Reliable and fast connection of large-cross-section Milliken-type copper conductors by using cold spraying technology.

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ABSTRACT

Conductors are increasing in size and complexity to meet future electricity demand. Large cross section Cu conductors for AC is often Milliken type with enamelled wires to mitigate issues related to skin effect. Connecting enamelled Milliken Cu-conductors using conventional connection principles normally requires a time-consuming, difficult, straining, and tedious conductor preparation procedure. This paper presents a novel connection principle utilizing cold spraying technology combined with a novel connection principle. Long term stability testing inspired by Cigre TB758 is performed. The results demonstrate a fast, reliable, and operator-independent connection solution for large cross section Cu conductors.

KEYWORDS

Connector, enamelled wires, Milliken conductor, AC systems.

INTRODUCTION

The growing global electricity demand is pushing cable manufacturers to develop new cable solution further increasing the current carrying capability. This tendency is resulting in increasing cable conductor cross sections both on DC and AC cable systems. Large cross section conductors above 1200mm^2 used in HV and EHV cables for AC systems will significantly be influenced by skin effect phenomena if not mitigated. Skin effect will increase the AC resistance of the conductor due to current density reduction towards the centre of the conductor. The changing magnetic field induces a strong opposing secondary current cancelling out the primary current towards the centre of the conductor. The skin effect in large cross section conductors can be reduced by utilizing Milliken conductor design (Fig. 1).

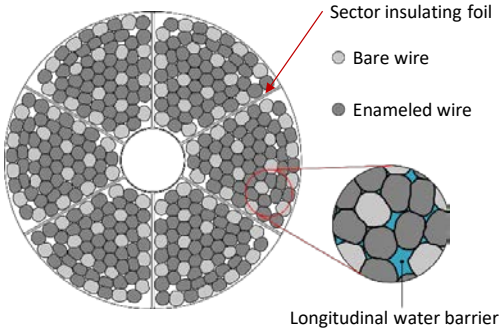

Fig. 1: Milliken conductor design with enamelled wires and longitudinal water barriers

The overall aim using the Milliken design is to divide the large cross section conductor into multiple smaller cross sections. An insulating foil can be introduced separating the large cross section conductor into several smaller sectors. Furthermore, insulation on the individual conductor wires can be introduced in the form of an oxide layer or an enamel/varnish, hence separating the large cross section conductor into several hundreds of smaller sectors. Longitudinal water barriers are often a part of the connector system to limit the damaging effect of accidental water intrusion into the conductor. Longitudinal water barriers are known to be in the form of swelling tapes, swelling powders as well as liquid water blocking compounds depending on conductor design and application.

Conductor connection and termination is an inevitable part of the cable system. The insulating foil, oxide, enamel and longitudinal water barriers are ensuring optimal cable conductor characteristics but all introducing significant complexity to the conductor connection process. These additional components will in this paper be referred to as Complex Conductor Components (CCC's).

Issues related to conventional connection principles

Conventional connection principles used today is commonly known to be welding, shear bolt connectors and hydraulic crimped connectors. CCC's needs to be removed prior the use of any of these conventional connection principles. Removal of CCC's is known to be time-consuming, difficult, straining, and potentially hazardous. Several removal methods exist such as special scraping tools, sandblasting, chemical removal, grinding etc. All removal methods require spreading out the conductor wires as depicted in fig. 2 to obtain sufficient access to the wire surface. Spreading out and recollecting conductor wires has a negative effect on the conductor structure as well as the conductor compactness and the procedure can potentially damage and/or break individual wires. Overall, this process can potentially reduce the current carrying capacity of the cable system if not carried out carefully, hence placing enhanced dependency on skills and cautiousness of the technician preparing the conductor.

Fig. 2: Spreading out conductor wires enabling prober cleaning of wires