# Magnetic Field Mitigation Techniques for different electrical installations

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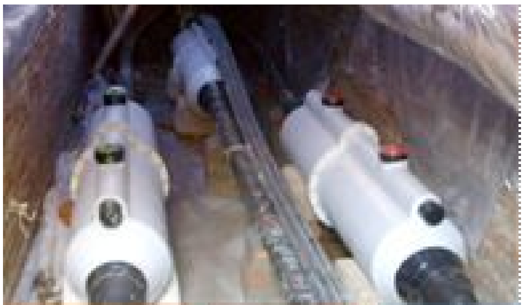
## Magnetic Field Limit

Electrical installations in Argentina that are under the jurisdiction of the National Regulatory Authority for Electricity (ENRE) must comply with the emission peak MF of 25 μT, considering values as low as reasonably achievable.

## Mitigation Techniques



Passive loops
HV Cable Joints

Compaction
OHL-MV/LV Substations

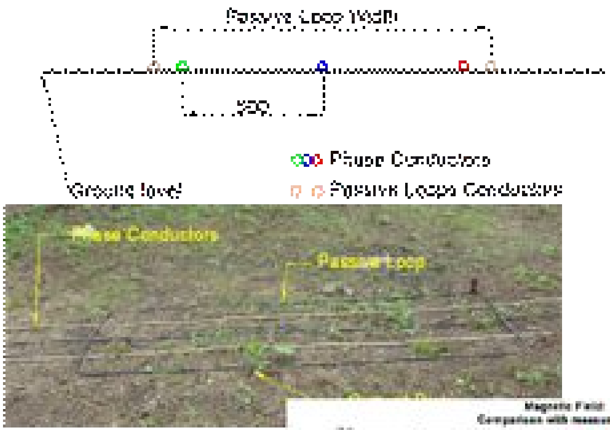
Passive Shields
Transsition HV OHL/Cables

## Shielding Factor

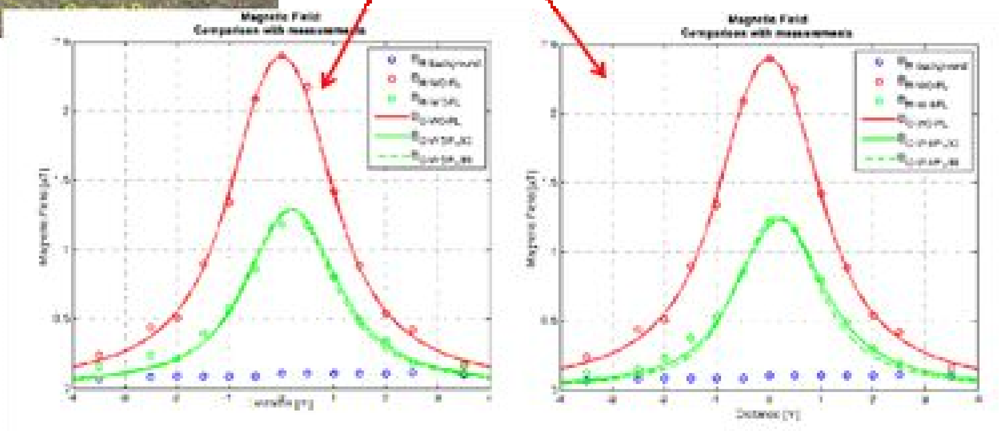
$$SF = \frac{B_0(P)}{B_S(P)}$$

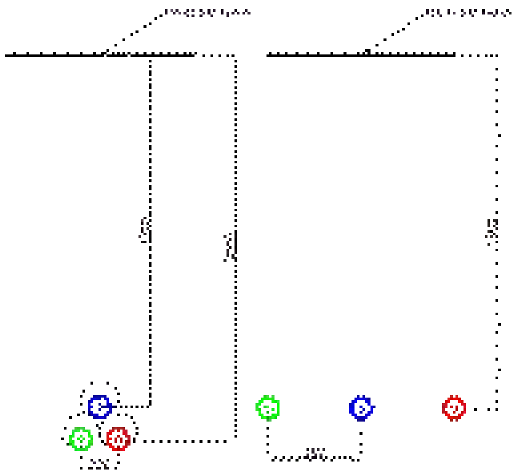
$B_0$: value of magnetic field without the use of mitigation at point P
$B_S$: value of the magnetic field with the use of mitigation at point P

