

Radiated fields of electrical equipment

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Electrical equipment (overhead lines, cables, transformers, ETV or radio antennas, radars) as well as home equipment (telephones, cooking devices, TVs, PCs) generate electromagnetic fields whose influence depends widely on the frequency.

Those electromagnetic fields, often called electrical pollution or ‘electrosmog’, may influence other equipment and be harmful for public health. The visual impact of the electrical equipment over the environment and the increasing fears of citizens about their medium- and long-term effects lead several countries to give emission limit values. Those concerning Switzerland are given by the ORNI (Ordonnance sur la protection contre le rayonnement Non Ionisant) and are among the strongest in Europe. They include exposition limit values, according to international recommendations, and are valid for any place where human beings may stay for a short period of time, as well as preventive limit values, more severe, and valid for peculiar places, such as apartments, hospitals and schools.

Low frequency radiation

We will study the low frequency radiation of electrical equipment such as high voltage overhead lines, cables and transformation stations. The corresponding frequency are between some Hz to some kHz. Limit fields relative to the ORNI standards are considered for nominal working.

Several methods may be used to limit the radiation of the equipment, such as:

- optimised configuration of the components in the transformation station
- position of the cables in those stations
- distribution of the phases in the HV lines
- limitation of the neutral current in the transformation station
- accounting for the radiation while designing transformers and distribution boards
- magnetic shielding.

Simulation is a valuable help when renewing or designing equipment. FLUX (3D) enables the computation of electric and magnetic fields, for steady and transient states. Some features are particularly well adapted for such computations:

- infinite region (modelling of open boundary cases and radiated fields at long distances)
- coupling to external circuits (to account for the coupling of the transformer, unbalanced loads, voltage supply)
- thin regions (modelling of shields, induced currents in transformer tanks, thin airgaps)
- modelling of laminated non linear materials (magnetic circuit of transformers)
- non-meshed coils (modelling of cables and distribution boards)
- account for non-linear properties in sinusoidal steady states.

Some examples of simulations are detailed below.

Radiated field of an overhead line

A 3-phase line is considered (Fig 1). The line voltage is 40 kV and the current is 535 A per cable. In Fig 2 two configurations have been modelled. The induction is represented along the line, 10 m below the lowest height of the line. The transverse distance is 70 m.

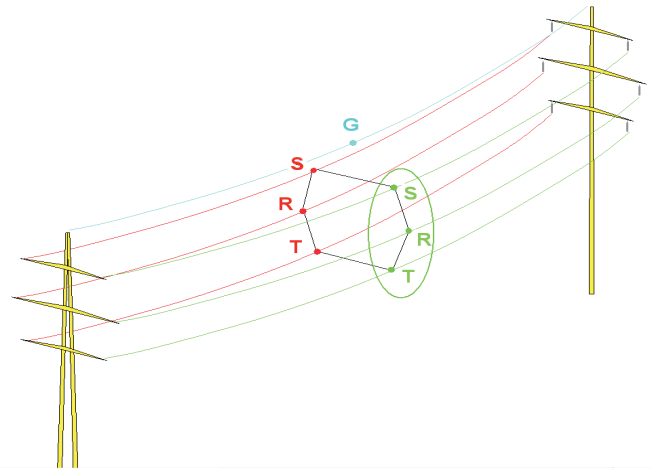


Fig 1 Overhead line 40 kV, 535 A, G: guard conductor

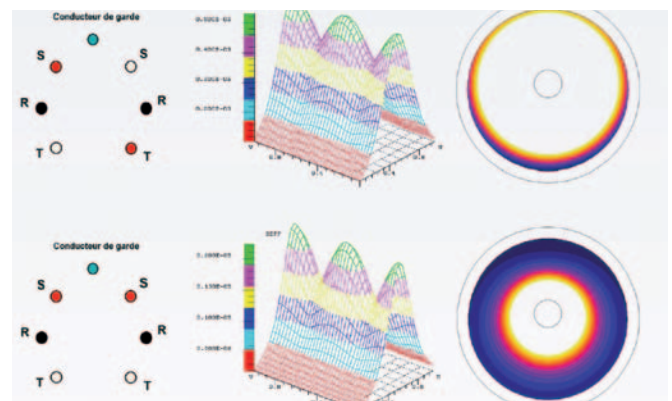


Fig 2 Induction for both configurations

The 1 μ T limit is represented inside the yellow curve. The outer boundary represents a 12 m diameter. We may notice that depending on the configuration, this 1 μ T limit may be divided by 2. In this case, the guard conductor current has been considered to be zero, but it may be also be taken into account, and a ground return current may be considered.

