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Conductor temperature estimation of underground cables

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Résumé

Une caractéristique souhaitable des systèmes de contrôle pour les appareils électriques est la connaissance des températures critiques. La mesure directe de cette température est souvent difficile. L'utilisation de modèles thermiques et la mesure des causes des sources de chaleur internes ainsi que des conditions extérieures, peuvent être utiles pour le calcul de la valeur des températures critiques. Cependant, il peut être difficile d'obtenir de bons résultats par l'intégration directe des équations différentielles des modèles. Dans cette présentation est illustrée une méthode, basée sur le filtre de Kalman, pour l'estimation de la température du conducteur d'un câble souterrain. Des applications numériques démontrent la pertinence et les caractéristiques de la méthode.

Abstract

The knowledge of critical temperatures is a desirable feature of the monitoring systems for electrical equipment. The direct measurement of such temperatures is often difficult. The use of thermal models, together with the measurement of the causes of the internal heat sources and of external conditions, may help in calculating the value of critical temperatures. However, it may be difficult to obtain good results by the direct integration of the differential equations the models are made of.

In the paper, a method, based on the Kalman filtering technique, is presented for the estimation of the conductor temperature of an underground cable. Numerical applications show the viability and the characteristics of the method.

Introduction

Overtemperature is one of the factors that mostly limit the exploitation of power system equipment. The consequences of overtemperatures are well known, and the correct operation always requires that one or more critical temperatures are kept below a maximum value, related to a maximum exposure time.

This requirement is met by imposing limits on the current flowing into the equipment; the limits are computed on the basis of thermal models of the equipment. With worst case heat exchange and loading conditions, conservative "static" current ratings are obtained; with the on-line monitoring of these conditions, it is possible to obtain "dynamic" current ratings [1].

The translation of maximum allowable temperature/time into maximum allowable current/time does not suppress the need of knowing the value of critical temperatures; it remains a desirable feature of the monitoring system for critical equipment [1, 2]. The direct measurement of such temperatures is often difficult; the instruments should be capable of resisting against the full phase-to-ground voltage, and the points at critical temperature may be difficult to reach. The use of thermal models, combined with the measurement of the causes of the internal heat sources (mainly the current flowing into the equipment) and of the external conditions, may help in obtaining by calculation the value of the critical temperatures.

The thermal model refers to a thermal system composed of the equipment, and possibly of the surrounding environment, up to a surface with a measurable or known temperature. If the thermal model includes the surroundings of the equipment [1, 3], measuring the external conditions means measuring the undisturbed ambient temperature and the characteristics of the surrounding environment that determine the heat exchange conditions. If the thermal model does not include the surroundings of the equipment [2], the external conditions are represented by the temperature of the assumed external surface (e.g. cable surface temperature).

Direct use of thermal models, however, may lead to errors in evaluating the critical temperatures. Weather (soil) conditions may be difficult to measure, and often their influence on the heat