Gravitational cooling of cable installations

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ABSTRACT

New possibilities are shown to eliminate hot-spot-regions in cable routes by means of a sectionalized gravitational water cooling. This type of cooling is characterized by low complexity as well as autarkical and reliable low-maintenance operation, without active elements like pumps, coolers etc.The cooling circuit is built-up by one heat absorbing pipe, closely neighboured to the cables and connected with one heat dissipating pipe which is installed parallel, as near as possible to the soil surface. The lower and the upper pipe are connected at both ends by vertical pipes. With increasing temperature of cables and pipes a water circulation will set on with surprisingly good cooling effects. The shown examples elucidate, that even severe thermal impacts by steam pipes, other cables etc. can be controlled by means of such arrangements, - even for very long cooling sections.

KEYWORDS

Gravitational water cooling, cable ampacity, current rating

INTRODUCTION

In this paper, new possibilities are shown to eliminate thermal bottlenecks in cable routes by means of a sectionalized gravitational water cooling. This type of cooling is characterized by constructional convenience as well as by autarkical and reliable low-maintenance operation, without active elements like pumps, coolers etc.

Exemplarily considered (fig. 1) is a twin system of 380-kV-XLPE-cables, segmental copper conductors of 6x1x2500 mm^2, installed in an outer jacket tube containing six regularly arranged XLPE-pipes (250 mm/15 mm, distance of axes 400 mm) in a phase-splitting arrangement (PowerTubes, comp. [1…3]). Up to the shown laying depth of h_u = 2,50 m (axes of the lower cables), the jacket pipe can be laid by means of a very effective half-open drilling procedure (with up to 800 m per day, [1]). The current rating of such an arrangement is high, but may be decreased in hot-spot-sections with increased laying depths or by partly laid parallel or crossing cables or steam pipes.

Principle of the gravitational cooling

For this example, fig. 1 elucidates the principle of the gravitational cooling. Two of the four cooling pipes are integrated into the cable arrangement, whereas the two other pipes are positioned as near as possible to the soil surface (here: 1.0 m depth).

In this paper, different thermal bottlenecks are considered, which can be mastered by means of the gravitational cooling. Two solve this bottleneck situation as shown in fig. 2, two closed cooling circuits are built-up by connecting a lower pipe with an upper pipe by means of vertical pipes at both ends of the cooling section (pipe P1 with P3 and P2 with P4, resp.), where these circuits are

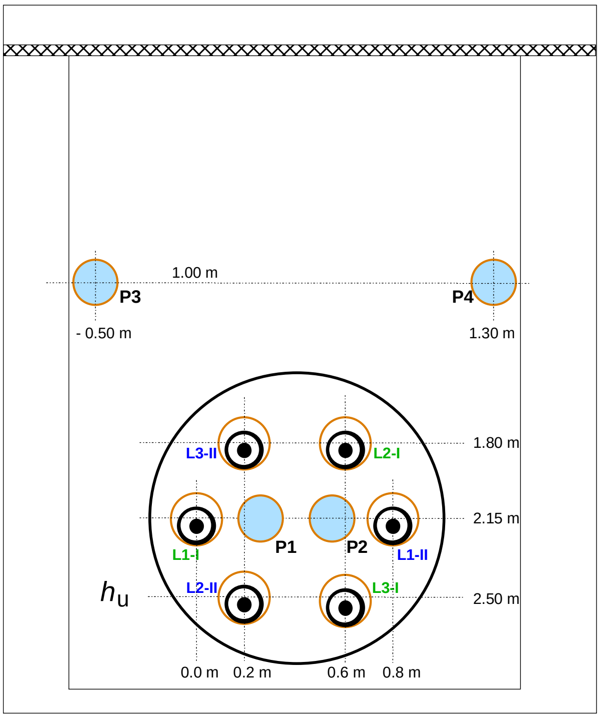

Fig. 1: Twin system of XLPE-cables in phase-splitting arrangement in an outer jacket pipe [1…3]; laying depth: h_u = 2.50 m; jacket tube with inner diameter of 1200 mm; 4 cooling pipes150 mm/10 mm; 2 cooling circuits: pipe P1 connected with pipe P3 and pipe P2 with pipe P4

filled with water. As subsequently shown, with increasing temperature of cables and pipes a water circulation will set on with flow velocities of only some cm/s but with surprisingly good cooling effects.

Basic equations

The function of the cooling circuits is as follows: the two vertical pipes at both ends in figs. 2+3 are spanning two oppposite, hydraulically connected water columns with a height of Δh. If the two water columns have two different (mean) temperatures Θ_{w1} und Θ_{w2}, they will differ in density and weight, thus causing a pressure difference of

$$\Delta p = \Delta h \cdot g \cdot \left[\delta_w(\theta_{w2}) - \delta_w(\theta_{w1})\right] \qquad (1)$$

where

$\delta_w(\theta_w)$	temperature-dependent density of water,
g	acceleration of gravity,
Θ_{w1}	water temperature at the entry of the lower pipe and at the outlet of the upper pipe and
Θ_{w2}	water temperature at the outlet of the lower pipe and at the entry into the upper pipe ($\Theta_{w2} > \Theta_{w1}$).

Thus, the temperature difference along the cooling section is $\Delta\theta = \Theta_{w2} - \Theta_{w1}$.