A VSP Field Trial Using Distributed Acoustic Sensing in a Producing Well in the North Sea

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SUMMARY
Introduction

Acquiring vertical seismic profiling (VSP) data in a well using conventional technology requires an array of seismic sensors to be lowered down the well, to record the seismic signals generated by a shooting vessel on the surface. Due to the expenses involved when interrupting production this is rarely done in producing wells and VSP has not been economically feasible for monitoring purposes. The intelligent Distributed Acoustic Sensing (iDAS) technology enables a fibre optic cable to be used as a massive acoustic sensor array. Presently, fibre optic cables suitable for iDAS measurements are deployed along many wells for other purposes. The iDAS can be retrofitted to existing optical fibres to acquire densely sampled acoustic measurements at low expense because the normal operation of the well is not disturbed.

The Technology

When a pulse of light is launched into an optical fibre, a small amount of the light is naturally scattered and returns to the sensor unit. By analysing these reflections, and measuring the time between the laser pulse being launched and the signal being received, the iDAS can measure the seismic signal at all points along the fibre, tens of kilometres long. Typically the spatial resolution obtained with such a distributed fibre sensor is about one metre.

The principle of distributed sensing is well known from the distributed temperature sensor (DTS) which uses the interaction of the source light with thermal vibrations (Raman scattering) to determine the temperature at all points along the fibre. Because the returning light level is very weak this measurement typically requires a few minutes averaging to get a reasonable signal-to-noise ratio. With the iDAS system measurements can be done at a rate of up to 100kHz, opening up possibilities for seismic measurements.

The iDAS measures from one end of a single mode, standard telecoms fibre, without any special components, such as fibre gratings, in the optical path. It can even be used on existing cables, although custom cables will give a better response.

The well

The Gulltopp field is situated in Block 34/10 in the North Sea approximately ten kilometres west of the Gullfaks field. The field, at a depth of approximately 2500 m, was discovered in 2002, and consists of Middle Jurassic sandstones of the Brent Group and Lower Jurassic and Upper Triassic sandstones of the Cook, Statfjord and Lunde Formations. Recoverable reserves are estimated to be 4 million standard cubic meters of oil and 500 million standard cubic meters of gas, where these reserves are included in those of Gullfaks Sør.

![Figure 1 Well 34/10-A-32-C with a length of 9910m was drilled from Gullfaks A platform to reach Gulltopp to the west in Block 34/10 in the North Sea.](image)
At a distance of ten kilometres from the Gullfaks field, Gulltopp was evaluated for development with individual subsea templates and pipelines to the Gullfaks field, or with Extended Reach Drilling (ERD) wells drilled from the Gullfaks A platform. A Gulltopp development with wells drilled from Gullfaks A platform was evaluated to cost a quarter of a subsea development. In March 2008 the Gulltopp well 34/10-A-32-C drilled from the Gullfaks A platform was completed. With a length of 9910 m the well, at the time, represented the world’s longest horizontal producing well drilled from an offshore platform. At the time the 34/10-A-32-C well was completed with a fibre optic pressure and temperature gauge to a depth of 7192 MD/2181 TVD RKB.

The experiment

The test took advantage of a 4D 4C survey in the Gullfaks field, with acquisition starting late autumn 2011. The iDAS was retrofitted to the fibre in the Gulltop well to measure the seismic signals in the well while the seismic vessel was shooting in the area around the well. After the test, the fibre was put back in its normal operation.

With the iDAS recording, the seismic vessel was shooting one 25 km long testline along the well path. This line was repeated in opposite and same direction and a part of it also with reduced gun volume. The test acquisition further included a cross line perpendicular to the well path and a short walk away line from the platform and outwards along the first part of the well path.

The results

The fibre in the Gulltopp well was not optimal for the test due to losses in the optical path. The excess loss at the beginning of the optical path was 5.0dB one way loss, equivalent to 26km of good optical fibre. Despite the high losses, the iDAS collected good quality seismic signals. An example of a single shot record is depicted in Figure 2. The shot position is situated vertically above and approximately at the middle of the cable. One trace is obtained for each metre of fibre optic cable.

![Figure 2](image-url) A raw shot record obtained by the iDAS recording system. The shot position is located vertically above the cable. S/N ratio is low due to high fibre losses and strong horizontal high frequency energy.

A combination of high pass, median and low pass filtering can be invoked to improve the S/N considerably as indicated on Figure 3 below. As the iDAS accurately records the phase of the signal, additional shot records may be stacked to further suppress the noise and prepare the data for migration.
Figure 3 The shot record after noise suppression. The presence and position of direct, reflected/refracted and converted events are as expected from walkaway VSP data in a highly deviated well.

Figure 4 Example single shots, at intervals of around 7mins, through a one complete test line. Shots were recorded approximately every 15s through this period.
The conclusions

The iDAS system has been successfully tested offshore. The iDAS was retrofitted to an existing optic fibre installed in the first 7100 m of the Gulltopp well and recorded acoustic signals generated by a seismic source on the surface. The test was carried out without disturbing the normal operation of the well.

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