MAGNETIC FIELD IN ENCAPSULATED BUS-BARS

Monica CUCU[1], Mihai Octavian POPESCU[2]

Lucrarea prezintă spectrul câmpului magnetic în sisteme trifazate de bare de curent intens. Vor fi investigate diferite situaţii şi anume: bare libere, bare parţial încapsulate şi bare total încapsulate.

Zonele de câmp magnetic intens şi respectiv efectele de ecranare produse de piesele feromagnetice ale canelului de bare au fost evidenţiate. Rezultatele arată faptul că echipamentele trifazate în regim simetric de sarcină au o zonă de influenţă magnetică relativ redusă, iar canalizaţiile metalice pot asigura o bună ecranare.

This paper presents the spectrum of magnetic field in three- phase three-wire systems current strength. Different situations like open bars, bars partially encapsulated and bars all encapsulated will be investigated.

Areas of intense magnetic field and the sheltering effects caused by ferromagnetic substance of enclosure have been evidenced in this study. The results show us that the three-phases equipments have a reduced magnetic influences in a symmetrically charge regime and the metallic clad can assure a good shielding.

Keywords: magnetic field, bar system phase, distribution board

1. Introduction

The installations used in systems of producing, transmission and distribution of the electrical energy, as well as the electrical and electronic equipments that are electrical energy consumers, represent frequent electromagnetic disturbances sources for the natural systems – living beings and industrial systems.

Firstly, power supply systems have become more powerful, which may cause electromagnetic disturbance (EMI), secondly, digital devices have proliferated and become more sensitive, and achieve a high data transfer, being used increasingly more for the safety of activities. This requires a high quality of electrical installations in all buildings in which incompatibility leads to high costs or an unacceptable reduction of safety standards.

Power distribution three-phased bars are main sources of magnetic field at industrial frequency and can generate perturbations by inductive coupling [1].

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[1] PhD. Eng., Dept. of Electrical Measurements, Electrical Apparatus and Static Converters, University POLITEHNICA of Bucharest, Romania, e-mail:monica.cucu@yahoo.com

[2] Prof., Dept. of Electrical Measurements, Electrical Apparatus and Static Converters, University POLITEHNICA of Bucharest, România

This boundary field is studied here and, fortunately, in a three-phased symmetric situation, the field attenuation with distance is high.

All sensitive equipments are protected from radiated disturbances by mounting inside screening can (generally steel).

During the last years, electromagnetic fields have been a permanent point of conflict due to the general public's growing awareness of the health risks. Although lots of biomedical studies have been carried out on this domain, none of them has been able to establish a clear relation confirming electromagnetic fields as a cause of any kind of illness. However, it is clear limits are imposed in order to control possible exposures.[2]

In the United Kingdom, the reference level for magnetic fields is a magnetic flux density of 500 µT= 0.5 mT, for occupational exposure to 50 Hz fields. The equivalent levels for public exposure are 100 µT=0.1 mT [3].

In Romania, according to the annex on limit values and exposure action values for electromagnetic fields triggering the decision no 1136 dated on 30th August, 2006, the reference level for magnetic fields is a magnetic flux density of 0.5 µT= 0.0005 mT (50 Hz) [4].

2. Geometric model

The current system is considered balanced on the three-phases and, due the time variation, two important moments are necessary to be taken into account, which will be analyzed independently.
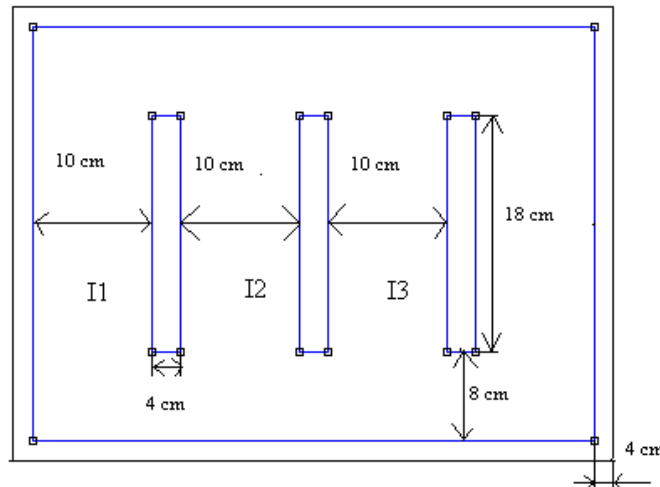

Fig.1. Current geometric location from ditribution panel

We have a bar phase (with currents I1 to phase 1, I2 to phase 2, I3 in phase 3, respectively) in a distribution panel made of steel (Fig. 1).

We chose the panel made of steel just to highlight its capability to screen against the magnetic field lines toward outside and raise them inside the panel. The study was made using the distribution of the magnetic field offer by the free software FEMM.

FEMM is a suite of programs for solving low frequency electromagnetic problems on two-dimensional planar and axidymmetric domains. The program currently addresses linear/nonlinear magnetostatic problems, linear/nonlinear time harmonic magnetic problems, and linear electrostatic problems. It contains a CAD like interface for laying out the geometry of the problem to be solved and for defining material properties and boundary conditions. Autocad DXF files can be imported to facilitate the analysis of existing geometries. Field solutions can be displayed in the form of contour and density plots. The program also allows the user to inspect the field at arbitrary points, as well as evaluate a number of different integrals and plot various quantities of interest along user-defined contours.

