Power Cable Under Inspection

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Conservation of raw materials in the production of power cable requires precise measurement of resistance and cross-sections.

Power cable production entails notably an enormous consumption of valuable raw materials such as copper and aluminum. In view of the increasing scarcity of resources, it is only logical to use these materials as sparingly as possible. One way is to manufacture cable exactly matching the requirements on resistance and cross-section. This necessitates precise measurements of these parameters while production is running. The AESA 8130 equipment, which works by the induction principle, enables nondestructive inspection of cable under manufacture.

Measuring Resistance & Cross-Section During Production

As the cross-sectional area of a conductor is a given quantity, one might be tempted to believe that specifications could be met by simply deciding which strand caliber to use, and accordingly calculating the correct number of strands to be assembled. In fact, as every cable manufacturer knows, the actual cross-sectional area, and thereby the resistance per unit length, will be influenced by a number of largely unpredictable factors introduced throughout the manufacturing process, starting from the initial coils containing the individual strands and ending with the finished insulated cable.

The resistance per unit length of strands coming from different coils is not precisely known; this unpredictability stems from the diameter and quality tolerances of the wire drawing process. Stretching and work-hardening effects may be produced during assembly, especially when compacting or sectoral forming phenomena exist. The individual strand will be longer than the actual cable, the length difference being determined by the lay of the wound strands within the cable.

Operations subsequent to the assembly of strands and the insulation process, involving recoiling of the finished cable, may also bring about changes in the resistance. However, experience has shown this effect to be both slight and reproducible from one production run to the next.

Other essentially random, fluctuations can be attributed to aspects of the assembly machines themselves. These fluctuations include the following:

- Irregularities in the braking of the various machine reels.
- Wear on the dies.
- Variations in tightening of the compacting rollers.

Excessive Material Consumption Through Over-Dimensioning

Aware of the above facts, the cable manufacturer is often compelled to overrate the strand cross-section, thus increasing his consumption of the conductive metal. Otherwise, the manufacturer's finished cables would run the risk not meeting specifications.

Continuous Measurements Enable Corrections

The resistance per unit length of the finished cable can be accurately predicted from that of the assembled conductor without insulation. Therefore, the solution consists in measuring the resistance per unit length of the conductor during assembly, while it is still possible to modify the parameters at work. In this way, the manufacturer can ensure that his finished cable will comply with specifications, while at the same time avoiding the need for overrating strand dimensions. The delicate economic balance between excessive consumption of metal and risk of non-compliance is thus bypassed. Ideally several readings should be taken over the whole production length, and this should be done at least once per run.

Traditional Measuring Techniques

Formerly, samples were taken from the cable head and tested in the laboratory before continuing with manufacture. Besides the fact that the resulting machine downtime led to a loss of productivity, this method was not sufficiently accurate either; a cable-head sample will not be representative of the conductor over the entire production length, as the particular mechanical forces at work during the machine start-up phase will strain the first few meters differently.

The result obtained by weighing takes no account of the actual resistivity of the metal. The use of bridge instruments is beset by problem of poor transversal conductivity between the strands of short samples of conductor; here the measurement current will not be evenly distributed, and the resistance per unit length will be read high. With aluminum alloy conductors, the error using this method can be highly deceptive if the sample ends—where the instrument grips are to be placed—are not carefully welded or crimped before testing. There also remains the problem measuring the temperature of the conductor with a thermometer and calculating the necessary correction.

Modern Techniques

The 8130 range of cross-section/resistance meters provides an accurate and rapid means for measuring the resistance of cables under manufacture. This is done directly on the assembly machine without the need for taking samples. The procedure consists in inducing a very low frequency AC current in the conductor, measuring this current and calculating the resistance from the voltage drop produced over a precisely defined length of conductor. The instrument takes the form of a mobile chassis containing the induction and current measuring transformers, with a measuring beam holding the voltage test contacts and conductor temperature sensor. The current generation, measurement and display circuits are housed separately in a control console. Readings are automatically temperature-corrected in accordance with the temperature coefficient for the metal used (copper or aluminum).

