ON THE IDIOSYNCRASIES, SAFETY ASPECTS, AND SOLUTIONS FOR EFFECTIVE TIME DOMAIN REFLECTOMETRY AND FAULT LOCATION ON LONG HVAC AND HVDC CABLES

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ABSTRACT

Long onshore and offshore HVAC and HVDC cables are going to be the crucial element for the future European supergrid, and for driving the green energy transition towards renewable generation. Due to their properties, they are challenging objects for cable fault location and time domain reflectometry. Transnational interconnectors such as North Sea Link, Viking Link, EuroAsia Link etc. reach cable lengths of more than 700 km. Cable faults on these critical and high value assets will cause unplanned outages and therefore significant economic losses. Fast fault location and repair is logistically involved but imperative. This paper examines the impact of cable properties on time domain reflectometry, fault prelocation, fault pinpointing strategies, and how to overcome technological limitations by utilising latest developments in the industry. The necessity for and the minimum viable parameters of proper fault location equipment are discussed.

KEYWORDS

Cable fault location; Interconnectors; DC links; Long cables; HV cables; Safety; Bipolar TDR; Fingerprint; Discharge unit; Prelocation methods; Pinpointing; Surge generator; ARM; ICE; Decay; Burning; Burn Arc Reflection

INTRODUCTION

In the renewables industry today, namely offshore wind, approximately 83% of the claimed cost (financial losses, insurance claims) can be related to failures of the power cable infrastructure. [1] At the same time, European Transmission System Operators (TSO) – the companies which are responsible and accountable for the HVDC interconnectors – reported surprisingly many disturbances and unplanned outages of various transnational DC links in the last 5 years. [2], [3] Some DC links such as NorNed or BritNed failed repeatedly with the root cause being subsea cable faults.

In contrast to the conventional medium voltage cable installations of Distribution System Operators (DSO), long HVAC and HVDC cables cannot be treated with the conventional fault location equipment that is commonly used by electrical utility companies or service provider companies. Long HV cables have higher voltage ratings, higher fault voltages, longer lengths, bigger capacitances, among other differences. Yet, it is still possible to locate main insulation faults and sheath faults safely and quickly on those cables when using a systematic, heuristic-algorithmic problem-solving approach.

CABLE PARAMETERS

In the power grid, MV cables can be characterised as (distributed) capacitors, low pass filters, and physically and geographically distributed assets. For long HV cables these properties are significantly amplified, so that long HV cables can be described as very big capacitors, considerable low pass filters, and extremely distributed assets. As can be seen in Figures 1 and 2, long HV cables have, in terms of fault location purposes, several electrical parameters in their equivalent circuit, where capacitance, impedance, impulse propagation, and velocity of propagation are dictated by the cable's physical parameters.

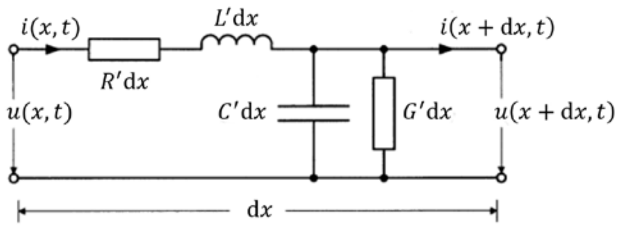

Fig. 1: Equivalent circuit of a line section of a cable

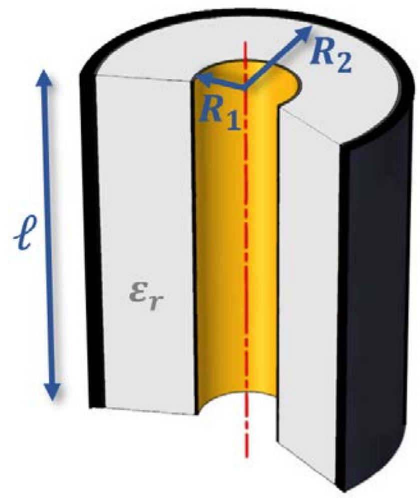

Fig. 2: Simplified geometry of the main insulation system of a cable, and associated cable parameters

Equation 1 shows the proportionalities regarding cable capacitance. The capacitance is a function of the electrical cable length ℓ, the relative permittivity of the insulation material ε_r, for example $\varepsilon_{r\,\mathrm{XLPE}} \approx 2.3$, and the cylindrical concentric geometry of the design, in particular the ratio of the radii R_1 and R_2. While the cable capacitance increases linearly with increasing length and higher dielectric constants ε_r, there is a non-linearity with respect to the geometry. The capacitance becomes exponentially larger as $R_2/R_1 \to 1$, e.g., for cables with large cross section.

Eqn.1:

$$C = 2\pi\varepsilon_0 \cdot \varepsilon_r \cdot \ell \cdot \frac{1}{\ln\left(\frac{R_2}{R_1}\right)}$$