3. Electromagnetic mark in the case of bars phase

The electromagnetic mark gives important information about the influences of the electromagnetic devices over the environment, the human beings and other electrical equipments found in their neighborhood. The electromagnetic fields have a great influence on the behaviour of all the living systems [5]. Electromagnetic mark describes a new concept in order to characterize electromagnetic field surrounding an apparatus or equipment respective current/voltage on conduction port. The mark individualizes the equipment and describes, in fact, the aggression generated by this one on the environment [6]. The concept is used as magnetic mark for a boat in the military technology [7].

A) If the distribution panel is close

This case highlights the effect of the steel panel to screen against the magnetic field lines toward outside; amplifying these field lines within the panel, the maximum values of this field around the conductor is met by the maximum current map.

The first moment (Fig. 3.A.1.) is characterized by the maximum value for the current on the first phase, I_1, and the value $-I_1/2$ for the second and the third phases.

The I moment : $i_1 = 400 \cdot \sqrt{2}$ A; $i_2 = i_3 = -200 \cdot \sqrt{2}$ A
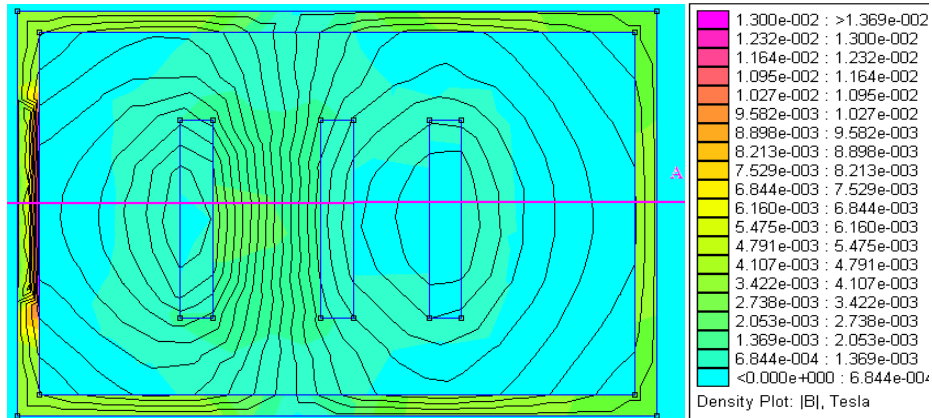
Fig.3.A.1. The spectrum of magnetic flux density for three-phase systems bus-bars in a closed distribution board (moment I)
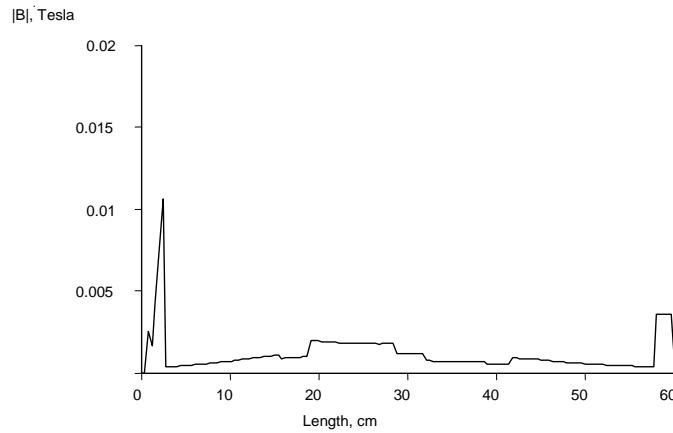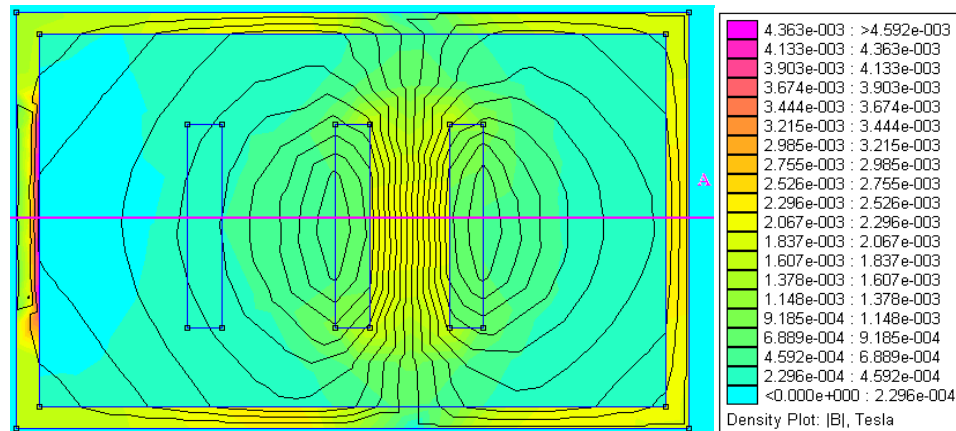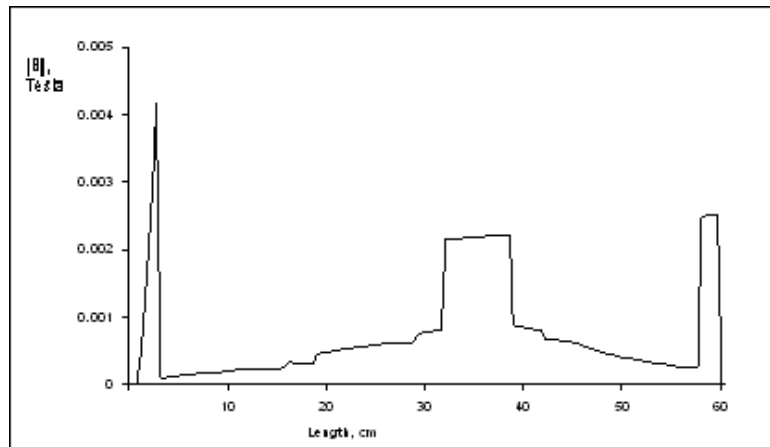

