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Fibre Optic Reservoir Monitoring: Field Trials and Results

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Abstract

A fibre optic multi-component ocean bottom seismic system, for permanent installations, has been developed and pilot test data from the system have been acquired and subject to analysis. The cable system contains high reliability fibre optic three-axis (3C) accelerometers and hydrophones, fiber Bragg grating (FBG) based sensor network and an electro-optic interrogation and read-out system for the sensors. The sensors, fiber network, in-sea components and the topside instrumentation system have been subjected to significant qualification programs. The results of analysis of the data from the pilot tests confirms the systems high degree of vector fidelity, high signal-to-noise ratio, very good ground-station coupling, reliability and excellent response in general to wave modes in connection with ocean-bottom seismic. Fibre optic sensor technology, for applications within permanently buried seismic acquisition systems, is viable and is now introduced to the industry. These systems can potentially be very valuable tools for the oil companies in their work for optimization of hydrocarbon recovery and production throughout the life of a field.

Introduction

Due to their passive nature, fibre optic sensors offer a huge reliability potential for several in-well applications including seismic imaging¹⁻³. The environmental conditions are challenging with temperatures possibly up to 200°C and pressures exceeding 1000 bars. Conventional electrical sensors will always suffer in reliability at such extreme temperatures and pressures. Over the last 20 years, increasingly sophisticated optical instrumentation for permanent in-well monitoring has been made available to the reservoir engineers – including pressure, temperature, flow and seismic measurements. A successful installation of the fibre optic permanent borehole seismic system in an offshore production well has been executed at Valhall in the North Sea⁴.

In connection with time-lapse seismic, repeating shot and receiver positions are important in order to minimize noise in connection with detection of production induced 4D signals. In towed marine surveys both receiver and source positions cannot be repeated completely, but permanent seismic cable installations have eliminated the receiver repeatability problems.

In addition to repeatability, the performance of the receivers over time is also highly important. A permanent seismic installation is expected to be giving on-demand data with higher resolution and greater fidelity over the life of the field⁵. Both for saving cost and avoid risky in-sea maintenance operations, it is crucial that the receivers and peripheral equipment are stable and that no significant changes over time will occur which can be misinterpreted as production related effects. This will enable the reservoir management to continuously acquire low cost high quality repeated surveys, to be used in 4D analysis during the production period of the reservoir. In addition, such installations can be used in between 4D surveys in passive mode to image micro-seismicity⁶ in the reservoir during production.

All sensor systems applied so far in connection with life-of-field seismic projects have been electrical. Electrical sensors may degrade over years and complete failure of electrical components which are trenched into the sea floor is a possibility. The result of this is that the field operator will have to retrieve and replace the damaged module/array in order to avoid coverage holes in the repeated seismic data to be used in the interpretation process of 4D effects.