UNIVERSITI PUTRA MALAYSIA

THEORETICAL ANALYSIS ON THE ELECTRICAL PERFORMANCE OF LONG COAXIAL CABLE AT DIFFERENT TEMPERATURE

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By

DEVARAJ KANISIN

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirement for the Degree of Master of Science

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DEDICATION

I dedicate this dissertation to my parents.

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

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November 2006

Chairman : Tang Sai Hong, PhD

Faculty : Engineering

Long coaxial cables are widely used in telecommunication industry and, in oil and gas industry. The telecommunication industry mainly uses these cables for telecommunication between island, countries, etc. While in Oil and Gas Industry, the long coaxial cable plays a central role in production and well maintenance services. The long coaxial cable is attached with the down-hole monitoring equipment and travels to the well of 6 to 7 kilometres depth without repeaters. It is used to supply power to down-hole equipment and also provide communication link with the computer located at the oil rig or ship. During the transmission period, the long coaxial cable is often subjected to temperature differences and external noise interference. Both elements can be considered as interrelated with address to the degradation on the performance of the long coaxial cable. Therefore, the aim of the research is to investigate the performance of the long coaxial cable. The objectives are to analyze and evaluate the performance of the long coaxial cable corresponding to temperature differences, and also to develop and analyze the thermal transfer analysis for long coaxial cable. The methodology used for the research consists of five main stages such as mathematical analysis, designing long coaxial channel model as FIR filter, theoretical analysis, practical analysis and thermal transfer modeling.

The study and the investigation were conducted on the MATLAB by designing a long coaxial channel model. The designed long coaxial model were experimented and analyzed for various length (eg:- 1 km, 3 km, 5 km, 6.096 km which equivalent to 20k feet, 8 km and 10km), various frequencies (eg: 10kHz, 50kHz and 100kHz) and various temperatures (eg: 20°C and 150°C). The experiment was repeated by considering the skin effect. Finally, the thermal transfer formula for the long coaxial cable is formulated and the same experiment above was repeated. In overall, the analysis shows the developed long coaxial channel model has the ability to evaluate and analyze the performance of any long coaxial cable at different temperatures leading to thermal transfer. Conclusively, four internal factors or criteria leading to thermal transfer have been identified, which plays the major role on the performance of the long coaxial cable at different temperatures. They are frequency, temperature, skin effect and length of the long coaxial cable.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

ANALISIS TEORI TERHADAP PRESTASI KABEL PANJANG 'COAXIAL' PADA SUHU YANG BERLAINAN

Oleh

DEVARAJ KANISIN

November 2006

Pengerusi : Tang Sai Hong, PhD

Fakulti : Engineering

Kabel panjang 'coaxial' digunakan secara meluas di dalam industri telekomunikasi serta di dalam industri petroleum dan gas asli. Bagi industri telekomunikasi, penggunaan kabel tersebut adalah untuk menghubungkan antara pulau, negara dan sebagainya. Manakala bagi industri minyak dan gas pula, kabel panjang 'coaxial' memainkan peranan yang penting untuk produksi dan servis penyelenggaraan. Kabel panjang 'coaxial' disambungkan dengan peralatan pemantauan 'down-hole" dan boleh mencecah jarak sehingga 6 ke 7 kilometer ke dalam telaga tanpa pengulang, 'repeater'. Ia digunakan untuk menyediakan perhubungan telekomunikasi dengan komputer yang terletak di atas pelantar minyak atau kapal. Semasa proses transmisi, kabel panjang 'coaxial' selalu dihubungkaitkan dengan perubahan suhu dan interferens bunyi luaran. Kedua-duanya boleh dikaitkan di antara satu sama lain dengan degradasi prestasi kabel dasar laut 'coaxial' tersebut. Oleh yang demikian, kajian lebih difokuskan kepada

penyelidikan di atas prestasi kabel panajang ‘coaxial’. Objektif kajian ini adalah untuk menganalisa prestasi kabel panjang ‘coaxial’ berhubungkait dengan perubahan suhu dan juga mereka berserta menganalisa pemindahan terma melalui kabel panjang ‘coaxial’. Metodologi yang digunakan merangkumi 5 tahap iaitu analisa matematik, mereka kabel panjang ‘coaxial’ sebagai FIR filter, analisa teori, analisa praktikal dan model pemindahan terma.

