# ELECTROMAGNETIC INTERACTION BETWEEN THE POWER DISTRIBUTION GRID AND THE HV SYSTEM OF AN ELECTRIC VEHICLE

# *INTERACȚIUNEA ELECTROMAGNETICĂ DINTRE REȚEAUA DE ALIMENTARE ELECTRICĂ ȘI SISTEMUL DE ÎNALTĂ TENSIUNE AL VEHICULELOR ELECTRICE*

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***Abstract:*** *In the paper it will be presented the history of electric vehicles (EVs), compared to conventional combustion engine cars. Environmental impacts produced the necessity of a cleaner transportation by reintroducing electrical cars in the automotive market. By increasing the EVs used in transportation, the level of pollution is decreased, but some major issues concerning electromagnetic compatibility are raised.*

*The ambient electromagnetic field was described, focusing on simulation of a MV power distribution line. Afterwards, it was analyzed the electromagnetic interaction between an electric vehicle and the power distribution line, simulating the magnetic field distribution.*

**Keywords**: electric vehicles, power grid, electromagnetic compatibility.

***Rezumat:*** *În lucrare va fi prezentată istoria vehiculelor electrice, în raport cu mașinile convenționale cu motor cu combustie internă. Impactul asupra mediului a produs necesitatea unui transport mai curat prin reintroducerea mașinilor electrice pe piața auto. Prin creșterea EVs utilizate în transportul rutier, nivelul de poluare va scădea, dar probleme majore privind compatibilitatea electromagnetică vor fi introduse.*

*Mediul electromagnetic ambiant a fost descris, punând accentul pe simularea câmpului magnetic produs de o linie de medie tensiune. Ulterior, a fost analizată interacțiunea din punct de vedere electromagnetic dintre linia de alimentare cu tensiune și un vehicul electric, simulând distribuția liniilor de câmp magnetic.*

**Cuvinte cheie:** vehicule electrice, rețea electrică, compatibilitate electromagnetică.

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## 1. Introduction

Having more and more electric vehicles used in transportation, the risk of electromagnetic compatibility hazard is increasing. The electromagnetic field is composed by electric field which is caused by voltages and magnetic field which is produced by flowing of the electric current.

Electromagnetic fields can be found everywhere in our ambient environment. There are both natural and human-made electromagnetic sources such as thunderstorms, the earth magnetic fields, medical devices which use X- rays, the power grid, TV antennas, radio stations and telecommunications stations. The main focus in this paper will be to analyze the interaction between ambient magnetic field produced by a medium voltage (MV) power line of 20 kV and the high voltage network of the EV represented by the power line between the electric motor which has already integrated the inverter and the smart battery system.

Magnetic field simulations were performed in a Finite Element Method Magnetics tool called FEMM which solves 2D planar and axisymmetric problems in low frequency.

## 2. History of transportation vehicles

With the invention of cars, the world has changed. They have driven global economic development and improved living standards by providing freedom of mobility.

The first means of transportation were the carriages that had as their main traction source the horse power, a unit of measure which is still in use for the power of a motor. In 1801, Richard Trevthick built a steam carriage, opening the era of mobility without horses. After 30 years of noisy and steam-dirty engines, the first battery electric vehicle was built in 1834. 50 years later, the first internal combustion engine vehicle was built in 1885.

Because internal combustion engine vehicles offered greater autonomy and were easier to operate, electric vehicles have not have the same success. The first electric vehicle used disposable batteries that could not be recharged. Half of century passed until battery technology has developed enough to be used in the construction of commercial electric vehicles.

Starting with 20$^{th}$ century, electric vehicles become a strong competitor in the future of road transportation. EVs have some advantages like no vibration, no unpleasant odor, no noise and the start-up was instantaneous, while internal combustion engines were polluting, needed manual start-up and shifting was considered the hardest part of driving.

In 1910 several hundred thousand EVs were produced and used as personal vehicles, vans, taxis and buses. Although the future of road transport seemed to be EV, when Charles Kettering invented in 1912 the electric starter for conventional cars, tipped the balance to cheaper internal combustion vehicles.

A major disadvantage of the batteries is the time required to recharge them. With a proper battery charging device, the time is several hours, while 45 liters of oil can be supplied in about 1 minute.

Another limiting parameter of electric vehicle batteries is their price, so any electric vehicle with batteries will not only have a low autonomy, but will have a considerably higher price compared to an internal combustion engine vehicle of the same size and constructive quality. Taking all these factors into consideration it is understood why the vehicles with internal combustion engines became predominant.