Fig.3.A.2. Magnetic flux density variation between phases distribution panel (plan A)

This magnetic flux density variation (Fig. 3.A.2.) highlights a very good screening, thanks to the steel panel. One can notice that its walls have the greatest magnetic field values (B=0.011T =11 mT in the left wall and B=0.003 T = 3 mT in the right wall).

Besides the magnetic flux density that was screened inside walls, it is to be observed a variation of the magnetic field between the first two phases (Fig. 3.A.3.).
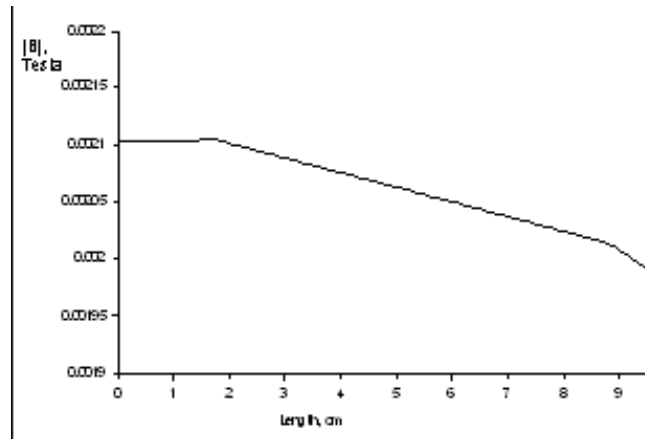
Fig.3.A.3. Magnetic flux density variation between the first two phases distribution panel (plan A)

We see how the magnetic flux density between the first two bars appears, the maximum value of the magnetic field being B = 0.0021 T = 2.1 mT.

The second moment (Fig. 3.A.4.) is characterized by the zero value for the current on the first phase, the value $200\sqrt{6}$ for the second, and the value $-200\sqrt{6}$ for the third phases.

The II moment : i_1=0 A; i_2=200$\cdot\sqrt{6}$ A; i_3=-200$\cdot\sqrt{6}$ A

Fig.3.A.4. Spectrum of magnetic flux density for three-phase systems bus-bars in a closed distribution board (time II)

Fig.3.A.5. Magnetic flux density variation between phases distribution panel (time II, plan A)

The second moment highlights how the magnetic field is moving between bus-bars, depending on the currents that we have in three phases. But now, the magnetic flux density variation between two and three phase has the same shape (Fig. 3.A.5.).

B) If the distribution panel is open without a lid.
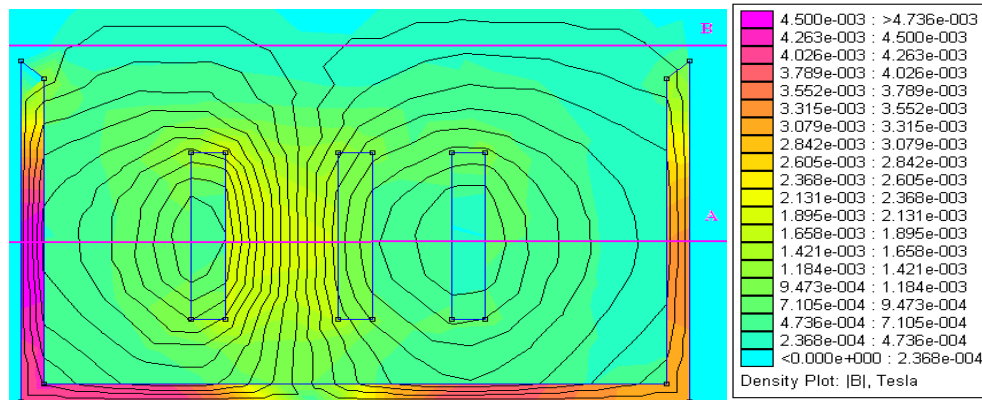The I moment (Fig. 3.B.1.): $i_1=400\cdot\sqrt{2}$ A; $i_2=i_3=-200\cdot\sqrt{2}$ A

