Zero carbon-emission field operations for onshore seismic acquisition

Jordan Bos[1]*, Nick Tranter[2], Ben Turner[3] and Guy Drijkoningen[4] present zero carbon-emission during field operations in an environmentally sensitive area at the border of the Netherlands and Belgium for the Einstein telescope.

Abstract

Reducing carbon emissions and minimising land disturbances are key motivators to use innovations for onshore seismic acquisition. Seismic Mechatronics BV, through its fully battery-powered electric seismic source, has now enabled zero carbon-emission from vibrators and project vehicles during seismic acquisition with minimal disturbance on land. It recently proved this in a seismic survey in a noise-limited zone at the border of the Netherlands and Belgium. Being able to minimise environmental impact and to acquire higher-quality results in an environment with a challenging sub-surface made this project a success. This article compares the results achieved by one Storm10 eVibe in combination with STRYDE autonomous nodes, operated with zero carbon-emissions, to results obtained in mid-2022 using three conventional Mertz M12 diesel powered Vibroseis trucks in combination with Sercel WiNG nodes. We demonstrate that even with challenging operational conditions, the results achieved with the eVibe are superior for both the near-surface and deeper subsurface.

Introduction

In March 2023, a 2D seismic profile was acquired in a noise-limited zone on the border of the Netherlands and Belgium for geotechnical purposes (Figure 1). A noise-limited zone is an area where sound has to stay below a certain threshold, in this case the A-weighted equivalent sound pressure level, $L_{Aeq,24\ h}$, should stay below 40 dB(A) over 24 hours. The goal of the seismic survey was to obtain higher resolution images compared with a previous seismic study carried out in 2022. Higher-resolution images were needed for the planning of the Einstein Telescope (ET) that will need three underground tunnels at a depth of 300 meters, each with a length of 10 kilometres, forming a triangular shape.

The primary target was to image the top 500 m, with a focus on the structures and horizons at the depth of the planned Einstein Telescope. The secondary target was to image the deeper roots of structures down to depths of 2000 m with higher resolution than the previous survey from 2022. For the project, the Seismic Mechatronics Storm 10 eVibe was fully battery-powered (Figure 2), providing a zero carbon-emission source during field operations (excluding the emissions for generating the electricity to charge the batteries). The Storm 10 eVibe was mounted on a full-electric Manitou MTE 625 carrier. For operational support a full-electric Polaris EV Ranger support vehicle was used. As a result, zero carbon-emission seismic acquisition was made possible for deep targets, a first for this region. As a secondary

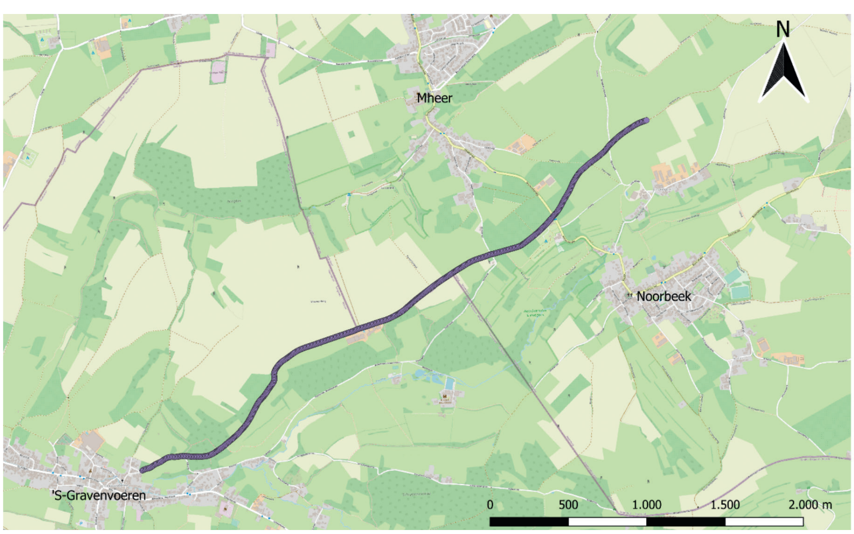

Figure 1 2D seismic profile surveyed with eVibe at border between the Netherlands and Belgium.

