A MEASURING SYSTEM OF CONDUCTOR AC AND DC RESISTANCE

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ABSTRACT

A measuring system of conductor AC and DC resistance has been developed using synchronous sampling. The current circuit is made coaxial to minimize the influence of external magnetic fields on the conductor and to minimize error due to mutual coupling to the voltage circuit. The measuring system is verified using standards with calculable AC resistance. Measuring results of cables of different designs are reported and an uncertainty analysis according to GUM is made.

KEYWORDS

High Voltage AC cable, AC resistance, skin effect, measuring system, uncertainty analysis.

INTRODUCTION

The ampacity of High Voltage AC cables strongly depends on the AC resistance of the cable conductor. In the development of, specifically, segmented High Voltage AC cables with large conductor cross-sections, there is a need to measure conductor ac resistances with high accuracy to verify their performance. The CIGRE Working Group B1.03 recommends in [1] that the AC resistance of large cable conductors should be measured when the cables designs are being type tested. The reason of this recommendation is the calculation complexity of existing theoretical models.

An improved measurement method was asked for by ABB to be able to quantify differences between conductor design changes. Based on the overview of electrical measuring methods given in [1] and the long experience at SP of digital sampling and data processing it was chosen to develop a measuring system based on digitizers and synchronous sampling.

MEASURING METHOD

The cable conductor is connected in series with a coaxial current shunt using a specially made current Tee connector. The screen of the cable is used for the return current to minimize the voltage drop along the conductor due to inductance. The current circuit is made coaxial to minimize the influence of external magnetic fields on the conductor and to minimize the generation of magnetic fields that can disturb the voltage measurements.

DC and AC current are applied to the circuit in a sequence and the output voltage of the current shunt and the voltage drop along the conductor are measured by a two channel digitizer. This allows the DC and AC resistance to be measured at the same time.

The AC voltages are measured by synchronous sampling. The measuring principle is based on equally-spaced simultaneous sampling of the voltage along the conductor and the output of a current shunt during an exact prime number of periods of the fundamental frequency. The RMS values and the phase-angle difference of the two signals fundamental harmonic are then determined by Fast Fourier Transform (FFT). This allows high accuracy in both magnitudes and phase angles even with relatively low sampling frequency [2].

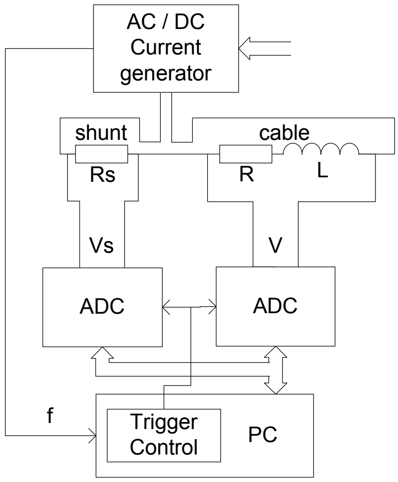

Fig 1. Schematic diagram of the measuring system.

The ratio of the AC resistance R_{AC} and the reactance ωL relative the DC resistance R_{DC} is then determined as:

$$\frac{R_{AC}}{R_{DC}} = \mathrm{Re}\left(\frac{V_{AC}}{V_{DC}}\frac{V_{SDC}}{V_{SAC}}\right) = \frac{|V_{AC}|}{V_{DC}}\frac{V_{SDC}}{|V_{SAC}|}\cos\theta \qquad (1)$$

$$\frac{\omega L}{R_{DC}} = \mathrm{Im}\left(\frac{V_{AC}}{V_{DC}}\frac{V_{SDC}}{V_{SAC}}\right) = \frac{|V_{AC}|}{V_{DC}}\frac{V_{SDC}}{|V_{SAC}|}\sin\theta \qquad (2)$$

where

V_{AC} is the complex RMS value of the fundamental harmonic of the measured voltage of the cable conductor

V_{SAC} is the complex RMS value of the fundamental harmonic of the measured voltage of the shunt output

θ is the difference in phase angle between V_{AC} and V_{SAC}

V_{DC} is the measured DC voltage of the cable conductor

V_{SDC} is the measured DC voltage of the shunt output

If the length L of the conductor between the voltage terminals is measured the value of R_{AC} and R_{DC} per unit length can also be determined as:

$$R_{AC} = \mathrm{Re}\left(\frac{V_{AC}}{L}\frac{R_{SAC}}{V_{SAC}}\right) = \frac{|V_{AC}|}{L}\frac{R_{SAC}}{|V_{SAC}|}\cos\theta \qquad (3)$$

$$R_{DC} = \frac{V_{DC}}{L}\frac{R_{SDC}}{V_{SDC}} \qquad (4)$$

where R_{SAC} and R_{SDC} is the AC and DC resistance of the current shunt, respectively.