Comparison of two circuit concepts to generate temporary overvoltage for DC cables

Sarath **KUMARA**, Kenneth **JOHANSSON,** Mikael **UNGE;** NKT HV Cables, (Sweden),
sarath.kumara@nkt.com, , kenneth.johansson@nkt.com, mikael.unge@nkt.com
Markus **SALTZER;** NKT Group GmbH (Germany), markus.saltzer@nkt.com

☐ **Young Researcher** (Proved full-time engineering and science university researchers and Ph.D.students under 35 YO)

ABSTRACT

This paper presents a controllability and sensitivity analysis of two test circuit concepts that could potentially be used to generate Long Temporary Over Voltages (LTOV). One circuit is based on superimposed double exponential impulse on DC with an Impulse generator whereas the other concept is based on two DC sources. Circuit parameters were tuned to generate a target LTOV for 525 kV nominal voltage. First controllability of waveshape by adjusting circuit parameters were studied by means of a commercial circuit simulation software. After that circuit was adjusted to generate target LTOV for a range of loads. Finally, a Mont-Carlo simulation was performed to understand sensitivity of the generated LTOV to component tolerances. Key advantage of the DC source-based circuit is possibility of peak shaping (or overshoot) allowing to control the duration of the peak almost independent from the rise time, peak magnitude, and plateau duration. Both the circuits allow to cater slightly higher or lower loads than designed load with some adjustments to resistors and voltage sources. Both the circuits have similar performance with respect to sensitivity to the component tolerances. For verification two LTOV wave shapes have been tested on 525 kV HVDC cable systems including accessories utilizing DC source-based concept.

KEYWORDS

Temporary over voltages (TOV), HVDC, circuit simulation, tolerances, impulse generator, Monte-Carlo, DC cables

INTRODUCTION

The temporary overvoltage (TOV) seen by HVDC cable systems have recently received increasing attention among both transmission system operators and cable manufacturers. The TOVs experienced by a cable system will have different magnitudes and wave shapes, depending on the location of faults and the converter configurations. Understanding potential impact of such TOVs on the performance of cable demands experimental investigations. Realization of those TOVs, specifically the long duration overvoltage, using standard test equipment remains a challenge. Recently we have analyzed few circuit configurations to generate long TOV (LTOV) and one of them, which was based on two DC sources, has been tested in laboratory scale [1]. Alternatively, publication [2] presents an impulse generator-based circuit concept, which also has been tested in other laboratories. However, for both circuit concepts control of the pulse shapes by the parameter settings and variation of pulse shapes due to tolerances need to be further studied.

In the present work, these two circuit concepts were analyzed by means of PSpice© circuit simulation software to better understand controllability and sensitivity. Built in tools such as Monte-Carlo simulations, sensitivity analysis and parameter sweep have been used for simulations.

TARGET TOV AND ANALYSED CIRCUITS

Based on the simulations in [3,4], a simplified LTOV waveform for multilevel modular converter (MMC) HVDC connections has been proposed in an earlier publication [5]. Fig.1 shows a schematic waveform of the target LTOV for 525 kV nominal voltage (i.e., 1 pu). Peak value of the TOV is twice as nominal voltage (i.e., 2 pu or 1050 kV) and time to reach the peak (t_1 - t_0) is 1 ms. Overvoltage stays above 1.9 pu threshold (~998 kV) for a duration of 20 ms (= t_2 - t_1 and refers as duration of the peak). Then it slowly decays until t_3 forming a plateau. Target duration of plateau (t_3 - t_1) is 150 ms. At the end of plateau, the TOV reaches a voltage level of 1.6 pu (840 kV). After that, the decay is allowed to reach nominal voltage at a faster pace. In this example 300 ms was chosen. It is worth to mention that duration time of the plateau and time to reach nominal voltage, respectively 150 ms and 300 ms, are lower limits and those times can be longer. The time to peak and the duration of the peak have been chosen to give a good representation on different system parameters, like cable system length, fault location, transient location along the line, etc. Specifically, the overshoot is smeared out for very long systems, like > 500 km, but becomes prominent for shorter cable systems of only a few hundreds of kilometers, see e.g. [6].

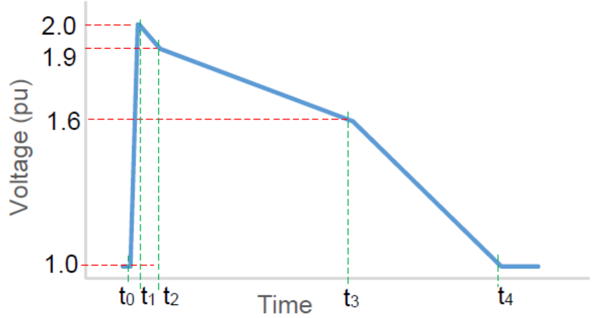

Fig. 1: Schematic waveform of the target LTOV [5]

Our recent study [1] presented few different circuit concepts that possibly can generate LTOV in laboratory environment. Within that study, a DC source-based circuit concept has been identified and tested at laboratory scale; nominal voltage of 52.5 kV and peak voltage of 105 kV. Measured TOV was in excellent agreement with the simulations. Publication [2] reports another potential circuit concept based on impulse generator, which has also been tested [7]. Fig. 2 proposes two circuits tuned to generate the proposed LTOV for a 525 kV cable sample having capacitance of 14 nF. One of the circuits is based on DC source-based concept whereas the other one is based on impulse generator concept. As operation principles of this circuit concepts have been extensively discussed in [1-2,7], only a brief introduction is given here.