

Shallow geothermal energy recovery and storage monitoring using Distributed Fibre Optic Sensing (DFOS) in Glasgow and Cheshire, United Kingdom.

Client: British Geological Survey

Background Information

Geothermal energy plays a key role in the transition to sustainable, low-carbon energy systems. It is critical for mitigating climate change and diversifying energy sources. Distributed Fibre Optic Sensing (DFOS) is a robust technology that provides flexible, multi-parameter measurements, facilitating the exploration and efficient use of geothermal resources. DFOS-based monitoring systems help unlock the potential of geothermal energy by enabling real-time subsurface monitoring and enhancing energy storage management.

The UK Geoenery Observatories are world-class facilities designed to investigate geothermal energy recovery and storage. With field test sites in Cheshire and Glasgow, these observatories provide critical infrastructure for understanding subsurface processes and harnessing shallow geothermal energy.

The Cheshire Observatory, located at the University of Chester's Thornton Science Park, focuses on subsurface heat transfer, thermogeology, hydrogeology, and ground behavior. The Glasgow Observatory, on the other hand, supports research into minewater geothermal and mine thermal energy storage (MTES) by studying abandoned and flooded coal mines, a resource potentially available beneath 25% of the UK's urban areas.

Challenge

The primary challenge is to advance geothermal energy recovery and storage solutions, ensuring they can support a faster transition to a decarbonized energy system by 2050. To address this, there is a need to develop better models of subsurface heat movement and improve the design of ground-source heating and cooling systems. This involves enhancing our understanding of geothermal resources and how they interact with the environment, as well as how energy can be stored and recovered efficiently.

Solution

DFOS presents an effective solution for geothermal projects by offering highly sensitive monitoring capabilities. By integrating temperature (Distributed Temperature Sensing, DTS) and acoustic (Distributed Acoustic Sensing, DAS) data, DFOS enables a comprehensive understanding of subsurface fluid flow and reservoir dynamics. This combination facilitates high-fidelity monitoring of geothermal systems, providing insights into environmental impacts, heat extraction/rejection processes, and the overall performance of energy storage systems.

The DFOS systems deployed in both the Cheshire and Glasgow Observatories support the study of shallow geothermal energy recovery and thermal storage. These systems can be installed on the surface using trenching techniques or within boreholes, offering long-term, permanent monitoring capabilities to track temperature, flow, and seismic activity.

Results - Cheshire Observatory

At the Cheshire Observatory, a fibre optic sensing array has been installed across 20 boreholes, each reaching depths of 100 meters into the Sherwood Sandstone aquifer. This array, which uses both single-mode (SM) and multimode (MM) fibres, includes Silixa's Constellation™ fibre, renowned for its high sensitivity and ability to achieve up to a 100x reduction in noise floor. The boreholes are equipped with both DTS and DAS cables, enabling real-time monitoring of subsurface temperature and acoustic signals.

This setup allows for advanced thermal response testing and flow field characterization within fractured sandstone rock formations. Additionally, fibre optic cables have been placed inside and outside closed-loop borehole heat exchangers to evaluate the impact of sensor placement on monitoring data quality.



Figure 1: (Left) Cheshire Observatory, United Kingdom, surface cable deployment and data collection

