Power Cable Analysis

Power cables, such as those found in subsea oil field operations, carry megawatts of power to a variety of mission-critical pumps and motors. Several cables can be bundled together into umbilicals that supply power to separate loads from a single source. Since these cables can be very costly to design, manufacture and maintain, the analysis underlying their specification must be thorough and accurate.

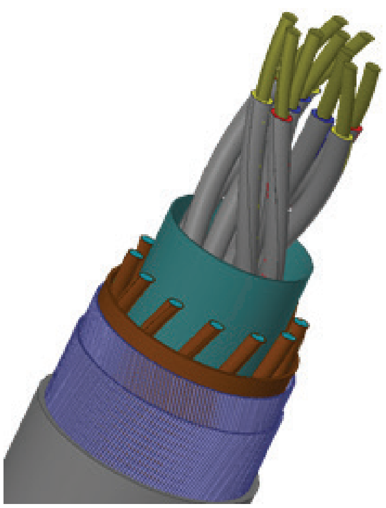

Figure 1. Cable umbilical showing power conductors in the center with shields, hydraulic tubes, and armor strands

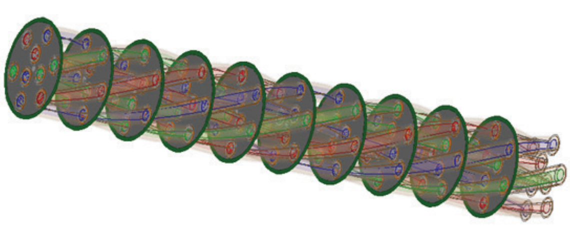

Figure 2. Parametric cross-sections along the length of the cable used for the 2D analysis

Products Used
ANSYS® Maxwell®, ANSYS Q3D Extractor®, ANSYS Simplorer®, ANSYS Workbench™, ANSYS Mechanical ™, cable design kit

Keywords
Cable, power transmission, umbilical, subsea, systems simulation, circuit extraction, thermal modeling

Introduction

Power cable bundles include several sets of three-phase power groupings carrying several hundred amps at several thousand volts. The main power conductors consist of three separate phases of stranded copper, semiconducting wraps around the conductors to mitigate unintended accumulations of charge, and high-strength dielectric insulation with individual shields to equalize and normalize the electric fields around high-voltage conductors. The entire cable bundle can be enclosed in steel strands that act as armor against unintended piercing. Each of the conductors can be slowly twisted about themselves and the cable bundle's center to create a more-structurally stable package.

Types of analysis typically performed for cables include:

- Cable losses due to frequency and proximity of conducting objects
- Cable electrical circuit (RLCG) and transmission line parameters (characteristic impedance, propagation velocity)
- Field visualization (flux density, electric field intensity, current density)
- Effects of twisting on cable behavior
- Heating and temperature due to rated loads or unintended transients, such as short circuit
- Effects of loads run at different frequencies on bundle
- Effects of external seawater and flooding on cable

Parametric Analysis

Most cable analysis is done in 2-D, so the 3-D effect of twisting is accounted for by using parametric analysis of the axial position of the cable to capture the averaging effect of all possible twisting positions (Figure 2). Additional parametric analysis can include losses as a function of the fields; input currents are also of interest, as are cable material and geometry. High-performance computing (HPC) can accelerate evaluating the large number of parameters involved in cable analysis.

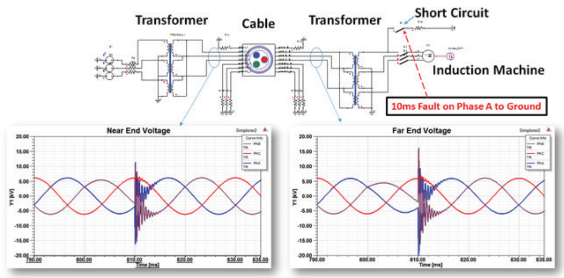

Figure 3. Circuit showing the effect of a 10ms short on a single phase of a motor load using several hundred feet of cable.

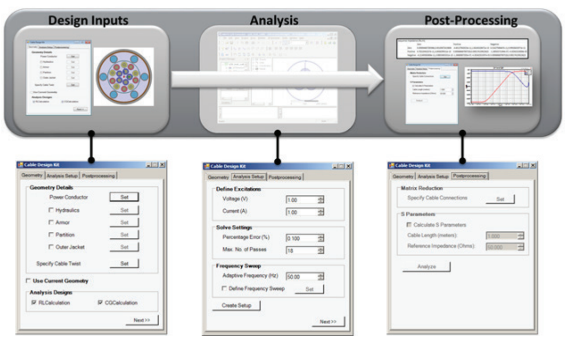

Figure 4. Process automation using customizable design kit for analysis

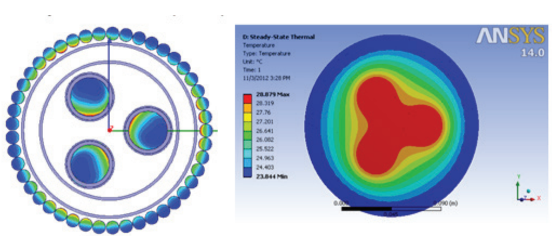

Figure 5. Steady-state losses (left) and temperature (right) for three-phase cable

System Integration

The cable can be represented in a circuit simulation using ANSYS Simplorer to account for various voltage excitations, such as square or sinusoidal. This helps to measure crosstalk or the effect of load transients, as seen in Figure 3. Circuit models are frequency dependent over a broadband range of frequencies to capture the harmonic content of any reasonable signals, and the models are transmission line-capable to describe spatial wave effects along the cable's length.

Cable Design Kit

Using the cable design kit as an add-on to ANSYS Maxwell or ANSYS Q3D Extractor, you can greatly compress the process — from problem definition and analysis to results extraction, shown in Figure 4. The design kit automates the input of common parameters for a set of typical cable configurations, generates all models needed for analysis, then analyzes and extracts the desired data. This process can greatly facilitate and automate the generation of parametric twist for 2-D models. A user can easily customize the design kit for any cable type of interest — it is written in Python, a widely used scientific computing language, which makes it easy to modify as needed.

Multiphysics

Electromagnetic losses can be used to determine the temperature within the cable by coupling with ANSYS Mechanical. The loss distribution is coupled spatially to capture any non-uniform heating effects. The effects are bidirectional: If the temperature change is large enough, the effect on electrogmagnetic resistance will automatically be determined. Figure 5 shows steady-state losses and temperature from a 200 A load.

Summary

ANSYS provides a robust solution for designing power cables used in subsea oil fields and other high-power applications. A comprehensive and automated multiphysics workflow provides ease of use along with accurate electromagnetic, circuit and thermal analysis of the cable prior to manufacture.

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