Thermal impedance of insulated overhead power cables heated by joule losses and solar radiation

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ABSTRACT

In this paper a dynamic thermal analysis of overhead power cables will be presented. The thermal properties are represented by thermal impedances rather than thermal resistances so that dynamic phenomena can be taken into account. Two kinds of heat sources will be taken into account: first of the all the Joule losses in the cable and secondly the additional heating due to sun radiation on the electric insulation of the cable.

KEYWORDS

Insulated overhead power cable, thermal impedance, Nyquist plots, joule losses, solar radiation

INTRODUCTION

Several papers have been devoted to the study of thermal fields in overhead power cables. In [1] Makhkamova et al present results from an application of a CFD technique for determination of the thermal state of a Lynx overhead conductor. The thermal state of the Lynx conductor is mainly defined by the magnitude of the transmitted electrical current, ambient temperature, wind velocity and its direction and also by solar radiation. Cimini and Fonseca evaluate in [2] the effect of progressive Aluminum wire rupture on the temperature profile of an ACSR (Aluminum Conductor Steel Reinforced) overhead electrical conductor, not only on the section of the damage but also along the length of the conductor. In [3], a probabilistic static thermal rating method based on typical weather conditions along a transmission line is described and analyzed. In [4], Schläpfer and Mancarella present a probabilistic modeling and simulation methodology for estimating the occurrence of critical line temperatures in the presence of fluctuating power flows. Cecchi et al [5] are deal with a transmission-line modeling approach that incorporates available ambient temperature information and propose a model with multiple nonuniform segments in order to capture the nonuniformity of line parameters caused by temperature gradients. In [6], Koufakis et al present a fire model that allows the estimation of the temperature rise of the conductors during a wildfire. Liu [7] proposes an analytical method – concerning that the cables in a bundle can be loaded with different currents and the heat-source density does not have to be uniform in all conductors - of calculating the steady-state and transient temperature rises.

In this paper a dynamic thermal analysis of electrically insulated overhead power cables will be given. Two kinds of heat sources are taken into account. First of all, the Joule losses in the cable and secondly the incident solar radiation falling on the cable. It may be surprising that both powers can be of the same order of magnitude. For a typical cable joule losses of 50 W/m have been reported. On the other hand if the cable with insulation has a diameter of 25 mm the incident solar power will be 25 W/m under full sunshine conditions (1000 W/m^2). Hence, the heat from joule losses and incident solar radiation can be comparable.

Also a dynamic analysis will be performed as well. Hence, thermal impedances instead of thermal resistances will be calculated.

In this contribution two temperatures will be taken into account. First of all, the temperature in the centre of the cable is monitored. This is the maximum temperature which is the most important from reliability point of view. Secondly, the temperature at the outer side of the electrical insulation facing the incident sun radiation is calculated as well. This temperature is normally measured when thermographic inspections of overhead cables are carried out. Hence it is essential to know how much the surface temperature of the electric insulation as measured by the thermographic camera can give us information about the core temperature of the cable.

THE USE OF THERMAL IMPEDANCES

Generally thermal problems related to power overhead cables are described under steady state conditions. The same statement holds for underground cables as well. This approach implies that the generated power losses are assumed to be constant in time and hence a constant or slowly varying temperature is obtained. The thermal problem can then be fully described by a thermal resistance Rth.

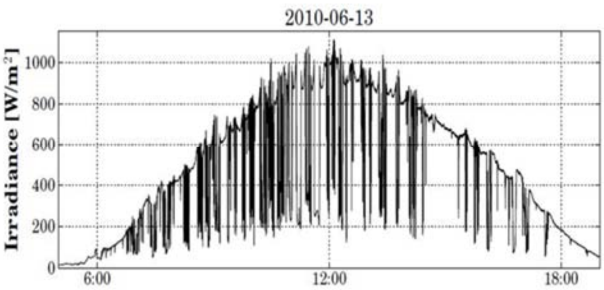

Fig. 1: Solar energy with a lot of fluctuations during one day