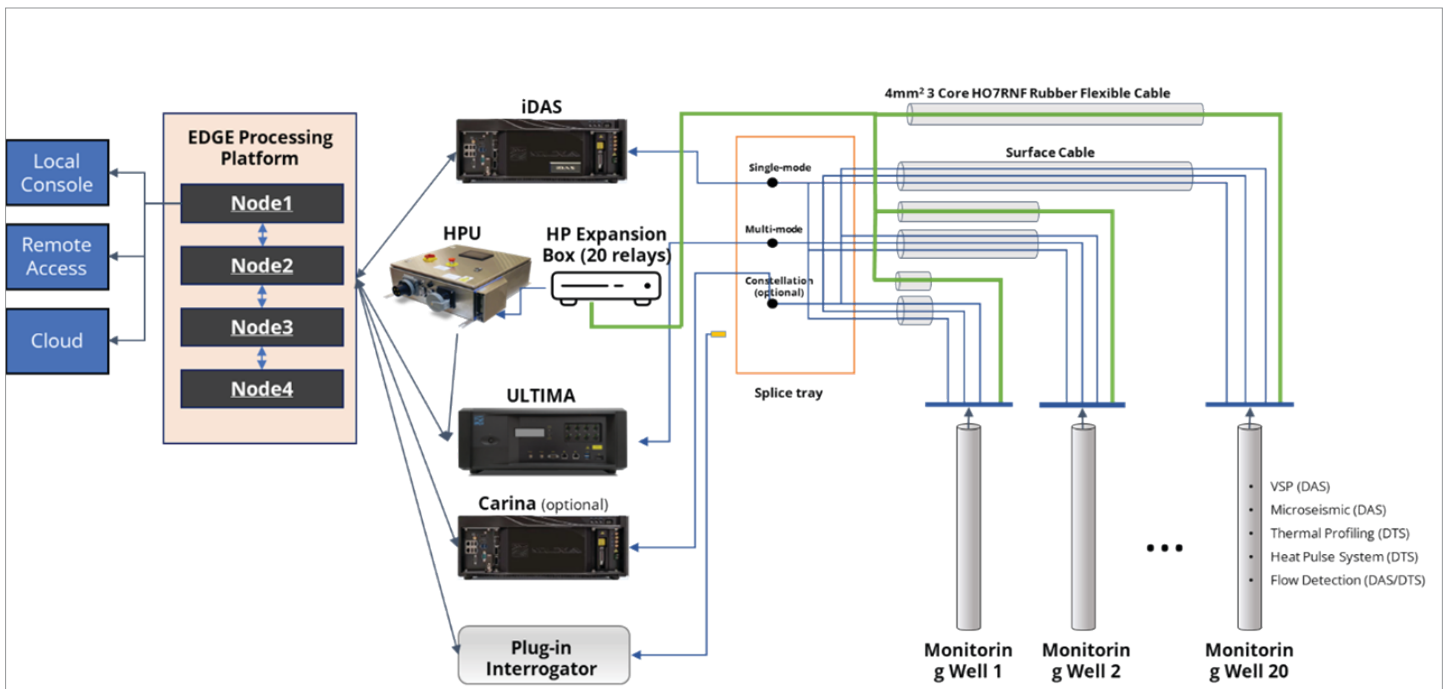


Figure 2: System architecture

Results - Glasgow Observatory

At the Glasgow Observatory, fibre optic sensing systems are used to monitor mine water boreholes in an unconnected heat user system, providing a platform for research and development. The facility includes two abstraction and two injection boreholes spaced between 10 and 190 meters apart. These boreholes are equipped with hybrid fibre-optic cables that allow for distributed acoustic and temperature monitoring, as well as active

heat pulse testing. High-quality data collection from the DTS system—at intervals of 25 cm along the fibre—has enabled precise detection of temperature variations as small as $\pm 0.01^{\circ}\text{C}$ during heat injection and extraction tests. This detailed data enhances our understanding of geothermal system dynamics and will contribute to improving geothermal energy modeling, system design, regulation, and public engagement efforts.



Figure 3 : Field deployment of the Silixa's XT DTS unit in an enclosure. (Centre) Fibre optic cable installation at a borehole in Glasgow observatory, (Right) Permanent infrastructure for heat and flow perturbations in a sealed, open-loop system.

Conclusion

The installation of Distributed Fibre Optic Sensing systems at the Cheshire and Glasgow Observatories offers the capability to obtain datasets with dense spatial resolution. The ability to collect data in real time, provides crucial information on subsurface behavior, improving the design and operational management of geothermal systems. This technology will play a vital role in supporting the transition to a low-carbon energy

future, helping to optimize geothermal systems and enhance their sustainability.

By continuously monitoring subsurface temperatures, fluid flows, and seismic events, DFOS technologies at the observatories are advancing the understanding of geothermal resources and their potential to provide clean, renewable energy for the UK.

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