Simulating extreme environmental conditions for control units

Intelligent Drilling

Temperatures of up to 200 °C and pressures of up to 1,500 bar, all this thousands of meters beneath the earth's surface – these are potential conditions in mineral oil and natural gas reservoirs. Because electronic controllers must be robust and reliable in this environment, Schlumberger uses dSPACE's MicroLabBox to simulate these harsh conditions during development.

Deeper, wider and faster – these are the requirements for drilling wells to develop new mineral oil and natural gas fields. At the same time, the geological conditions are becoming increasingly complex, because easily accessible oil and gas reservoirs have already been exploited. This raises the demands for drilling technologies. Schlumberger, one of the world's leading service providers for exploration and production in the oil and gas industry, uses innovative drilling technologies to access reservoirs that could not be exploited until now. The company invests intensively in research and development to improve the efficiency and reliability of the tools used.

Detour to Destination

For the last few decades, with advancement in drilling technologies such as rotary steerable systems and monitoring while drilling systems, mineral oil and natural gas were no longer extracted with only the classic vertical drilling methods. Increasingly, directional and even horizontal drilling are being used. Although the latter two technologies are more complex, they increase the yield and allow for greater flexibility with regard to the drilling location. This means reservoirs that are normally hard to reach can now be exploited. Therefore, one production facility that allows exploitation of multiple wells or different reservoirs is often enough. This reduces costs significantly, especially in offshore drilling (figure 1). Drilling along severe side slope poses risks associated with horizontal directional drill (HDD) since you cannot run in defined rock layers or soil strata. It is difficult to drill the borehole when intercepting strata at low angles, which can create deflection of the borehole and steering misalignment. However, this means the drill string must be stopped whenever there is a change of direction. For "intelligent drilling", multiple adjustable bias units are placed close to the drilling head (steering actuator pads, figure 2). To ensure that the adjustment leads to the required drilling direction, sophisticated control electronics are used.

Information from the Depth of the Earth

In addition, these drilling systems can be equipped with modules that gather various types of information about the surrounding rock and fluids during the drilling process (logging while drilling, LWD). In previous years, only data such as pressure and temperature could be determined (measurement while drilling, MWD). To improve the existing drilling technology, Schlumberger uses a test environment that consists of dSPACE tools with which the control algorithms for the drive of the steering actuator pads at the drilling head can be

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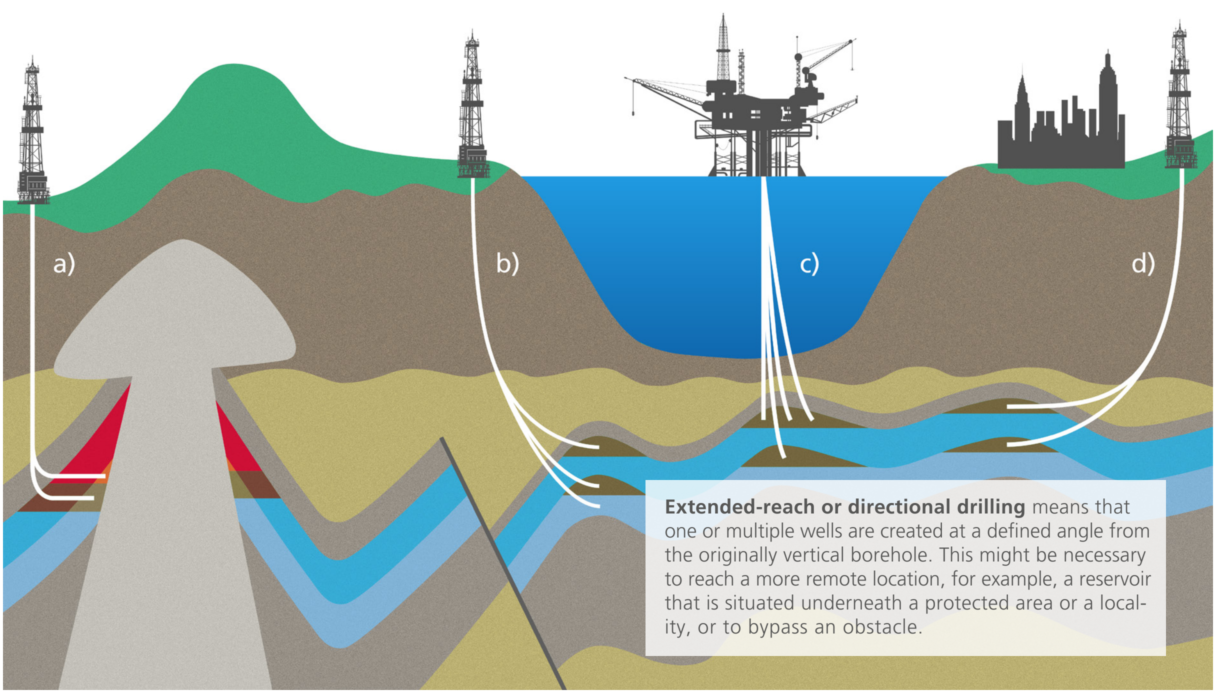


Figure 1: Examples of directional wells (red: natural gas, dark brown: mineral oil):
Bypassing a geological obstacle (a), production from reservoirs that are not vertically below a production facility (a, b, d), production from multiple reservoirs through one borehole (a, b, c, d), using multiple wells with one production facility (c).

