A Deep Water 4C 4D Permanent Installation Pilot

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Abstract

This poster presentation outlines some of the challenges faced with the installation of a buried 4C-4D seismic cable over a deep-water oil-producing field in the Gulf of Mexico.

A single 6km 4C cable was laid on the seafloor and tied back to recording equipment on the platform.

The MARS field utilizes a "Tethered Leg Platform" design because its location in over 1000 metres of water. The 4C installation design had to take into account the harsh environmental conditions of the Gulf such as frequent hurricanes and its infamous loop currents that move the platform topside by up to 50 metres laterally.

Detailed finite element analysis was carried out to ensure that the 4C riser cable did not mechanically interfere with the many existing risers that hung in catenary from the TLP's deck level to the seabed.

The 4C seismic cable was installed *underneath* 5 existing risers in catenary.

Parts of the cable were trenched so that comparisons could be made between 4C stations that were buried and those that were not. These are presented in this poster together with an analysis of recorded data from special source lines that were shot at 45 degrees to the cable azimuth.

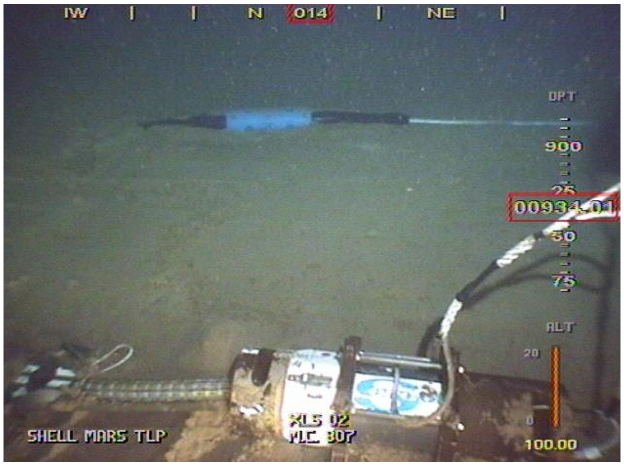
Introduction

The end of the hurricane season may not seem the most ideal time during which to install the world's deepest permanent seismic monitoring system offshore the Louisiana coast, but during October 2004, Shell did exactly that.

The project entailed burying a 6km 4-component seismic cable into the sea floor almost directly beneath the tension leg platform at Shell's Mars field. The cable was then connected to a recording unit on the platform itself via a fibre optic riser or umbilical. Beyond that the project calls for several repeat 4D seismic surveys using the cable sensors over the next year or so. The first of these was acquired immediately the cable had been installed.

Shell had already recognised the use of 4D seismic data for managing the Mars field and has acquired 4D data using towed seismic streamers. However, they have also recognised that the best way to acquire 4D data in this area is with a permanently installed sensor system.

The investment required to install a permanent monitoring system over a large field such as Mars is significant, as is the technical risk. Therefore in order to de-risk such a project Shell elected to proceed with this pilot project over Mars with a single buried cable to evaluate not just the technical benefits of 4-component 4D data, but also the basic issues of design and implementation in deep water close to field infrastructure. To help in these evaluations the pilot project included: burying the cable to different depths along its length; simultaneous acquisition with 4-component seafloor nodes that were placed next to some of the 4-component cable sensors, and a calibrated hydrophone placed near the seafloor to record the far-field airgun source signature.



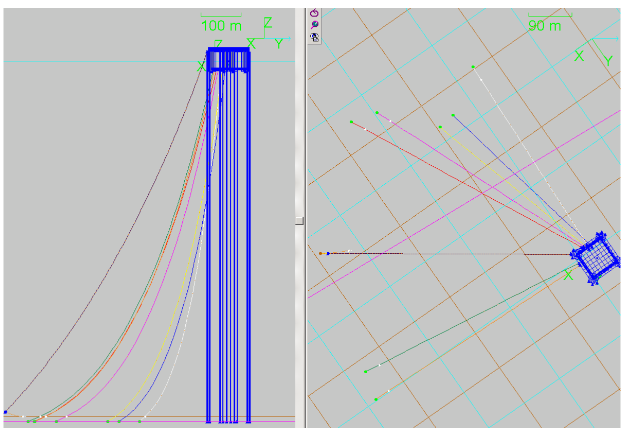
The main challenges during the installation were the surface and near surface environment, which was dominated by the weather and currents, and the sub-sea environment which included production risers and other infrastructure around the TLP.

