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# PRIVREMENA OPTEREĆENJA KABLA NAKON KVARA INSTALIRANOG U VAZDUHU

# EMERGENCY CABLE RATING IN AIR

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**Kratak sadržaj:** Za kablove instalirane u vazduhu temperatura provodnika se brzo menja s promenama struje opterećenja, zato ciklična opterećenja su ista kao i trajno dozvoljena struja kablovskog voda. Kratkoročne vrednosti dozvoljenih struja nakon kvara za kablove instalirane u vazduhu mogu se značajno razlikovati od trajno dozvoljene struje. Rad će opisati probleme sa standardom IEC 60853-2: Proračun vrednosti ciklične struje i struje preopterećenja u kablovima — Deo 2: Vrednost cikličnog faktora za kablove napona viših od 18/30 (36) kV, a u slučaju preopterećenja u kablovima za sve vrednosti napona koji se koristi za tranzijente i ciklične struje kabla: -privremene struje kabla u slučaju kvara mogu se izračunati kada je privremeno opterećenje 2.5 puta manje od trajno dozvoljene struje. Ako ovaj uslov nije ispunjen, formule iz standarda ne važe. - samo ograničeni slučajevi su navedeni unutar standarda - proračun se sastoji od više koraka Ovaj će rad predstaviti moguća rešenja za proračun privremenih opterećenja kabla nakon kvara instaliranog u vazduhu.

***Ključne reči:*** *privremeno opterećenje, tranzijenti, struja, vazduh*

**Abstract:** For cables installed in air, the conductor temperature changes rapidly with changes in load current, and hence, daily load cycles do not allow cyclic rating to exceed the steady-state value. However, short term emergency ratings may significantly exceed steady-state values without exceeding permissible temperature limits. The paper identifies issues with the IEC 60853-2 (Calculation of the cyclic and emergency current rating of cables. Part 2: Cyclic rating of cables greater than 18/30 (36) kV and emergency ratings for cables of all voltages). This standard gives manual methods for calculating cyclic rating factors for cables whose internal thermal capacitance cannot be neglected; in general this applies to cables for voltages greater than 18/30 (36) kV. It also gives a method for calculating the emergency rating for cables of any voltage. However, the emergency rating calculations are not applicable where load applied exceeds 2.5 times the steady-state current value, if this condition is not met, the formulas become irrelevant. This paper will present possible solutions for calculation for emergency cable rating in air which are outside the scope of IEC 60853-2.

***Key words:*** *emergency, transient, rating, air*

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# 1 INTRODUCTION

The thermal capacitances and resistances, which represent the constituent parts of the cable and its surroundings, determine the transient temperature response of a cable system. For cables in air, generally the conductor temperature follows changes in load current sufficiently rapidly that the usual daily cycles do not permit peak loads greater than the steady-state value. However, this may not always be the case for transmission circuits with large conductor sizes and short-term emergency ratings for cables installed in air may differ significantly from steady-state values. A method of assessing such transient ratings is given in IEC standard [1].

The speed of heating or cooling in air is 300 times faster than in XLPE insulation due to the difference in thermal diffusion [2]

# 2 IEC 60853-2

This standard [1] gives methods for calculating the emergency ratings applicable to cables buried in the ground, either directly or in ducts, but also for cables in air. Other installation arrangements, such as multiple cables per phase or the thermal effects of multiple circuits, are not covered by the standard.

Methods for calculating emergency rating factors are intended for emergency loads not greater than about 2.5 times rated full load current (100% load factor). If this condition is not met, the formulas become irrelevant.

An equivalent thermal circuit requires many elements to represent parts between conductor and outer surface of cables of complex construction. As per IEC 60532-2 to simplify the calculation, and to standardize the procedure for all cable types not dealt with in this standard, are given method for combining the several elements in such a circuit into two sections.

The criteria for selecting the thermal circuits to be used for calculating the individual transients depends on the duration of the transient. The standard provides two sets of equations for different durations of emergency rating:

- short duration typically from 10 minutes up to 1 hour, for single core cables up to $\frac{1}{3}T \cdot Q$ (where $T$ is the total thermal resistance of a cable from conductor to outer surface, $Q$ the total thermal capacitance of a cable, and $T \cdot Q$ the thermal time constant of the cable).

- long duration typically greater than 1 hour, for single core cables $> \frac{1}{3}T \cdot Q$

As per [1] for cables in air, it is unnecessary to calculate a separate response for the cable environment. The complete transient temperature rise of conductor above ambient, without correction for variation in conductor loss $\theta(t)$ is obtained by replacing $T_B$ element of equivalent thermal circuit by ($T_B$ + $T_C$) in the constituent terms of the formula for $\theta_c(t)$ transient temperature rise of conductor above the outer surface of a cable.

