Permanent Reservoir Monitoring (PRM)

PRM System from Siemens and Octio

Permanent Reservoir Monitoring (PRM) is a key technology for sustainable oil recovery. Operators are faced with the need for enhanced recovery, strict regulations and HSE requirements. PRM systems help increase both safety and recovery by allowing operators to monitor the behavior and environment of their reservoirs.

Siemens Subsea and Octio:
Delivering Permanent Reservoir Monitoring (PRM) solutions to customers on a global basis.
Siemens and Octio PRM System

Reducing risk and increasing recovery

The Siemens and Octio PRM system is a reliable sensor network based on open standards, composed of a centralized hub, and of sensor modules installed in cable arrays covering the complete field.

In active operation, an air-gun source is deployed either by a dedicated seismic vessel or a supply vessel. Using a supply vessel as opposed to a seismic vessel not only reduces costs, but also enables flexible on-demand surveys with short interval repeats when the production or injection profile deems it necessary.

Reducing the intervals between surveys to three to six months allows better and faster well management decisions, significantly enhancing water injection and production.

The system operates in passive mode, 24/7. Any activity that emits acoustic signals can be monitored. This aids wellbore placement, and provides the information needed to ensure fracturing does not reach the surface and cause harm to the environment.

In addition, early warning is provided when injection processes start to cause unwanted fracturing; this includes fractures from water, cuttings and CO2 injection.

Offshore production challenges

The growing demand for more efficient offshore oil recovery poses major challenges.

Improved reservoir imaging is addressing wellbore placement issues and optimizing water and CO2 injection, as well as other EOR/IOR effects (Enhanced Oil Recovery/Improved Oil Recovery). In addition, operators need to ensure that fractures or faults do not open up and result in seeps to surface.

Failure to address these challenges may result in the poor utilization or exploitation of resources - and in severe cases, in the emission of fluids and harm to the environment.

The Siemens and Octio new seabed seismic system is designed to meet the increasing demands of the offshore oil industry today.
PRM system details

ReM sensors
The main ReM (Reservoir Monitoring) sensor is a 3-component VectorSeis from ION Geophysical, enabling shear wave detection and directional readings. The sensors are unique in their design, using a purely digital process to detect axial frequencies from 0 to 500 Hz, and feature a high dynamic range, where the lowest detectable signal is 40 Nano G.

The system includes a bypass feature, which allows for the failure of two consecutive sensor modules. In addition, the sensor modules are bidirectional. This provides additional redundancy when the sensor lines are installed in a loop. In this case, the Reservoir Monitoring system will operate even in the event of a cable cut.

Siemens hub
The sensors are tied into a Siemens hub, which utilizes proven Siemens technology and incorporates redundancies and safety features. The sensor lines are bidirectional, which provides additional redundancy when the sensor lines are installed in a loop. In this case, the Reservoir Monitoring system will operate even in the event of a cable cut.

High flexibility and easy expansion
The Reservoir Monitoring network is highly flexible and can be easily expanded. Due to the fact that it is based on standardized communication, it can also incorporate third party sensors and systems.

The Siemens and Octio PRM system utilizes high quality materials and has a lifetime of 25 years.
PRM concept studies, customized to your field’s challenges and requirements

**Concept Study**
Siemens and Octio address and help overcome various challenges and very specific requirements in regards to the monitoring of oil and gas fields. We offer permanent seafloor cable-based acquisition systems for monitoring cap rock integrity using passive and active seismic data acquisition. The cap rock integrity monitoring can be provided by the use of passive seismic.

By listening to smaller seismic activities (micro-seismic events) caused by the fault reactivation, optionally in combination with quick repeated 4D sourced seismic surveys using a typical acquisition system, the cap rock can be monitored, and thereby avoid harm to the environment caused by leakage to the surface.

**Combined Team**
We put together a skilled team that will conduct a study and scoping work, evaluating and developing what a PRM solution would look like for your field. The scope of our study is tailored specifically to our clients' needs. The team will examine all aspects - from the feasibility of the system, via the planning of sensor arrays design to the installation and commissioning in the field.