Radiated fields of transformer

A model of the transformer is used in FLUX. It has been parameterised as an object, and may be re-used in a new case, or even modelled several times in the same case. The tank is modelled as a thin region, taking into account eddy currents that may be induced in it. The non-linear magnetic circuit is laminated and the phases are described with non-meshed coils. Using the external circuit coupling, it is possible to model balanced or unbalanced loads, with return current in the neutral. Sinusoidal steady state is computed, to get the radiated fields for a fundamental current waveform. Fig 4 shows the 1 μ T limit for a balanced case.

Radiated field for a transformation station

MV–LV transformation stations (medium to low voltage) are a sizeable source of magnetic radiation. Many people live close to such stations. Installation of new stations, displacement or renewal of such stations need to be closely studied, as the corresponding investments are sizeable. Simulation is of great help as it allows the determination of the main radiation sources or critical devices and test different methods to decrease the radiated fields.

A MV–LV station is constituted of MV cables, one or several transformers, distribution boards and connection cables.

We may see in Figs 6a and 6b that the 1 μ T limit is widely out of the station’s walls. Hence, changes in the station are needed to respects the ORNI standards.

It is interesting to see that the main radiation sources are the connection cables and the distribution boards. Various methods may be used to limit the low frequency radiations. They need a better positioning of the cables (length decrease, underground path, shielding) and the boards (bars spacings, decrease of the distance transformer-boards, positioning of the supply cables). These methods may be simulated to lower the renewal costs.

