Approach for a comprehensive definition of the electrical interface between HVDC converter and cable

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ABSTRACT

For high voltage direct current (HVDC) projects, it is important to describe the electrical interface between converter and cable system thoroughly. The interface in this respect is defined by continuous and transient voltage and current parameters. The actual stress levels and wave shapes occurring in an HVDC cable system differ from standard test parameters. In this paper, a set of parameters is derived based on the analysis of occurring transients utilizing electromagnetic transient (EMT) simulations. Since the stress levels depend on both cable system and converter design, an iterative procedure to derive project specific values is proposed.

KEYWORDS

Extruded cable; converter; VSC HVDC; electrical interface; voltage stress; transients

INTRODUCTION

Most HVDC systems in the past decades have been realized with overhead line or mass-impregnated (MI) cables. Extruded cable systems have benefits regarding cost and environmental impact over MI cables. However, HVDC systems used with line-commutated converters (LCC) require a voltage polarity reversal in order to change power flow direction, which is a challenge for extruded cables.

With the commercial introduction of HVDC systems based on voltage source converters (VSC) in half-bridge (HB) modular multilevel converter (MMC) topology, e.g. the Trans-Bay cable project in 2010 [1], extruded DC cable systems have gained increasing interest, since polarity reversal is no longer required to change the power flow direction.

VSC technology is developing at a rapid pace. Available voltage levels and active power capacity are increasing and new technologies such as full-bridge (FB) MMC (only considered for overhead line transmission so far) are already in the realization stage. Furthermore, MMC-projects in bipolar (see [2]) and rigid bipolar configuration (see [3]) as well as mixed overhead line – cable systems will be built. Based on this progress, further developments can be expected in the near future.

Extruded cable technology can be used for all these configurations. However, each configuration causes different electrical stresses for the cable. And the available test practices (see e.g. [4], [5]) are either not applicable for all relevant voltage levels or it is not clear, if the given recommendations and standards cover all the transient stresses observed in the actual HVDC systems.

Therefore, and in order to cover all the relevant stresses independently of the actual HVDC system configuration, a *comprehensive electrical interface* is required that contains the relevant parameters to describe the occurring stresses.

This electrical interface is especially relevant when HVDC converter and cable system are sourced independently. In this case, a procedure is required to derive the values for the considered parameters.

Furthermore, this electrical interface definition can be a valuable input to a further development of HVDC cable test practices.

In this paper, a procedure for such an electrical interface definition is introduced and several typical values are given for an illustrative example. Also, an iterative design procedure is proposed that enables derivation of the relevant parameters on a project specific base.

ELECTRICAL INTERFACE DESCRIPTION

Voltage requirements and testing

The relevance for a thorough analysis and determination of continuous and transient voltage stresses results from insulation coordination principles. In 2001, Cigré JWG 21/33 studied the matching of the required withstand capabilities with actual service requirements for AC underground cable systems [6], however, focusing primarily on cost reduction at that time.

Furthermore, the importance and correlation between ageing aspects, characterized by the "lifetime curve", and actual overvoltage stresses in the network has been pointed out therein (see Figure 1).

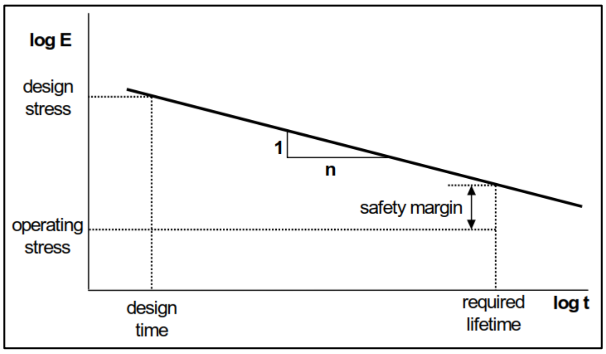

Figure 1 – Typical lifetime curve for cables with extruded insulation (AC and DC) [6]

Like in all subsequent IEC standards for AC and DC cables with extruded insulations, the continuous withstand voltage tests are expressed by *multiplication factors* for the "design voltage" U_0 and a duration.

Furthermore, a safety margin between design stress and operating stress is recommended, to account for the consumption of lifetime during routine, sample and type testing. Finally, a long term "pre-qualification test" (long-term test) has been postulated in [6] as a pre-requisite for