[1] Seismic Mechatronics | [2] STRYDE | [3] Dayboro Geophysical | [4] CITG
* Corresponding author, E-mail: j.bos@seismic-mechatronics.com
DOI: 10.3997/1365-2397.fb2023082

Figure 2 Battery-powered Storm 10 eVibe during production.

Figure 4 The three Mertz M12 VibroSeis trucks in the same area in 2022, as comparison.

result, noise-limited zones have now also become accessible for seismic acquisition with minimal disturbance.

For the survey line, 812 STRYDE nodes were deployed at 5 m spacing along a line of 4.1 kilometres. A secondary 'parameter test line' of 89 STRYDE nodes was deployed in parallel to the section of the main line. This was used to test sweep parameters for production. The source spacing was 5 m along both the production and the test line. The mobilisation of the Storm 10 eVibe system, the deployment of all 901 STRYDE nodes, retrieval of 89 'test' receivers and acquisition of the test line was performed in a single day with a team of 5 people.

Based on the sweep parameter tests, the log-log upsweep with a bias towards longer sweeping at the low-frequency end, shown in Figure 3, was selected for production. Having 10,000 Newton peak amplitude, ranging from 2 to 100 Hz in P-wave mode, 24 second duration, -1 dB/octave after correlation, with 1.02 second cosine start taper and a 0.3 second cosine end taper. It was also determined during the test, that two sweeps per source point were sufficient. In the previous study [Waldvogel, 2023], three Mertz M12 VibroSeis trucks were used in a row (Figure 4) to generate 4 sweeps with 16 second duration per vibrator point over a range of either 6-90 or 10-90 Hz. A source point spacing of 20 m and a receiver (Sercel WiNG nodes) spacing of 10 m was used.

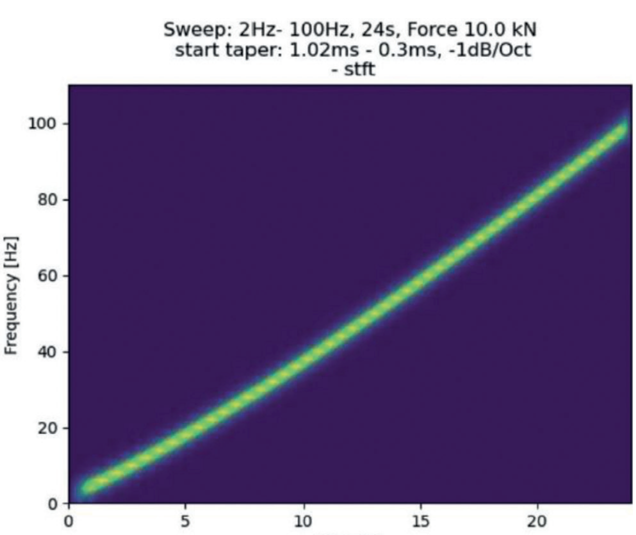

Figure 3 Low-dwell sweep, short-time Fourier transform.

As the seismic profile ran through an environmentally sensitive area, operations were conducted during the day and only on pathways. 812 vibration points were completed in approximately 46 hours split over 6 days, resulting in an average production rate of ca. 35 sweeps/hour. The eVibe source crew consisted of just two people, one observer travelling in advance and one Storm10 eVibe operator. The source crew experienced heavy rain and snow with subzero temperatures (Figure 5) for multiple days, without any equipment issues. Retrieval, cleaning and demobilisation of the 812 STRYDE nodes from the main 2D survey line, together with cleaning and demobililsation of the Storm 10 eVibe system, was completed within one day by 6 people. No equipment malfunctions were experienced during the programme, and all operations went smoothly, with no reported HSSE incidents. The permit to work in the noise-limited zone was easily granted, due to the compact, quiet and fully electric seismic source, carrier and support vehicle (Figure 6) which where all battery-powered.

