Technology and Solution for deep-water permanent seismic reservoir monitoring in the Jubarte field in Brazil

Authors S. Seth*, S. Maas, B. Bunn, R. Metzbower and T. Rekdal (PGS), P. Johann, E. Thedy and W. Filho (Petrobras).

This paper was prepared for presentation during the 13th International Congress of the Brazilian Geophysical Society held in Rio de Janeiro, Brazil, August 26-29, 2013.

Abstract

The world's first full-solution deep-water PRM (Permanent Reservoir Monitoring) project in the Jubarte field in Brazil for Petrobras was deployed in water depths between 1200 – 1350m in 2012.

The project includes a fully fiber-optic 'Wet-End' on the seabed, topside 'Dry-End' on the P57 FPSO, marine installation of the system in deep-water, the acquisition of active data using a shooting vessel, the acquisition of passive seismic data as well as data-processing of both active and passive data.

The paper presentation shall also briefly describe how the unique optical system works. The system itself includes a wide range of items – from top-side Opto-electronics to a riser and lead-in cables, a sub-sea hub with optical wet-mates, as well as the actual seismic array cables with optical 4C (4-component) sensor stations over the field.

Introducing and implementing new technology has traditionally been a challenge in the oil industry. This project was started initially at Petrobras CENPES research center. In projects such as this one, the successful implementation of a full solution required a multi-disciplinary team from the operator as well as the service company and this case demonstrates a successful joint effort by Petrobras Reservoir Geophysics and Jubarte asset teams as well as PGS.

Introduction

Reservoir management teams are aware of the need to recover more than the typical present ratio 1 out of every 3 barrels of oil that is found, and that reservoir management, optimization and control are key tools to achieve the same.

4D Seismic, complemented in future by techniques like multi-transient EM, is considered by many to be the only direct wide-scale reservoir monitoring tool we have to get information make such decisions, given the need for information far from the well-bore.

Permanent monitoring systems can be very useful in complex reservoirs, especially where alternate techniques are not good enough and better imaging is needed. This includes fields where there are production zones below sections that are difficult to image through, such as gas clouds and salt. 4D4C seismic data can help production optimization teams improve their models and make them more accurate, for example to understand connectivity and compartmentalization.

Thedy, et al (reference 1, 2) presented their objective at the 2011 EAGE PRM workshop: To monitor oil and water flows inside the reservoir and pressure changes due to the injection (close to injecting wells and to the oil/water contact) and to production (close to the horizontal wells in the upper portion of the reservoir). In addition, a goal is to identify possible discontinuities, which would impact the flow and that couldn't be identified using regular 3D seismic data, will be revealed by 4D seismic data as an anomaly limit for difference volumes.

Method

The full solution PRM project from Petrobras covered several different aspects as follows:

<u>Performed one-time at start of project:</u>

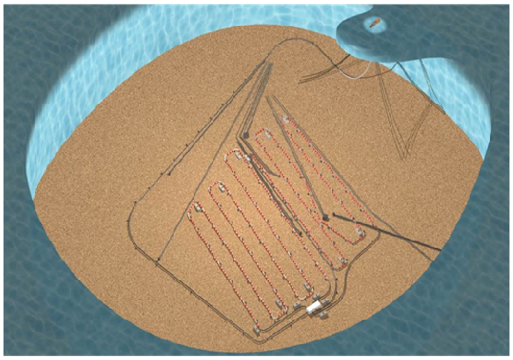
- Planning, seismic modeling, contracting.
- System supply: Seismic system with 4C sensor stations which have Hydrophones and accelerometers were used to measure both pressure and shear wave seismic energy.
- System Installation: Marine installation of the Wet-end using a marine installation vessel as well as topside Seismic room with Dry-end.

<u>Operations that are repeated:</u>

- Active Seismic Data Acquisition (SDA): Air guns on a source vessel to generate seismic energy.
- Passive Seismic Data Acquisition: Record natural and production driven seismic energy.
- Data Quality control onboard P57.
- Data Processing (DP) of active and passive seismic data onshore.

Interpretation and Reservoir management activities are subsequently performed with the seismic data over the life of the field.

The seismic array cables, which have 4C sensor stations every 50m, were laid in 2 loops with cables 300m apart, as shown below. The target area is about 9 km^2. A larger area is expected to be covered in future.