In 1970, the return of electric vehicles begins with energy problems caused by the Middle East oil crisis. Since 1990, environmental concerns have intensified, so the need for clean mobility, increased efficiency, longer service life and a reasonable cost for rechargeable batteries and modern electric motors that can meet the criteria has emerged.

In the latter part of the twentieth century and the beginning of the 21st century, the electric vehicle began to regain ground in the automotive industry due to the new regulations related to environmental protection and due to the development and improvement of the construction of rechargeable batteries, the engine and the controllers. [1], [2]

## 3. Description of electromagnetic field

The electromagnetic force is part of the four main fundamental forces. The other forces are: the weak nuclear force, the strong nuclear force and the gravitational force. [3]

Electromagnetic environment is the totality of electromagnetic phenomena present at a given point.

The electromagnetic spectrum covers electromagnetic waves with frequencies between 1Hz and $10^{25}$ Hz. In figure 1 can be observed the distribution of electromagnetic field from radio to Gamma ray.

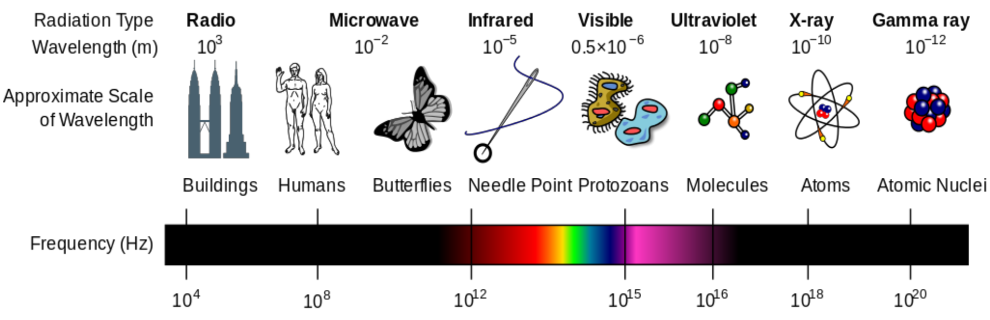


**Figure 1:** Electromagnetic spectrum [4]

Electromagnetic compatibility is the ability of any electrical, electronic device or assembles to function properly in their electromagnetic environment without introducing electromagnetic perturbations in that environment.

Electromagnetic immunity represent the ability of any vehicle or any separate electric, electronic technical unit to function properly in the presence of electromagnetic disturbances which can include radio transmitters, in-body medical apparatus, internal or external to the vehicle. [5]

## 4. Simulation of magnetic field produced by a MV power transfer line

For simulation of the magnetic field produced by a power distribution line of 20 kV, it was used a 2D tool called FEMM.

There were simulated the 3 active conductors of a pillar represented in 2D, which are positioned at a height of 7m from the ground. The diameter of the conductors was chosen to be 20 mm and the current which is flowing through the cables has the value of $I1 = 310\sqrt{3}$ A, $I2 = -310/2$, $I3 = -310/2$. The simulation was performed at 50 Hz, having alternative current.

It can be observed from figure 2, how are distributed the magnetic fields lines near the 3-phase power supply line. In the right side it can be observed the legend which shows that the maximum value which is reached for this case is 1.957 T.

In figure 3 it is showed the magnetic field distribution inside one of the 3 conductors. The maximum value of 2.06 T is reached on the contour of the cable.