**Phase 1: Feasibility Study**

**Rock Physics**
A rock physics workflow is offered to reduce ambiguities arising from areas with challenging geological environment and hence reduce the risk in production. From the rock physics an assessment of 4D effects such as changes in pressure, fluid and/or lithology is used to evaluate whether potential leakage from fractures and cap rock could be observed on the seismic response in an early stage. Prediction and quantification of reservoir qualities/behavior with respect to fracturing, fluid changes, pressure effects and diagenetic changes is outcomes of such a rock physics workflow.

**Passive Monitoring**
Ray tracing modeling is used to determine the fracture mechanism of existing fractures and to establish the surface area being illuminated by possible micro-seismic events. This is used to improve prediction of possible failure in the injection layer and/or cap rock. For sensor configuration, finding the number of sensor needed to detect specified level events and to evaluate the detectability as a function of distance and event magnitude, a workflow of using existing information from models and data acquired is applied. Tests and implementations strategies of advanced processing (noise reduction) are offered to evaluate micro-seismic data.

**Active Monitoring**
From a towed source shooting grid, the subsurface area is illuminated and an optimization of the placement of the receivers and survey parameters are achieved. This gives a desirable resolution of the target area and hence makes it possible to detect 4D effects such as fluid and pressure changes during depletion/injection in reservoir. For optimizing survey parameters, a 3D ray tracing modeling is constructed from geological model and this will be used as a guide when designing a survey setup for optimizing the resolution in the reservoir.

Shot gathers from previous surveys will be analyzed with regards to noise and spatial aliasing. When the frequency band of interest and the direction of incoming events are established, the receiver spacing with respect to aliasing, receiver and shooting aperture with respect to migration aperture can be proposed.

**In detail: How we conduct our PRM concept studies**

The scope of work is divided into two phases.

**Phase 1**
*Feasibility Study:*
Rock Physics, Passive Monitoring and Active Monitoring

**Phase 2**
*Concept Study:*
PRM system structure design

**Deliverables**
- Rock physical evaluation and synthetic data showing 4D responses of various scenarios of interest i.e. pressure, saturation and fracturing.
- Illumination maps.
- Proposal for a priority surface area to be covered by a seismic seafloor array.
- Minimum signal magnitude needed for detection as a function of depth and frequency.
- Recommendation of number of sensors in order to improve signal to noise.
- Recommendation with regards to sensor spacing to avoid aliasing.
- Recommendation with regards to sensor layout with respect to migration aperture.
- Array layout diagram.
- Recommendations on processing procedures to be tested in the field after installation.
- Proposal for sensor network with recommendation for optimal setup for reservoir imaging.
- Recommendations for source layout and size.
- Recommendation with regards to receiver spacing, source and receiver aperture.
Phase 2: Concept Study

PRM System Structure Design
- Identification of the necessary subsea and topside equipment.
- Description of the permanent reservoir monitoring system including the general arrangement for the PRM system infrastructure.

Topside Equipment
- Evaluation and description of the topside equipment of the permanent seismic system.
- Specifications for topside hardware, including recording system, communication system, control system, power distribution system and different system interfaces.
- Evaluation of possible locations for topside equipment, cable routes, and interface methods for power, data transmission and synchronization.

Seafloor Infrastructure
- Evaluation of PRM impact of subsea installations.
- Derivation of a map showing the sensor network/cables superposed on the existing infrastructure, including recommendations regarding pipeline/cable crossings.

Geophysical Model Building
- The soil conditions must be considered, evaluating whether or not trenching is required, and if so, selection of trenching method.
- The need for a site survey (side scan sonar) along the proposed cable routes can also be evaluated.

Subsea Equipment
- Assessment and recommendations to be performed on the PRM system components:
  - Umbilical; power and communication requirements.
  - HUB; protection structure.
  - Connectors; wet mate electrical and fiber optical connector; cable terminations.
  - Sensor arrays, including sensor lines, seismic sensor station, sensor array cable, sensor lead-in cables, loop cables and jumper cables.