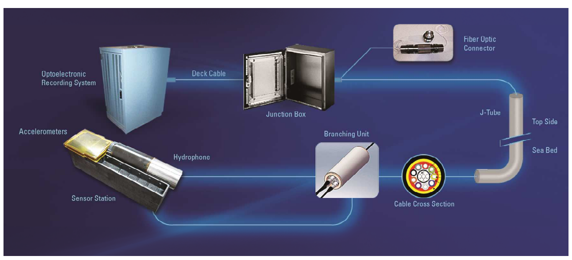


Jubarte PRM layout schematic

System Overview:

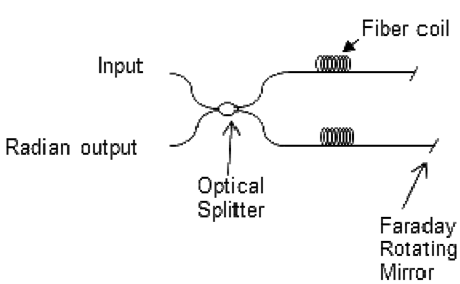
The PRM system at Jubarte consists of the following:

- Seismic Room on P57 with Optoelectronics for operating, control and recording.
- Riser cable from P57 to the seabed.
- Lead-in cables to a wet-mate telemetry node.



The reliability of the system has been certified by DNV, which is based on extensive testing.

The underlying optical technology of the optical system described, based on a Michelson interferometer, has several advantages over other optical systems and offers high Data Quality with unmatched top end performance.



Optical Sensor Basic Construction

Prior field tests (ref 10,11,12) have demonstrated excellent data quality. Data from these tests show low frequency operation below 1Hz with high bandwidth operation. Noise floors below 10ng have been demonstrated.

The same technology is also being used to develop a million-channel land system. (ref. 3,13,14).

Fully Fiber-optic systems have several advantages over conventional electrical systems. These optical systems have a fully passive 'Wet-End', the array that is placed on the sea-bed over the reservoir. An optical Wet-End has no electronics or in-sea electricity. Optical fiber sensors are inherently more capable to survive long periods of time than electrical components, as electronics need to be housed in 'water-tight pressure-vessels' that must last decades and are prone to corrosion or leakage over time. The optical sensors are placed in fully molded housings/pads that are robust to water intrusion. Glass, or the silica based material of optical fibers, is inherently better suited to aging survival in a subsea environment than metal components used in electrical systems.

Optical systems have advantages over conventional electrical systems. In addition to improved seismic data quality, since a large percentage of the total system cost of an optical system is on the surface, in the Opto-electronic cabinets called the Dry-End, if certain types of surface repairs or even technology upgrades that are needed over the life of the system, this task maybe easier and cheaper than with a conventional electrical system where a much larger percent of the total cost is on the sea-bed and requires more expensive in-sea intervention.

Optical systems are also easier to use when one needs to cover large areas with high channel counts, as one can transmit higher quantities of data in physically smaller media, and one needs smaller hubs and connectors.

Amongst optical systems, the technology used at Jubarte, has several advantages over other optical systems. It offers high Data Quality with unmatched top end performance. The system uses a combination of Frequency and Wavelength Division Multiplexing (FDM/WDM) telemetry, which enable high optical bandwidth and a very low Noise floor - critical as you increase folds. It also has low cross talk, and low cross axis distortion, resulting in excellent seismic data quality. The system has a genuine high dynamic range and it retains specifications even with high channels/fiber. A high channel count per fiber makes it more economical in large deployments.

Example method of operation

The authors of this paper are presenting a paper at EAGE 2013 describing the method of operation of this project.

A PRM project requires a multi-disciplinary approach, the successful completion of which needs personnel from various engineering teams, and aspects to be covered are much wider in scope that typical seismic data acquisition. Personnel involved include experts in areas such as sub-sea, risers, top-side as well as marine operations. Including this expertise from an early stage is very helpful in improving operational effectiveness.

The system used included equipment that was manufactured at the factories of different specialist firms, which was followed by a System Integration Test, or SIT at a PGS facility in Austin.

The system was then shipped, imported and loaded onto a Marine Installation vessel at a location near the field. In the project that is the subject of this paper, a specialized cable-lay vessel was used. Teams from the prime contractor were present on both the vessel and FPSO. The deployment ended with the field acceptance of the system.

A specialized source vessel was used on this project with additional trained personnel on board P57 to perform onboard quality control during active SDA.

After a short gap, the system is to be used to acquire passive seismic data.

Safety and HSEQ are important aspects of the project that are constantly at the forefront of all such operations. The learning from prior projects (Maas, 2004, 2008) and sea-trials helped make it a safe and efficient operation.

Results

The system deployment was concluded with Field acceptance from Petrobras following which SDA was started. Once data had been acquired during SDA, processing of the seismic data was started in 2013.

Image of a sensor station on the seabed

Image of a seismic room on P57 FPSO

The authors expect separate complementary papers to be presented to discuss the data acquired and results.

