# EM MEASUREMENTS AND MITIGATION TECHNIQUES ON MV INSTALLATIONS

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## INTRODUCTION

The Dutch Distribution System Operator Alliander uses the stakeholder philosophy. Within this philosophy one of the stakeholders is environmental impact. Alliander takes care of the environment within the design of the grids and substations. Approximately 95.000km of grid and 170 substations are under administration of Alliander. Within Alliander, Liandon is the project, consultancy, building and maintenance department.
With respect to the magnetic fields emission a limiting value of 100µT is obtained for general human population. However, for new overhead lines this value is dramatically reduced to the challenging value of 0,4µT as an annual average. Also in special cases (e.g. schools and residential areas) customers or local authorities are requesting for these low values.

Anticipating on the magnetic fields discussion, Liandon performed a pragmatically research program with respect to:

- Measuring
- Appropriate measures

## MAGNETIC FIELD AROUND A TYPICAL 10 KV TRANSFORMER STATION

The MV transformer stations in the densely populated areas of the medium voltage grid are powered through a mazed regional electricity distribution network. These MV transformer stations convert the incoming 10kV voltage to a low voltage of 220/380V. As shown in the figure below, these typical stations consist of a transformer, a medium voltage switchboard and a low voltage switchboard. The stations are suitable for a standard transformer with power rating of 400 or 630 kVA.


**Figure 1:** Arrangement of a standardized MV transformer station

The magnetic fields around one of the standardized MV station are measured in several directions by a calibrated instrument at a height of 1m. The secondary current of transformer and the outgoing LV feeders are also measured during the magnetic field measurements. The measured magnetic field around this MV station is shown in the figure 2. As can been seen from the figure the highest concentration of the measured magnetic field is in direction "A" which is directly behind the LV switchboard. In figure 3 the attenuation of the magnetic field is shown in direction "A".

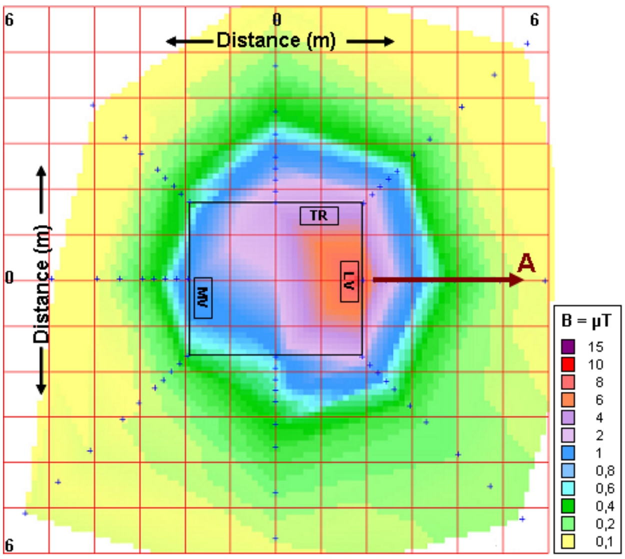


**Figure 2:** Instantaneous magnetic field

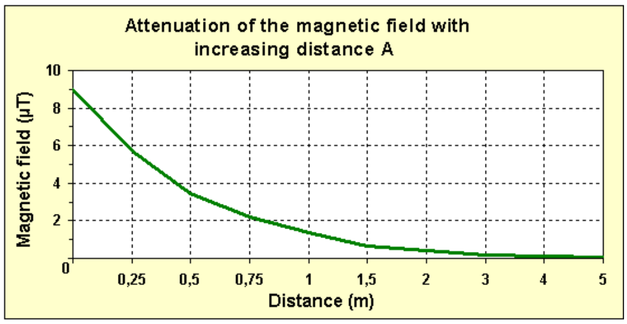


**Figure 3:** Attenuation of the magnetic field of direction "A"

To correlate the measured magnetic field and current to a yearly magnetic field pattern the current of the MV station was measured during a week. The weekly pattern of the measured current is shown in figure 4. This weekly pattern, which is repeated more or less throughout whole year, can be used to determine the average load value of the year.