Fig.3.B.1. Spectrum of magnetic flux density for three-phase systems bus-bars
in an open distribution board (time I)

A few and insignificant number of magnetic field lines leave the cage in the case of the three-phase bus-bars system from an open distribution board or from the distribution board with air perforations, but most of all are captured by the board walls (Fig. 3.B.2.).
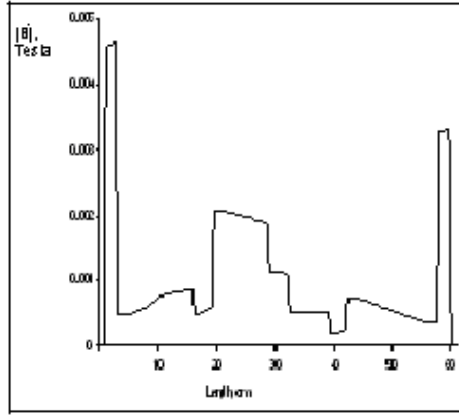
Fig.3.B.2. Magnetic flux density variation
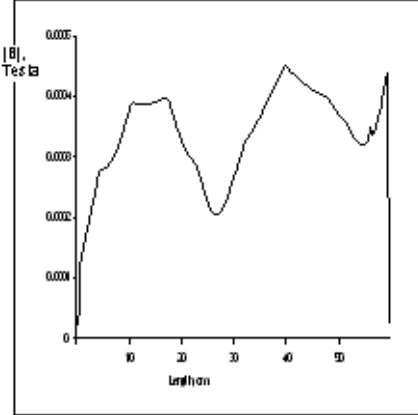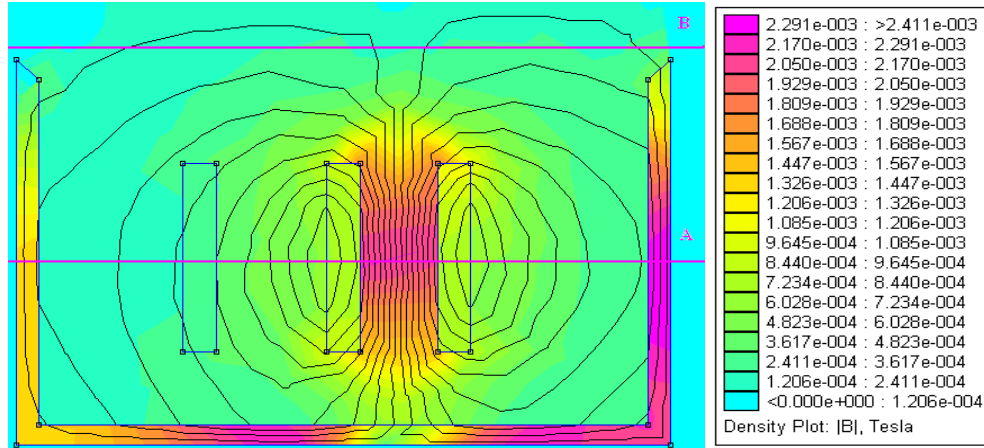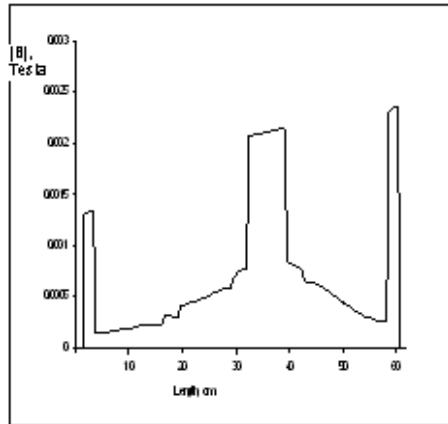between phases distribution panel
(time I, plan A)

Fig.3.B.3. Magnetic flux density variation
between phases distribution on top panel
(time I, plan B)

In Fig. 3.B.3. the magnetic flux density is represented on top panel, to see what is the value of the magnetic field leaving the panel, or near the panel. We conclude that, the maximum value of magnetic field is B= 0.00045 [T]=0.45 [mT] The II moment (3.B.4.): i_1=0 A; i_2=200·$\sqrt{6}$ A; i_3=-200·$\sqrt{6}$ A

Fig.3.B.4. Spectrum of magnetic flux density for three-phase systems bus-bars in an open
distribution board (time II)

Fig.3.B.5. Magnetic flux density variation
between phases distribution panel
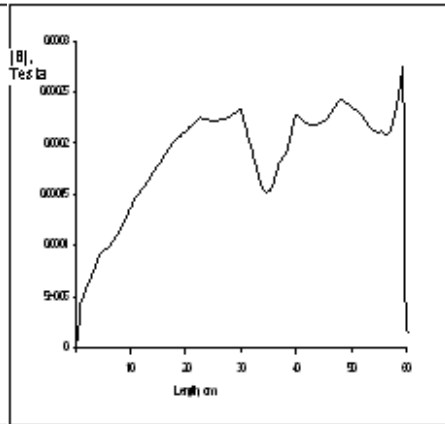(time II, plan A)

Fig.3.B.6. Magnetic flux density variation
between phases distribution on top panel
(time II, plan B)

As we can see (Fig. 3.B.6.), the value of the magnetic flux density on top panel is B=0.00028 [T]= 0.28 [mT]. So we can say that if we have an open distribution board (for both moment), we will find a value of magnetic field approximately equal B=0.36 [mT] on top panel.