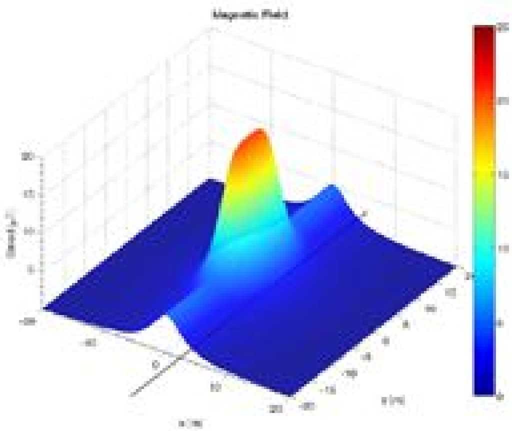
## Passive loops

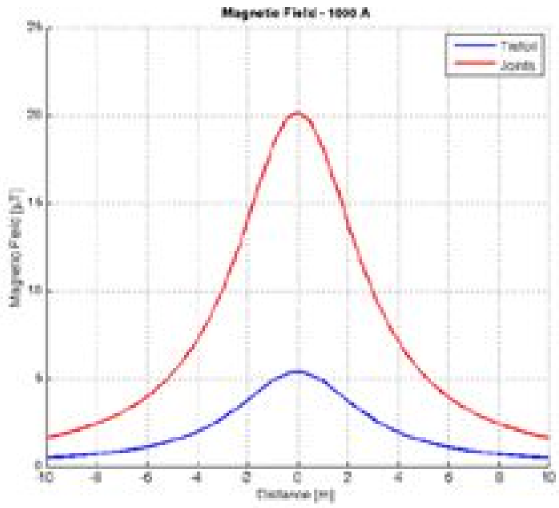



| Case | Conductor Section [mm²] | Conductor Radius [mm] | PL Configuration Width | PL Configuration Large |
|---|---|---|---|---|
| 1 | 95 | 6,5 | 1 | 4,25 |
| | 95 | 6,5 | 1,4 | 4,35 |
| | 70 | 5,25 | 1,8 | 12,4 |
| 2 | 95 | 6,5 | 1 | 4,25 |
| | 95 | 6,5 | 1,4 | 4,35 |
| | 70 | 5,25 | 1,8 | 12,4 |
| | 70 | 5,25 | 2,2 | 13,5 |

