Lifetime Simulation and System Reliability for Electrically Heat-Traced Flowlines (EHTF)

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ABSTRACT

Electrically Heat-Traced flowlines are now used in the Oil&Gas industry to transport fluids over long distances by maintaining their temperature high enough to ensure flowability even in case of shutdown. The heating system must function for decades without possibility for repair. Redundancy is used to ensure the reliability of the system, and different usage scenarios can affect the final lifetime of the heating system. This work draws from the lifetime data for the cable connections (the weak points of the system) to simulate the lifetime of the whole heating system depending on project-specific parameters (length, voltage, redundancy, …) and heating scenarios.

KEYWORDS

Accelerated Electrical Aging, Lifetime, Weibull Distribution, Monte Carlo Simulation, Heating System

INTRODUCTION

Electrically Heat-Traced flowlines (EHTF) are pipelines systems consisting of an inner pipe, in which the fluid is transported, inserted in an outer pipe (pipe-in-pipe system) [1]. These two pipes delimit an annulus space which had historically been filled with thermal insulation lower the heat lost by the fluid during transport and thus help maintain its flowing viscosity. This thermal insulation increases the amount of time the product can stay in the pipeline in case of shutdown before requiring complex and expensive operations to be fluid enough to flow again.

In the case of Electrically Heat-Traced flowlines, a heating system is added between the inner pipe and the thermal insulation. This heating system consists of cables wound along the pipe with connections made typically every 1.5 km, organised in triplets and powered with 3-phase AC. A cross section of such a pipeline system is shown in figure 1.

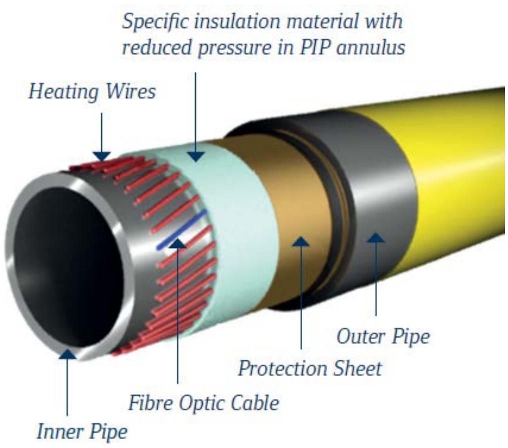

Fig. 1: Typical cross section of an EHTF system. [1]

The heat, generated by resistive heating, is dissipated inside the inner pipe and, with effective thermal insulation, the power necessary to maintain fluid temperature is limited (≈10W/m). However, to obtain this effective thermal insulation, the pipe-in-pipe annulus, including the heating system, is placed under reduced pressure. This means that the cables and their connections operate above the Paschen curve and are subject to partial discharges. Furthermore, due to the location of these EHTF systems (sometimes several hundred-meter water depths), the heating system cannot be repaired in case of a breakdown and must operate reliably for decades. Thus, redundancy (installing more cable triplets than strictly necessary) is used to ensure the reliability of the system. This redundancy opens the possibility for different usage scenarios that can affect the final lifetime of the heating system.

ELECTRICAL SYSTEM

To handle the high temperatures the heating system sees under normal flowing conditions, the cable is made of nickel-plated copper strands insulated with fluoropolymers extruded in three layers: inner semi-conductive, insulating and outer semi-conductive. While the insulating one provides the dielectric barrier, the inner semi-conductive layers homogenizes the electric field around the copper strands, and the outer semi-conductive one puts the whole outer section of the cable at the earthed potential of the inner pipe, thus preventing the Corona discharge that would otherwise happen between the cable and the pipe.

These cables are laid on the inner pipe during the pipe-in-pipe assembly over lengths typically around 1 km. Between these lengths, the cables are connected to each other with splices (figure 2).

Fig. 2: Splices positioned on the inner pipe.

These splices are themselves comprised of several elements. The two copper cores are each crimped twice to a barrel. The outer semi-conducting layers are stripped at each end and a semi-conductive thermos-retracting sleeve is shrunk on top of the crimp barrel and each side of the