Fibre optic permanent reservoir monitoring breakthrough

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Abstract

The largest ever offshore fibre optic permanent reservoir monitoring installation was successfully finished in October 2010 at a producing oil field in the North Sea. All the channels are working and recording seismic traces (i.e. channel status is 100%), which is a great achievement for such large seismic spread in the marine environment. The decision to install an optical sensing system was mainly due to the design life expectancy of the fibre optic system. The installation of the seismic system is expected to contribute to enhancing the remaining production, which will extend the life of the field and ensure optimal location of future production wells.

We advocate optical sensing technology as an important part of the toolbox for maximizing field production in a cost efficient way. The “optical oil field” may represent the next significant step in technology for reservoir monitoring and improved hydrocarbon recovery.

Introduction

With maturing basins and ever deeper and more complex frontiers, the importance of extending the life of and maximizing recovery from producing fields has never been greater. Hydrocarbon exploration and development has seen several step-change technologies during recent decades and time-lapse, or 4D, is a seismic method whose value is now recognized worldwide. In fact, in mature basins such as the North Sea, Gulf of Mexico and Brazil; 4D seismic reservoir monitoring is seen as mandatory by some operators.

Where frequent surveys will be required for monitoring the reservoir over its lifespan, a permanent receiver array installation using Ocean Bottom Cables (OBC) is the most cost-effective solution. The additional benefits of such an installation using fixed trenched cables include full freedom in azimuth and offset, better receiver coupling and repeatability, low background noise which together lead to increased sensitivity to production effects in the reservoir.

One of the bottlenecks for marine 4D seismic monitoring is vessel availability. However, with a permanent receiver array the timing of monitor surveys can be far more flexible and frequent since only a source boat is required, thus improving turnaround and providing “seismic on demand”. In addition, between surveys passive seismic monitoring can be conducted to “listen” for the micro-seismic events in the reservoir and overburden due to stress changes and pressure depletion.

The interest in fibre optic technology has come from the telecom industry which was revolutionized by the significant development of fibre optic components for data transmission over the last 40 years. This technology has established a base for advanced sensing systems where fibre optic components are used for both data transmission and sensing. We are now starting to see the impact of this technological development in the seismic industry (Eriksrud et al. 2009 and Eriksrud 2010).

A key advantage of the fibre optic sensor technology is that it provides greater durability and reliability compared with systems that use electronic sensors. The longer life-time of components, high sensitivity, high dynamic range, lower intrinsic noise, lack of corrosion of sensing components, fewer parts and higher reliability all give the fibre optic system an advantage over electronic systems. The goal is that fibre optic sensors provide data over the life of the field without the need for costly recovery, repair and re-trenching, so that there are lower maintenance costs. In addition it is potentially cheaper to produce fibre optic systems. All these factors make the fibre optic technology the perfect choice for life-of-field seismic (LoFS) systems which are aimed to operate for several years.

The development phase of the fibre optic system has involved several small-scale tests and climaxed in connection with the installation of a full-blown monitoring system of 200 km of trenched fibre optic seismic receiver cables over the Ekofisk field in Norway in 2010. The installation of this seismic system is expected to contribute to enhancing the remaining production, which will extend the life of the field and in addition ensure optimal location of future production wells.

North Sea installation campaign

The excellent performance of the fibre optic system has been verified in several small-scale field tests (Thompson et al. 2006 and 2007; Langhammer et al. 2008). A test system of 10 km cable was successfully installed and qualified at the Snorre field in the North Sea in 2008 (Morton et al, 2009a and 2009b). The main goals of the project were to achieve insight into installation, data acquisition and monitoring procedures. With the fibre optic system ability to provide high-quality repeatable seismic data, the test objectives were met. The breakthrough for the fibre optic technology in 2008 was the decision to install a fibre-optic system to monitor the Ekofisk field in the North Sea. The operator came to the conclusion that the increasingly complex reservoir, with decreasing 4D seismic changes over the years, needed more frequent surveys with higher repeatability and sensitivity (Folstad, 2010a and 2010b). The solution was a permanent seismic recording system trenched about a meter down into the sea floor. The campaign of installation involved 200 km of seismic cables, covering about 60 sq.km of the field, using 3966 4C-sensor stations (in total 15864 channels), the largest installation to date. Separation between seismic receiver cables is 300 m and receiver station interval is 50 m. The basic elements of the system are shown in Figure 1 and consist of top-side instrumentation, riser cable, backbone cables and seismic receiver cables trenched at the sea floor.