Method

The originally-planned installation period of October 2004 saw hurricane Ivan wreak havoc in the Gulf of Mexico and its coastal regions which delayed some of the pre-installation preparation work on the TLP itself. The prevailing loop currents also caused some delays. These are ocean currents that can be likened to rivers of fast flowing water that meander across sections of the Gulf.

The strength of some of these loop currents cause structures such as the Mars TLP to move tens of meters when the currents are at their highest and give the platforms the appearance of being towed through the water with a very distinct wake. Such currents of course made the necessary surface and near surface activities of the cable deploying vessel, some of which was very close to the TLP, even more of a challenge.

It was appropriate, therefore, that the first phase of the project included a detailed design study for the installation itself, part of which addressed the engineering design of the equipment. This had to take into account the various environmental conditions that might prevail at the offshore site. Major weather systems, including hurricanes, and the infamous Gulf of Mexico loop currents are high-potential events that required modeling. Finite Element Model (FEM) catenary analyses of the existing 1200-metre production risers, together with the new 1300-metre fibre optic umbilical to the buried multi-component seismic cable were undertaken using 10 year statistical environmental data for sea-states, winds (hurricanes) and loop currents. Position shifts of the Tension Leg Platform (TLP) surface structure due to these same 10 year conditions were also added to the overall dynamic model of the new fibre-optic umbilical.



Analysis of the geotechnical data of the sea-floor was carried out in order to design the most appropriate umbilical anchoring and cable burying method. Finally, dynamic stresses, tensions and bending moments were calculated for each component of the installed equipment.

Other aspects of the detailed design study included: a project-safety plan; step-by-step field installation procedures; project and task-based risk assessments; a survey-plan, and an offshore communications plan. Combined with an extremely comprehensive set of detailed engineering drawings for every piece of hardware involved, the study represented a proof-of-concept for the overall project. Regular stakeholder review meetings added to the confidence that the installation project would be a success.

At the seafloor, the main problem faced was that of placing the cable between the tension legs and a group of five production risers. Multiwave developed a technique to do this, that they dubbed “keel hauling”, which used a strategically placed weight on the seafloor, a winch on the platform with an acoustically positioned winch wire, and an ROV. This technique involved creating a large loop in the 4-C cable in order for it to be passed safely underneath the risers and taken up by a winch on the TLP at the same time as it was paid out from the dynamically positioned cable deploying vessel.

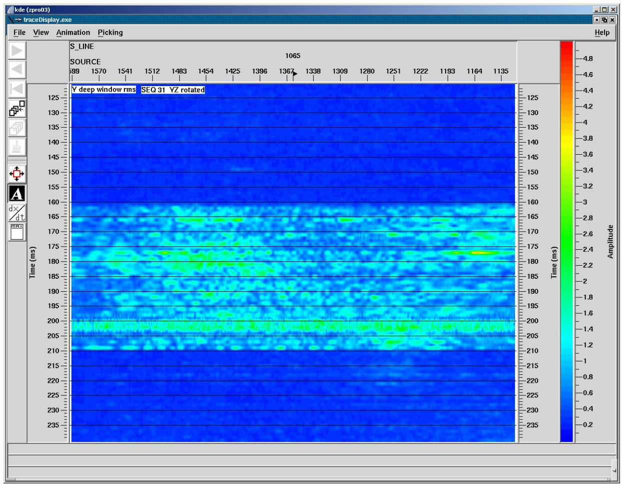
The cable was then placed in a straight line on the seafloor to within 5m of the planned position using their Near-seabed Deployment System (NSDS). Given the water depth of between 900m and 1000m at the Mars location this deployment accuracy itself is a major feat and unprecedented in the industry. A fibre-optic umbilical, barely one inch in diameter, was then passed up to the platform and connected to the recording system.