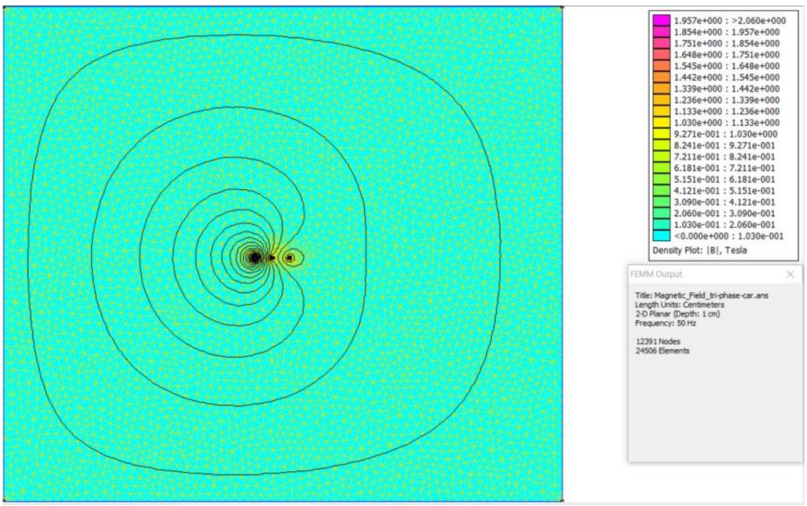


**Figure 2:** Magnetic field distribution of a 3-phase MV distribution line

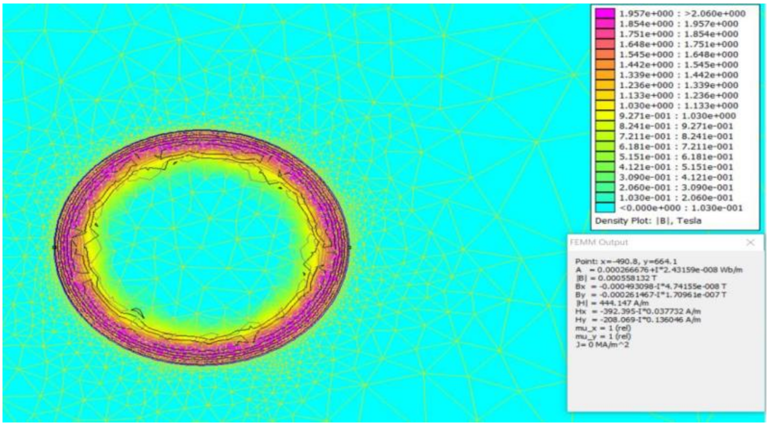

**Figure 3:** Magnetic field distribution inside one conductor of the power line

## 5. Simulation of magnetic field produced by a MV power transfer line in the presence of an EV cabin

For the second case, in the simulation it was introduced an EV cabin. For the moment, no circuit with current was introduced in the car, the scope being to see how the electromagnetic environment interacts with the cabin of the EV.

In figure 4 it is represented the interaction of magnetic fields between the MV power transfer line and an EV cabin. It can be observed that magnetic flux density lines are not interfering with the body of the car.

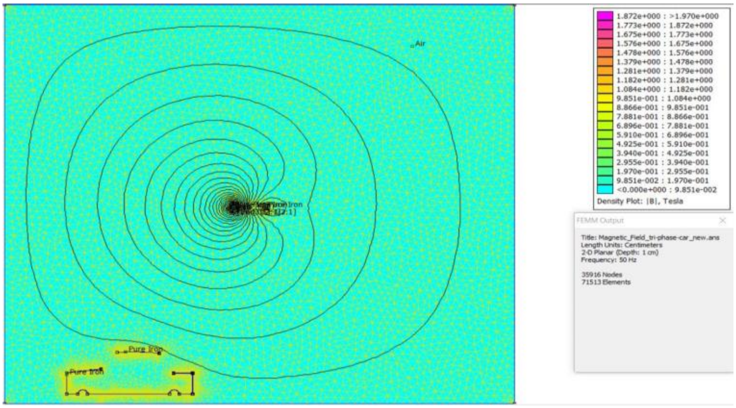

**Figure 4:** Magnetic field interaction between the power grid and an EV cabin

In Figure 5 can be observed how magnetic field flux density lines are distributed near the contour of the cable. The maximum value of 1.97 T is reached inside the conductor on the contour of it.

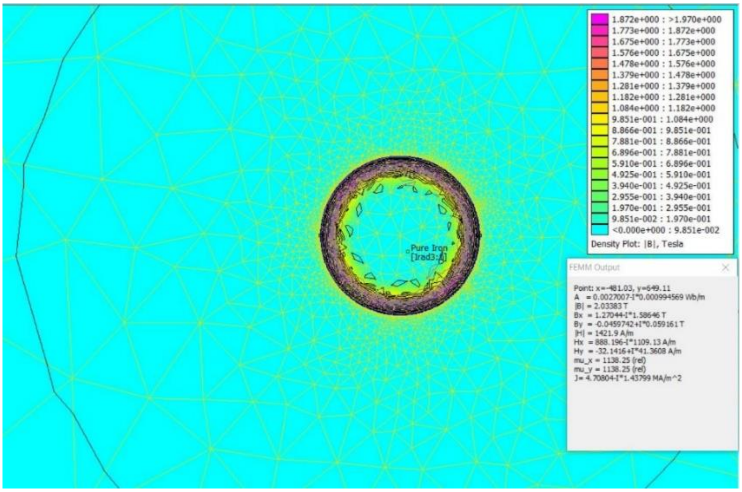


**Figure 5:** Magnetic field distribution inside one conductor of the power line | in the presence of the EV cabin

## 6. Simulation of magnetic field produced by a MV power transfer line in the presence of the HV network of an EV

EVs have in principle 3 main sources for magnetic field radiation: the smart battery system which includes the power converters used for battery charging, connection to the power grid and the management of voltage levels, the electric motor which can have the inverter integrated directly into it and the HV network of the car which interconnects the smart battery system to the electric motor.

