THERMAL AND ELECTROMAGNETIC MODELLING OF POWER UMBILICALS

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ABSTRACT

This paper describes the most important steps in the design of a 12 km umbilical feeding two subsea motors of about 2 MW. A specific umbilical design is evaluated in detail. The highest temperatures occur inside the platform's air filled J-tube. The temperature of the fibre optic and filler elements was close to the limit. The most favourable power conductor arrangement has been determined. The cross talk in the low voltage circuits is within acceptable limits. The only potential problem is air gap torque oscillation due to the currents in the other circuit. Based on results obtained, it was possible to optimise the umbilical design.

KEYWORDS

Umbilical, design, thermal rating, cross talk, single layer, motor drives, torque oscillation

INTRODUCTION

The development in oil and gas production is more subsea processing which requires electrical power supply from platform or onshore installations by umbilicals. The umbilical often includes power circuits, signal transmission circuits, fibre optic cables and steel pipes containing chemicals (hydraulic oil, methanol). There are various umbilical configurations depending of the field requirements. A single layer design is often preferable from a mechanical point of view but there is a potential problem due to the inductive coupling between conductive elements. The coupling can be reduced to an insignificant level by a suitable multilayer design.

Comprehensive electrical and thermal analyses are required to make sure that the operating temperature and electrical performance are within acceptable limits. The thermal analysis must assure that the maximum operating temperature of the various elements is within acceptable limits. A "worst case" configuration for the temperature conditions must be defined as a base for the analysis. The maximum temperature occurs often at "hang off" on the platform, where the umbilical may be located inside an air filled I- or J-tube. The submerged part of the umbilical may be covered by seabed sediments, rock dumped or trenched. These different boundary conditions along the umbilical must be considered in the thermal analyses.

Long umbilcals give considerable voltage drop and electrical analyses require accurate data for the series impedance and the capacitance of the electrical cables in the umbilical. The frequency dependence of the series resistance and inductance must in some applications be taken into account. The series impedance cannot be determined by analytical formulae due to the complex geometry of the umbilical. Finite element methods have during the last decades proven to be a suitable tool and the software, [1], is used in this work. The resistance depends on the temperature and the applied software is able to perform a combined thermal and electromagnetic analysis.

Cross talk between power cables and signal cables must be considered for elements in the same layer and to some degree between elements in different layers.

SYSTEM DESCRIPTION

The actual system has to be analyzed in detail when designing an umbilical and a particular system is therefore selected in this paper.

The actual system consists of two subsea motors that are operated independently. Each motor is fed by an individual VSD located at a platform 12 km away as shown in Fig.1. The main focus in this paper is on the common umbilical between the topside installation and the subsea installation. Some simplified introductory analysis showed that it reasonable to use 240 mm^2 power conductors as shown in Fig.1.

UMBILICAL DESIGN

Fig.2 shows an initially proposed umbilical configuration based on the required number of power conductors, fibre optic cables, quads for LV control and steel pipes. All cables and pipe lines are located in one layer, which implies that their relative position is not altered along the umbilical. The one layer design is favourable from a mechanical point of view but there is a potential problem regarding the inductive coupling between the conductive elements.

The particular umbilical design is based on a self-supporting elements principle. This means that the design, materials selection and fabrication ensure that fibre cables, quads, power cables, steel tubes (for fluid/hydraulic supply) and weight/strength elements (if required) are embedded in plastic profiles and twisted in a certain way, so that the overall strength capability and proper dynamic behaviour is ensured based on friction, twisting forces, and axial stiffness / weight. The basic idea is to use steel tubes as strength members, and this saves weight since external steel armouring is not required. The friction between the plastic profiles and the various elements ensures that cables in many cases will not require any kind of armouring, even at relatively deep waters. In cases where extra weight or strength is required, steel wires or carbon fibre rods can be added. Such power umbilicals are typically used for subsea flow line heating and subsea multiphase/water injection pumps and gas compression.