# Challenges with development and optimization of process parameters in design and production of EHVDC submarine cable flexible factory joints

Hossein **GHORBANI,** PeakVolt Professionals AB, (Sweden), ghorbani@peakvolt-professionals.com,
Mikko **LAHTI**, Timo **MÄKELÄ,** Maillefer (Finland), mikko.lahti@maillefer.net, timo.makela@maillefer.net

## ABSTRACT

*With ever increasing demand for extruded submarine cables of higher DC voltages and longer lengths, having a good understanding of factory joint production methods and its process parameters is of great importance.*

*It is well-known that process parameters such as time and temperature during curing and degassing impact the conductivity of EHVDC XLPE insulation materials. For cables, strictly following the process settings in combination with sample and routine tests help to obtain desired chemical composition and electrical properties in the insulation system. However, production of factory joints is very different and more complicated than cable, therefore optimization of process parameters and quality control of the final product is more challenging.*

*In this paper a description of XLPE insulated tape molded factory joints is presented. Most critical moments and related process parameters are highlighted, discussed and a development procedure involving experimental joints, FEM simulations and design optimization software is presented.*

## KEYWORDS

Cable, High Voltage, HVAC, HVDC, EHVDC, Joints, Factory Joint, Crosslinking, By-Products.

## INTRODUCTION

Imense invenstments in offshore wind projects, need for stronger interconnectors and ambitious energy island projects are just a few examples of market pull for submarine HVDC cables with higher ampacity. This has lead to large investments by cable suppliers and sub-suppliers for HVDC cables with higher current and/or higher ratings. Introduction of modern cable insulation compounds has fascilitated possibility of EHVDC cables with voltage levels as high as 640 kV [1]. Today there are submarine cable systems with voltage level of 525 kV commercially available [2].

Although perhaps less emphasized than other part of the cable system, flexible factory joints are a key component in submarince cable systems. Factory joints are basically a method for connection of two extrusion lengths by reconstruction of the cable insulation system with the same materials as in the cable, Fig. 1. This makes factory joints quite especial; while sometimes they are referred as belonging to the 'cable accessories' category, factory joints are integral part of each submarine cable delivery length and will go through similar stresses and tests as rest of the submarine cable. Factory jointing procedure for large HVDC cables is a very complicated, delicate and sensitive procedure involving many manual handling steps as well as a large number of process parameters to be tuned. While having control over many parameters can be an advantage for engineering and optimization, it can be a huge challenge to find the 'right settings' achieving a robust procedure that produces good quality joints every time.

The purpose of this paper is to open up and discuss some of the most critical steps and parameters for HVDC and EHVDC factory jointing procedure. Impact of these parameters are discussed and suggestions are made for how to address them. Furthermore, the R&D methodology followed by the authors of this paper is presented to give an example of how one can maneuver the vast space of factory jointing process parameters.

With relation to the insulation system, in essence two main methods for factory jointing exists: extrusion molding and tape molding. Since the latter is currently the dominant technology used in the industry, this paper will solely focus on this method. With regards to insulation systems, from processing perspective two main types exist: polypropylene-based thermoplastic insulation systems, and crosslinked polyethylene insulation (XLPE) systems. While HVDC cable systems with thermoplastic insulation systems are commercially available, unlike crosslinked insulation systems, thermoplastic insulations systems currently are not made commercially available by all high voltage submarine cable manufacturers. Therefore we focus only on crosslinked insulation systems. Nevertheless, it is notable that procedure for factory jointing of thermoplastic cables is at least as challenging as crosslinked cable systems because above the melt-point,

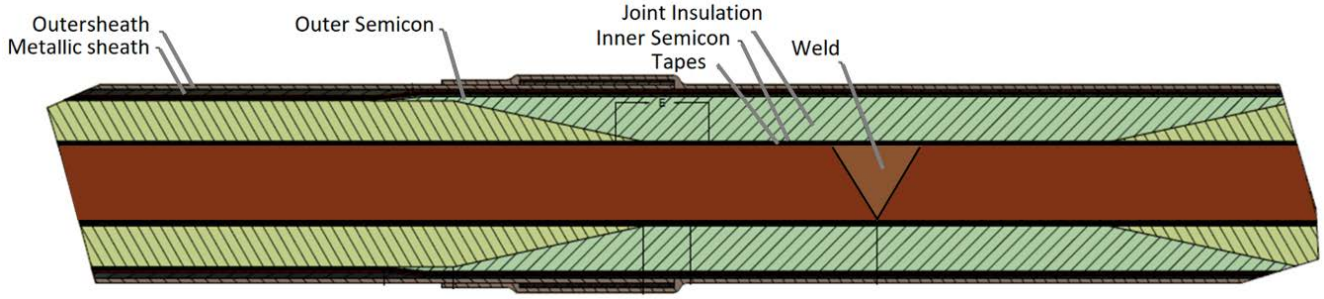


**Fig. 1: General design of a factory joint**