Pengkajian dan penyelidikan terhadap situasi terbabit dilakukan dengan menggunakan MATLAB dengan cara mereka-cipta model kabel panjang ’coaxial’. Model rekaan ini dianalisa dengan menggunakan beberapa parameter seperti panjang kabel (contoh: 1km, 3km, 5km, 6.096km bersamaan dengan 20k kaki, 8km dan 10km), frekuensi (contoh: 10kHz, 50kHz dan 100kHz) dan suhu (contoh: 20^{o}C dan 150^{o}C). Eksperimen ini diulang beberapa kali untuk mempertimbangkan ‘skin effect’. Akhirnya, formula pemindahan terma bagi kabel dasar laut ‘coaxial’ direka dan eksperimen tadi diulang. Secara keseluruhannya, kajian dan hasil penyelidikan menunjukkan model panjang laut ‘coaxial’ ini mampu menilai dan menganalisa pemindahan terma untuk pelbagai jenis kabel panjang ‘coaxial’. Oleh yang demikian, terdapat empat faktor atau kriteria yang disabitkan dengan pemindahan terma telah dikenal pasti, yang mana ia memainkan peranan yang penting di dalam prestasi kabel panajang ‘coaxial’. Faktor-faktor tersebut adalah frekuensi, suhu, ‘skin-effect’ dan panjang kabel panjang ‘coaxial’.

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I certify that an Examination Committee met on 17th November 2006 to conduct the final examination of Devaraj Kanisin on his Master degree thesis entitled "Theoretical Analysis on the Electrical Performance of Long Coaxial Cable at Different Temperature" in accordance with "Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

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This thesis submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the Supervisory Committee are as follows:

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Date: 10 MAY 2007

DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.

DEVARAJ KANISIN

Date: 6 APRIL 2007

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CHAPTER 1

INTRODUCTION

1.1 Preface

This chapter recalls the scientific environment of this thesis with a non-exhaustive enumeration of prior work and existing solutions in the major areas covered. It highlights the research aims, objectives, scopes and organization of the thesis. Long coaxial cables are widely used in telecommunication industry and, oil and gas industry. The telecommunication industry mainly uses these long coaxial cables for telecommunication between islands and countries. While, the oil and gas industry use these long coaxial cables on the oil rig or ship to supply power and communications to monitoring equipment in the subsea environment and down-hole wells. This type of long coaxial cable is also known as wireline in oil and gas industry. This research will emphasize and focus on the oil and gas industry. In addition, the research will evaluate and analyze the performance of the long coaxial cable at different temperature leading to energy transfer.

1.2 Problem Statement

In Oil and Gas Industry, the long coaxial cable plays a central role in production and well maintenance services. This cable is also known as wireline cable. The current well known cable providers are The Expro Group and Schlumberger (The Expro Group Ltd, 2006 and Schlumberger Ltd, 2006). This cable is attached with the down-hole monitoring equipment and travels to the well of 6 to 7 kilometres depth without repeaters as illustrated on the Figure1.1.