C) If the distribution panel are vents

The I moment (Fig. 3.C.1.) : $i_1=400 \cdot \sqrt{2}$ A; $i_2=i_3=-200 \cdot \sqrt{2}$ A
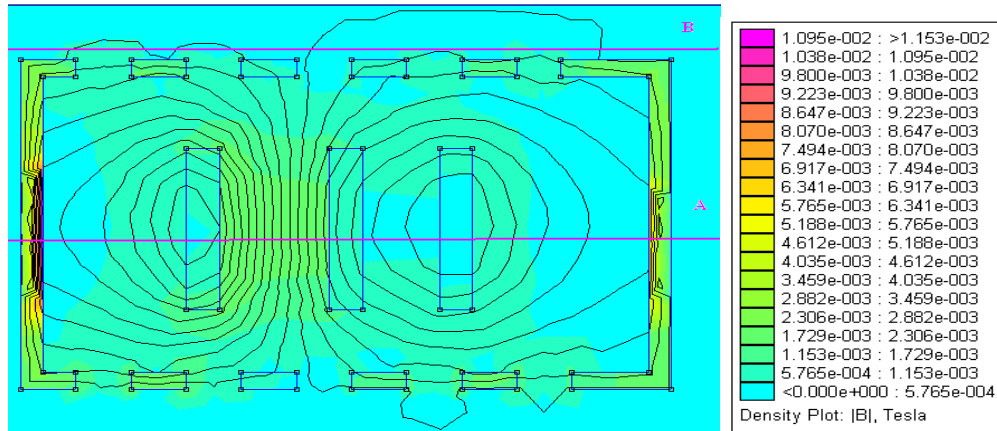

Fig.3.C.1. Spectrum of magnetic flux density for three-phase systems bus-bars
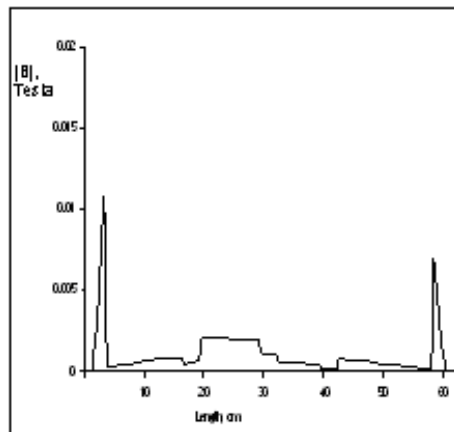in a distribution board with air perforations (moment I)

Fig.3.C.2. Magnetic flux density variation between phases distribution panel (moment I, plan A)
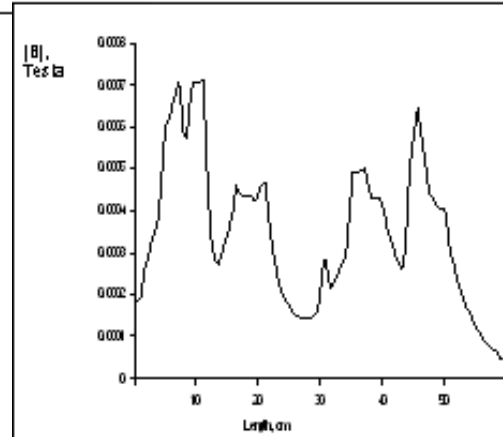
Fig.3.B.6. Magnetic flux density variation between phases distribution on top panel (time I, plan B)

The maximum value of electromagnetic field that touches on the walls of the screen is B=0.011 [T] =11 [mT], and between the first two bars is B=0.002 [T] =2 [mT].We note that on top panel the value of magnetic flux density is B= 0.0007 [T]= =0.7 [mT].

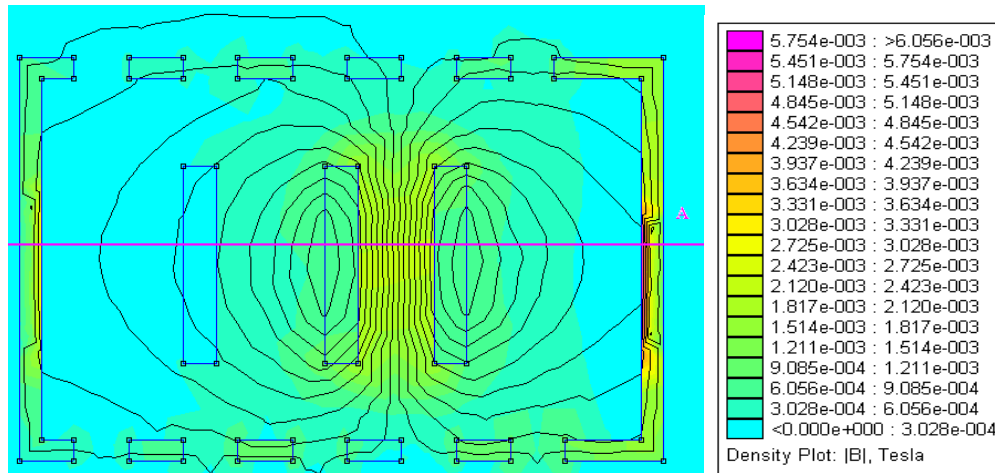The II moment (Fig. 3.C.3.): i_1=0 A; i_2=200$\cdot\sqrt{6}$ A; i_3=-200$\cdot\sqrt{6}$ A

