ADAPTIVE MONITORING PROGRAM FOR DYNAMIC THERMAL RATING OF POWER CABLES

Heinrich BRAKELMANN, University of Duisburg-Essen, Germany, heinrich.brakelmann@ets.uni-due.de
Holger HIRSCH, University of Duisburg-Essen, Germany, holger,hirsch@ets.uni-due.de
Armin RÖHRICH, University of Duisburg-Essen, Germany, armin.roehrich@ets.uni-due.de
Hans-Peter SCHEIFFARTH, University of Duisburg-Essen, Germany, hans-peter.scheiffarth@ets.uni-due.de
Jörg STAMMEN, University of Duisburg-Essen, Germany, joerg.stammen@ets.uni-due.de

ABSTRACT

Real-time thermal rating of cables has the fundamental problem that not all parameters of the cables and the trench, e.g. material properties and geometry, are well-known along the cable route and, moreover, that they may change unnoticed and undefined along the route and may vary by time.

An RTTR-system has been developed, which is able to compute predictions of heating trends and/or of load reserves respectively, using measured temperatures provided by customary monitoring systems. Critical system conditions can be identified at an early stage and alarm messages can be sent to the operator.

Parameter adaptation is realised by means of an evolutionary algorithm, the continuous execution of which has been proved to be accurate and extremely robust.

Tests have been performed for extreme situations, e.g. for neighboured district heating pipes and cables, which are not initialised in the thermal model, as well as for a consecutive drying-out of the soil. Situations such as extremely bad initial values are analysed and adapted in the model. Forecast errors normally remain below a limit of 1 K.

KEYWORDS

Real Time Thermal Rating, Power Cables, Temperature, Monitoring, Parameter, Adaptation, Prediction

1. INTRODUCTION

Temperature measuring systems for power cables with integrated optical fibres are a well established state of technology. During operation these systems provide information on the present sheath temperatures along a cable route up to approx. 20 km length within an uncertainty of about ± 1 K and a spatial resolution of ± 1 m.

Real time thermal rating (RTTR) means the interpretation of the incoming measured data of the sheath temperature with respect to typical questions as:

- What are the actual conductor temperatures, and where are the hot-spots?
- How long can the present current be transmitted before the condition becomes critical?
- Retaining the present load, which conductor temperature will arise at the end of a given time interval?

Theoretically, questions like these could be answered by means of well-approved thermal models as proposed by International Electrical Commission (IEC) [9, 10]. However, there are some fundamental problems applying the equations given by the IEC to real cable routes: not all of the construction parameters of cables are well-known along the cable route. They may change extremely along the route or they may depend on time. Most of the time-dependent changes are simply not noticeable by the operator, for example the drying-out of the adjacent soil or the subsequent installation of parallel or crossing cables or district heating systems are not noticed.

In a study [1] sponsored by the Deutsche Forschungsgemeinschaft (DFG), the fundamentals for an RTTR-system have been developed. This RTTR-system is able to compute predictions of heating trends and/or of load reserves respectively, using measured temperatures and current loads provided by a customary monitoring system. Uncertainties and variations of the cable route's parameters are considered by means of a continuous parameter adaptation. Critical system conditions can be identified at an early stage and transferred to adequate alerts for the operator.

Before the RTTR is operated, the parameters of the thermal model are identified and initialised as exact as possible by means of a simulation tool using the Finite Element Method (FEM) [2] or, alternatively, by the calculation rules of IEC-publ. 60287 and 853-2. In certain time intervals during operation, all model parameters are adapted to the incoming informations, so that predictions can be made on the base of a well-adapted thermal model. Special temperature-dependencies, i.e. of the cable losses, can be modelled by specific parametric elements, which are also submitted to the optimisation procedure.

Parameter adaptation is done by means of an evolutionary algorithm. The continuous optimisation by this genetic algorithm has been proved to be accurate and extremely robust [1].

Tests have been performed for extreme situations, e.g. for neighboured district heating pipes and cables, which are not initialised in the thermal model, as well as for a consecutive drying-out of the soil. Situations like bad initialisations are as well analysed and adapted by the model, e.g. by initial values deviating by 50 % or more from the actual parameters.