Direct Electrical Heating

Flow assurance is often vital to successful development of deepwater fields. As the industry explores deeper-water wells, longer transportation distances have become more common; this presents a specific challenge for subsea production flowlines. The combination of low temperatures and high pressure present on the seabed can result in hydrate formation or wax deposits inside flowlines, limiting or even blocking the flow. Some methods for flow assurance rely on thermal insulation and chemical injection. But the disadvantage is that they require large amounts of chemicals to be injected into the well stream, which then must be removed topside, increasing running costs and environmental risks.

Another possible approach for flow assurance involves controlling the temperature on the pipe directly. Electric alternating current can be passed through the pipe wall; the pipe acts as a conductor in a single-phase circuit and, therefore, heat is generated to maintain the fluid´s temperature above critical values, usually around 25 C.

Keywords

Electric heating, pipe heating, subsea, power system, flow assurance, direct electrical heating (DEH)

Products Used

ANSYS® Maxwell® 15.0, ANSYS Simplorer® 10.0, ANSYS Fluent® 14, ANSYS Workbench™ 14

Description

Electric heating of pipelines is attractive for long step outs, as running costs can be considerably lower compared to the expense of using chemicals. Three possible methods to heat pipe with electric current (Figure 1) are:

- Pipe in pipe: closed-current loop into one pipe and return on other
- Open loop: current loop into cable (piggyback cable) and return in pipe and seawater
- Induction: three-phase cable with no return path, induced currents only

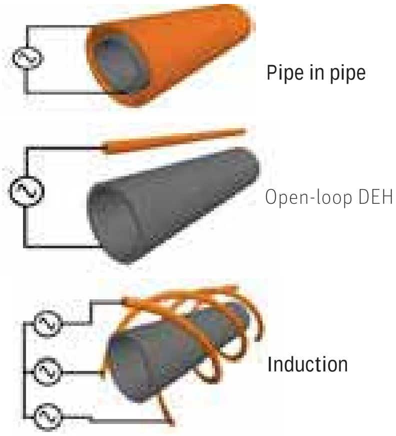

Figure 1. Various direct electrical heating configurations

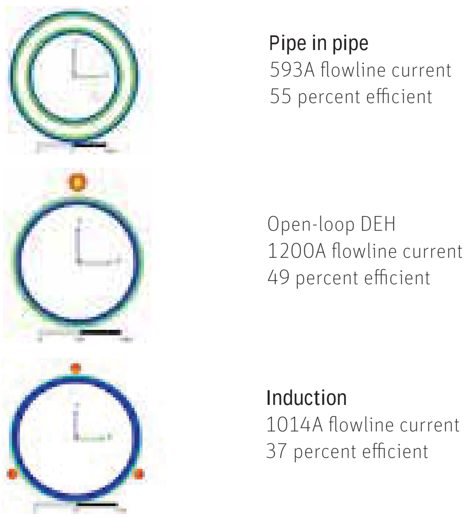

Figure 2. Loss distributions with efficiencies for various DEH configurations excited to 85 W/m on pipe

The efficiency of total heating to dissipated heat on the material carrying pipe varies for each of the above methods. Figure 2 shows results from 2-D electromagnetic simulation in which a power density of 85 W/m is used to heat the pipes. The current is varied until the same 85 W/m is achieved in each design, and the efficiency is measured by the ratio between pipe losses and total losses.

There are several challenges in electrical design of a DEH system, such as determining the power loss for a given input current and determining DEH electrical impedance for rating the top-side power supply.

Applying ANSYS Maxwell, a user can:

- Perform electromagnetic simulations of a 3-D model or 2-D cross section of the pipe cable considering nonlinear and frequency-dependent characteristics, such as skin and proximity effect for determining power-loss field distributions
- Automatically extract the impedance matrix of a given cable structure for use in circuit simulation with the top-side power supply
- Parameterize geometry, input excitations, or materials, then sweep these variables to calculate losses vs. parameters curves, and compare different topologies searching high-efficiency designs

Once the cable topology and power ratings are identified, the power supply needs to be designed to guarantee that the DEH system will receive the correct amount of current. ANSYS Simplorer can be used to determine the necessary supply voltage considering the DEH impedance, and then size and rate passive electrical components to ensure correct phase balancing and power factor correction. Figure 3 shows a basic schematic for a given supply-DEH structure. A load-balancing network and power factor correction capacitors are designed to distribute current among phases and to increase power factor close as close to 1 as possible, respectively.

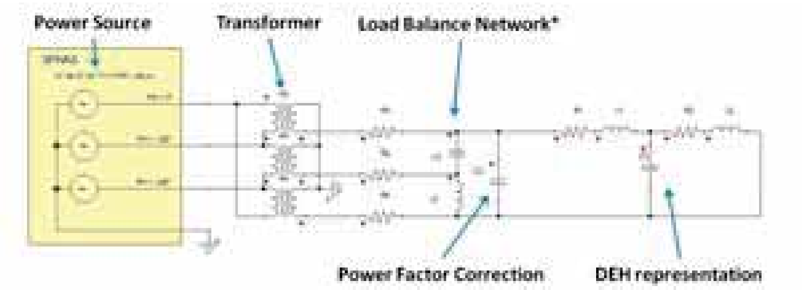

Figure 3. Circuit diagram for power distribution network with load balancing and power factor correction for single-phase open-loop DEH configuration

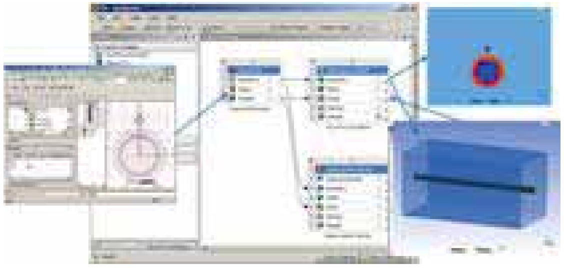

Figure 4. Multiphysics schematic in ANSYS Workbench for coupling electromagnetic losses to fluid flow for heat transfer

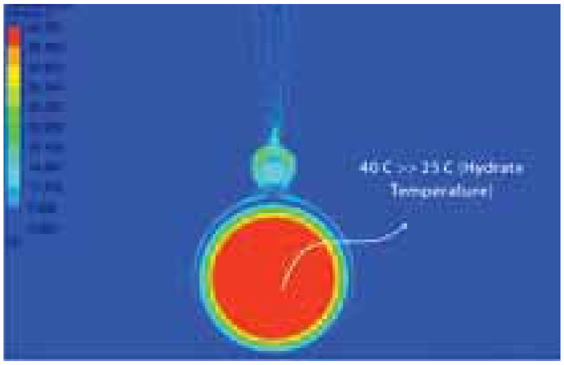

Figure 5. Temperature with surrounding seawater convection for open-loop DEH configuration

For a final verification of temperatures, including heat transfer into the surrounding seawater, a computational fluid dynamics model of the pipe can be coupled with the electromagnetics to predict the flowline temperature. Using the localized loss density calculated by the electromagnetic solver, ANSYS Fluent simulates the final temperature considering material properties for all solid and fluid regions. Figure 5 shows the resulting steady-state temperature for a given current and ambient conditions.

ANSYS coupled-field solutions are useful for efficiently designing electrically heated flowlines and elevating multiphysics simulation to a higher level. Using its best-in-class features of electromagnetics and fluid dynamics software, a user can to examine field distribution, compare design efficiencies, configure the best options for the power supply system, determine optimum power distribution with different flow conditions, and perform studies on transient start-up or shut-down operations.

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