Reliability and Installation Guidelines
Reliability and robustness of the system are of utmost importance which is why the feed study will do an initial reliability assessment based on typical components. In addition, we develop an outline of the execution plan with guidelines for installation and commissioning of the PRM system.

Seismic Modelling (Active and Passive)
- Active seismic modeling is done using 3D ray tracing on the model to define optimal survey design for good illumination of the target reservoir and caprock. 4D seismic modeling is obtained by utilizing the output from the rock physics scenarios.
- Passive modelling is done performing ray tracing with the source in the area of interest (e.g. in the caprock). This way illumination of the sensor layout design is evaluated based on the location of a micro-seismic event. Different event magnitudes are evaluated together with attenuation effects affecting the received signal of the event.

Geophysical Model Building
- Rock physics evaluation is used as input for building up a geophysical 3D model for the target area defining elastic parameters in the defined area of interest.
- The model requires geological input from client in order to reproduce the actual geology of the target area as detailed as possible.

Rock Physics Evaluation
- Well log and seismic data analysis of insitu data followed by rock physics modeling to describe physical behavior of rock properties as seen on seismic.
- By utilizing the rock physics modeling, evaluation of expected 4D responses is carried out by scenario modeling of expected dynamic behavior in the reservoir. I.E. Fluid effects, pressure effects and fracturing.
The Siemens and Octio Partnership

Partnering Approach
In 2011, Siemens and Octio AS started a formalized partnership in digital reservoir monitoring sensing technology and associated systems to customers on a global basis. The consortium is set up with Siemens as contractual lead. Responsibilities are split, based on taking the best from both partners to the combined solution.

Putting Siemens Technology on the Seabed
Siemens is a technology leader for land-based power generation, transmission, distribution, and drive technologies.

The Oil & Gas Division of Siemens has a comprehensive portfolio of Electrical, Instrumentation and Telecommunication (EIT) solutions, rotating machinery, as well as products and systems for deep-sea power supply, covering a broad spectrum of applications. In addition to our core power and distribution competence, we also possess pioneering technologies in the areas of subsea control and surveillance. With our extensive marinization expertise and exemplary service and support, we provide answers from the concept phase throughout the entire life of the field.

In the joint Permanent Reservoir Monitoring offering with Octio, Siemens delivers subsea system design and manufacturing, power and communication as well as project management and execution.

Octio’s Capabilities: Sensors and Network
The company was established in 2006 by a group of engineers with broad background from seismic systems in general and ocean bottom seismic systems development and operation specifically, dating back to the early days of offshore seismic data acquisition. Octio’s team of experts has been involved in the development of some of the first OBS systems in the industry. In addition to in-depth geophysical and seismic expertise, Octio are experts in reliable subsea sensor design and interface, mechanical packaging, power distribution, data transmission, continuous recording, and QC software development.

In regards to the combined solution, Octio is responsible for sensors and network - sensor node design, network layout, sensor software, data collection system and QC software, seismic operations and geophysical planning and coordination.

G&G Study Group:
The group consists of a team of geophysicists with large experience from the seismic/geophysics industry. It offers services within 4C/4D reservoir characterization, rock physics evaluation, seismic modeling and micro-seismic evaluation, addressing challenges such as overburden fracturing and reservoir compaction. The services provide guidance to predict the benefits of oilfield monitoring solutions reducing operational risk for the operator and increasing recovery.

Main PRM System Benefits
Control and real-time warning: The joint solution enables operators to control the development of the reservoir, the overburden and the environment: The data acquisition system provides seismic data in the reservoir development plan and supports a real-time warning system in case of seabed leakage of oil, gas, waste or polluted water.

Improved reservoir imaging and optimized models:
For production, reservoir drainage and asset lifecycle.

Robustness and long lifetime:
The system is built for permanent deployment on the seabed with a lifetime of 25 years.

High flexibility and easy expansion:
Due to the fact that the PRM network is based on standardized communication, it can also incorporate third party sensors and systems.

Project Management
• General project management, comprising the intended close interaction and relationship with the field development team.
• Coordination of all relevant Siemens and Octio experts and offices.