (CPEM 2014), pp. 614-615, 2014-08

The Establishment of High Current DC Shunt Calibration System at KRISS and Comparison with NRC

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***Abstract* — The application of a simple binary step up method for possible calibration of high current DC shunts up to a few thousand amperes in which a pair of HCDC shunts are used to evaluate the current dependence of the shunt resistance. It was found that a complex exponential linear model can be applied to separate the drifts in voltage measurements from the contribution of the current coefficient of the shunt. This approach allows one to extract the information on the current coefficient of the shunt and together with low current measurement of the shunt resistance to calibrate the current output of HCDC source, which in turn can be used as a reference for calibration of customer's shunts. In order to validate the step up method, the calibrated HCDC source was used to obtain DC current ratios which is to be compared with NRC's high current ratio measurements of a multi-ratio 3000 A reference DC CT.**

***Index Terms* — High current DC, calibration, current coefficient, drift of voltage, voltage measurement, comparison, current ratio, DC CT.**

I. Introduction

The high precision measurement of the high current (HC) DC shunts is expected to play significant role for the HCDC related calibration. High current DC comparator technology has been developed [1]-[3] which can be used to provide shunt resistor calibrations over a few thousand amperes with a high precision. However, if the shunt resistor can be calibrated by a simple potentiometric method with digital voltmeters it would be easily available in many calibration laboratories. On the other hand, it would be also interesting to compare the measurement using the current comparator and the potentiometric methods. The key part of the HCDC shunt calibration is how to measure the high current effect of the shunt resistor and how to link its resistance at the high current to the resistance calibrated at low current. In this paper, we will describe the step up method developed to obtain the information on the current dependence of the shunt resistor, the significant influencing factors discovered during the development, the solutions to overcome the influencing factors as well as test result. The test measurement was also carried out for the current ratio which in turn is to be compared with NRC measurements on a reference DC CT, which is used as the transfer standard.

II. Step Up Method

The principle concept of the step up method is to successively calibrate the double current using a pair of shunts in parallel of which the resistance values given at the initial test current are already known. The calibrated double current is, in turn, used as a test current to calibrate the shunt resistances at the double current. Then the calibrated shunt resistances at the double current forms the basis for further calibration of the quadruple current. In this way, repeating the step up procedure by n times allows one to extend the current calibration range up to 2^n of the initial reference current. This method can also provide a way for validation of ratio stability with respect to the test current of the HC DCC bridges which are used to calibrate HCDC shunt resistance. In a calibration lab which has no HCDC DCC bridges, a simple potentiometric measurement system with high resolution digital voltmeter may be used to measure the double currents. Contrary to the DCC bridge, the potentiometric measuremnt system sensitively requires a good stability of the HCDC current source at least for a short time during which the circuit is changed from a parallel to a serial/separate connection to deliver the double current information to the shunts until a single step up procedure is completed. This may be the main disadvantage of the potentiometric method, but not completely overshadowing its advantages.

III. Influencing Factors and Possible Solutions

A. Stability of the Current

The ability of the HCDC source to keep the output current stable is the most important requirement for the potentiometric step up method. The output current should be stable not only during the time of the step up but also during the load change from parallel to series connection. A linear drift model with a first order of approximation can be applied for the steady state change after the decay of exponential components.

B. Drift of the Voltage during Measurement

The voltage reading can also change/drift due to the transient effect of the shunt resistor when measurement is made too soon before the shunt resistance is stabilized due to heating effects from the test current. The time constant of the shunt stabilization should be considered in using the step up measurement method.

C. Accuracy Margin at Low Voltage

Since the voltage drop across the shunt is of low voltage range, high resolution and high accuracy voltage measurements are required. A small voltage deviations can result in a large error. Therefore, the zero drift of the voltmeter should be checked and monitored.

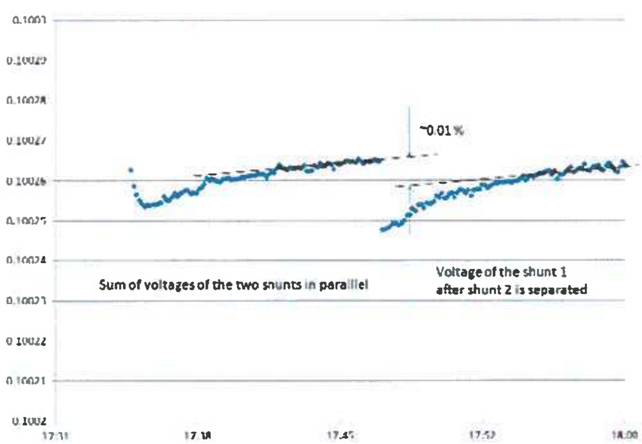

Fig. 1. Voltage readings for the evaluation of the current dependence of the 1000-A shunt during the 500 A to 1000 A step up procedure.

IV. Test Result

In order to evaluate the current dependence of the HCDC shunt, a single step up procedure for operation of the test currents from 500 A to 1000 A was implemented. A commercial HC DC source system was used. Two commercial 1000-A HC shunts connected in parallel were measured with the HC DC source at a 1000 A setting. The two corresponding voltages were read with two commercial high resolution digital sampling voltmeters. After a stabilization period, one shunt, denoted by shunt 2, was disconnected to allow shunt 1 to be subjected to the full current of 1000 A. The first part of the Fig. 1 is the sum of the two voltages from the two parallel connected shunts, which is the calibration procedure for the 1000 A HC source output using the two shunts. The second part of Fig. 1 is the voltage reading across shunt 1, which represents the calibration result of shunt 1.

A linear drift model is applied for the steady state drift of the voltage readings part after the fast exponential decay. As a first order approximation, the calculation of the drift in the voltage reading is assumed to mainly come from instability/changes of the HCDC source, giving the following result on the current dependence of the shunt 1:

$$R_1' / R \approx V_1' / (V_1 + V_2) \qquad (1)$$

Where, R_1' is the shunt resistance at the test current of 1000 A, R is the mean resistance of the shunt 1 and shunt 2 at the test current of 500 A, V_1' is the voltage of shunt 1 at the test current of 1000 A, and V_1, V_2 is the voltage of the shunt 1, 2 at the test current of 500 A, respectively. The test results of Fig. 1 indicate that the voltage drifts with approximately the same rate after parallel and non-parallel shunt connections, confirms that the initial assumption is justified. Thus the relative deviation of approximately -0.01 % means that the relative change in resistance of shunt 1 for the test current of 1000 A is with respect to the mean resistance of the shunts at the test current of 500 A. Further work is continuing to extend the calibration range up to test currents of 3000 A using the step up method, including the application using the HCDC comparator. This will coincide with the comparison of shunt calibrations and applications of a reference 3000 A DC CT that will be calibrated by NRC.

V. Comparison with NRC

The comparison of high current DC ratio measurements with NRC is being done by using a commercial transfer standard of a multi-ratio 3000 A DC CT. The comparison results, including differences in HC DC shunts calibration methods at NRC, will be discussed and presented at the conference.

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