Extended Approach for Calculating Thermal Stress and Ampacity of High Voltage Cable Systems Based on Experimental Data

Florian **AINHIRN**, Rudolf **WOSCHITZ;** High Voltage Test Laboratory Graz Ltd., Austria, florian.ainhirn@tugraz.at, woschitz@tugraz.at

Andreas **BOLZER;** Wiener Netze GmbH, Austria, andreas.bolzer@wienernetze.at

ABSTRACT

Thermal rating calculations of high voltage cable systems are normally performed using either analytical or numerical methods. Nevertheless, both methods face problems through simplifications, approximations or the insufficient modelling of the surrounding soil. The High Voltage Test Laboratory Graz Ltd. is currently developing an extended approach, which combines these methods for higher accuracy. The research so far shows, that a more detailed modelling of the surrounding soil as well as an increased region to be discretized can improve accuracy.

KEYWORDS

High Voltage Cable Systems, Thermal Rating, Ampacity, Enviromental- and Soil Dynamics, Multiphysical Simulation

INTRODUCTION

The calculation of cable rating (“thermal rating”, “amapacity” or “ampere capacity”) basically aims for two things, which are either to determine the amount of current that can be applied to a cable system without exceeding a maximum conductor temperature, 90 °C for cables with XLPE insulation, or to determine the conductor temperature for a given current. The established analytical calculation method to do so is given by IEC 60287 [1 - 3], which is based on the equations of Neher-McGrath [4]. This method and the assumptions, approximations and simplifications that were made in its development lead in many cases to rather high values for temperature and therefore to lower ampacities than in reality.

This has been acceptable in the past since high voltage cables are normally not loaded to their thermal limits and are rather operated in cold conditions relatively speaking. However, due to a change in load profiles, the trend in recent years goes towards increasing loads. This applies in particular to cable systems in urban areas, where high voltage cables are preferred for their social acceptance and due to the infeasibility of overhead lines to run through densely built-up areas. The renewal or expansion of those cable systems is always attached to high installation costs. Therefore, the real operation limits of new and existing cable systems are becoming more and more important for grid operators. This and the fact that the analytical calculation method provided by [1 - 3] can’t be applied to complex geometries led to new calculation methods based on the finite element method like described for example in the IEC TR 62095 [5].

Even though the high capabilities of computer aided calculations, the established methods still face difficulty in boundary conditions and the accurate modelling of the surrounding soil.
Moisture migration in FEM for example is usually implemented by a two-layer model for thermal conductivity of the soil. This may give an approximation for the relatively fast dry out of the surrounding soil but is insufficient for the slow return of moisture in the cable vicinity. Also environmental influences (solar radiation, precipitation etc.) are normally not taken in account even though they have a significant effect on the temperature and therefore on the ampacity of high voltage cable systems. Thus, the High Voltage Test Laboratory Graz Ltd. is currently developing an extended calculation approach based on multiphysical simulation and algorithms. In order to validate and compare the results, an actual 400-kV-cable system with a typical urban laying profile was set up in cooperation with Vienna’s grid operator Wiener Netze GmbH.

TEST SETUP

Cable

The cable used in the test setup is a 400-kV-XLPE cable, type XDCU-PBT 1x2500DB mm² 380/220 kV, with cooper conductor with a cross section of 2500 mm², with a copper wire screen and lead sheath.

Laying profile

The laying profile was based on optimization calculations, in terms of phase distance and coverage, done by the High Voltage Test Laboratory Graz Ltd. in advance, to, on the one hand minimize the occurring magnetic field on the earth surface and on the other hand maintain the highest possible ampacity. The cables therefore were laid in a non-touching trefoil formation, which combines the advantages of a touching trefoil formation, namely the reduction of the magnetic field while saving space, and the advantages of a flat formation, hence good heat dissipation.

Cable trench

The cable trench, which is 1.2 meters wide, 2.7 meters deep and 30 meters long, consist of three layers, the thermally stabilized lean concrete block, in which the cables are laid in, a layer of self-compacting concrete and a layer of backfill material. In addition, a street profile was realized on top of the trench.

Generation of test current

The equivalent circuit diagram is shown in Figure 1.

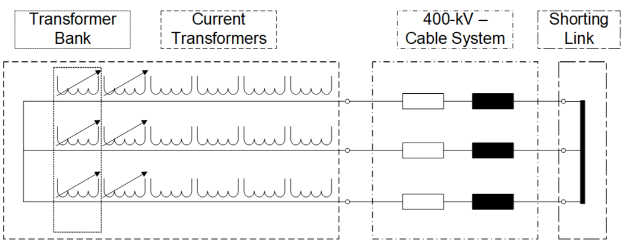

Fig. 1: Circuit diagram of test setup

The three single core cables are short circuited on one side