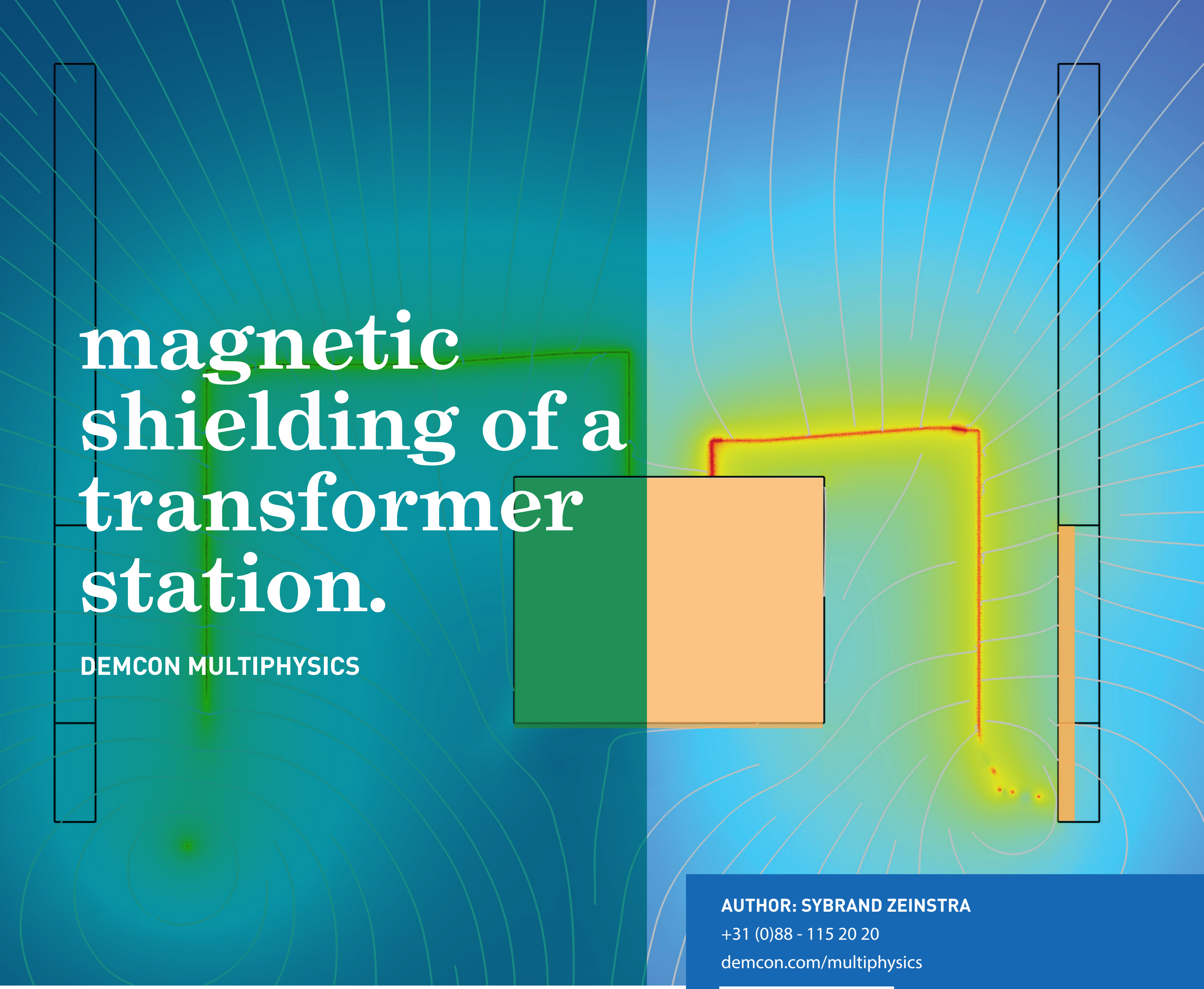

magnetic shielding of a transformer station.

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Goal

This project focused on the design of magnetic shielding in a transformer station. These stations are part of the electricity network and are used to transform the incoming current to a lower voltage, as well as to distribute the transformed current. The currents that are carried by the electrical cables give rise to magnetic fields around the cables. For an AC current, these magnetic fields vary periodically in time, at the frequency of the current – in this case 50 Hz. To prevent health-relevant interactions with electromagnetic fields, exposure limits have been defined by the International Commission on Non-Ionizing Radiation Protection (ICNIRP). For 50 Hz, the maximum allowed magnetic field is 100 μT. In the transformer station in this case, the magnetic field strength on the outside of the station reached levels above the exposure limit.

Therefore, we designed magnetic shielding to reduce the magnetic field strength in areas that are accessible to the public.

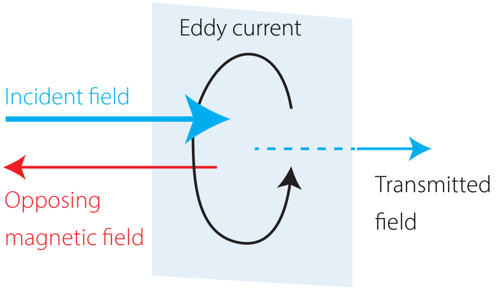

Figure 1. Aluminium plate with principle of eddy current shielding.