Fig.3.C.3. The spectrum of magnetic flux density for three-phase systems bus-bars on a distribution board with air perforations (moment II)
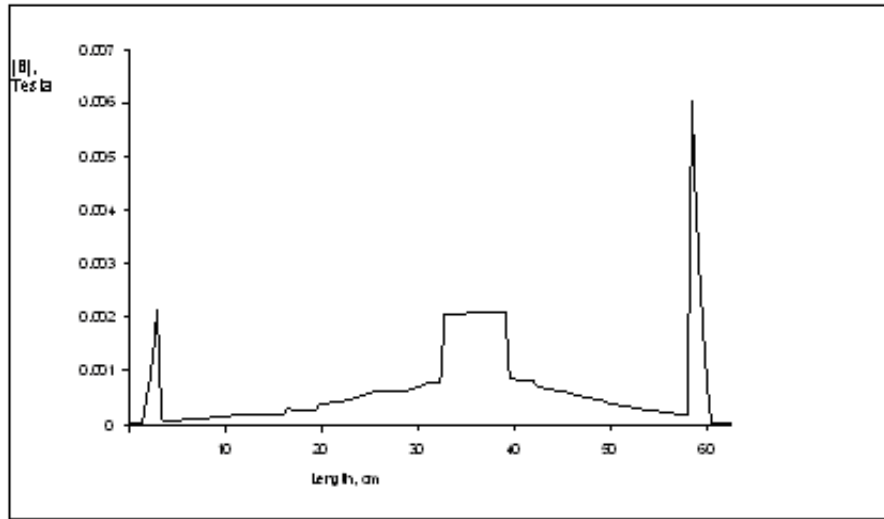
Fig.3.C.4. Magnetic flux density variation on phases distribution panel (moment II, plan A)

In the following screen, less air vents will be used to see if the number of vents affect in any way the shielding or the value of magnetic flux density, at the same times (Fig. 3.C.5.).

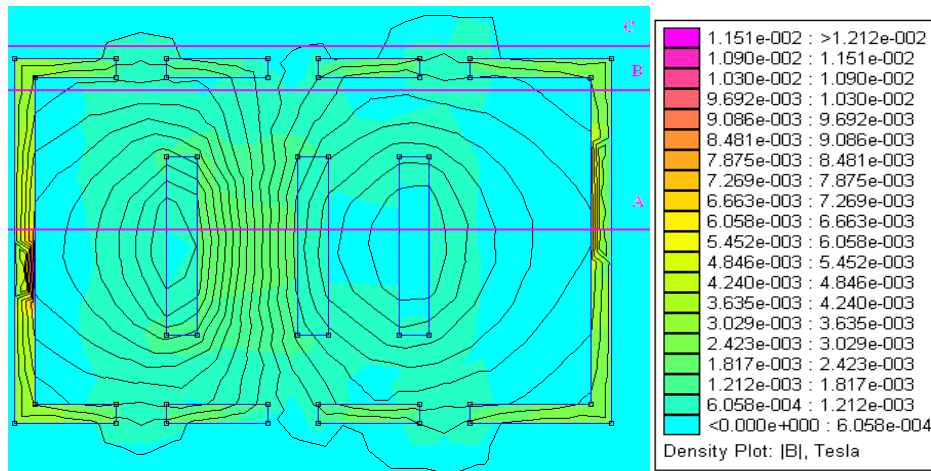The I moment: $i_1 = 400 \cdot \sqrt{2}$ A; $i_2 = i_3 = -200 \cdot \sqrt{2}$ A

Fig.3.C.5. Spectrum of magnetic flux density for three-phase systems bus-bars in a distribution board with air perforations (moment I)
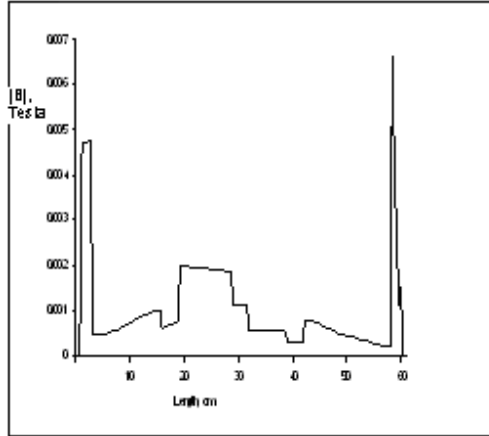
Fig.3.C.6. Magnetic flux density variation
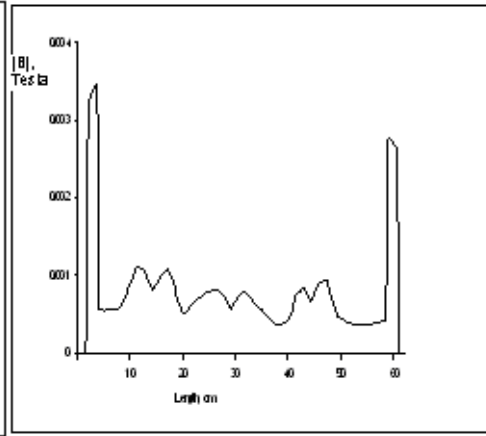on phases distribution panel
(moment I, plan A)

