Jubarte PRM System Manufacturing and Installation Lessons Learned

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SUMMARY

Upon successful installation and acquisition of 4D data from the Jubarte pilot PRM system, we would like to share some of the lessons learned from the Jubarte experience. Discussion includes the technical challenges and supply chain difficulties that needed to be overcome. We successfully dealt with manufacturing and installation challenges, leading to the delivery of the system in 2012. After the third active acquisition of seismic on the field, the system continues to operate providing excellent data to Petrobras. As a result of the data from the Jubarte PRM system, decisions have been made by Petrobras to relocate various well placements. During the process we have taken the issues and incorporated them into a new revision of the system which shall also be explained, comparing the current "Next Generation" OptoSeis design to that which was installed on the Jubarte field. While the design changes are subtle they will lead to a more cost effective and reliable system in the future.

Introduction

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The Jubarte deep water PRM installation

The fiber optic deep water pilot PRM installation over the Jubarte field in Brazil's Campos basin consists of 712 seismic recording stations along two cables, covering an area of approximately 9 square km (Figure 1). A subsea assembly merges these cables into an umbilical leading up to a FPSO, where the optic signals are demodulated and digitized. With water depths from 1250 to 1350 m, this is currently the world's deepest fiber optic PRM installation.

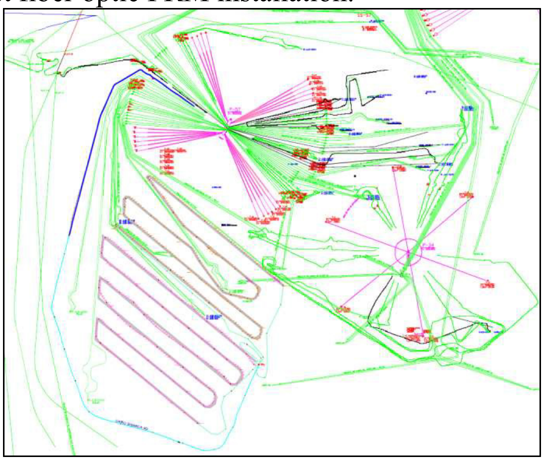

Figure 1 Layout of the fiber optic ocean bottom cable and field infrastructure. The array covers an area of about 9 square km.

Jubarte Pilot System consists of:, Topside instrument room, Deck cables and riser junction box, 6km Fiber optic riser umbilical, 10km seafloor lead-in cable, Seafloor wet-mate distribution hub with 12 wet mate connectors, and more than 35km of active seismic array cable.

Each sensor station consists of 4 seismic channels; one pressure sensor, and three non-gimballed, orthogonally-oriented acceleration sensors, overall an air-backed optical hydrophone design and fluid filled 3-axis accelerometer package. A sensor station was attached to the cable in 50m intervals on a section length of 1.6km. The cable utilized steel stress members and embedded stainless steel tubes to house the optical fibers, there were spare fiber tubes in the cable design. A bi-directional redundant optical telemetry scheme was used to distribute (and collect) the light from the fiber optic sensors.

In process testing was performed on the sensor, station and section level for the in-sea hardware. The sections were then assembled into the north and south array groups during a System Integration Test (SIT).

Figure 2 *4C sensor station and cable during system integration and SIT.*

The most significant manufacturing issue occurred when the initially received raw cable failed to meet depth specifications. The stainless steel cable tubes carrying optical fibres were found to be failing along the weld line during high pressure testing. The modern tools used by the cable manufacturer to check the laser seam weld integrity failed to catch weld penetration flaws below surface later found during pressure testing of the section assemblies. With the spare tubes provided in the cable we were able to rework many of the cable terminations but in some instances full sections of cable were scrapped, proving to be a costly quality and design mistake. This example, as well as other issues found in the manufacturing process will be discussed in more detail.