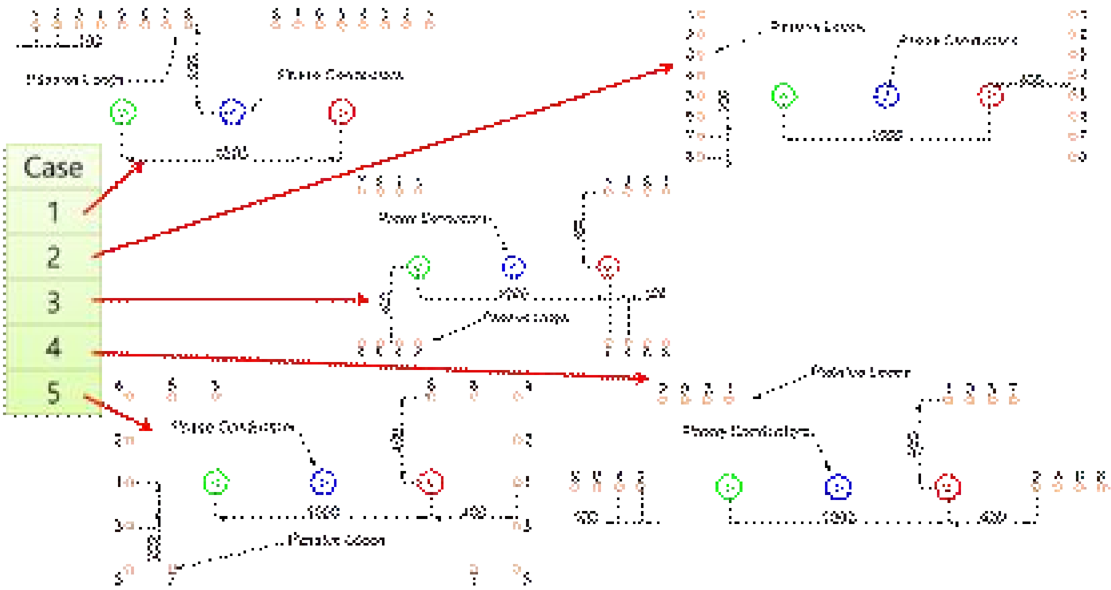


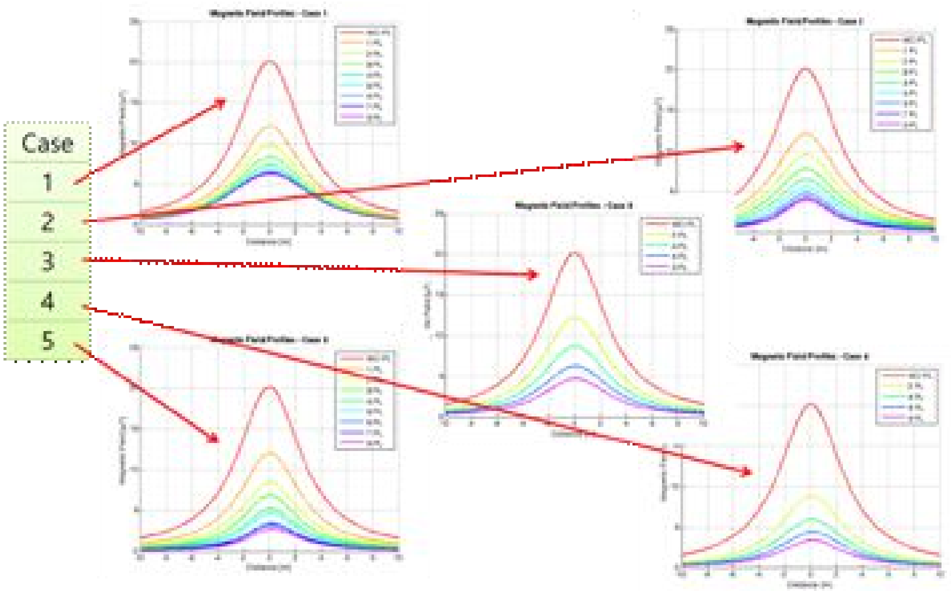





- Case 1: PL are arranged in a plane above the phase conductors.
- Case 5, PL are considered distributed on the perimeter of the phase conductors.
- For all cases, PL conductors are considered of: - Section: 630 mm$^2$, radius: 15 mm and resistance 0.0407 ¥Ø/km.
- A considered variable is the number of loops to be used.The number was increased up to a maximum of 8.
- For the different cases, magnetic field transversal profiles are drawn, considering a current of 1000 A per phase conductors.
- In all cases, it is considered a minimum distance of 400 mm between the phase conductors and the nearest PL conductor.


