

## AC resistance of submarine cables

Paolo **MAIOLI** (1), Massimo **BECHIS** (1); Gaia **DELL'ANNA** (2)

1 Prysmian S.p.A, Milan, Italy,

[paolo.maioli@prysmiangroup.com](mailto:paolo.maioli@prysmiangroup.com), [massimo.bechis@prysmiangroup.com](mailto:massimo.bechis@prysmiangroup.com)

2 Prysmian Power Link S.r.l, Milan, Italy, [gaia.dellanna@prysmiangroup.com](mailto:gaia.dellanna@prysmiangroup.com)

The development of HV large section three core power cables is a great challenge because of the correct determination of losses dissipated into the armouring. The paper illustrates measurements, calculations and modelling of losses in order to design a state-of-the-art cable, with optimised use of materials.

The design of such large cables, to be used for example in off-shore wind farms, necessitates a precise knowledge of the losses, in order to provide accurate values of the electrical characteristics.

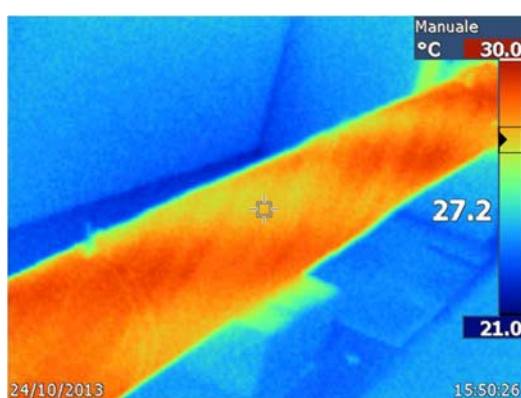


Fig.1 Infrared image

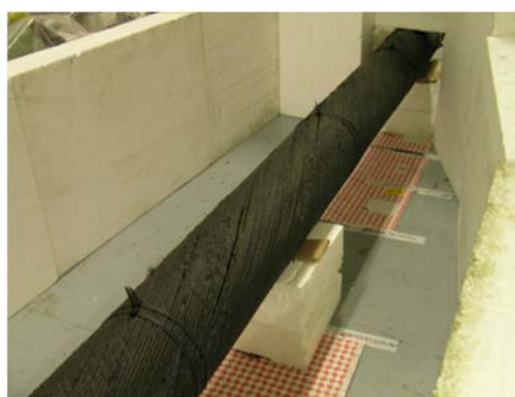


Fig.2 Visible image

Figure 1 shows how the losses are generated into the armouring (armoured cable shown in Figure 2); losses are detected with a thermo camera. It can be clearly seen that the losses are concentrated in the part of the armouring closer to the power cables and follow the direction of the power core and not that of the armouring wires. The paper clearly describes that heat is definitely generated into the wire and it is not coming from the conductors.

The experimental evidence is that the losses are affected by the way how the cable is designed.

It is also known that conductor resistance increases with current, so that it is important to make the measurement at the rated current and frequency: a test bench has been developed in order to provide accurate measurement of the electrical characteristics of these large cables. The cleanness of the power frequency sine wave has been verified and any distortion detected and eliminated. The paper describes the effects of presence of superposed harmonics on cable resistance and impedance.

The length of the cable sample is important for the accuracy of the measures, from one point of view to limit side effects and from the other to economically inject the rated current; cable arranged in straight configuration and without close extraneous metallic parts is of great help in reducing uncertainties and facilitate the operations of removing the armouring. The power requested for the injection of the current into the sample is proportional to the cable length and increases rapidly with the frequency when harmonics of the current are added.

It is possible to disassemble the armouring progressively, until the whole armor is removed. In this way the effect of the number of wires and the electric contact between them can be studied. The paper shows that wire-to-wire insulation has negligible effect on total losses and that the losses increase almost linearly with number of wires. It has been verified that left handed and right handed currents systems give the same losses.

Connections on conductors and sheaths, at sample extremities, have to be realised with care and expertise, because they can introduce additional resistance and thus reducing the current circulating in the sheaths and the corresponding measured losses.