Since the Jubarte system was the first deep water PRM application, the system delivery was contingent on the completion of DNV qualification. Extensive FEMCA resulted in a robust product qualification testing program. The qualification hardware used for DNV validation was manufactured by PGS in Austin, Texas, using production equipment and procedures. As such DNV RP 203 certification was obtained prior to transferring fabrication of the seismic array cable for the Jubarte system to an external manufacturer. This gap resulted in multiple quality control challenges while attempting to instil the similar build quality that ultimately resulted in a 10 month delivery delay. More recently DNV has revised their qualification requirements to mandate identical production systems and processes be used for qualification samples to thwart this challenge.

Optical back reflection of available wet-mate connector technology was limited to -30dB causing unwanted reflection in the optical path which could lead to higher noise. Additionally, the quantity of fibers per connector was limited to 8 fibers. The insufficient back reflection performance resulted in development of improved APC connectors to support the Jubarte system. An improved wet-mate connector utilizing and updated design for improved back reflection performance was created. The wet-mate structure was a custom design that housed head and tail connection modules for both of the array cables, 12 8-way optical connectors were used. During the cable installation ROV handling of wet mates went well. Functionality of wet mates was good apart from one. This one bad connector required the set of the redundant optical paths to be used to bring the signal back to the instrument room.

Figure 3 *wet-mate telemetry node (WMTN).*

The last new part of the system was the optoelectronic hardware. A new generation of optical demodulator (demod) was fabricated for the Jubarte system. Each board had the capability of processing 32 sensor channels, and the boards were then packaged into a 6U cardfile. The optoelectronic system has operated very well, with extremely low downtime compared to conventional systems. Laser modules and optoelectronics boards are all manufactured to be easily removed/repaired as necessary. Three laser modules were running improperly so they were replace by spare lasers and were sent back to the manufacturer for repair. The faulty laser have been fixed and returned to the spare bank on the FPSO.

Figure 3 *Optical demodulator and complete optoelectronic system that was installed on the Jubarte P57 FPSO. Left to right, UPS battery backup rack, laser rack, (2) optoelectronic racks, Test equipment rack and data acquisition and storage rack.*

The system completed installation in late 2012 and seismic acquisitions so far included a baseline and monitor active seismic survey, and two passive recording periods of 2 months duration each. The installation requirements were to not trench the optical cable. Our geophysicists were concerned about the seismic integrity of the system so there was a soil analysis performed and it was determined that the cable should be buried 50cm to ensure no movement due to current and storms. Anchors were placed every 300m along the cable during the installation. During analysis of the data from the first active survey we could only see very minor movement in some of the sensor stations. This appeared to be much lower during the first monitor survey. An NMRSD of <5% was achieve between the first two active surveys. While an NRMSD of <5% is very good, slight movement and reduced coupling compared to trenching could have improved this. That being said, laying cable on the seafloor without trenching provided much better response than a towed streamer application

The handling equipment on the deployment vessel worked well with the OptoSeis equipment. Sea trials prior to the actual deployment played a large part in the preparation and success of installation. The cable slack management was excellent with 1% budgeted, cable was well coupled to seabed, this lead to excellent coupling and optimal data quality. A large telecom vessel was used, they have advantages over mobile deployment equipment installed on PSV or CSV vessels. Dedicated work areas were used for on board optical fiber integration and repair work. However, the DP systems are inherently a lot weaker than oil field support vessels and working close to infrastructure would need to be supported with tug boats. Prior arrangements were made by Petrobras to give the installation vessel priority in the field, this made for very efficient operations and with a vessel of limited DP this was critical. The cable did land outside deployment corridor on occasion, but deployment route was adhered to. To verify cable deployment accuracy, acoustic pingers were attached to the cable during deployment, the accuracy of acoustics was as expected. The time taken to deploy sensor cable was small compared to rest of project. The turns were negotiated reasonably well, anchors placed at the corners were put to good use. Our weakest link during the cable installation was the ROV reliability, this had been predicted and use of ROV was kept to a minimum.

