Distributed Fibre Optic Sensing for CO_2 injection monitoring

Fibre optic cable-based sensing can be used for multiple areas of CO_2 storage monitoring, including monitoring CO_2 injection into the well, monitoring where the CO_2 plume goes, induced seismicity and temperature effects.

Fibre optic cable-based acoustic sensing, technical name 'Distributed Acoustic Sensing' (DAS), can be very useful in CO_2 storage. It can be used to better understand the storage site before injection starts, to monitor the injection and check for leaks in the well, to make seismic surveys of the whole storage area and monitor the progress of the CO_2 plume deep below the surface, to listen for 'induced seismicity' which could be indicative of movement of CO_2 outside the storage area, and to monitor for deformation of the well.

Anna Stork, senior geophysicist with Silixa, a company which provides the technology, explained how it is used, speaking at a Finding Petroleum forum in London in May.

Silixa's DAS instrumentation have and are being used in CCS projects and research in Canada, USA, Iceland, Spain, Norway, Italy, Turkey, Australia, South Korea and Japan, she said. For some projects Silixa provides equipment; for other projects the company also provides data collection and analysis services.

The systems are used at the Otway Project in Australia, a CCS research site. At Otway, Silixa has 40 km of DAS cable installed in 5 different wells, put in place over 2014-2020.

After only 580 tonnes of CO_2 had been injected, it was possible to identify the CO_2 plume on 2D seismic images, with seismic data captured using the DAS systems.

"We were able to track very quickly, and with great detail, the movement of the CO_2," she said.

Anna Stork, senior geophysicist with Silixa

The seismic source, a surface orbital vibrator (SOV), used was the size of a washing machine drum. This is much less disruptive to agriculture than Vibroseis trucks. It can be switched on automatically – something which proved particularly useful when Covid lockdowns made it difficult to travel to the site.

A second case study is the Aquistore Project in Saskatchewan, Canada, a demonstration and technology testing site. It is connected to the Boundary Dam power plant which has carbon capture attached. Most of the CO_2 from Boundary Dam is used for EOR projects elsewhere but CO_2 has been injected at the Aquistore site since 2015, with over 400,000 tonnes stored so far.

Silixa has recorded repeated seismic surveys since 2013, which provide a baseline pre-injection survey and post-injection surveys, enabling imaging the CO_2 plume evolution over time.

As the volume injected increased from 36,000 tonnes to 141,000 tonnes, the plume could be seen growing. If you were able to look at it from above, you would see it grow first towards the North and East, then a bit to the South, she said.

Following these deployments, Silixa has developed a monitoring "solution" specifically for CCS including a range of technologies, called Carina CarbonSecure.

It aims to provide as much processing on site as possible with an "Edge Computing" set-up to reduce the amount of data which needs to be sent off site.

The system can be configured to provide alerts if unusual activity is detected. In this case, a decision can be made to stop injecting.

The technology

DAS technology makes use of the way vibrations and sound waves modulate light going through an optical fibre. The light pulse is produced by an 'interrogator' which also records and processes the returning light from the fibre. The changes in the light are detected by analysing "back scattered light", because some of the light is reflected or 'scattered' back to the starting point of the cable.

The distributed fibre optic sensing family also includes temperature (DTS) and strain (DSS) sensing. The light is modulated by temperature variations and changes as small as 0.01 degrees C can be detected, and strain (stretching of the cable) can be measured at one microstrain (part per million) resolution.

The technology can use the same fibre optic cables which are used for telecommunications. Or it can use a special fibre optic cable designed in a way to increase the amount of backscattering – this means that there is more information coming back to the instrument which can be analysed.

The cables can be tens of kilometres long. The cables are usually about a quarter of an inch thick, and fibres are often encased in a metal tube. The cables do not need any maintenance and are designed to last for decades. In a well, the cable can be clamped to the casing or tubing, or cemented behind the casing.

One cable can contain multiple fibres, and each fibre can be used to measure different parameters (temperature, seismic and strain signals) simultaneously.

Measurements can be made with a resolution of less than 1m along the cable. The measurement is made by taking a moving average of neighbouring points on the fibre.

It is possible to make simultaneous measurements at all points. This way, it is possible to detect changes which only happen at narrow areas of the cable, something which may not be detected if you have a recording system with a limited number of individual receivers.

With the source in one position, it is possible to take seismic 'readings' for each metre of the cable, thus along the full wellbore if it is a borehole deployment. By moving the seismic source to different locations and taking multiple readings, it is possible to make a 3D seismic image. The quality of the signal is monitored throughout a survey.

In acoustic sensing, as used for seismic measurements, the system can record sounds with a dynamic range of 120 dB, at frequencies from millihertz to kHz.

The alternative recording device for seismic in wells is geophones. These are much harder to deploy downhole, being bulkier, and often breaking in harsh environments, Dr Stork said.