Case
1
2
3
4
5


Case
1
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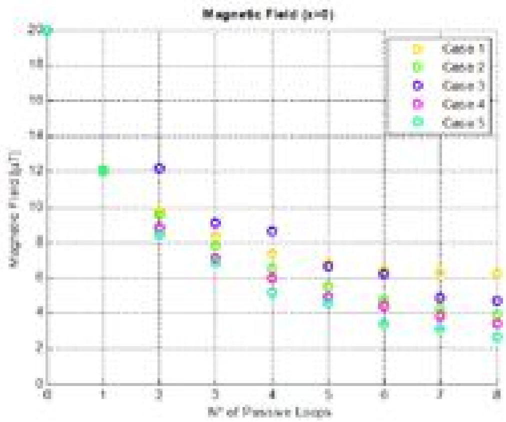
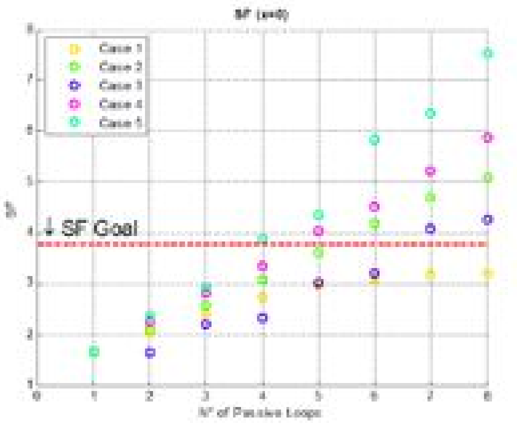
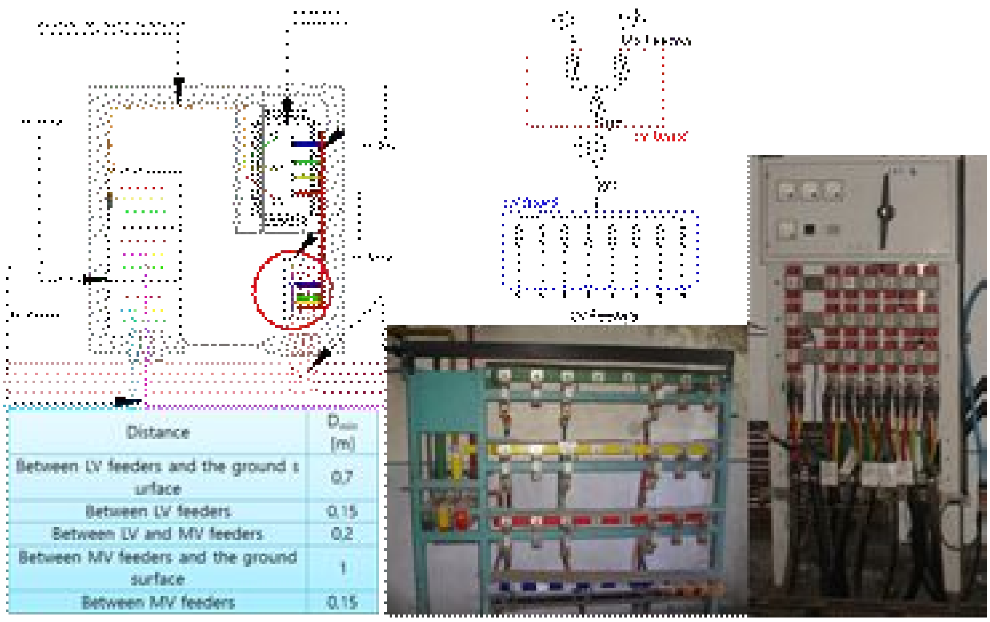



MF, Case 1 to 5(X=0)