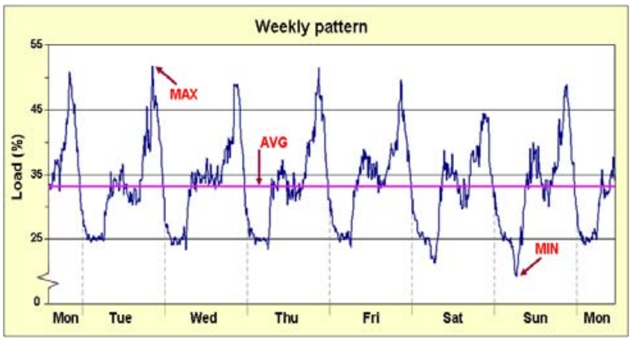


**Figure 4:** The weekly pattern of the MV transformer station

From figure 4 can be seen that based on the measured weekly pattern the average current is 33%.
Based on the measured magnetic field and the average current, figure 5 shows the average year magnetic field pattern of the MV station.

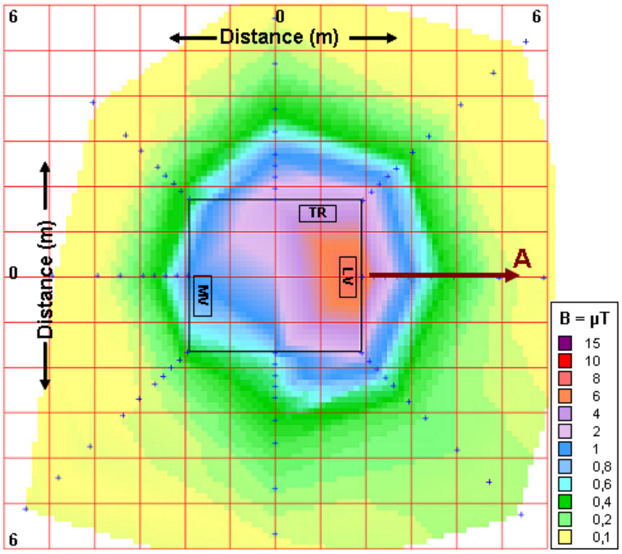


**Figure 5:** Average magnetic field based on the weekly load profile

From figure 2 and 5 can be seen that the pattern of the measured and the yearly average magnetic field are more or less the same.

In order to describe the growth of the magnetic field pattern an average annual load growth of minimum 2% and maximum 5% each year is taken into account. The figure below shows the minimum and maximum load growth over 10 years. The average magnetic field of the weekly load profile is used as reference at year 0.

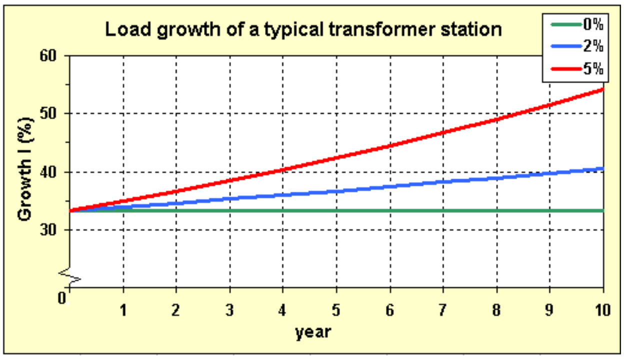


**Figure 6:** Load growth of the MV transformer station over 10 years.

In respectively figure 7 and 8 the magnetic field pattern is shown with an annual load growth of 2% and 5% after 10 years.