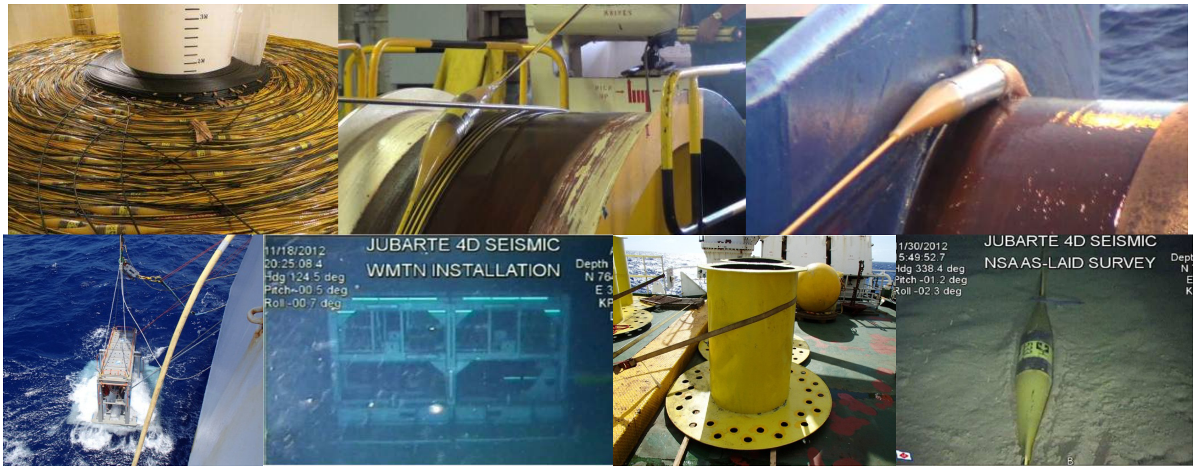

Figure 4 *Optical system installation; cable in the tray of the belly of vessel, capstan winch, overboard winch; Wetmate node entering the water; WMTN on seafloor; anchor used for turns on the seafloor, station placed on sea floor.*

Based on the lesson learned from the Jubarte system manufacturing and installation, PGS has made design revisions to improve the process reducing cost and manufacturability. The biggest difference in the seismic array cable is changing the hardware design to aid in the in-process assembly of the cable, reducing cycle time and simplifying repair. The cable also adopts the philosophy of accommodating pressure instead of resisting it; the cable is now like a fish where the initial revision was more like a submarine. These design improvements shall be discussed.

The insufficient fiber quantity and poor reliability of the wet-mate connector resulted in PGS joint development of high density APC connectors to support the next generation system.
A wet-mate connector design has been updated to include 24 optical contacts, reducing the connector count by a factor of three. The optical performance of the connector also exceeds the performance of the design used during the Jubarte pilot. Reducing the connector count also greatly reduces the seafloor node requirements for the wet-mate connection.

The final big system improvement includes and updated optoelectronic system that increases the channel count per board from 32 to 112 sensor channels. Also expanding the network capability of all boards, all boards are networked on an Ethernet backbone and can be individually accessed remotely to communicate the system integrity.

Conclusions

The Jubarte pilot PRM system has been considered a successful project by all parties involved. The system is providing excellent 4D data on a difficult reservoir. Many lessons were learned through the process of manufacturing, testing and installing fiber optic seismic cable in the deep water of the Jubarte field. We have shared some of the lessons learned from the Jubarte experience, including the technical challenges and supply chain difficulties that were overcome to lead to successfully manufacturing and installation. The system was delivered in 2012 and after the third active shoot of seismic on the field, the system continues to operate providing excellent data to Petrobras.

Design revisions as a result of the lessons learned have led to a more cost effective and reliable system, preparing for continued expansion of the PRM market.

Acknowledgements

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