SF, Case 1 to 5

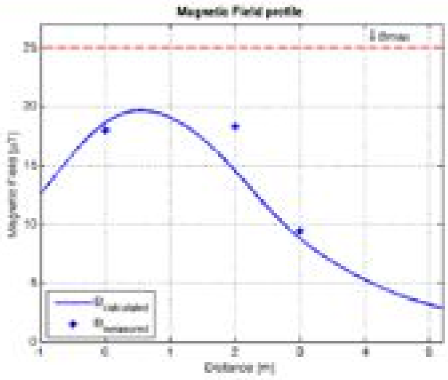
- In Case 1, with the conductors arranged in a plane located over the phase conductors, SF values are bigger than 3 butless than 3.7, which is considered the goal.
- With the configuration of Case 2, the goal is reached using 6 PL. SF values greater than 5 are achieved using 8 PL.
- In Case 3 using 7 PL, SF values greater than 4 are obtained.
- In case 4, the goal of SF greater than 4 is reached using 5 PL. With the use of 8 PL values close to 6 are achieved.
- Case 5, when the PL located on the perimeter, presents the best performance. The goal is reached using 4 PL. With 8PL, the SF exceeds 7.
- Evaluating the different options, it appears that not all configurations represent a solution.
- In Case 1, with the use of 8 PL the goal is not reached. In Case 3 the object is achieved by using 7 PL. In Case 2 the objective is achieved by using 6 PL. Case 4 meets the goal with 5 PL. Case 5 shows a solution using 4 PL. In addition, the Case 5 achieves the highest values of SF, using 8 PL.



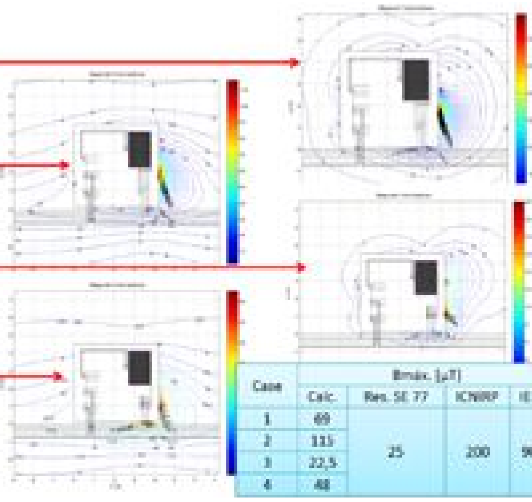
| Distance | $D_{min}$ (m) |
|---|---|
| Between LV feeders and the ground surface | 0.7 |
| Between LV feeders | 0.15 |
| Between LV and MV feeders | 0.2 |
| Between MV feeders and the ground surface | 1 |
| Between MV feeders | 0.15 |

| Case | Currents [A] | | | | | | |
|---|---|---|---|---|---|---|---|
| | IBTr | IBTs | IBTt | IBTn | IMTR | IMTS | IMTT |
| B | 490 $e^{j-30}$ | 490 $e^{j-150}$ | 490 $e^{j90}$ | 0 $e^{j0}$ | 14,9 $e^{j0}$ | 14,9 $e^{j-120}$ | 14,9 $e^{j120}$ |
| U | 500 $e^{j0}$ | 490 $e^{j-125}$ | 555 $e^{j120}$ | 100 $e^{j128}$ | 14,6 $e^{j27}$ | 14,7 $e^{j-90}$ | 15,2 $e^{j148}$ |

| Cases | LV Board | Load | $I_{neutral}$ [A] |
|---|---|---|---|
| 1 | Conventional | Balanced | 0 |
| 2 | | Unbalanced | 100 |
| 3 | Compact | Balanced | 0 |
| 4 | | Unbalanced | 100 |

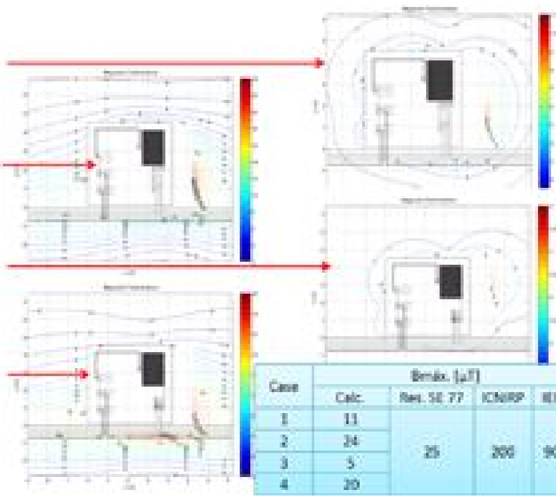



- Case 1
- Case 2
- Case 3
- Case 4



| Case | Bmáx. [µT] | | | |
|---|---|---|---|---|
| | Calc. | Res. SE 77 | ICNIRP | IEEE |
| 1 | 69 | 25 | 200 | 904 |
| 2 | 115 | | | |
| 3 | 22,5 | | | |
| 4 | 48 | | | |