For the third case, in the simulation it was introduced an EV cabin which has represented the HV cable of the car, with a diameter of 8 mm and the value of the current of 100 A.

It will be analyzed how magnetic field produced by the MV power network interacts with the HV network placed in the car. For simulating the cable power inside the car it was assigned a circuit of 100 A inside the cooper cable and another circuit of -100 A inside the body of the car. [6]

In figure 6 can be observed how magnetic flux density lines are distributed. In the legend we can see that the maximum value for magnetic field flux density takes values up to 2.061 T, value obtained inside the conductors of the MV power supply line.

If we are zooming on the electric vehicle cabin we can observe how magnetic flux density lines are concentrated near the 100 A cable. Under the legend we can see the values of a point on the contour of the conductor which takes values up to 0.004 T.

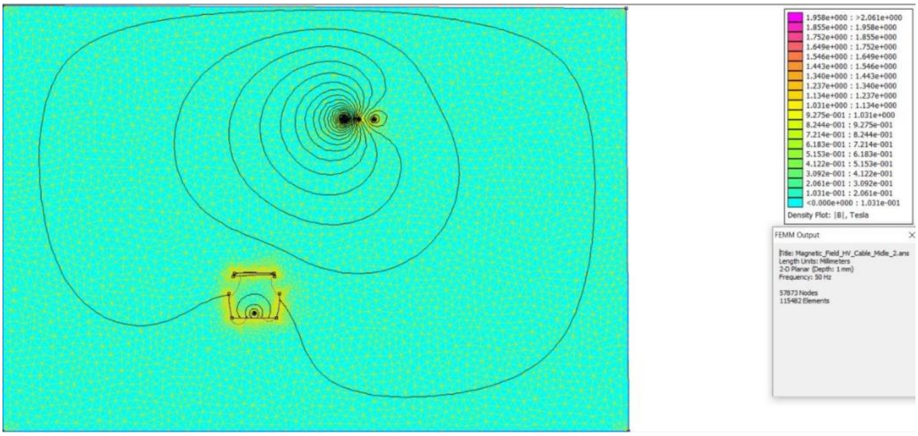


**Figure 6:** Interaction between magnetic fields of the power supply and the HV network of the electric vehicle in symmetrical construction

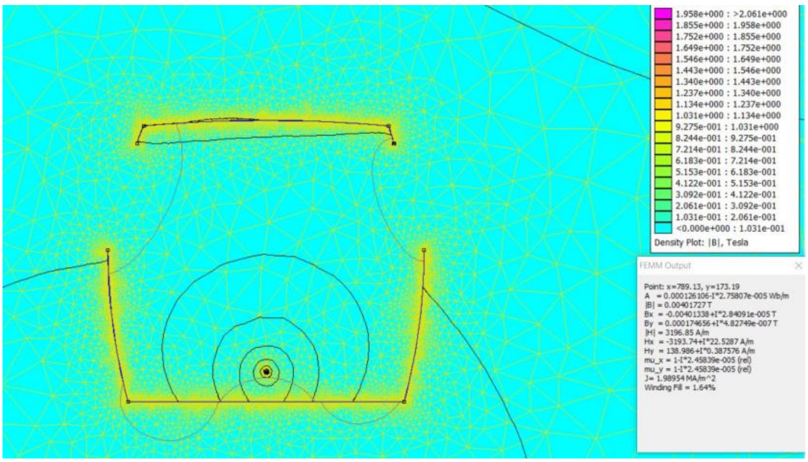


**Figure 7:** Interaction between magnetic fields of the power supply and the HV network of the electric vehicle in symmetrical construction

## 7. Conclusions

Because the level of pollution has reached a critical level and the resources of oil are estimated to finish in 50 years, the conventional cars need to be replaced in the future with EVs or other non-polluting alternatives.

Introducing EVs in public transportation will raise some electromagnetic compatibility issues. In current paper there were analyzed from the magnetic point of view, 3 cases. In the first case the MV power supply network was analyzed and we saw that the maximum value reached for this case was 2.06 T.

In the second case, besides the power supply network it was introduced at the ground level a vehicle cabin and we saw how are distributed the magnetic field lines near the 3 active conductors. In this case the maximum values were 1.97 T.

In the third case, a symmetrical construction of the HV cable inside the car was represented in the presence of the power line supply. For this simulation the maximum value for magnetic flux density was 2.061 T.

Comparing all these results with ICNIRP 2010 regulation, it can be concluded that all the values at the surface of the ground, are lower than the required reference level for general public which is 400 mT.

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