Seismic source

The Storm 10 eVibe is an electric seismic source that enables 'zero carbon-emission' seismic acquisition, through battery-powered direct-drive electromagnetic motor technology. These fully electric motors are highly efficient (>90% IEC4/5) creating reliable and high-quality seismic signals across a broadband frequency range [Noordlandt et al, 2015 & Brodic et al, 2021]. The technology is compact, and achieves a great depth of penetration. This technology has already been shown to operate effectively in a challenging and restrictive urban environment [Tranter et al, 2022]. Using a fully battery-powered source in combination with an all-electric carrier (Figure 6) for field support, all carbon emissions per vibrating point can be eliminated in the field.

There are various eVibes commercially available, the Lightning eVibe, the Synchro eVibe and the Storm10 eVibe. For this project, the Storm10 eVibe was used with a volume of ca. 0.50x1.37x1.0 m^3 and a weight of ca. 950 kg. The Storm 10 is a P- and S-wave source with a full-force sweep frequency of 3.6 to 240 Hz, capable of sweeping between 2-450 Hz at lower force. The source can be attached to locally available carriers. The combination of the source, auxiliaries and electric Manitou MT 625 carrier created a total weight of approximately 6700 kg with a width of 1.81 m.

The receivers

STRYDE nodes represent a new generation of onshore seismic autonomous nodal receivers. The nimble nature of STRYDE's miniature nodes (Figure 6) enables agile, fast, and low environmental impact seismic acquisition operations. A STRYDE node weighs 150 g and is 129x41mm in dimension, which allowed the seismic crew members to carry and deploy more receiver devices by foot than ever before and eliminated the need for multiple deployment transportation vehicles on this project. As a result of this, significant operational efficiencies, and reduced exposure to HSSE risk were demonstrated on this project with:

- 901 nodes deployed in 1 working day and 817 nodes retrieved in 6 hours with a 4-person crew.
- Only one compact (all-electric) vehicle being required for deployment and retrieval operations, which had a significant impact on safety.

The STRYDE nodes recorded in 'calendar mode' for 12 hours/day with 60 min GNSS wake-up, 8 min GNSS search time and 60 second lock time at 1 millisecond sample interval. The nodes were used for a total of 11 days in the field. The nodes were mostly buried into the soil along a pathway to minimise interference and tampering. Of the 901 STRYDE nodes deployed, only 4 were lost, giving a 99.5% recovery rate.

In summary, the use of STRYDE nodes on this acquisition enabled operational efficiency gains, leading to a significant reduction in environmental footprint and land disruption.

Processing and data results

The data were processed through a comprehensive processing flow, utilising pre-stack time migration and advanced adaptive noise attenuation techniques, with attention focused on velocity analysis and statics correction. One of the primary objectives of the survey was to achieve an understanding of the very near surface. The near surface here consists of a 70-100m layer of very slow (700 m/s) material. Ordinarily, static corrections are calculated and applied as part of the processing flow to compensate for this low-velocity layer. However, in this case the application of the statics has a strongly detrimental effect on the very near surface image. For this reason, two processing flows were implemented, one designed to achieve an optimal image of the very near surface, without the application of statics and the second focusing on the deeper section with the near surface velocity regime corrected for by the application of statics corrections. The signal processing for the two processing flows was essentially the same, with just the velocities and post-stack processing parameters differing.

Processing flow:

- Reformat
- Define and Apply Geometry
- First Break Picking – Tomostatics (Application only for Deep Section)
- Squelch – Adaptive Spurious and Random Noise Attenuation
- Quash – Adaptive Linear Noise Attenuation
- Spherical Divergence Correction
- Surface Consistent Deconvolution

Figures 5 Heavy snow- (left) and rainfall (right) was experienced during production with the eVibe.

Figure 6 All-electric support vehicle.

Figure 7 STRYDE node deployed in the ground.