- Case 1
- Case 2
- Case 3
- Case 4



| Case | Bmáx. [µT] | | | |
|---|---|---|---|---|
| | Calc. | Res. SE 77 | ICNIRP | IEEE |
| 1 | 11 | 25 | 200 | 904 |
| 2 | 24 | | | |
| 3 | 5 | | | |
| 4 | 20 | | | |

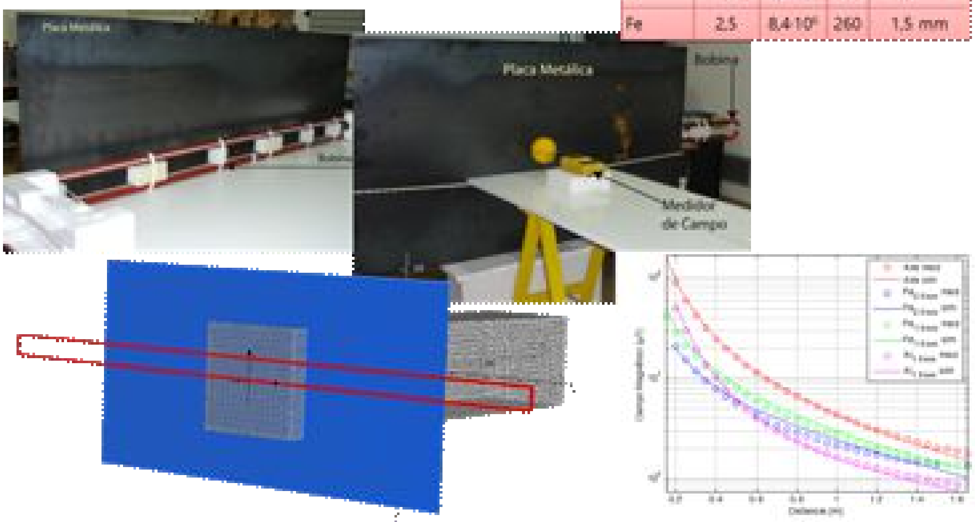
- Analyzing the results, it can be said that the implemented models allow calculations who represent a good approximation to the values generated by the existing facilities.
- This is evident when a comparison is made with measurements.
- The calculation tools allow us to know the impact of installing new substations or modifying existing ones. Considering different designs influence on magnetic field levels.
- When considering new facilities, it is possible to decide what is the best solution for each case, from the point of view of the distribution of magnetic field.
- In addition, is possible to check if the values exceed the magnetic field limit, indicated by current regulations. To which one must consider the different load cases.
- Considering an existing installation, is possible to register the load curve of a substation, recording values of phase and neutral LV current, in module and phase. From this estimate what the magnetic field levels that are generated, for a full load or greater neutral current value.