AC Measurement

The use of induced AC current is a technically superior-solution to the problem of how to introduce current into the test section. Further, the effects of return paths through the machine structure are eliminated, and no insulation or modification is required of the machine. Problems with contact voltage drop, inevitable with DC bridges, are also avoided, as there is no DC in the test section.

Finally, the use of a very low frequency means that the accuracy of readings will not be affected by skin effect. Frequency is set at a submultiples of the mains 50 or 60 Hz, so as to minimize the effects of the inevitable surges found in industrial environments. Small current levels are used, thus avoiding undesirable heating in the conductor.

Temperature Considerations

As a general rule, and this applies especially to the case of aluminium conductors, readings are taken between the last assembly head (die) and the capstan. At this point, the conductor is taut and in a fixed position. However, its temperature may still be quite high as a result of work hardening effects, and commonly reaches 50% °C or more. Although the cross section/resistance meter does include temperature correction, to give equivalent 20°C or 25°C values (depending on specifications), it is nevertheless necessary to let a certain period of time elapse before taking the reading. During this time, the reading will rise slowly as a result of the uneven distribution of temperature over the conductor under test.

The temperature will be highest at the die end, and lowest where the conductor comes into contact with the capstan. Between these two points, the heat distribution is further complicated by the relatively cold surfaces of the measuring beam jaws; several heat fluxes are at work here, going from the centre of the test section to the jaws, from the die to the die-end jaw on the measuring beam, etc.

These heat fluxes are shown in the simplified diagram (**Figure 1**), which shows that the conductor temperature cannot be considered as well-defined, even though the location of the temperature sensor with respect to the voltage test contacts could reasonably be supposed to measure the average temperature of the test section. Further a radial temperature gradient exists as a result of the surface being cooled by contact with the ambient air. **Figure 2** shows the variation in this effect with time.

Overcoming the Temperature Problem

With the above considerations in mind, the 8130 version works by regulating the temperature of all elements in contact or proximity with the conductor to the same temperature as that measured by the temperature sensor. This sets up an isothermal system, whose temperature after a short transitory phase, remains stable apart from a very slight and controlled drift. The jaws, the conductor enclosure, and the measuring head holding the voltage test contacts are all fitted with heating elements and temperature sensors, and the temperature of each element is regulated individually.

The variation in temperature as a function of time for this new temperature-controlled system is clearly illustrated in **Figure 3**.

Time savings are not the only advantage of the new system.

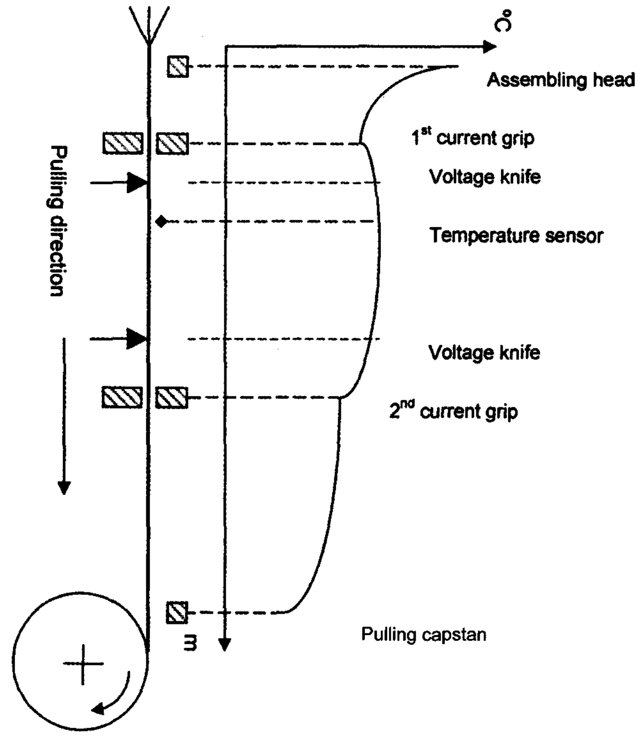


Fig. 1 — Different heat fluxes in the moving condutor.