- First Pass Velocity Analysis (250 m increment)
- First Pass Residual Statics
- Second Pass Velocity Analysis (250 m increment)
- Second Pass Residual Statics
- AGC
- Migration Velocity Analysis (250 m increment)
- Kirchhoff PSTM
- Final Velocity Analysis (125 m increment)
- Mute – Stack
- FK Power Filter
- FX Domain Running Mix
- Spectral Shaping
- Time Variant Filter
- Multi-window Trace Balance
- Move to Final Datum

The mid-2022 survey data [Waldvogel, 2023], for which three VibroSeis sources were used, were compared to the data acquired using a single eVibe for both the shallow and deep section and are shown in Figures 8 and 9, respectively. Based on the comparison, the eVibe data shows improved resolution, better continuity, sharper images and additional reflectors in the near-surface section. The deeper subsurface data appears to be an improvement compared to the legacy data.

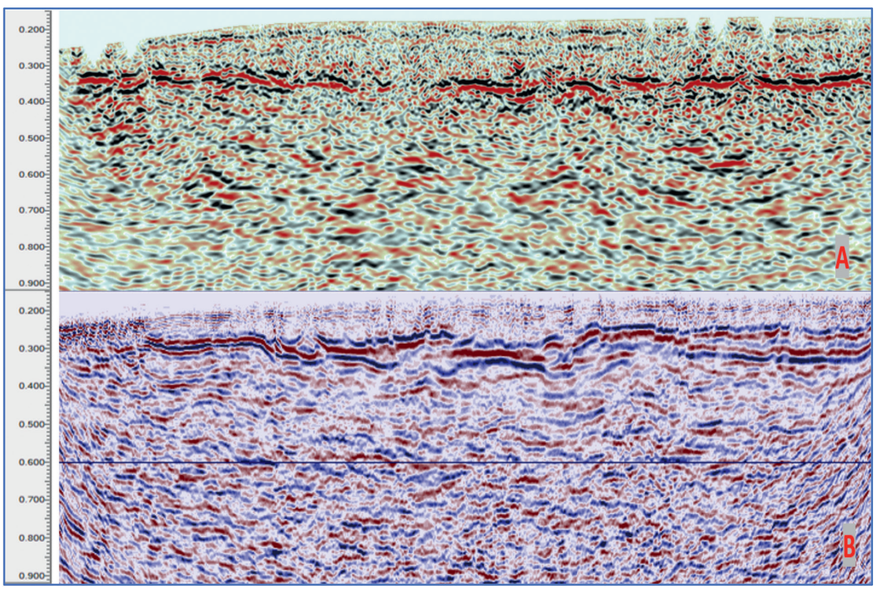

Figure 8 Comparison of the shallow (0-900 ms) data between (A) part of three Mertz M12 Vibroseis data [Waldvogel, 2023], and (B) one Storm eVibe data.

