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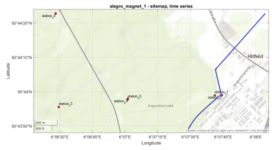
High Voltage DC Power Lines in EM: Preliminary Results

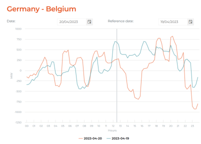
DC Powerlines

Direct current power lines are built for low-loss long-distance transmission of electricity. At the moment in and around Germany, they are mainly used for transmitting electrical Power between Countries through the North Sea and from offshore wind parks to shore. There are plans to use the technology to transmit power from the north of Germany to its southern parts (Project Suedlink). This poster will focus on a power line "Alegro" operating at 320 kV and a power of up to 1 Gw that was built as a test project connecting the power grids of Germany and Belgium. The main purpose of Alegro is balancing the varying loads between the power grids of the two Countries. We take a first look at the EM Signal this power line emits, whether it is relevant as a noise source or could even be used as a signal for EM.

Aachen Measurement

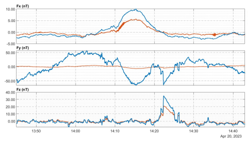
As a first measurement site, we chose a forest south of Aachen. Most of the Alegro power line is parallel to a standard 50 Hz power line and or goes close to the autobahn, therefore there were few Positions suitable for measuring mostly the signal coming from the DC power line. The goal of this Measurement was to get a first Idea about the spectral content of the DC power line due to changes in its load. The power is only measured as 15-minute averages which have hardly any uses for the frequencies typically used in EM. Therefore, we measured with two fluxgate magnetometers at different positions.

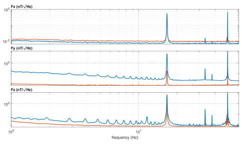




Data

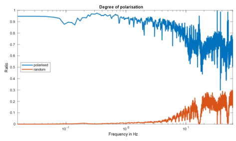
The data collected from the area is quite noisy due to the proximity to Aachen and subsequently the large number of other sources. However, upon analysing the magnetic field in the time domain, it appears that there is a lot of similarity over a distance of 800 m which suggests that one source is dominant in both stations. The figure on the right shows a broadly distributed spectral density.

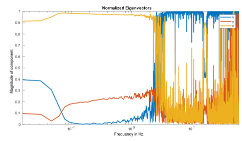




Polarisation of an EM Signal

Given a measured time series can we calculate the degree of polarization?
The starting point is the Cross-spectral density matrix $W_{ij} = \langle B_i^*(\vec{r},\omega) B_j(\vec{r},\omega)\rangle_a$. Calculating the Eigenvalues λ_i and Eigenvectors $\vec{v}_i$, the direction of polarization is given by the direction of the eigenvector corresponding to the largest eigenvalue λ_1. [1]
Based on those Eigenvalues we can define the Degree of polarization $P = \frac{\lambda_1 - \lambda_2}{\lambda_1+\lambda_2+\lambda_3}$ and the unpolarized part of the signal $R = \frac{3\lambda_3}{\lambda_1+\lambda_2+\lambda_3}$.





The Results show a high degree of polarisation up to 20 Hz. For higher frequencies the the degree of polarisation drops. The second figure visualises the Eigenvector corresponding to the largest Eigenvalue. This is the direction of the polarised part of the signal. The direction of polarisation is dominated by the z-component for lower frequencies and shifts to the x-direction for higher frequencies.

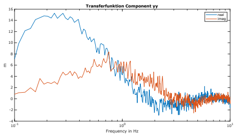
Therefore, it can be concluded that for frequencies below approximately 20 Hz, the signal is dominated by a single emitter, probably the Alegro DC power line.

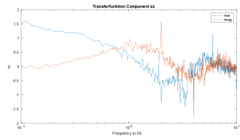
Interstationary transfer function

In CSEM one typically calculates the transfer function describing a relationship between the source and the measured fields. In the following we consider two ground stations measuring. Since both signals depend linearly on the current, there should be a frequency-dependent relation between components of the two stations. Since all other dependencies are constant, we can assume that the relation can be described by a scalar (univariate problem). Considering the data at the local station d_{obs} and at the reference station G, we can use the Ansatz:

$$d_{obs} = Gm$$
$$m = \left(G^{\dagger}G\right)^{-1} G^{\dagger} d_{obs}$$

to estimate the model Parameter m.

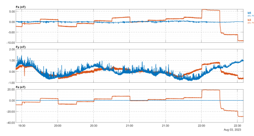




The Figures show the frequency dependency for the model parameter m for different components between station 0 and station 1.

Büsum

Due to the comparatively high amount of infrastructure in the first measurement, we decided to search for a second testing site in a less populated area. Four DC power lines are running in parallel through the test site. Three of them come from the Offshore Windmills by Helgoland and Sylt and one connects the German and Norwegian power grid (Nordlink). In total they can transmit up to 3.5 GW.



Two ground stations (b2 and b3) were positioned directly above the cables. They showed distinct steps every 15 minutes. But even at a distance of 400 m, those steps could not be found in the time series. A potential reason could be the small distance between the cables with current going in opposite directions. This would lead to a quadratic decay considering only two cables and neglecting the conductivity of the Ground.

Conclusions

- Although both sites have dc power lines, the signals are quite different.
- In Aachen, we observed a relation between signals indicating the same source up to 580 m away from the power line, while in Büsum, even the closest station, at a distance of 400 m, did not record the distinct features from the station above the cable.To gain a better understanding of the emitted signal and its decay, further measurements for intermediate distances are needed.
- For the Measurements in Aachen, we applied a simple yet insightful way to obtain information about the polarisation and the relation between stations, both leading to the conclusion of a single source dominating the recordings at both stations.
- In summary, DC power lines do emit an EM signal that should be taken into consideration when doing MT or CSEM Measurements close by. However, it decays faster than expected probably due to having two cables with currents in opposite directions next to each other.
- Using DC power lines as a Signal, the main challenge is the lack of information about the current. Multiple simultaneous measurements may be used to still obtain information about the ground using interstationary transfer functions as a first step.

References

[1] Ellis, J., & Dogariu, A. (2005). On the degree of polarization of random electromagnetic fields. Optics communications, 253(4-6), 257-265.

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