Measures to reduce skin-effect losses in power cables with optimized conductor design and their evaluation by measurement

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Due to a rising power consumption, HV cables have to carry larger currents. This is done by increasing the conductor's cross-section and optimizing its design. An improved design decreases the skin effect losses and hence increases the effective cross-section. Nevertheless the AC-losses can reach the DC-losses in recent conductor designs at 50 Hz/60 Hz. Thus, the influenceable AC-losses present a great potential for energy savings.

To evaluate recent and future optimized conductor designs, it is crucial to have an efficient measurement method. Previous methods used a calorimetric approach. Heavy currents (often more than 1000 A) drive the conductor into steady state condition, so that no more joule heating occurs. From measuring the temperature one can derive the total losses produced by both DC- and AC-resistance. Beside high energy costs and long waiting times (commonly more than 10 hours), bigger cross-sections make it harder to bring the cable into the steady state condition.

A much faster and precise measurement method is presented and was already shown in [1]. A small current of only a few ampere is inserted into the inner conductor on one side, and short-circuited with the cable screen on the other side of the cable. By using the cable screen as the return conductor, this setup prevents the proximity effect on cable-drums because no magnetic fields exist outside of the cable screen. The inserted current is frequency variable. To avoid EMC troubles, measurement values around 50 Hz/60 Hz are taken and interpolated for the AC-resistance at 50 Hz/60 Hz. The current is measured with a highly precise reference shunt and used together with the voltage drop over the inner conductor to determine the AC-resistance.

In addition to the fully automated measuring, this method features a plausibility check by measuring the DC-resistance, which can also be calculated analytically and AC-resistances at frequencies up to 10 kHz. The data obtained by the AC-resistances at higher frequencies can be used to gain further insights in the behavior of optimized conductor geometries.

This work describes the fundamentals of the new measurement method and furthermore shows how it can be verified by analytical solution for known conductor geometries and numerical simulations for more complex structures. The made observations by both, measurement and numerical simulation can be used to optimize conductors of power cables even more and thus reduce the costs for cable manufacturers.

[1] G. Schröder, J. Kaumanns, R. Plath, "Advanced Measurement of AC Resistance on Skin-Effect Reduced Large Conductor Power Cable", Jicable 2011, paper A.8.2

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