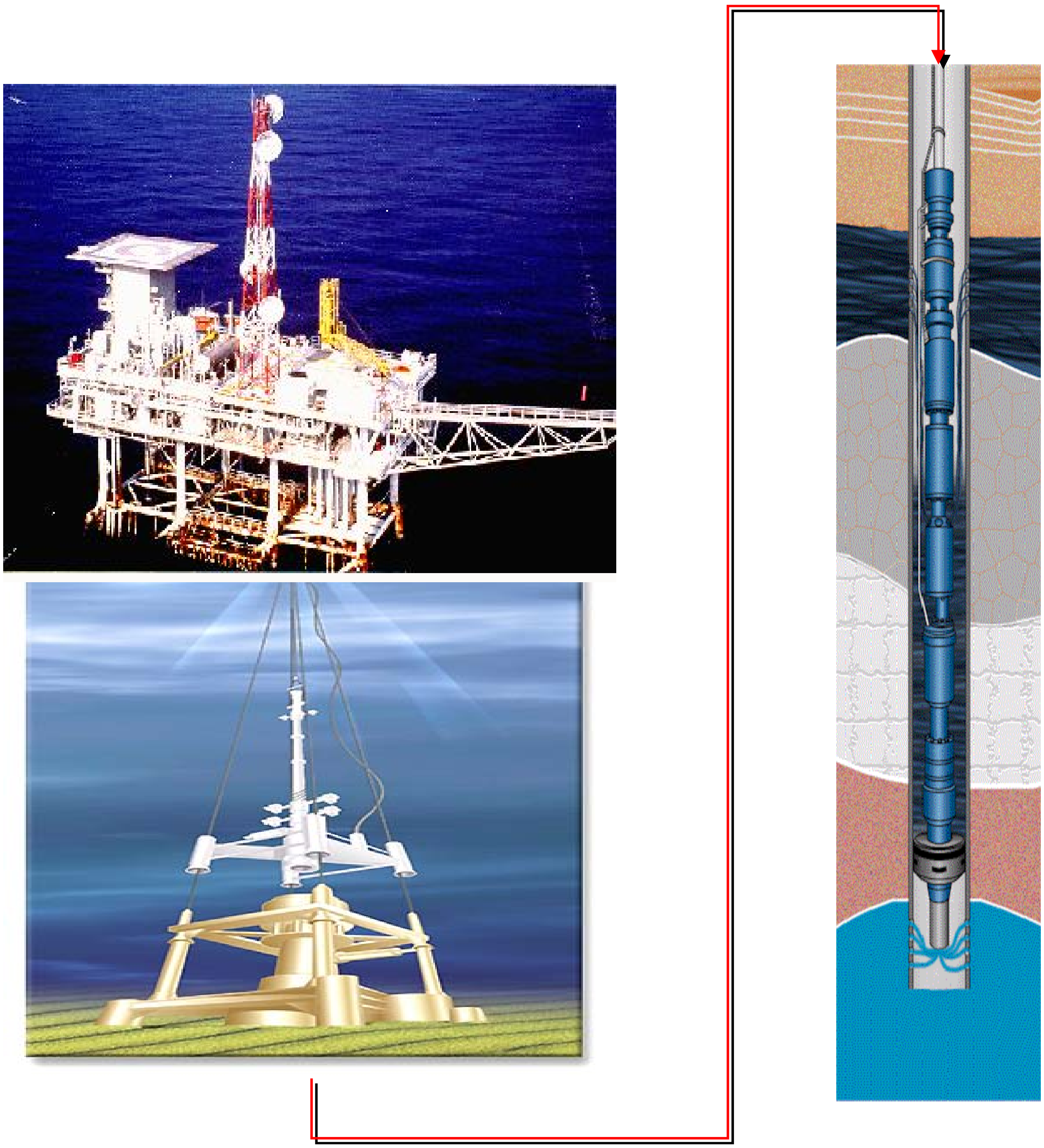

Figure 1.1: Long Coaxial Cable and Offshore Environment

This cable is used to supply power to down-hole equipment and also provide communication link with the computer located at the oil rig or ship. The down-hole monitoring equipment is assigned to measure the temperature and pressure of the well. In addition, it is also used to scan and detect the cracks on the surface of the casing by using gamma-ray technology. This information will be transmitted via the long coaxial cable to the computer at the oil rig or ship. During the transmission period, the long coaxial cable is often subjected to temperature differences and external noise interference (Richardson, 2001). Both elements can be considered as interrelated among them with address to the degradation on the performance of the long coaxial cable (Kanisin, 2002).

Therefore, this research will be focused on investigating the performance of the long coaxial cable corresponding to temperature differences. It will be emphasized on finding the possible factors or criteria that degrade the performance of long coaxial cable.