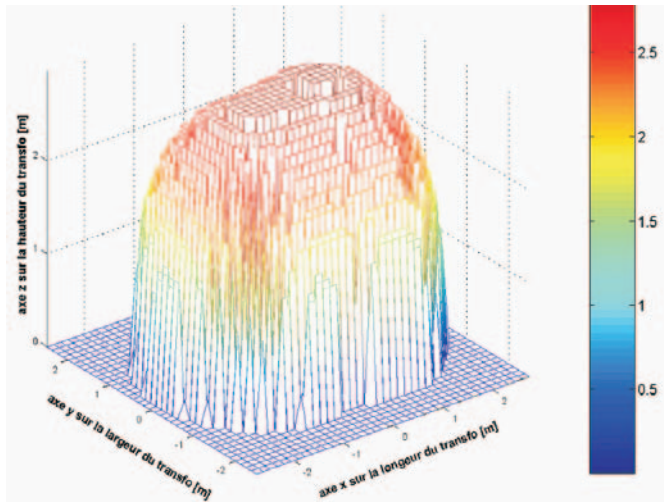


Fig 4 1 μ T limit for the transformer

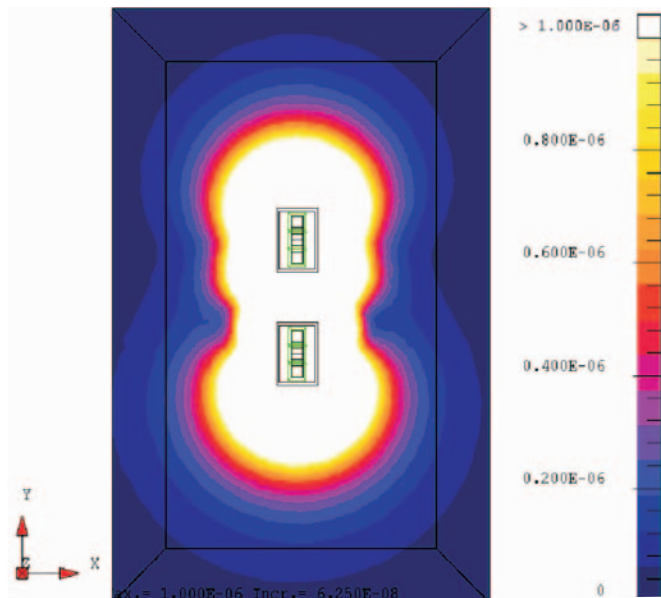


Fig 6c Induction radiated by the transformer, 1 m above the ground

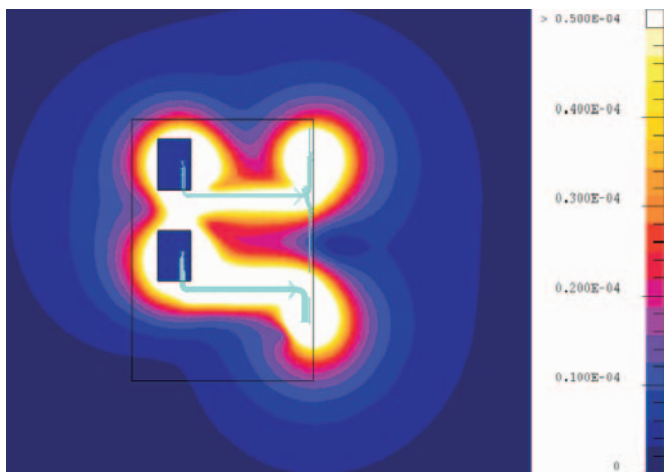


Fig 6a Induction radiated by the cables, 1 m above the ground

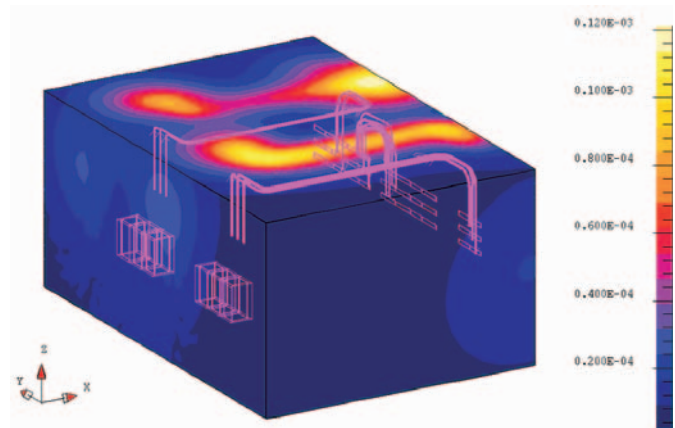


Fig 6d Global induction on the station's walls

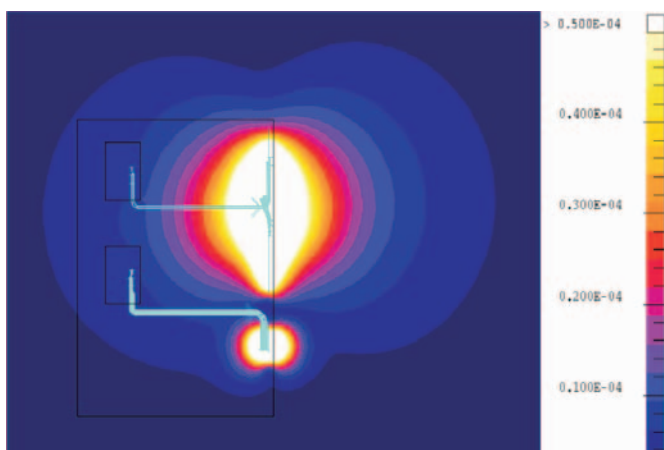


Fig 6b Induction radiated by the LV boards, 1 m above the ground

Conclusion

As radiation standards are raised, many electrical installations need to be modified, and new design rules need to be applied. Finite element simulation is of great interest to predict magnetic and electric fields that are radiated by the low frequency equipment. With features such as thin regions, external circuit coupling and infinite region, FLUX enables the rapid and precise radiated fields prediction of many devices (transformers, cables and lines, boards). As each of those

devices may be independently simulated, it will be possible to determine the influence of each device, and study solutions to reduce the radiated fields.

Depending on the investments that will be needed, various solutions may be chosen: shielding, positioning of the cables, and better phase distribution.

Finite element solutions allow also the manufacturers to adapt their equipment to new environmental standards.

For further details contact CEDRAT Group, tel: +33 (0)4 76 90 50 45, www.cedrat.com

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Please see page 11 for further details of the Student Bursary Scheme and the Dennis Hadfield Memorial Prize.