There is common understanding of the very basic requirement to bury a permanent cable in order to prevent it from being disturbed by future activity at the field for example. But the depth of burial and its impact on the quality of the seismic data, and in particular the 4D data, is largely untested and much less understood. Shell therefore included this aspect of permanent installations within this pilot study by having a portion of the cable unburied and the remainder buried at two different depths.

Examples

Intuitively it is appreciated that the data from any buried portion of the cable will be susceptible to less ambient noise than the portion that is unburied. However from the data that has already been collected at Mars with this system it is possible that a good case could be made for burying sensors for normal OBC (ocean bottom cable) acquisition.

This is particularly the case with the crossline geophone. Once trenched, the natural tendancy of a cable to roll is constrained. Micro-rolling may be induced by sea currents that pass over the cable and cause it to “strum” or the may be a result of torsional stresses generated during the deployment process.

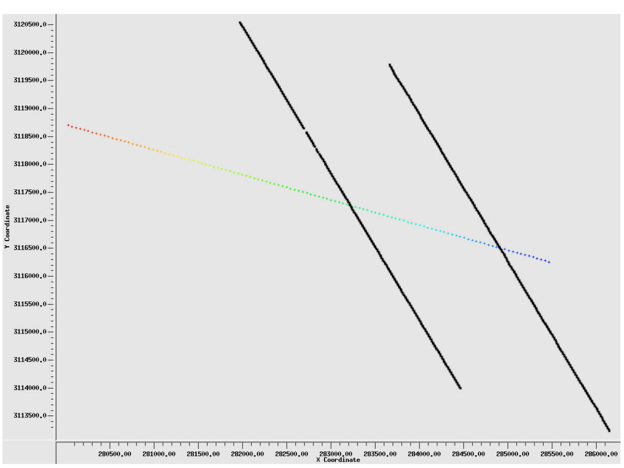


The RMS display shown above illustrates the extreme sensitivity of the crossline geophone to above-mudline events. The 6km cable is represented by the vertical axis with time along the horizontal axis. The upper 2 kms of cable were trenched to 2 metres, the middle 2 kms were left on the surface of the seabed whilst the lower 2kms were trenched to 1 metre.

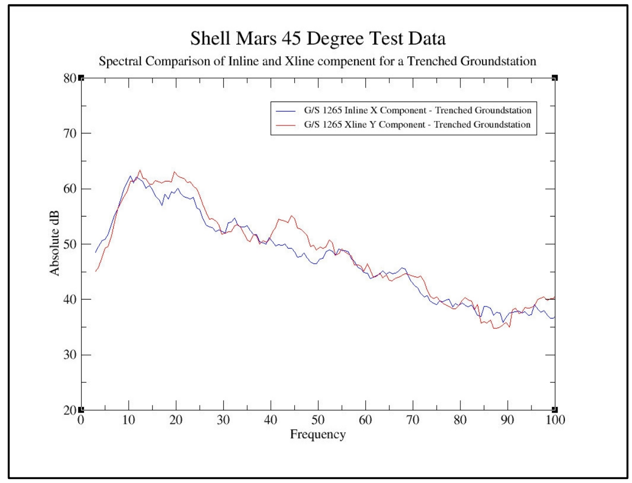
The same trend can be seen with the two other orthogonal geophones, although to a very much lesser degree.

Results

A further investigation into the advantages of trenching a 4C cable was carried out by shooting two source lines over the cable. One source line over an untrenched ground station (i.e. mid cable) and another source line over a trenched ground station.



During the Poster presentation, the equalizing effect of trenching upon the crossline and inline geophone will be seen. Once trenched, their spectra are far similar and exhibit slightly more energy in the higher frequencies.



Receiver gathers will be presented that illustrate the improvement in earth coupling.

Conclusions

Trenched geophones typically exhibited seismic noise reductions, in some cases up to 12 dB. Furthermore, superior vector fidelity is also shown to be a technical success of the MARS permanent installation pilot. Whilst it is too early to evaluate the 4D benefits, it is clear that the receiver-side of this technique has been given the best possible start.

In achieving this condition, however, the months of project planning must be recognized: five months of pre-planning and detailed design so that two weeks of installation in the Field could be executed without incident.

Acknowledgments

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EP-TS – Shell Houston

EPP Shell Engineering - Houston

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