Accurate Measurement of Losses in Three Core Armoured Cables

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ABSTRACT

It is widely acknowledged within the cable community that the existing IEC 60287 recommendations for determining the losses in three core, SL type armoured cables are not representative of the real cable system. This leads to more frequent requests for measurements to be taken on real cable systems to determine the losses of the system as built. It is important to consider carefully the different causes of error in such measurements; this paper presents an overview of experience gained from conducting measurements across a range of difference cable sizes.

KEYWORDS

Cable losses; cable armouring; current ratings.

INTRODUCTION

It is widely acknowledged that the existing IEC 60287 equations do not adequately calculate the losses of 3 core, SL type magnetically armoured cables as tend to be used for wind farm export connections. This has been the subject of a number of papers at previous Jicable events, at Cigre sessions, and in other technical journals, and a Cigre working group B1.64 is reviewing this issue.

Calculations

In an effort to provide improved calculations for these losses, a number of researchers have developed calculation routines. For example, Hatlo et al presented the initial development of a set of analytical equations in [1]. A series of equivalent circuit models have been developed by Goddard et al in [2], which seek to accurate capture the effect of the armour on the losses in both the armour itself and in the sheath. The models were shown to generate comparable outputs to complex finite element models. Although finite element calculations have been used by a number of different researchers, they are not straightforward to implement for this type of cable. This is due to the differing lay lengths of the power cores and the armour wires, meaning that the electromagnetic problem can't be modelled in a plain 2D geometry. Attempts have been made to overcome this using a 2.5D geometry, where equivalent properties of the armour layer are used to try to capture the effects arising due to the helical twisting of the different components. Work by Sturm [3] has investigated the use of full 3D models, however such models can become very large computationally. This is because very small mesh elements must be used to try to capture the skin effects present in the conducting components.

Need for Verification

Although significant progress has been made in developing calculation methodologies for the losses in this type of cable, there remains a need for further verification tests. Different modelling assumptions can yield variations in calculated losses for the same cable design. To build confidence in the outputs of the models and calculation tools, it is natural to consider whether the desired properties can be measured directly. However, it is not possible to directly measure the armour losses themselves.

Even where there is good confidence in the applicability of a model for the cable type concerned, there may be variations between the design modelled and the exact properties of the produced cable. Taking measurements of losses on the complete cable provides further confidence that the results of the calculation are fully representative of the cable in question. This additional verification can be critical for projects where a small increase in the calculated losses would lead to the need to use a larger conductor size. For this reason, some clients may request that the actual losses of a cable sample are measured.

Aim of this paper

The authors of this paper have been involved in measurement and analysis of the losses on a large number of armoured 3 core cables. Our intention is not to provide a single recommended measurement method; we have used a number of different measurement methods depending upon the cable design and the exact objective at the time. Indeed, the ongoing work of Cigre Working Group B1.64 is expected to address this need. Instead, we wish to highlight the importance of some potential sources of error that might affect the measurements. This information is believed to be helpful for others seeking to carry out measurements in the future.

MEASUREMENT METHODS

A range of measurement results have previously been reported, for example [4] and [5]. This section presents an example of a practical series of tests that will allow the losses of an armoured cable to be measured. It should be noted that this method is not intended to allow a detailed allocation of the losses to different components in the cable sufficient for extensive model validation. This would require substantially more measurements, and a far more detailed analysis methodology. As such, it is likely to be beyond the requirements of routine testing and would only be of interest for R&D purposes. The method proposed is sufficient to allow comparison of cable losses under test conditions with the outputs of models, and is given here to inform the subsequent discussion of measurement errors.

Cable Sample Preparation

Correct preparation of the sample is vital for providing high quality measurements, and in particularly the minimisation of end effects. Typically a sample length of more than 20m is required, as the error in conductor resistance measurements can become significant for shorter samples.

At one end of the cable ("Earth End"), the conductors and sheaths are star pointed together (see Figure 2). The