Cable constraints due to background harmonic amplifications

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ABSTRACT

The use of long EHVAC cables is today a tendency of grid development, expected to be even stronger in the years to come. Because such cables are capacitive elements and transmission grids are rather inductive, their association can create resonances. As a consequence, when inserting a long EHVAC insulated cable in the grid, RTE is now investigating background harmonic distortions. When necessary, harmonic voltages are kept under specified limits thanks to passive filters while the impact of remaining harmonic currents on cables design is evaluated.

KEYWORDS

Resonances, harmonics, EMT studies, filters, cable design.

INTRODUCTION

When inserting long EHVAC cables in the grid, RTE is used to study reactive energy compensation for voltage control issues taking into account zero-miss effect. Transient overvoltages are also phenomena watched during studies because of resonance [1]. Indeed, insulated cables are capacitive elements and as transmission grids are rather inductive, their association creates series or parallel resonances depending on the grid point where they are seen from.

These resonances are today also investigated by transmission system operators (TSO) for harmonic distortions assessment [2] [3]. In recent studies, it was observed these phenomena are responsible for background harmonic amplifications which can reach several times the initial harmonic amplitudes mostly on the first odd harmonics. This issue is especially expected with the use of cables to connect the future first French offshore wind farms.

Aiming 23% of renewable in its energy mix by 2020, France has decided the construction of six offshore wind farms for a total of 3 GW. RTE, as the French TSO, is in charge of their connection to the 225 kV grid which will be achieved by AC XLPE insulated cables from 38 km to 60 km long.

This paper is going to explain the phenomenon of background harmonic amplification. It gives the results of the study of harmonic constraints for the connections of offshore wind farms and eventually explains the impact of harmonic currents on cables designs.

This paper is focused on the amplification of background harmonics, which means harmonics coming from the grid. In wind farms examples, harmonics generated by wind turbines are not in the scope of this paper.

BACKGROUND HARMONIC AMPLIFICATIONS

Phenomenon Explanation

Here is proposed a simplified analysis of the phenomenon of background harmonic amplification. Let's consider a client located in a remote area who needs to be connected to the transmission grid. For diverse reasons, the connection is realized with a long EHVAC insulated cable. Electrically, this situation can be represented by the circuit described on Fig. 1:

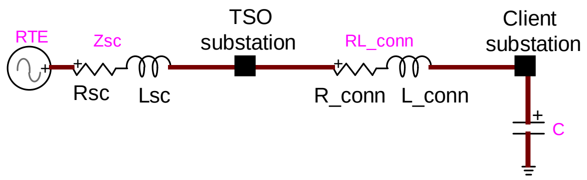

Fig. 1 Simplified model of a client connection.

Z_{sc} is the short circuit impedance of the grid at the connection substation. Z_{sc} is mainly an inductance as the grid is rather inductive. RL_{conn} and C represent the impedance of the connection. The impedance RL_{conn} represents a transformer and the capacitor C the submarine or/and underground cables which are very capacitive elements. This circuit is a well known RLC circuit, which is resonant at the frequency f_0 defined by (1). As a consequence, voltages and currents can be highly amplified near the resonance frequency as described by equation (3):

$$f_0 = \frac{\omega_0}{2\pi} = \frac{1}{2\pi\sqrt{LC}} \quad (1)$$

Where $$L = L_{sc} + L_{conn} \quad (2)$$

$$\left|\frac{V_{client}(f_0)}{V_{RTE}(f_0)}\right| = \frac{1}{\omega_0 RC} = \frac{1}{R}\sqrt{\frac{L}{C}} = \frac{\omega L}{R}\frac{1}{\omega\sqrt{LC}} = \frac{X}{R}\frac{\omega_0}{\omega} \quad (3)$$

With $$R = R_{sc} + R_{conn} \quad (4)$$

As an example, S_{sc}=3500 MVA, X/R=5 and ω_0/ω=5, which gives R=2.8 Ω, L=45 mH. With C = 9.0 µF, equation (3) leads to $\left|\frac{V_{client}}{V_{RTE}}\right| = 25$. Therefore the 5th harmonic client voltage can be 25 times higher than the 5th harmonic grid voltage in this simple example. With a more appropriate modeling of the network and the connection, RTE expects that amplifications are not going to be so high but this example shows how important it is to investigate background harmonic amplifications.

Study method

RTE's assessment of harmonic issues consists both in on-site measurements and simulations with the EMTP simulation tool.

Measurements are made to assess the level of harmonic voltages currently existing on the grid. They are performed for several weeks in the grid substation where the client is going to be connected. Then, simulations allow knowing the amplification of these harmonics due to the connections of the client.

Background harmonic amplification is a steady state phenomenon so it is satisfactory to perform simulations in steady state. Time domain simulations are necessary if