Fig.3.C.7. Magnetic flux density variation
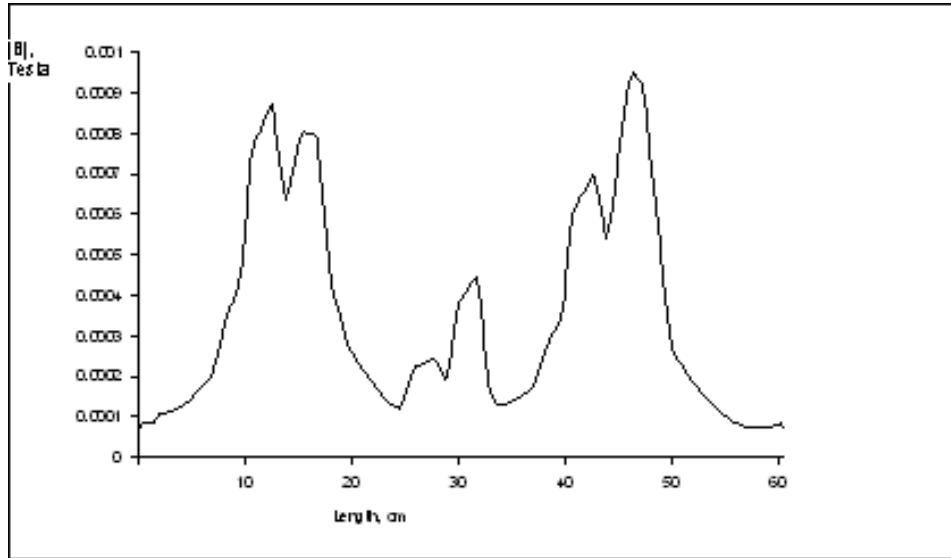on phases distribution panel
(moment I, plan B)

Fig.3.C.8. Magnetic flux density variation on phases distribution panel (moment I, plan C)

It is observed (from Fig. 3.C.6. and Fig. 3.C.7.) that the value of the magnetic flux density around the walls of the screen is not changed, in comparison with that in the case of multiple screen vents. On top panel it is a value approximately equal B=1 [mT] .

The II moment (Fig. 3.C.9.) : i_1=0 A; i_2=200$\cdot\sqrt{6}$ A; i_3=-200$\cdot\sqrt{6}$ A
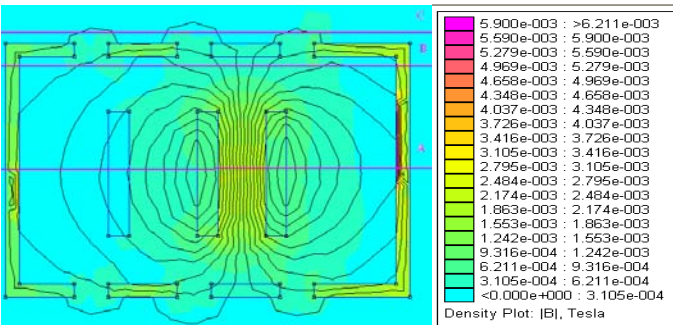
Fig.3.C.9. The spectrum of magnetic flux density for three-phase systems bus-bars
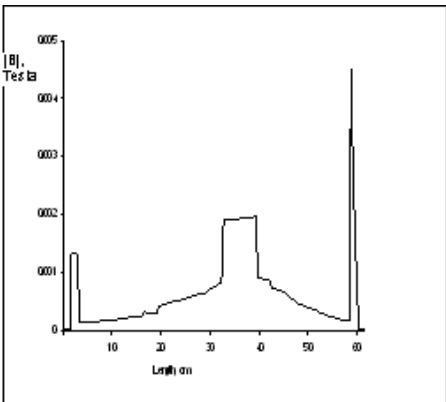on a distribution board with air perforations (moment II)

Fig.3.C.10. Magnetic flux density variation
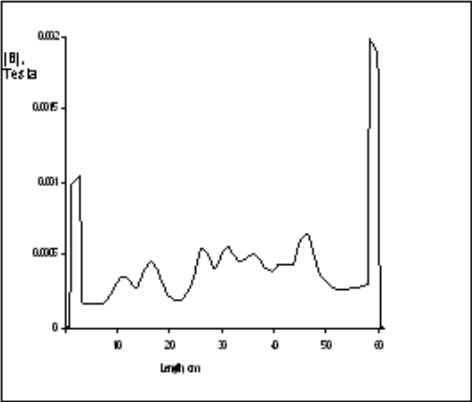on phases distribution panel
(moment II, plan A)