These factors are determined so that, the performance of the long coaxial cable can be evaluated and improved. Furthermore, this finding has not been done by any researcher so far. In addition, the research uses a new concept of evaluating the performance by using temperature differences which lead to energy transfer on the long coaxial cable. Firstly, the long coaxial cable is analyzed using transmission line theory. Then, a channel model is developed to evaluate the performance corresponding to temperature differences and determine the factors lead to energy transfer. Finally, the energy transfer formula is formulated and the energy transfer analysis is performed. This new concept above basically, has combined the electrical and electronic technology with computer software technology to solve a mechanical problem. Conclusively, this concept has merged and integrates the technologies above together to produce better performance of the long coaxial cable.

In overall, this research will contribute towards the process of enhancement and further development of the long coaxial cable focusing on the performance and emphasizing on the possible factors or criteria corresponding to temperature differences leading to energy transfer on the long coaxial cable. The energy is referred to the electrical energy which has been transferred mainly to heat energy.

1.3 Research Aim and Objectives

The aim of this research is to investigate the performance of the long coaxial cable. The objectives are:

i. To analyze and evaluate the performance of the long coaxial cable corresponding to temperature differences.
ii. To develop and analyze the energy transfer analysis for the long coaxial cable.

1.4 Significance of the Research

The primary motivation for this research stems from finding the possible factors or criteria corresponding to temperature differences that lead to energy transfer on the long coaxial cable. These factors are determined so that, the performance of the long coaxial cable can be evaluated and improved. Furthermore, the energy transfer on the long coaxial cable can be minimized based on the scenario by manipulating the factors values in order to get the best performance of the long coaxial cable. In addition, the research uses a new concept of evaluating the energy transfer on the long coaxial cable.

1.5 Organization of the Chapters

The chapters of the thesis are presented and organized as below:-

a) Chapter 1 recalls the scientific environment of this thesis with a non-exhaustive enumeration of prior work and existing solutions in the major areas covered. It highlights the research aims, objectives, scopes and organization of the thesis.

b) Chapter 2 describes brief reviews on the cables. It also covers some of the previous research on different types of cable. In addition, the chapter also emphasized on the latest findings related to the research.

c) Chapter 3 describes about the methodology used for the research. It consists of five main stages such as mathematical analysis, designing long coaxial channel model as FIR filter, analysis without skin effect, analysis with skin effect and energy transfer model.

d) Chapter 4 describes the mathematical analysis of the research. The primary and the secondary parameter of the long coaxial cable have been analyzed. The transmission line theory derived was based on the long coaxial cable structure. The derived theories were used to design the long channel model on MATLAB.

e) Chapter 5 describes about the modelling of the long coaxial channel model. The long coaxial cable is unlike a filter circuit, which is a "lumped network" as individual components appear as discrete items. The long coaxial cable can be represented as a digital filter. Therefore, a channel model of a long coaxial cable was developed in the form of a FIR Filter using MATLAB in order to analyze and evaluate the performance corresponding to temperature different which leads to energy transfer on the long coaxial cable.

f) Chapter 6 describes the results and discussion part of the thesis. It is divided to three important stages. Below are the summary of each stages:-

    i. Analysis without skin effect:- To experiment and analyze the long coaxial cable on MATLAB for various length (e.g: 1 km, 3 km, 5 km, 6.096 km which equivalent to 20k feet, 8 km and 10 km), various frequencies (e.g: 10 kHz, 50 kHz and 100 kHz) and various temperature (e.g: 20°C and 150°C).

Note: Three criteria have been identified, which plays the major role on the performance of the long coaxial cable. They are frequency, temperature and length of the long coaxial cable.

ii. Analysis with skin effect:- To consider the skin effect on the long coaxial cable and repeat the experiment and the analysis as on (i) above.

Note: The performance of the long coaxial cable was good at frequencies of 10 kHz to 20 kHz, but the skin effect of the cable degraded the performance of the cable above 20kHz.

iii. Energy Transfer Model:- Develop and analyze the energy transfer analysis for the long coaxial cable on MATLAB.

Note: In overall it shows that, heat generated degrades the performance of the long coaxial cable. It shows that factors such as higher frequency or longer cable or higher temperature plays it role with the skin effect of the cable. Therefore, it can be concluded that, all these factors plays an important role on the performance leading to energy transfer on the long coaxial cable.

g) Chapter 7 briefly summarizes and concludes the thesis, contribution of the research and their implication for future research.