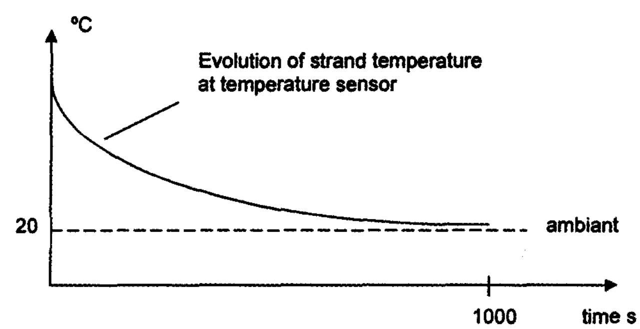


Fig. 2 — Surface cooling caused by ambient air.

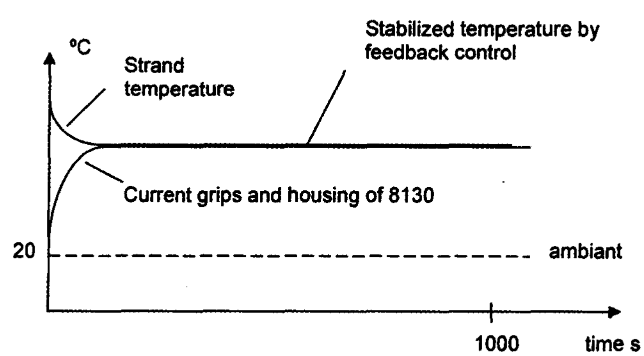
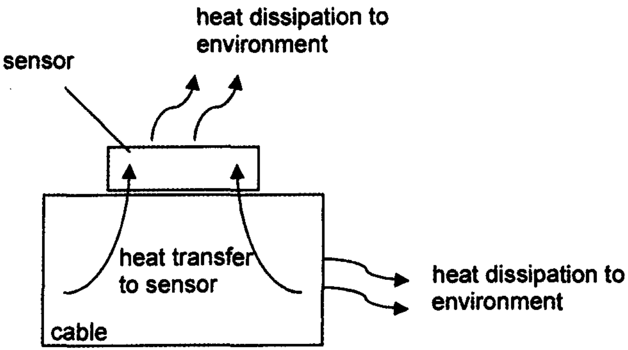


Fig. 3 — Temperature control as a function of time.

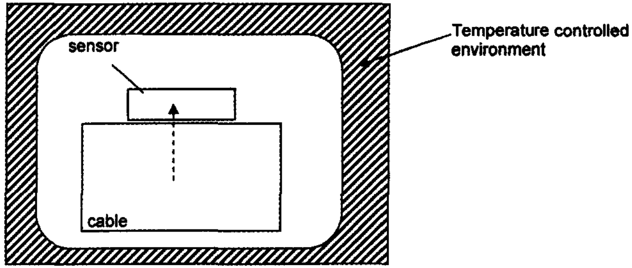
The accuracy of contact methods to measure temperature of a solid body is usually jeopardized by the presence of a heat flux between test piece and sensor (**Figure 4**). But in a temperature-controlled system, this heat flux and the resulting measurement error will be negligible as the temperature gradient between test piece, sensor and immediate environment will have been removed (**Figure 5**). The benefits of the increased accuracy afforded by the new system can be appreciated if it is recalled that an error of 1°C on the temperature reading corresponds to an error of 0.4% on the resistance.

The cable producer can himself calculate the financial impact that an increase in accuracy could have on the company's material costs. WCTI



Permanent situation: heat transfer from cable to sensor = heat dissipation from sensor to environment

Fig. 4 — Inaccuracy of measurement result caused by heat flux between test piece and sensor.



Initial situation: small heat transfer from cable to sensor for warm-up
Permanent situation: no heat transfer as all elements are at the same temperature

Fig. 5 — Negligibility of heat flux in a system with temperature control.

About the Company:

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