Analysis of Technical Planning Principles for Partial Underground Cabling in Meshed Extra-High Voltage Grids

Kishan **VEERASHEKAR**, Friedrich-Alexander University Erlangen-Nürnberg, (Germany), kishan.veerashekar@fau.de
Carsten **SIEBELS**, TenneT TSO GmbH, (Germany), carsten.siebels@tennet.eu
Piergiovanni **LA SETA**[1], TenneT TSO GmbH, (Germany), piergiovanni.laseta@gmx.de
Bernhard **FUCHS,** RWTH Aachen University, (Germany), fuchs@ifht.rwth-aachen.de

ABSTRACT

The presence of underground cables (UGC) as part of extra-high voltage (EHV) transmission lines in combination with overhead lines (OHL) can be identified as a trend in new line projects mostly in densely populated areas. However, different technical and economic aspects of this solution compared to traditional OHL have to be faced. In this paper, several exemplary cases with different configurations of UGC and OHL, so-called mixed lines, together with a case having only OHL are considered both in steady-state and in transient conditions. The key aspects with respect to dimensioning and positioning of shunt reactors, short-circuit currents and switching overvoltages are investigated, since they play an important role during planning of transmission lines with partial amount of UGC.

KEYWORDS

Underground cables, extra-high voltage, overhead lines, mixed lines, shunt reactors, short-circuit currents, switching overvoltages.

INTRODUCTION

Recently, Germany has decided not only to cover 35% of the gross consumption by means of power generation from renewables by 2020, but also to shut down all its nuclear power plants at the latest by 2022. Therefore, the optimisation, reinforcement and expansion of the existing German EHV transmission grid are very crucial [1]. Major delays in the realisation of transmission line projects are caused due to the problems associated with the public acceptance. The partial underground cabling is a promising way to increase the public acceptance for the expansion of EHV grids [2].

In the past few decades, there have been remarkable developments in the EHV cable technologies. Since the end of the last century, the UGC at EHV level have been installed in the European cities like Berlin, Copenhagen, London, Vienna etc. [3]. Currently, the share of UGC in the German EHV grid is just less than 0.5% [4]. The present experience with the operation of power cable integrated in EHV grids is relatively less.

Due to the dissimilar electrical characteristics of the classical OHL compared with UGC, integrating them into EHV grid changes the behaviour of the transmission system not only under steady-state but also under transient condition. Therefore, in-depth technical investigations are highly important when employing UGC in the OHL dominated EHV grid.

The main purpose of this paper is to ascertain the fundamental aspects that must be taken into consideration during planning of transmission lines with partial amount of UGC. Several cases with various configurations of OHL and UGC are studied both in stationary and transient mode.

This paper is structured as follows: In section *Methodology*, the examined cases, the considered lines and the performed investigations are described. The results of the executed simulations are presented in section *Simulation Results*. Finally, in the last section *Conclusion*, the main conclusions are drawn.

METHODOLOGY

A complete overview of the investigated *cases* corresponding to the type of configuration along with the length of each section is presented in Tab. 1. Due to the fact that the distance between the German extra-high voltage substations are not relatively too long, each case is characterised by a 120 km long double-circuit line between two generic substations (SS-1 and SS-2), which are connected to two *extended* grids. Fig. 1 shows the graphical representation of Case-1, where the extended grids are represented by *equivalent* grids. While case-0 comprises pure OHL, the remaining three cases have different configurations of OHL as well as UGC. These lines with OHL and UGC are called as *mixed lines*, where the total length of OHL and UGC amounts to 105 km and 15 km, respectively. In contrast to OHL, each UGC's circuit is made up of two parallel systems because of UGC's lower ampacity compared to that of OHL.

Case	Configuration	Length in km
0	OHL	120
1	UGC – OHL – UGC	7.5 – 105 – 7.5
2	OHL – UGC – OHL	50 – 15 – 55
3	UGC – OHL – UGC – OHL – UGC – OHL – UGC	3 – 30 – 5 – 50 – 2 – 25 – 5

Tab. 1: Overview of the studied cases

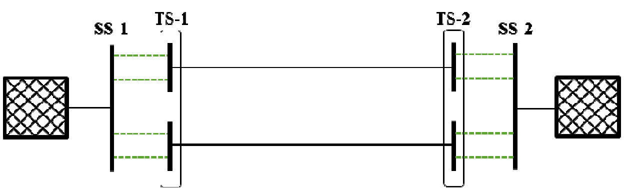

Fig. 1: Configuration of UGC and OHL in case-1

Tab. 2 lists the different electrical characteristics of the considered OHL and UGC having nominal and rated voltages of 380 kV and 420 kV, respectively. The capacitance per km of UGC is nearly 18 times greater than that of OHL. As a result, UGC have relatively lower surge impedance and higher surge impedance loading.