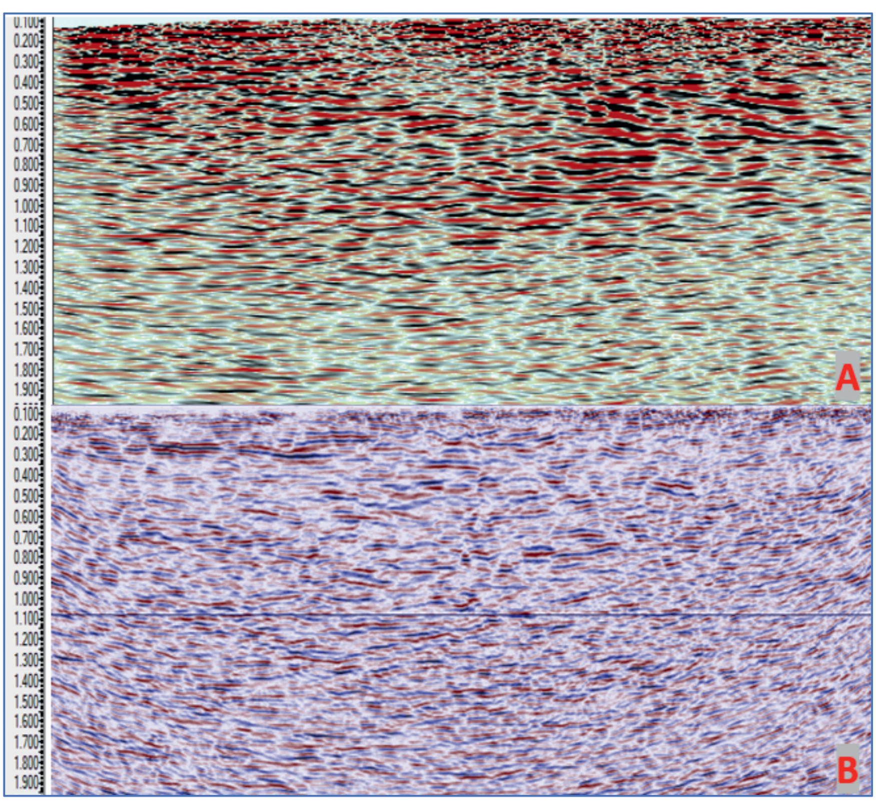

Figure 9 Comparison of the deep (until 1900 ms) data between (A) part of three Mertz M12 Vibroseis data [Waldvogel, 2023], and (B) one Storm eVibe data.

Conclusion

A seismic survey with zero-carbon emissions from the seismic vibrator and project vehicles during field operations was successfully performed in a noise-limited zone, with challenging geology, at the border of The Netherlands and Belgium. We demonstrate that even with challenging operational conditions, the results achieved with one Storm eVibe with a smaller (high-density) source spacing are superior for both the near-surface and deeper subsurface, compared with a recent 2022 survey using three M12 Mertz Vibrioses trucks, using a larger (lower-density) source spacing. Being able to minimise environmental impact and to acquire higher-quality data has been made possible with recently developed technology, namely a battery-powered Storm eVibe from Seismic Mechatronics as seismic source in combination with STRYDE nodes as the seismic receiver system. These technologies continue to demonstrate their ability to operate effectively in challenging environments: minimising land disruption, risk and environmental footprint by reducing the project duration, the number of people and vehicles required for seismic acquisition, when compared with conventional surveys. Last but not least, with all equipment being fully electric and battery-powered, zero carbon-emissions from the vibrator and vehicles during field operations have now been enabled for onshore seismic acquisition.

References

Brodic, B., De Kunder, R., Ras, P., Van den Berg, J. and Malehmir, A. [2019] Seismic imaging using electromagnetic vibrators-Storm versus Lightning. *25th European Meeting of Environmental and Engineering Geophysics, Extended Abstracts*, Tu_25th_B04.

Brodic, B., Ras, P., de Kunder, R., Drijkoningen G. and Malehmir A. [2021]. Seismic imaging using an e-vib — A case study analyzing the signal properties of a seismic vibrator driven by electric linear synchronous motors, *Geophysics,* **86**(3), 1-13. doi:10.1190/GEO2020-0181.1

Noorlandt, R., Drijkoningen, G., Dams, J. and Jenneskens, R. [2015]. A seismic vertical vibrator driven by linear synchronous motors. *Geophysics*, **80**(2), EN57–EN67.

Tranter, N., de Kunder, R., Turner, B. and Drijkoningen, G. [2022]. Acquiring sustainable, efficient high-resolution seismic data for geothermal exploration in an urban environment. *First Break,* Volume **40**(10), October 2022, 47-50.

Waldvogel, M. [2023]. Active seismic surveys in the EMR. Presentation 'T4MariusWaldvogel.pptx' on the *2nd SPB Workshop for the Einstein Telescope*, 24-01-2023, Thiessen Wineries, Maastricht, The Netherlands.

ADVERTISEMENT

CNPC BGP BGP Inc. | http://www.bgp.com.cn E-mail:marketing@bgp.com.cn