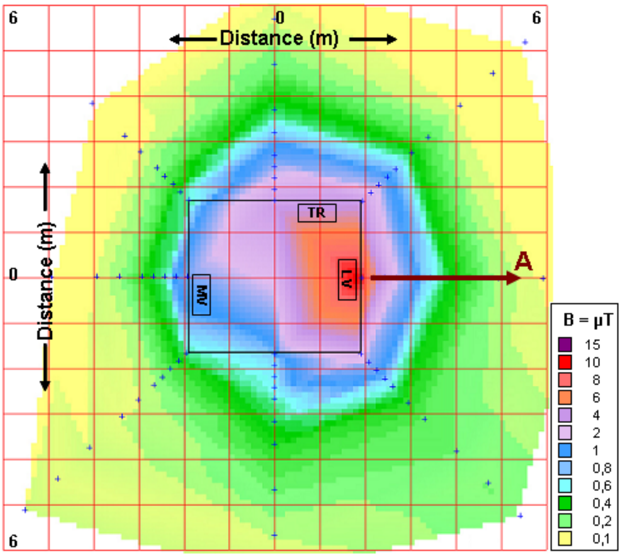


**Figure 7:** Magnetic fields related to an annual load growth of 2% after 10 years

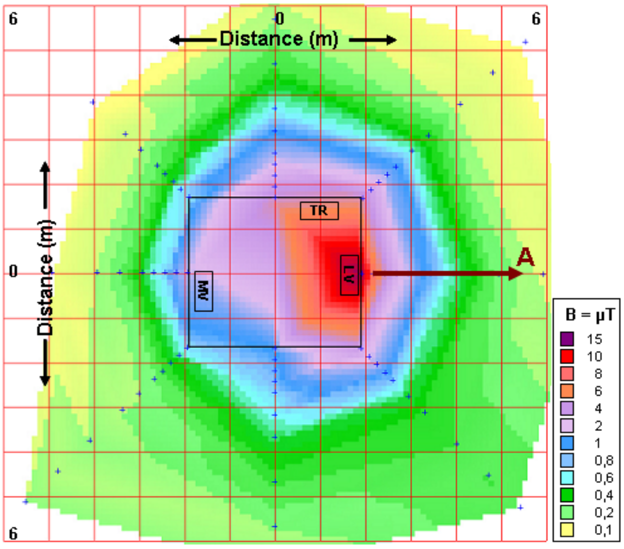


**Figure 8:** Magnetic fields related to an annual load growth of 5% after 10 years

Figure 9 shows the attenuation of the magnetic field for direction "A" for respectively the measured, the weekly average, the minimum load growth after 10 years and the maximum load growth after 10 years. From the figure can be seen that the influence of load growth is only effective at short distance of the LV switchboard. At greater distances the magnetic field converges.
For instance, the shift of the magnetic field zone of 0,4µT with a load growth of 2% and 5% after 10 years is respectively 30 and 70cm. This can be seen in figure 10.

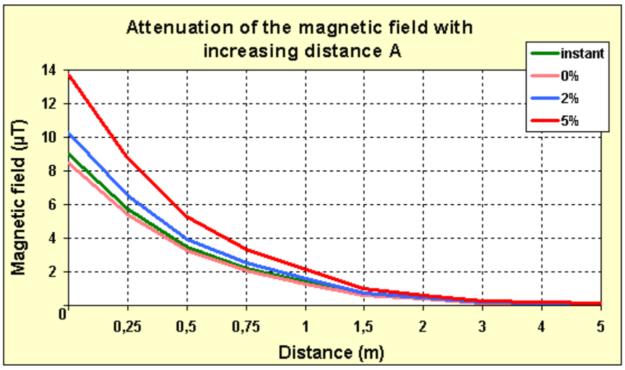


**Figure 9:** Attenuation of the magnetic field in direction "A" with respect to different load growth scenarios

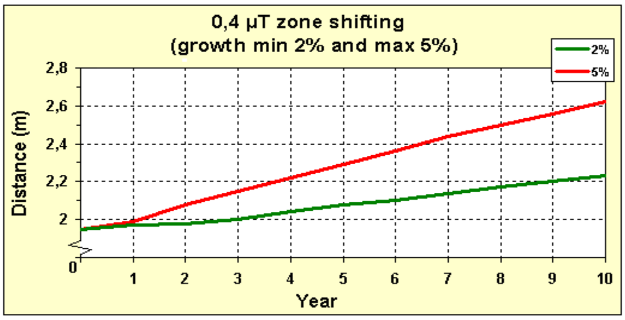


**Figure 10:** 0,4 µT zone shifting at a load growth of 2% and 5%

## APPROPRIATE MEASURES

One of the developments with very effective shielding properties is the so called "Sandwich construction". Basically the sandwich construction consists of 2 touching metal plates respectively Aluminium and Steel with each a thickness of 1-2mm.
The theoretical description of this application is as follows: the steel plate takes care of the magnetic field whereas the aluminium plate takes care of the conductivity of the induced current.
For demonstrating the effectiveness of the shielding method experiments have been conducted on an air coil with and without sandwich housing. The sandwich housing consists of 2 separate boxes of respectively steel and aluminium. In figure 11 the test arrangement is shown.

**Figure 11:** experimental set up of sandwich construction

For the test a symmetrical current was injected of 150A and the coils had an impedance of 0,3ohm.
At several distances from the air coil the magnetic field was measured. In the figure underneath the results are shown with respect to the different shielding formations. The represented lines are the measured magnetic fields in the direction of the back of the set up.

