Transient Studies of Power Cable Sections in 380-kV Transmission System

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ABSTRACT

Use of XLPE cables at higher voltage levels to transmit bulk power has started in the beginning of this century. For last 15 years several cables have been installed in tunnels or underground. First connections were realized in the urban areas, where underground transmission or distribution is appropriate. In coming years new high voltage transmission lines will be erected. Alone in Germany 3500 kilometres of new extra high voltage lines are required for the transmission of wind power from North to South. Geographical constrains and dense settlement areas may change the structure of the grids in near feature. More and more connections consist of cable sections with shunt reactors. Among other issues, the focus on study of system transients of mixed line has grown up in the last years. EMTP software is well suitable to investigate mixed lines with cable sections.

KEYWORDS

XLPE cables, mixed line, energization, secondary arc, arc extinction

INTRODUCTION

Application of EHV AC power cables in transmission grids is nowadays a challenging issue for many TSOs. Also in Germany new EHV corridors are planned or existing ones will be upgraded to higher voltage level. Another field that influences the rising demand on high voltage AC cables is offshore wind parks. The energy that is generated by large offshore wind park can be transported to the onshore substation via an AC cable. Moreover, abandonment of nuclear power plants forces modification and extension of transmission grids. Implementation of overhead line (OHL) would be easier and faster to erect and more economical. Geographical conditions, dense settlement areas and no acceptance from society circumvent finding of suitable corridors for overhead transmission lines. EHV cables have become recently appropriate alternative to OHL. Reasonable solution would be erecting mixed line that consists of cable as well as OHL. Lack of experience in integration of high range of EHV cables makes reasonable to investigate their influence on behavior of transmission grid. The response on disturbances of cable and mixed lines differs from response of overhead lines. The transients program EMTP-ATP [1] is well suited to analyze transient on transmission line.

This paper investigates different electromagnetic phenomena likely to occur in ca. 120 km long line with mixed cable/OHL sections regarding switching operations. In particular, phenomena that can occur during energization of mixed line with directly connected shunt reactor were considered. Relevant issue related to application of EHV cables is reactive power that is produced in low loaded periods. Compensation is carried out by shunt reactors. The implementation of a shunt reactor is necessary in particular for lines with cable sections that produce relatively more reactive power than OHL [2]. That line will be operated at 400-kV voltage level. Furthermore secondary arc behaviour was studied for a mixed line with and without shunt reactors. Cable sections can influence extinction time of secondary arc.

SYSTEM MODELLING

The simulation studies were performed using EMTP-ATP and ATPDraw software, version 5.9. The system configuration has been studied is shown in Fig. 1. The three-phase double circuit line consists of two OHL sections and one cable section. The shortest section consists of 8-km underground cable. Remaining two sections are realized as OHL. At the transition point (dotted vertical lines in Fig. 1) one system of the overhead line (3 four-bundle conductors for 3 phases) is substituted by the suitable cable system (with 6 single-core cables, one phase needs 2 parallel cables). Remaining part of the transmission system is simplified in both substations by a Thevenin equivalent consisting of the voltage source and short-circuit impedance of the positive- and zero-sequence systems. The line transposition is also interesting aspect. There are two transpositions between cable and substation B. This is a partial transposition with regard to an ideally transposed line. With that solution asymmetry in phase currents was reduced to ca. 2% (I_2/I_1) and ca. 1% (I_0/I_1).

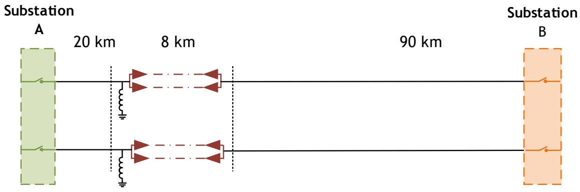

Fig. 1: 400-kV mixed transmission line

Cable Modell

Available line models in EMTP-ATP have been compared with the measurements referring to accuracy of XLPE cable parameters [3]. The three-phase cable is laid in the flat formation 1.5 m below the earth surface. The circuit consists of six single-core cables of type 2X(Fl)2Y 1x2500 RMS/400 230/400 kV. Due to the transportation limitation a cable section is allowed to be around 900 m of maximum length. The cable sections are divided into nine ca. 900 m segments. The cross-bonding of the cable sheaths is considered in the simulation model. Basic electrical parameters of the cable section are compiled with the subroutine CABLE PARAMETERS [1] based on