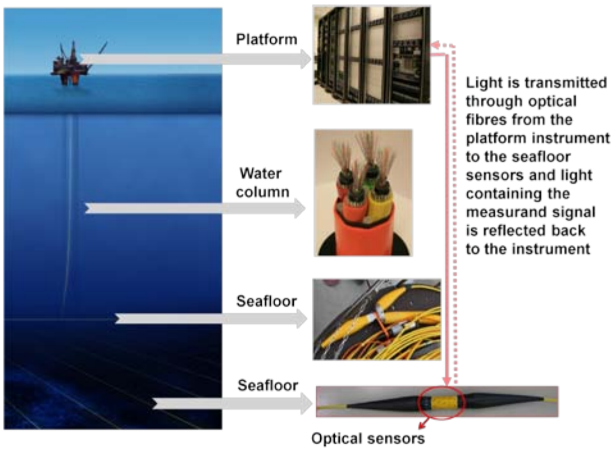

Figure 1: *Basic elements of installed LoFS system.*

Dedicated installation equipment has been developed to facilitate installation and reduce the overall cost. The installation of the system in the North Sea was completed in October 2010. The full installation included 4 backbone cables installed from rotating baskets, and 42 seismic cables installed from containers. All seabed cables were trenched into the sea floor. The splicing of fibres was performed in a dedicated container at the installation vessel and more than 1000 individual optical fibre splices have successfully been performed offshore. The splice loss (and cable integrity) have been remotely monitored in real time from onshore during the whole installation campaign. The laser interrogation unit and recording system for data storage and QC were installed in a dedicated offshore rated instrumentation module at the platform. Figure 2 shows equipment in connection with installation of backbone and seismic cables.

a)

b)

c)

d)

Figure 2: *The two photos, a) and b) show installation and equipment in connection with the backbone cables and the two photos, c) and d) show installation equipment for the seismic cables.*

Examples of RMS-noise displays (GIS-display) from the whole cable spread, of hydrophones, x-, y- and z-components are shown in Figure 3. All the channels were recording noise, which means that all channels were functional. Due to the fact that the 3-component accelerometers record in different directions, different noise patterns are observed at the different components. Figure 4 shows the hydrophone responses to propagating seismic waves from different shots.

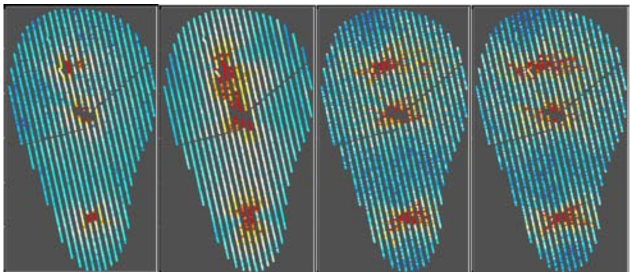

Figure 3: *Area displays of the cables deployed at Ekofisk Field in the North Sea when measuring background noise at the field. The displays show from left to right the hydrophone and the accelerometer components x, y and z (not-rotated). The red are areas with high energy levels (extensive noise from field activity and supply vessels) and the blue are areas with less noise.*

The life-of-field seismic system will provide data for improved understanding of reservoir depletion zones and intra-reservoir injected water expansion fronts. This is expected to lead to drilling of future production wells with better precision for increased hydrocarbon recovery (Folstad, 2010a and 2010b). In addition, the converted-wave data (PS-data) can be used to improve structural imaging of the gas-obscured area at the crest of the field and reduce drilling risk in the overburden. The trenched seismic system will allow for cost-efficient, high-quality and highly repeatable 3D-4C seismic surveys twice a year, which will fulfil the concept of “seismic-on-demand”.

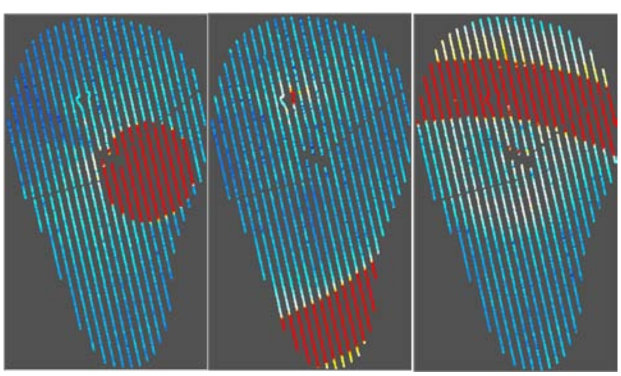

Figure 4: *Screen dumps of GIS-display, showing snap shots of the wave propagation and response of the 3966 hydrophones installed in the North Sea from different shots. Red colour is high energy level and blue is low energy level.*

In between the seismic surveys, portions of the receiver spread can be activated for passive listening and monitoring of micro-seismic events. However, it is of course not a problem to activate the full receiver spread for passive monitoring, but this will lead to such a large acquired data volume over just a few days which will be overkill for the purpose of detecting micro-seismic events from different parts of the field.

Conclusions

There is no doubt that fibre optic technology has revolutionized the telecom industry based on significant development of optical fibre components over the last 40 years. This technology development has established a base for advanced sensing systems and we are now starting to see the impact of this technology development in the seismic industry.

The largest ever offshore fibre optic permanent reservoir monitoring installation was successfully finished in October 2010 at Ekofisk field in the North Sea. All the channels are working and recording seismic traces (i.e. channel status is 100%), which is a great achievement for such large seismic spread in the marine environment. The decision to install an optical sensing system was mainly due to the design life expectancy of the fibre optic system (Folstad, 2010a and 2010b). We advocate optical sensing technology as an important part of the toolbox for maximizing field production in a cost efficient way. The “optical oil field” may represent the next significant step in technology for reservoir monitoring and improved hydrocarbon recovery.

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