Detailed formulas are given in the standard [1]. But only limited cases are provided within the standard and multiple steps are challenging due to requirement to superimpose current steps.

Following the steps from the standard [1] especially for a smaller preload and short postfault duration, large values of the emergency rating can be obtained. The reason for this, as stated in the standard, is that the formulas cannot be applied when the emergency rating exceeds 2.5 times the steady-state current value.

## 3 EXTERNAL THERMAL RESISTANCE $T_4$

IEC standard 60287-2-1 [3] describes a calculation method for the external thermal resistance $T_4$ of cables installed horizontally in free air, without or with solar radiation. The method includes an iterative procedure for calculating the difference between the cable surface and the ambient air temperatures.

The thermal resistance $T_4$ of the surroundings of cables in air and protected from solar radiation is given by the formula:

$$T_4 = \frac{1}{\pi D_e^* h (\Delta\theta_S)^{1/4}} \quad (3.1)$$

where

$$h = \frac{Z}{(D_e^*)^g} + E \quad (3.2)$$

$D_e^*$ is the external diameter of cable, h is the heat dissipation coefficient obtained either from the formula 3.2 or using the values from [3], $\Delta\theta_s$ is the difference between the cable surface and the ambient air temperatures.

While buried cables transfer heat to their surroundings by conduction, cables in free air dissipate their heat by convection and radiation, which is highly dependent on the temperature difference between the cable outer surface and the surrounding air. For an installation in air, $T_4$ is not constat as for buried cables but depends on the cable temperature.

The high sensitivity of $T_4$ for installations in air may explain lack of accuracy for emergency rating.

## 4 THERMAL LADDER

One of the solutions for calculation of emergency ratings in air can be to use the energy balance matrix method to solve for temperature. Calculated numerically by solving the energy balanced defined by the matrix equation [5]:

$$[W] = [K]\,[\theta] \quad (4.1)$$

where:

$[W]$ is the vector of losses injected into each node in the thermal ladder.

$[K]$ is the matrix of thermal conductance's defining the connections between nodes in the thermal ladder.

$[\theta]$ is the vector defining the temperature at each node.

Figure 1 presents thermal leadder diagram for cable instaled in air.

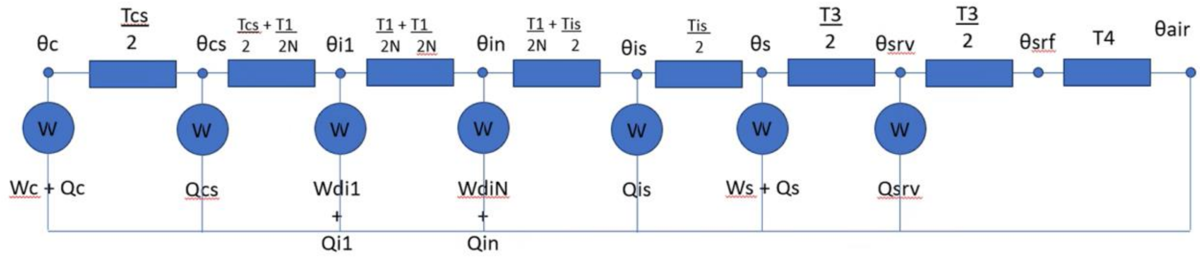


Figure 1: Cable thermal ladder

Table 1: Thermal ladder parametars

| Parameter | Value |
|---|---|
| Wc | Conductor loss of cable |
| Wdi1 | Dielectric loss of cable node 1 |
| WdiN | Dielectric loss of cable node N |
| Ws | Metallic sheath/screen loss of cable |
| θc | Temperature of conductor of cable |
| θcs | Temperature of conductor screen of cable |
| θi1 | Temperature of insulation midpoint of cable |
| θin | Temperature of insulation of cable |
| θis | Temperature of insulation screen of cable |
| θs | Temperature of metallic screen/sheath of cable |
| θsrv | Temperature of oversheath midpoint |
| θsrf | Temperature of surface of cable |
| θair | Temperature of the air |
| Tcs | Thermal resistance conductor screen of cable |
| T1 | Thermal resistance between conductor and metallic screen/sheath |
| Tis | Thermal resistance insulation screen of cable |
| T3 | Thermal resistance of cable oversheath |
| T4 | Thermal resistance of environment |

The development of software tools has made it easier to apply complex mathematical tools. The matrix method can be applied to even more complex cases such as multiple cables per phase, and to represent parts between the conductor and outer surface of cables of complex construction.

## 5 CONCLUSION

The use of matrix methods for calculating emergency response in the air is made easier by modern computer tools. For calculation emergency rating cables installed in air the energy balance matrix methods can be used for calculation.

## 6 REFERENCES

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