Approach

The physical phenomenon responsible for the shielding is eddy-current cancellation, as seen in Figure 1. The working mechanism of magnetic shielding can be explained using Faraday's law of induction. It states that a time-varying magnetic field induces an electric field and therefore a current (in a conductor). The resulting current induces another magnetic field, which is opposed to the external field. Hence, a current is induced in a magnetic shield (made from conductive material), which produces a magnetic field that reduces the strength of the original magnetic field.

Using COMSOL Multiphysics, we simulated the magnetic fields generated by the electrical cables in the transformer station and evaluated the magnetic field outside the transformer station (a public area). Thereafter, we designed magnetic shielding and simulated the effect of the shielding on the magnetic field outside the station. The 3D model, shown in Figure 2, that was used includes the electrical cables that go into and out of the station. The transformer itself (represented by an orange block in the figures) was excluded from the simulation, as it is magnetically shielded and is considered to not 'leak' any magnetic field.

The simulation was performed in two steps. First, a continuous current distribution along the cable segments was calculated, by solving a Laplace partial differential equation along the edges of the cable. Second, the magnetic field resulting from the cables was calculated, using the results of the current distribution as a boundary condition (without magnetic shielding). Next, shielding was applied to part of one side of the inner wall of the transformer station. As a shielding material, we used aluminium sheets, as aluminium has a high conductivity. We simulated the effect of the shielding by means of a transition boundary condition, which represents a discontinuity in the tangential electric field. This is computationally advantageous, as the shielding does not need to be modeled in detail. The dimensions of the shielding were varied to determine the amount of shielding material required to sufficiently reduce the magnetic field on the outside of the transformer station.

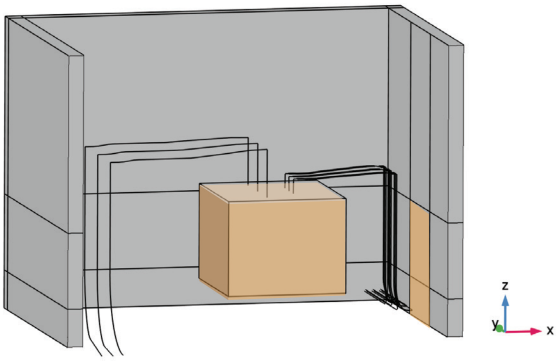

Figure 2. Overview of the geometry of the transformer station showing the electrical cables and the part of the wall where shielding was applied.

Results

To compare the magnetic field to the target value of 100 μT, we considered the norm of the Root-Mean-Squared (RMS) value of the magnetic field, $|B_{RMS}|$. A view of $|B_{RMS}|$ in the xz-plane with shielding included is shown in Figure 3.

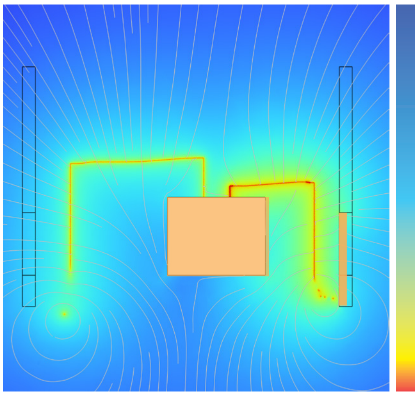

Figure 3. $|B_{RMS}|$ in the xz-plane, centered on the middle of the transformer. The magnetic field lines are considerably affected by the magnetic shielding at the right wall of the station.

To illustrate the effect of the magnetic shielding, we plotted the 3D $|B_{RMS}|$= 100 μT contour in Figure 4. It contains two contours. The cyan contour is the 100 μT contour for the situation without any shielding included. The dark blue contour is the situation where magnetic shielding is included. Due to the magnetic shielding, the magnetic field outside the transformer station was reduced. The 100 μT contour becomes mostly confined to the interior of the station, apart from a small region, which is inaccessible due to its height. With these simulations, we were able to design effective magnetic shielding in the desired region around the transformer station.

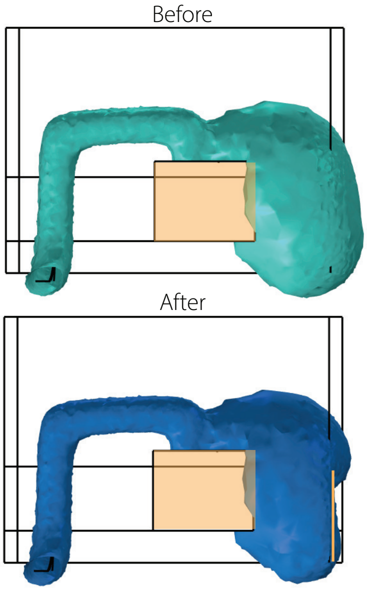

Figure 4. 3D contour of $|B_{RMS}|$ = 100 μT before (top: cyan) and after (bottom: blue) magnetic shielding was included.