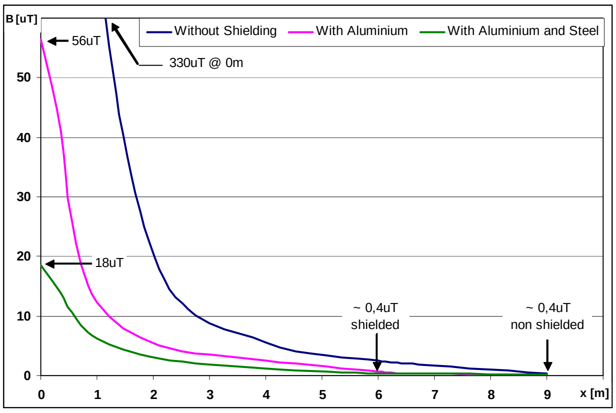


**Figure 12:** attenuation of the magnetic field with use of shielding material

From the figure can be seen that there is a strong reduction of the magnetic field directly behind the sandwich construction; up to 18 times to the non shielded situation.
With reference to the 0,4µT zone, there is a distance shift of approximately 3m between de non shielded and shielded situation.
After this successful test is was decided to perform a first pilot project in practice. The pilot project involved a MV transformer station set up as used in the previous paragraph. The transformer has a power rating of 400kVA.
In figure 13 a representation is shown of the MV transformer station with the sandwich construction placed at the inner wall.

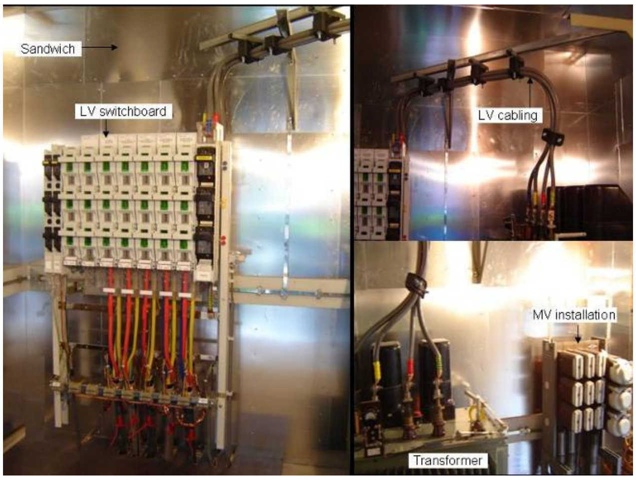


**Figure 13:** overview of the sandwich construction within a MV transformer station

After installation the same evaluation method was done in accordance with the previous paragraph in order to determine the effectiveness of the shielding for the present load but also for the future load growth. In this case a load growth to 100% of the transformer power rating was taken into account. The load pattern was measured during one week and scaled to the power rating of the transformer. From this maximum profile, an average load was deducted of 70%.

During the magnetic field measurements respectively before and after shielding the load of the transformer was 50% and 60%.

To correlate the measured magnetic fields and the maximum average load of the MV transformer station the following correction factors were used:

- Non shielded: 1,40 (=70/50)
- Shielded: 1,16 (=70/60)

The sandwich construction mitigated the magnetic field sufficiently. The following shielding factors were achieved:

- behind the LV switchboard: ~15 times
- behind the transformer: ~3 times
- above MV transformer station: ~12 times

The magnetic zone of 0,4μT zone shifted at some positions by meters towards the MV transformer station. Even at some points almost to the outer wall of the station.

## LESSONS LEARNED

First of all discussions about limiting values of the magnetic field have to be made in a sensitive way.

In order to make the behaviour of magnetic fields in complex situations more understandable, the pragmatically approach was chosen to perform measurements around a standardised MV transformer station and to experiment with a sandwich construction for mitigation purposes.

From the gained experience of the performed magnetic field measurements the following is learned:

- The magnetic field from a MV transformer station is predominately defined by the LV switchboard and the LV cabling towards the transformer. This is due to the interaxial distances between the conductors and bus bars. Therefore it is advisable to reduce the interaxial distance to a minimum to minimise the magnetic paths.
- The magnetic field in direction of the highest field concentration is reduced to a value less than 1μT within 1,5-2m for a transformer of 400kVA.
- The effect of the load growth is mostly noticeable in short distance of the station. The shift of, for instance, the 0,4μT is only 70cm at a load growth percentage of 5% after 10 years.
- In order to evaluate the magnetic field for the lower regions (<1μT) it must be physically understood that a slight difference in amplitude has a big influence on the distance.

With respect to the developed sandwich construction the following can be mentioned:

- The sandwich construction is a cost effective way to mitigate the magnetic field.
- A special approach has to be taken into account when installing the metal plates in order to maximise the effectivity of shielding.
- In the vicinity of at the sandwich construction shielding factors of ~15 can be reached.
- Also for shifting the lower magnetic field values towards the source this method it is experienced that the sandwich construction a workable and practical solution.