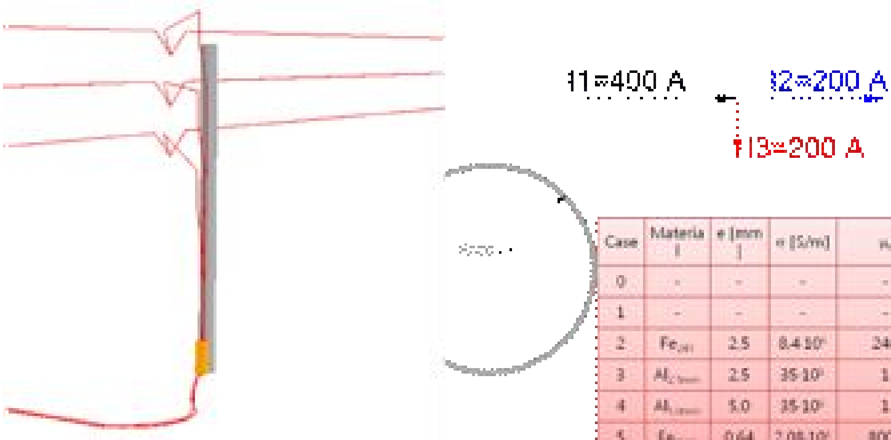
## Passive Shields

- Evaluate the efficiency of magnetic field mitigation caused by transition OHL/Cables.
- Use passive and open shields made with metallic plates.
- Considered the effect produced by the presence of metallic towers.
- The problem is analyzed from numerical simulations(MEF).
- Thickness, electrical conductivity and magnetic permeability are considered.

## Measurements

| Material | e [mm] | σ [S/m] | $\mu_r$ | δ @ 50 Hz |
|---|---|---|---|---|
| Al | 1,5 | $35 \cdot 10^6$ | 1 | |
| Fe | 1,5 | $8,4 \cdot 10^6$ | 260 | 1,5 mm |
| Fe | 2,5 | $8,4 \cdot 10^6$ | 260 | 1,5 mm |

