



A.9.1.

Calculation of thermal ratings of cable systems using generalized matrix method

HIRANANDANI A., DTE Energy, USA

Abstract

Present cable standards[6] do not facilitate calculation of cable thermal ratings when mutual heating between cables becomes significant. The Method of Finite Differences[1] can be used to calculate cable temperature distribution of a cable configuration by applying a matrix approach, where the elements of the matrix represent the cumulative effect of self and mutual heating of the cables. Temperature distribution of a typical cable system has been calculated and compared to an actual installation (Fig:4) and to existing standards[6]. This method can be applied to any general system including electronic circuits and mechanical systems.

KEYWORDS Finite Difference Matrix Method, Cable Temperature, Thermal Resistance

1. Introduction

A two-dimensional solution for conductor temperatures in the steady state can be determined by considering the heat sources to be nodes and a residual equation formulated for each node and the set of equations solved for temperatures at each node [3]. At steady state the net input to each node must be zero or

$$Q_i + \sum (T_j - T_i) / R_{ij} = 0 \tag{1}$$

where Q_i is the heat delivered to the node i by heat generation from node j and R_{ij} is the thermal resistance between node i and node j summed over all nodes N .

The solution of the matrix equations for a cable system for cable temperatures is as follows including mutual thermal resistances [1]:

R matrix including mutual thermal resistances

$$R = \begin{bmatrix} 1/R_{11} & 1/R_{12} & \dots & 1/R_{1m} \\ 1/R_{21} & 1/R_{22} & \dots & 1/R_{2m} \\ \vdots & \vdots & \dots & \vdots \\ 1/R_{m1} & \dots & \dots & 1/R_{mm} \end{bmatrix} \tag{2}$$

Resume

Les normes actuelles de calculs de charge de câbles souterrains [6] ne traitent pas avec facilité les cas d'échauffement mutuel. La méthode Différences Finies [1] peut être utilisée pour calculer l'échauffement de différentes configurations de câbles en utilisant l'approche de calcul matriciel où les éléments de la matrice représentent l'effet cumulatif de l'échauffement propre et mutuel. Un exemple de calcul d'échauffement d'une installation typique est présenté (figure 4) et les résultats sont comparés à des mesures expérimentales et aux normes existants [6]. Cette méthode pourrait être utilisée pour analyser n'importe quel système incluant des systèmes mécaniques et électroniques

Q matrix

$$Q = \begin{bmatrix} -(Q_1 + T_{1a} \cdot K_f / R_{1a}) \\ -(Q_2 + T_{2a} \cdot K_f / R_{2a}) \\ \vdots \\ -(Q_m + T_{ma} \cdot K_f / R_{ma}) \end{bmatrix} \tag{3}$$

T matrix

$$T = \text{Inv } R \times Q \tag{4}$$

where R is an $m \times m$ matrix of R_{ij} , Q, T are $m \times 1$ matrices respectively, and

$1/R_{ij} = 1/R_{ji}$ where i and $j = 1$ to $m = N - 1$

R_{mm} / R_{im} = self/mutual thermal resistance in $K \cdot m / w$

$Q_1 \dots Q_m$ = total heat dissipated per cable per unit length [5]. For ac this will include skin and proximity effects in w/m

R_{ia} = thermal resistance between node i and ambient node a . in $K \cdot m / w$

$T_1 \dots T_i$ = Conductor temperatures for each cable i in the cable system in deg C

$K_f = 1$ when current flows in conductor and $= 0$ otherwise.

N = total no. of nodes including ambient [1, 3].

Inv = Inverse of matrix