SELECTING THE OPTIMIZED CONDUCTOR DESIGN

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ABSTRACT

The choice of the conductor plays an important role in the design of a cable system. In fact, the cable current rating and the total cable Joule losses are strongly dependent on conductor construction, conductor cross-section and conductor material.
Nowadays a wide range of conductor design is available to cable system engineers in order to provide the optimal solution for the specific cable project. Traditionally, the technical soundness of the system design and the cost of the cable system were considered the decisive design criteria. However, modern engineers need to consider additional aspects when selecting the optimized conductor design, such as: the overall cost of the cable project, the cost of losses and environmental features.
This paper gives an overview of conductor designs and design criteria. Additionally, some focus is given to the Dutch service experience on solid aluminium conductors.

KEYWORDS

Conductor, conductor design optimization, conductor losses, Joule losses, solid conductor, Netherlands

INTRODUCTION

Two materials have been commonly used in cable conductors for decades: copper and aluminum. For high-voltage (HV) and extra-HV (EHV) insulated cables, normally the conductors are produced by stranding bare copper or bare aluminum wires with specific electrical properties resulting in round conductors. For many applications, this is the preferred construction for copper (up to 1000mm^2) and aluminum (up to 2000mm^2) conductors. However, in other cases, other constructions are more preferred.

Milliken conductors

The use of especially copper Milliken conductors leads to lower skin-effect and hence to a more efficient power transport. This design is well known up to 2500mm^2 cross sections. But also the application of aluminum Milliken conductors is increasing; especially the very low skin effect versus costs is appealing for users.

Milliken conductors with treated wires

Copper Milliken conductors still present a non-negligible skin effect when bare wires are used [1]. The application of oxidized and enameled wires leads to conductor designs with lower skin effect and hence the higher transportation capacity of the cable system.

In specific cases, typical constructions can represent an attractive alternative, such as:

Solid aluminum conductors

The benefits of solid aluminum conductors are the small diameter, the longitudinal water tightness by nature and the light weight. The benefits resulted in a wide production range, up to a 1600mm^2 solid aluminum conductor, even tested in a 290/500kV XLPE insulated cable system.

Some important criteria to select the appropriate conductor design are

- cable (conductor) handling;
- accessories installation and conductor connection techniques to be used;
- overall Joule losses of the a cable system, using IEC60287-3-2 standard [2], for determining the break even point between the initial cost and the cost of the losses over the economic life of the cablesystem.

Fig.1: Example of different conductor design: 1) copper stranded; 2) copper Milliken; 3) copper Milliken with treated wires; 4) Aluminum solid; 5) aluminum stranded; 6) aluminum Milliken.

JOULE LOSSES AND TOTAL COST OF OWNWERSHIP

For the owner of the cable connection, an important selection criterion is the Total Costs of Ownership (TCO). The TCO consists of two terms:

- Cost of investment (at year “zero”)
- Cost of energy losses (during a certain “time horizon”, for instance 20 or 40 years)

The cost of investment consists of the costs of the cable, cable accessories, installation and civil works. For a certain cable system, the costs of accessories, installation and civil works can be usually considered the same independently of the cable type. For this reason it is common practice to consider only the costs of the cable when comparing different cable types.

In general, the cost of investment of a cable increases with the conductor cross-section of the cable.

The cost of energy losses consists of the costs of the