Fig.3.C.11. Magnetic flux density variation
on phases distribution panel
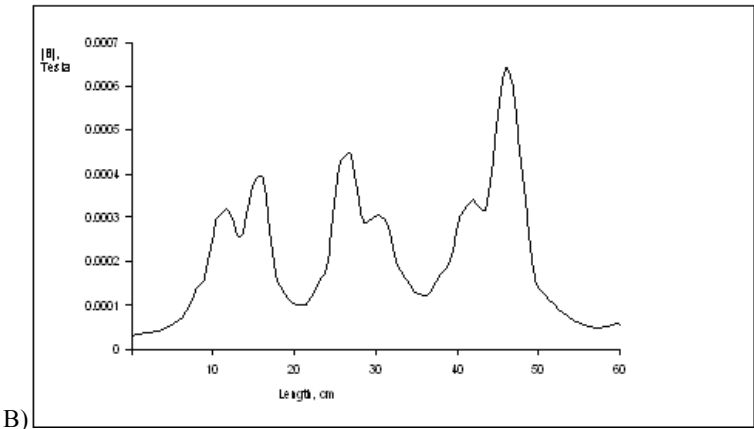(moment I, plan

B)

Fig.3.C.12. Magnetic flux density variation on phases distribution panel (moment I, plan C)

Consequently, we can say that the number of vents on the screen does not affect the shielding or the value of B[T], magnetic field lines closing through vents.

The following figures (Fig. 3.C.13. and Fig. 3.C.14) represent the determination of dangeours distance.
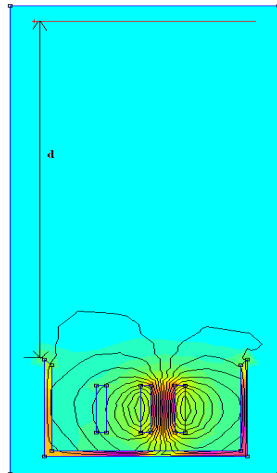

Fig. 3.C.13.The spectrum of   Fig. 3.C.14. . Magnetic flux density variation
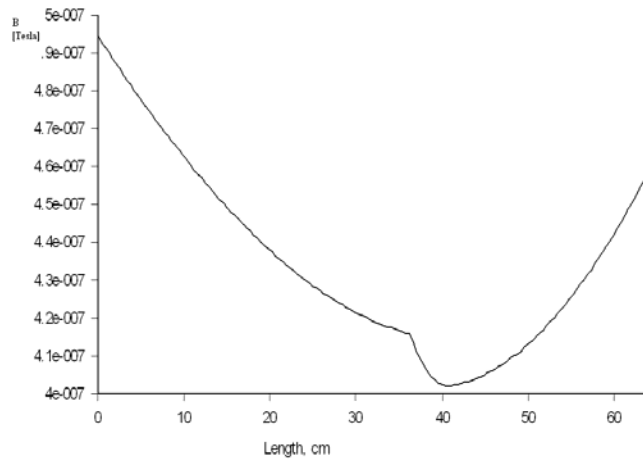magnetic flux density

Magnetic flux density is about B=0.00049 mT at the distance d= 130 cm.

4. Conclusion

Bar-phase systems are a power frequency magnetic field source. We have a good screening for encapsulated systems (with sheet steel). For open channels or channels with vents, boundary field expand outside and is enclosed in screening can. Magnetic field inside spectrum is plotted between maximum and null moments of currents.

The impact of the electrical equipments from the installation on the electro energetic systems represents an important electromagnetic compatibility problem. The magnetic induction decreases while the distance of the calculation increases. This conclusion suggests some caution measures must be taken into account when an electromagnetic device is designed. So it is important to know the dangerous distance.

The cases analyzed in this paper are common in the electrical installations, so the results have a relevant importance. The first device analyzed is the distribution board with 6 different situations given by two distribution of the current in the three-phase systems bus-bars and the geometry of the board: totally

closed, partial closed (the upper cap being removed) and with air perforations up and below. The cage of the board is made by low carbon steel and, for the simulation, we choose a material from FEMM library, named 455 Stainless Steel, characterized by nonlinear B-H curve. The comparisons show us that the steel cage that captures almost the entire spectrum has the major influence. In the absence of the upper cap or the presence of the air perforations, the spectrum of the magnetic field becomes insignificant. In order to have a good shielding, one must choose the proper steel for the distribution board, fact which is very important.

As mentioned at the beginning, the reference level for magnetic fields is a magnetic flux density of 0.0005 mT (for 50 Hz). In our case, on top panel, near the screen B=0.7 [mT], this value being upper to exposure limit. But this decreases while the distance of the calculation increases. At a distance 130 cm of screen, magnetic flux density is 0.00049 mT (the value is below to exposure limit). This is the dangeours distance in our case. In conclusion, our distribution panel ensures a good shielding.

R E F E R E N C E S

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