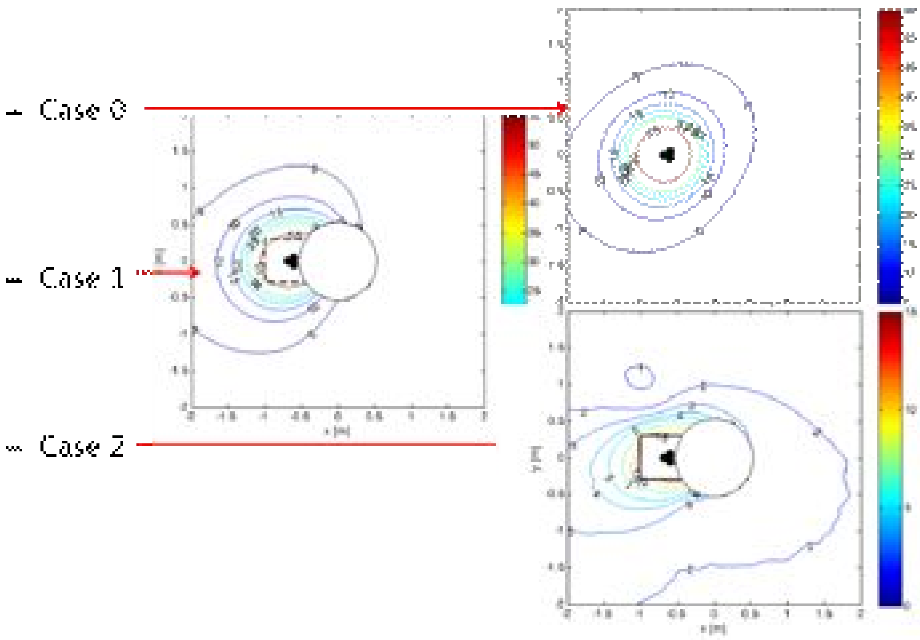


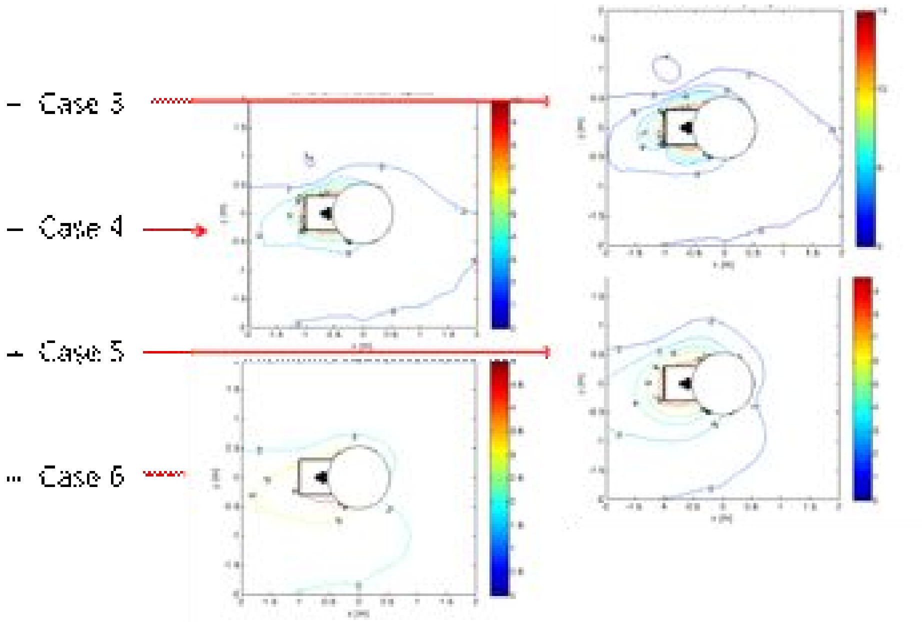



Tower: = 8,4¡¤106 S/m yelr = 240

| Case | Material | e [mm] | σ [S/m] | $\mu_r$ |
|---|---|---|---|---|
| 0 | - | - | - | - |
| 1 | - | - | - | - |
| 2 | $Fe_{(A)}$ | 2.5 | 8.4·10[illegible] | 240 |
| 3 | Al | 2.5 | 35·10[illegible] | 1 |
| 4 | Al | 5.0 | 35·10[illegible] | 1 |
| 5 | Fe | 0.64 | 2.08·10[illegible] | 8000 |
| 6 | Fe | 0.64 | 1.8·10[illegible] | 30000 |

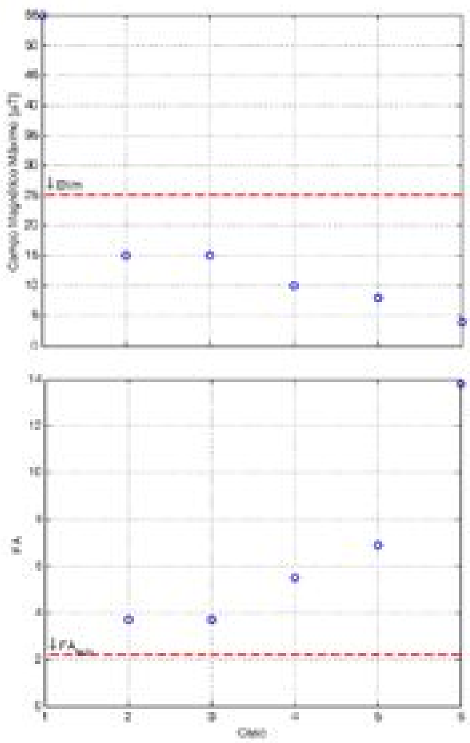
## Results






**Resume**

| Case | B [µT] | FA |
|---|---|---|
| 1 | 55 | 1 |
| 2 | 15 | 3,7 |
| 3 | 15 | 3,7 |
| 4 | 10 | 5,5 |
| 5 | 8 | 6,9 |
| 6 | 4 | 13,8 |



- If the structure is metallic, it will influence the magnetic field distribution. It is very important to know its electrical characteristics.
- The use of metal plates commonly used in mechanical cable guards represents a viable technical-economic solution and is simple to implement.
- If higher values of mitigation are required, without modifying the dimensions, it is possible to resort to other solutions, such as the use of Aluminum (Cases 3 and 4). The use of thicker plates gave better results.
- In addition it is possible to contemplate other materials with high value of $\mu r$(Cases 5 and 6).
- Materials of high permeability value are usually much more expensive than conventional sheet or aluminum. In addition, these materials are sensitive to deterioration due to corrosion.
- It also highlights the use of simulation tools, validated by measurements.
- It is possible to ensure that the limit values of 25 μT (Res. SE 77 Argentina) are confined within the mechanical protections of this installation using the appropriate materials and dimensions.