Current rating of power cables with temperature limit imposed on backfill/duct bank boundary

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Core temperature has been typically the limiting parameter for rating insulated cables installed underground. There are, however, recent interests to rate underground cables based on the temperature at the most external boundary in direct contact with the native soil. This could be the cable jacket, duct or pipe for directly buried circuits and backfill/duct bank boundary for duct banks or backfill installations. The purpose is to limit the temperature of this boundary below the critical value above which moisture migration and consequently soil dry out could happen.

Calculation of the cable component temperature can be easily handled with the lump parameter equivalent of a cable thermal circuit. However, obtaining the backfill/duct bank boundary temperature is not a trivial task, especially when there are several circuits of different types in one installation including many duct banks and backfills. Actually, since there is only one point on the backfill/duct bank boundary with the highest temperature, the number of unknown currents is higher than the number of available equations. The temperature at different points on the backfill or duct bank boundary can be significantly different and the hottest point could change position when different current distributions are considered. This is in contrast with direct buried installations where one can assume all points on the duct, pipe or cable's surface are approximately at the same temperature.

In addition to obtaining the currents that avoid soil dry out, we are also interested in maximizing the total ampacity of the installation. Hence, for a given target temperature imposed on the most external boundaries of a cable installation in contact with the native soil, the unknowns are the currents through each circuit. This paper presents a new method for cable rating calculations when the temperature limit is imposed on the duct bank/backfill boundary or the most external cable layer for direct buried installations. The method uses a combination of a numerical and analytical solution and is described in detail in the paper.

Several approaches can be envisaged to handle this problem. Three are described in the paper. One of them is an iterative procedure where the current $I(k)$ for cable k found at the previous step has been changed by the value of $\Delta I(k)$ to meet the required temperature change $\Delta\theta(k)$ at the point *M* on the backfill boundary in order to reach the desired value. The equation developed in this work to affect this change is shown below, with the same notation as in the IEC Standard.

$$\Delta I(k) = \frac{\pi}{\rho_{eq}(k)} \frac{\Delta\theta(k)}{\left[1+\lambda_1(k)+\lambda_2(k)\right] R(k) I(k) \log\left(\dfrac{d'_{kM}}{d_{kM}}\right)}$$

Key part of the proposed method is to find the location of the point *M* with the highest temperature on the backfill boundary and take into account the multiple heating sources. The employed procedure is described in the paper.

Figure below shows the results of the analysis for a system composed of cables located in a duct bank (lower installation with 2 circuits) and a single circuit in a backfill above the duct bank. The temperature limit of 50°C is imposed on the backfill/duct bank boundaries. We can observe that the highest conductor temperature is, in this case, below 60°C.

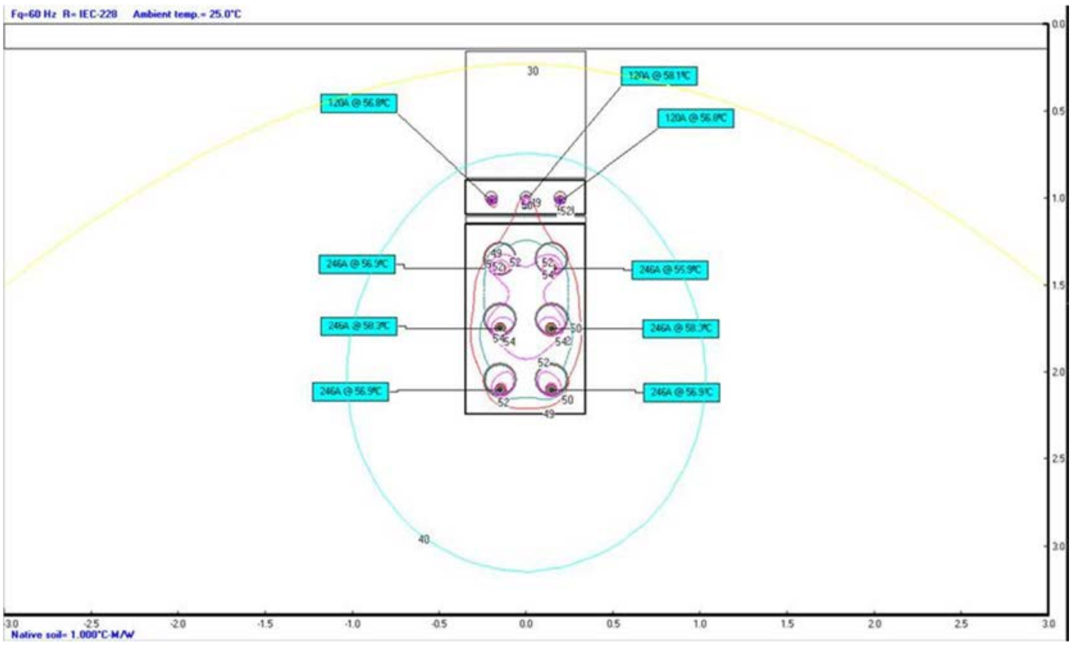

Fig.1 Cable rating with backfill boundary limited to 50°C

Another example involves two different circuits and a heat source and the cable surface temperature is limited to 50°C.

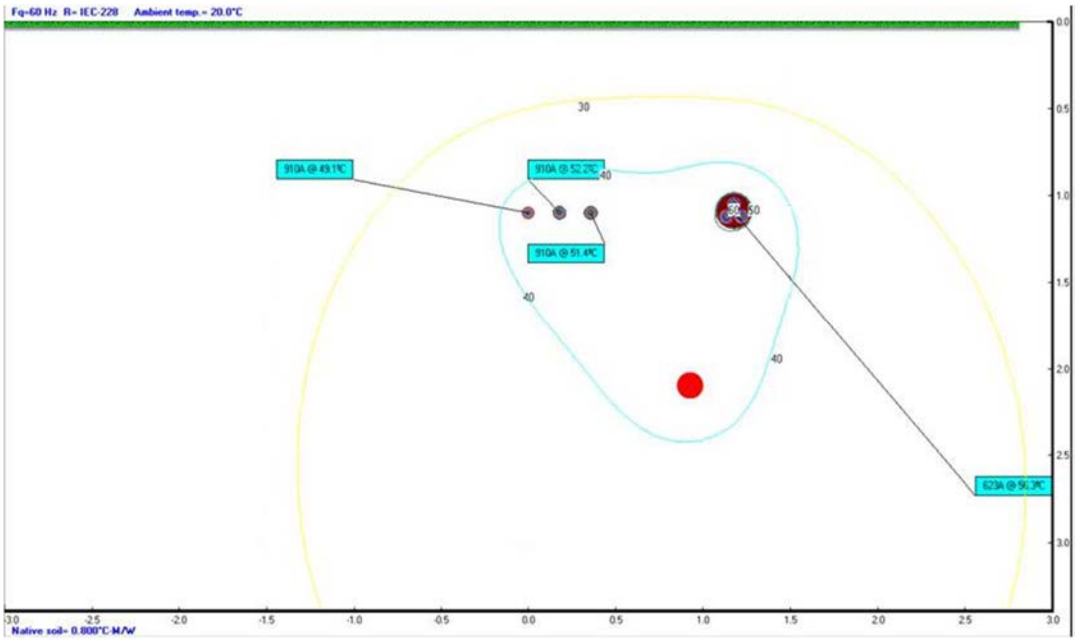

Fig. 2 Cable rating with outer surface of the pipe type cable and jackets of the direct buried cables limited to 50°C