This data and information is used subsequently by a multi-disciplinary team of reservoir/production engineers and geophysicists/geologists to interpret the data and utilize the results. The interpreted results shall help the reservoir team manage the field and its challenges (Thedy et. al., 2011).

Conclusions

Permanent seismic monitoring systems fit with the major trends in advanced seismic and offer several advantages over other seismic techniques available commercially.

Trends in the industry include goals to increase recovery, targeting fields of increasing complexity and a widely accepted need for better reservoir modeling and imaging.

New Seismic techniques & tools are available, and they include wide & multi-azimuth surveys, higher density surveys, improved repeatability to lower noise and to enable repeats 4d more frequently.

To do the above, we need lower overall cost to enable more 4d seismic and the ability to see smaller changes, preferably sooner. Permanent systems may help achieve the above.

As additional data becomes available from passive monitoring and as operators and service companies learn more from systems in place, the authors believe that such techniques will play an increasingly important in oil recovery from reservoirs.

The challenge with permanent systems is that one has to plan ahead to do multiple 4D surveys and incur a higher upfront cost, offset by lower repeat costs, instead of spreading the same as one incurs the same (Capital expenditure versus Operating expenditure). Although new technology adoption is typically slow, we expect this to accelerate as costs fall with progress along the experience learning curve.

The learning from the Jubarte PRM project should help the industry. Given that the information will help operators see bypassed oil, water-flood fronts, see production driven natural fractures from passive reservoir monitoring, the authors believes that in a short time O&G companies will accept that more and improved 4D, made economical with PRM systems, on their fields is a real option that they cannot afford not to try, especially since it may also help image the overburden and reduce operational risk.

Acknowledgments

The authors would like to thank the management of Petrobras and PGS for the opportunity to do the project as well as to present the same.

References

1. ‘Challenges for Jubarte Permanent Seismic System’. Edgar A. Thedy, Wilson L. R. Filho, José G. R. da Silva (Petrobras), Samir N. Seth and Steve J. Maas (PGS). SBGf Rio de Janeiro, 18 Aug 2011.

2. ‘Jubarte-PRM in ultradeep water and with an innovative optics system’. Poster, EAGE workshop ‘Permanent Reservoir Monitoring Using Seismic Data’ 28Feb-3Mar2011, Trondheim, Norway . E.A. Thedy, W.L. Ramos Filho, P.R.S Johann (Petrobras), S.N. Seth & S.J. Maas (PGS).

3. ‘Next Generation Land Seismic Acquisition’. Presentation to the Geological Society, London, 25 Jan 2010. Dr. Wim Walk (Shell).

4. ‘OptoSeis LoFS System Focus on Reliability’. Rick Metzbower, Judo Lemuel. (PGS).

5. ‘Qualification Procedures for New Technology, Recommended Practice DNV-RP-A203 2001’. (DNV).

6. ‘Reservoir Optimization & Increasing Oil Recovery using 4D4C Seismic Permanent Reservoir Monitoring’. S. N Seth. (PGS) Presentation PRAVAP, Petrobras-CENPES Rio de Janeiro, 3Aug2011.

7. ‘4D4C Permanent Seismic Reservoir Monitoring to optimize reservoir production and recovery’. S.N. Seth. (PGS) 1st Joint Int’l Workshop for the Earth's Surface & Subsurface 4D Monitoring in 2012. Riyadh.

8. ‘Field Optimization & Oil Recovery increase using permanent seismic monitoring’. S. N. Seth. (PGS) NPF : Business Opportunities in Mature Fields. 10-11 May 2011, Stavanger.

9. ‘Reservoir Optimization: Permanent Seismic Monitoring using Fiber Optics’. S. N. Seth. (PGS) Third OilVoice Forum at The Geological Society, London. 22 April 2009.

10. ‘Advances in Fiber-Optic Sensors for Permanent Reservoir Monitoring using 4C Seabed Cable’. 30Jan2008 Steve Maas. PESGB-2008.

11. ‘Fiber optic 4C seabed cable for PRM’. S. Maas, B. Bunn, (PGS). OTC 2008.

12. ‘Fiber Optic 4C Seabed Cable Field Trials’. S. Maas*, J. Bunn, B. Bunn, R. Metzbower, J. Bowlus and J. Bielinski. (PGS). SEG 74th Annual Meeting. Denver, Colorado October 2004.

13. The underlying technology powering two game changing fiber-optic seismic sensing systems – 1M channel land and Deepwater PRM. EAGE2012. B. Bunn, S. Maas, and S. N. Seth. (PGS).

14. Toward Million Single Channel Acquisition. Kuwait 2012. Dr. W. Walk (Shell).