UNDERGROUND POWER TRANSMISSION THEORY AND TECHNOLOGY OF HIGH VOLTAGE CABLES

A THESIS SUBMITTD
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STATEMENT

This dissertaion is submitted to Ain Shams University for the degree of Ph.D. in Electrical Engineering.

The work included in this thesis was carried out by the author in the department of Faculty of Engineering Ain Shams University, from November 1983 to May 1991.

No part of this thesis has been submitted for a degree or a qualification at any other University or institution.

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ABSTRACT

The thesis presents the thermal and the electric stress analysis for single and three core cable joints. Different types of cable joints are analyzed and constructed. An extensive experimental work has been carried out to prove the validity of the technique used in the analysis.

The thermal analysis of two types of cable joints are considered (páper sterling and X.L.P.E). An equivalent circuit for the joint is presented for the heat transfer differential equation. Solution of the heat equation leads to a group of curves illustrating the temperature profile. Studying the effect of joint dimension, dielectric type and joint profile on the temperature level at the conductor surface have been carried out. Due to the variation of the thermal performance of the different material parameters of the joint, an examination of all the effects have been presented. The effects of conductor coefficients, insulation thermal behaviour, sheath conductivity, sheath losses and environment thermal behaviour on the temperature level are considered and computed. The three core cable joint was examined using a proposed superposition method in which the results of the single core joint were used.

The field analysis of single core cable joint is discussed. A charge simulation method is applied to solve

the field analysis of such cable joint. Different field components at different sections and insulation layers are examined. The effect of joint dimension (length and midjoint thickness) on the field components are computed and discussed. The position of the maximum field, which represents the weakest point, inside the dielectric is determined. Design parameters are optimized for low field component.

The verification of the above thermal analysis implies a construction of cable joints and measuring circuit for monitoring the temperature profile inside the joint. A set up of coarse and fine measuring instruments was done using the diode sensors. These sensors were located inside the cable joint at different regions (on the conductor surface, inside insulation and on the cable region). A group of graphs representing the different temperature measurements with the time are sketched. Comparison between the theory and the experimental work is discussed.

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CHAPTER I

INTRODUCTION

I.1. GENERAL

The ever increasing demands for a high current carrying capacity (c.c.c) stimulates the need of investigation and development of high power cables. Consequently of studying the different joints used in electric networks. To the best of our knowledge, numerous problems are still under research. This work presents a theoretical and experimental study of the underground transmission line joints from the thermal and electric field strength points of view.

I.2. SCOPE OF THE THESIS

The main objectives were to clarify the following points for designers and engineers:

1- The thermal behavior inside different joints and its dependence on the geometrical dimensions of the joints and loading currents.

2- Highlight the abnormal faults which may occur due to misdesign of cable joints. Also to clarify some important precautions during the construction of these joints.

3- The potential and electric field strength distributions around the different joint regions which determine the quality of insulation and the locations of possible charge accumulations.

4- Development of temperature measurement unit which enables us to picture out temperature profiles at different locations inside the joint.

I.3. CHAPTER CONTENTS

The thesis comprises six chapters ending with conclusions and proposal for future work.

Chapter 2 includes a survey of the previous work concerning the thermal and electric field distributions. The basis of temperature measurements were surveyed in which primitive and inaccurate devices were used. Also, some efforts have been pointed out to the charge simulation techniques, which have been used in the field analysis in the present.

Chapter 3 contains a theoretical analysis of single and three core cable joints from the thermal point of view. An equivalent circuit for the joint is presented for the heat transfer differential equation. Upon solution of this equation, we get the main temperature relations for both cable and joint. In this chapter, the thermal behaviour of different cable joint components are examined. Conductor, insulation, and sheath thermal behaviour are presented in the form of modified thermal relations. These relations are used for more accurate results. A group of graphs representing the different relationships of the temperature profiles versus the joint dimensions are sketched. Different loading currents are used for convenience.

The thermal analysis of three core cable joint are calculated using the proposed superposition method. This method is adopted in the study of the effect of temperature coupling between the three loaded joints in a closed volume. This proposed method is investigated using an imaginary joint. Factor M representing the ratio between the actual and imaginary joint areas is introduced and calculated.

In Chapter 4 the electric stress analysis for power cable joints is discussed. In this respect, different techniques for solving the Poisson's or Laplace's equation with appropriate boundary conditions are presented. Some of the methods are analytical and the others are numerical. The analytical techniques showed many difficulties due to the severe approximation involved in the solution. On the other hand, the numerical techniques overcome this drawback and they can be safely used with reasonable accuracy. Among the numerical techniques; the ring charge simulation method showed a convenience to our application. The used model searches for the number and location of the ring charges that fits our boundary configuration. Some quality measures were used to test the validity of this model. A set of curves and graphs are sketched to show the potential distribution along many sections and layers. The electric field components along the sections and the ratio of the field components ($\frac{E_{t\ell}}{E_{n\ell}}$) along the layers are also shown. The effect of joint dimension (length and thickness) on the field components inside the dielectric are examined. The positions of maximum and minimum field components are also determined.

Chapter 5 deals with the experimental procedure adopted with temperature measurements at various locations for different cable joints. The effect of loading currents, joint type and sensor locations have been investigated. To the auther's best knowledge, this is the first time that such measurements have been carried out on cable joints. This novel measurements shed more light on temperature profile inside the cable joint. Three types of cable joints are constructed as typical and experimental cases. Single phase (X.L.P.E) and three-phase (X.L.P.E and paper sterling) are used in the measurements. Coarse and fine temperature measuring instrument are used for monitoring the temperature profile and its variation with time. Group of auxiliary equipments are helpfull in the experimental set up. For the temperature time variation and temperature profile, a group of curves are presented for the different joints and currents.