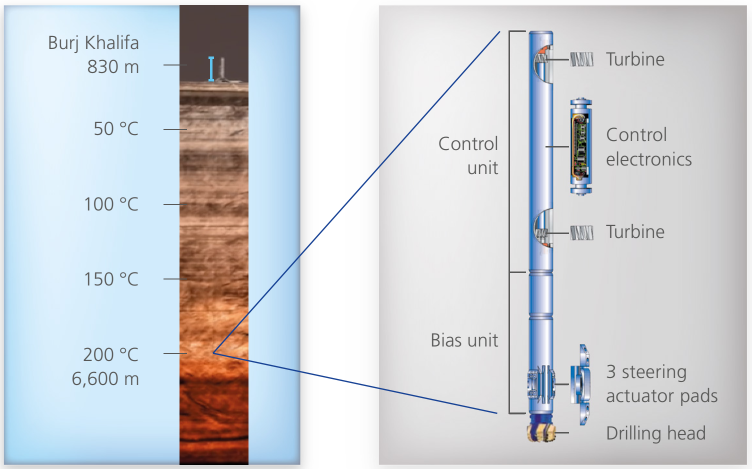
developed and optimized in the lab under the same thermal, pressure, and working fluid conditions as the while-drilling environment. "This testing platform provides engineers with real-time information that lets them make important decisions with regard to the continued drilling path or zoned production tests," says Dr. Mustafa K. Guven, Electrical Machinery and Controls Division at Schlumberger.

The Environment – Pressure, Heat, Vibrations

"One of the biggest challenges when accessing oil and gas reserves are the extreme environmental conditions in the reservoirs," Guven resumes. Heat, pressure, and vibrations as well as geomechanical stress influence the durability of the expensive electronic equipment. Several data acquisition modules that are attached close to the drilling head transmit data to report its position and location to the surface in real time and enable the drilling team to precisely drill towards the reservoir. For this, the reliability of these data acquisition modules and the electronic control units (ECUs) is decisive.

If control units or sensors fail during the drilling process, either the drill string has to be pulled out of the borehole, which is costly and time-consuming, or the data is so inaccurate that the team will not be able to reliably get to the reserve. Additional costs reaching millions of dollars or the complete failure of the drilling program become a possibility.

Figure 2: Position of the control electronics and the control pads near the drilling head.



Directional Drilling – Getting to the Point with dSPACE

The Challenge:
Extreme conditions in an environment that is not accessible require robust and reliable equipment that is maintenance-free during operation.

The Solution:
Creating a test platform for control unit development that can simulate the conditions of a reservoir during an active drilling process in the laboratory.

The Benefit:
Control units can be developed and tested without risk and without cost-intensive disassembly.

Testing in a Reservoir Environment

To reduce the risk of losing time and incurring exorbitant costs, Schlumberger uses engineering methods, such as the failure mode effects analysis (FMEA), reliability qualification testing (RQT), and computer simulation. These methods help predict the maintenance requirements of systems, components, and prototypes. Schlumberger is currently developing a prototype drive for the laboratory, the D3S (figure 3). D3S stands for DEMT Development Drive System, where DEMT means Down-hole Electric Machine Technology. The drive system is intended for supporting the development and test phases of individual components and complex systems. D3S is a flexible drive system with state-of-the-art electronic hardware. It includes a dSPACE MicroLabBox as the tool for rapid control prototyping (RCP). "The system offers a platform for testing and optimizing the controller software as well as for setting parameters in real time," explains Guven.

Building an Efficient Test Platform

By building an efficient test platform, Schlumberger achieves multiple goals at the same time. The platform determines the performance and the behavior of engines in the environmental conditions of a mineral oil or natural gas reservoir. Among others, parameters such as torque, rotational speed, and efficiency can be evaluated. The platform also tests and evaluates the sensors of the engine drive and generates algorithms for developing the model-based control unit. According to Dr. Guven, this is to help the engineers ensure that validation is performed during the early phases of tool development, before the electric drive components become

> "Several kilometers below the earth's surface, the reliability of all components is vital, because every failure costs millions of dollars. dSPACE MicroLabBox emulates the real, often harsh, conditions at great depths and thus supports testing and validating the controller during development."

Mustafa K. Guven, PhD, Principle Engineer at Schlumberger Ltd., Sugar Land, Texas, USA, is responsible for developing a new tool for testing machines and generators as well as for writing the relevant control algorithms as part of the Electrical Machinery and Controls – 3MT project.

available. The MicroLabBox not only serves as a main I/O interface for communication between peripherals (actuators, sensors, etc.), it is also the central computation unit for executing the controller software. dSPACE Real-Time Interface (RTI) is used for the model-based I/O integration and dSPACE ControlDesk helps access the real-time applications during run time.

Tackling Test Obstacles

Before the D3S drive system, Schlumberger had no standard platform for testing new electromechanical drive systems. There was also no defined optimization process that helped coordinate individual tasks. In addition, only few control electronics were available to support the evaluation and validation of new concepts and additional systems. The D3S, equipped with a MicroLabBox, made it possible for Schlumberger to successfully tackle many of these challenges. The D3S is currently in its development phase. Once this system is proven, it will be employed in every project that requires an electromechanical drive system. ■

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Figure 3: System configuration of the D3S with the MicroLabBox as its central communication system. Signals that are used for spatial orientation (incremental encoder, Hall sensor, torque transducer, and resolver) are digital, signals for temperature, voltage, and electrical current are analog.