2009년도 대한전기학회 전기기기 및 에너지변환시스템부문회 춘계학술대회 논문집 (2009. 4. 23 ~ 25)

송전선과 분전반 모선으로부터 발생하는 극저주파 자기장 저감을 위한 연구

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Study on minimizing Extremely-Low-Frequency magnetic fields around power cables and busbars

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Abstract - Extremely-Low-Frequency(ELF) magnetic fields are generated around power cables and busbars in power systems. Such the stray fields may cause disturbances to nearby electronic apparatus and affect even human health. In order to seeking out a proper way to reducing the fields, the first thing to do is to accurately predict field distribution around analysis models of interest. Then, optimization techniques should be applied for finding a more improved design than the initial one. To achieve this goal, commercial electromagnetic software, MagNet, is combined with evolution strategy algorithm. For verification of the proposed method, three-phase power line cables and busbar systems have been tested.

Key Words : Optimization, ELF, Finite Element Method

1. Introduction

Extremely-Low-Frequency(ELF) magnetic fields generated by various electrical components may cause disturbances to nearby electronic apparatus and affect even human health. Recently, the topic especially on human body has attracted many interests in social and industrial areas as international regulations on such the stray fields is strengthened. Intensive research has been made to date in order to mitigate the fields around power systems. However we are still not free from the topic because a lot of stray field sources exist very close to residental districts.

2. Theory

2.1 Governing equation

In electromagnetism, there are four partial differential Maxwell's equations that describe the properties of the electric and magnetic fields and relate to their sources such as charge density and current density.

When the wavelength of time-varying fields is much larger than the dimensions of the problem (i.e. in the near field zone), then the four Maxwell's equations are simplified as

$$\nabla \times \vec{E} = -\frac{\partial \vec{B}}{\partial t}$$
$$\nabla \times \vec{H} = \vec{J} + \frac{\partial \vec{D}}{\partial t}$$
$$\nabla \cdot \vec{D} = \rho$$
$$\nabla \cdot \vec{B} = 0 \qquad (1)$$

where $\vec{E}$ is the electric field intensity, $\vec{H}$ is the magnetic field intensity, $\vec{D}$ is the electric flux density, $\vec{B}$ is flux density, ρ is free volume charge density, $\vec{J}$ is the volume current density.

For quantifying the performance of shielding effect, the concept of shielding effectiveness (SE) is introduced here. The shielding efficiency depends on the ratio of the field evaluated at the point(x,y,z) for two different circumstances and depends on the frequency. It is defined as (2).

$$SE = 20\log_{10}\left[\frac{B_o(x,y,z)}{B_{shielded}(xy,z)}\right] \qquad (2)$$

where B_o is the magnetic field without the shield, $B_{shielded}$ is the magnetic field after placing the shield.

2.2 Description

The three-phase conductors, R (90°), S (120°) and T (−30°), shown in Fig.2 consist of 5 meters long cables and carry current of 100 A at 60 Hz.

Possible different phase arrangements of nine conductors with diameter of 20 mm are presented in FIg. 2 where the distance between each conductor is 40 mm. The aim of the first problem is to find the best phase combination which provides the lowest B field around the cables.

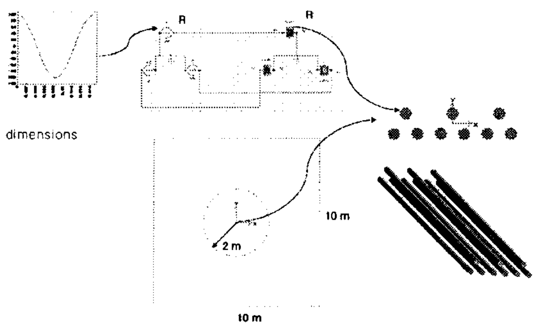


Fig.1 Power cable model

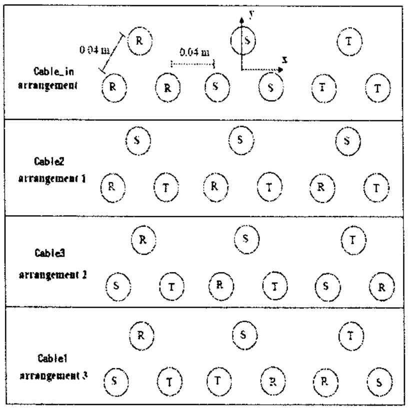


Fig.2 Different phase arrangements

Electromagnetic shielding is the process of limiting the penetration of stray fields by blocking them with a barrier made of conductive material. The three-phase busbars model shown in Fig.3 is the second design problem.

The peak current value of 100 A flows to each phase and the variables, FlyH, ShieldH, ShieldW, Dis and ShieldZ, predicted in Fig. 4 are selected as design variables. The initial design values are shown in Table 1.

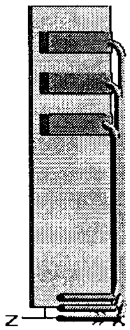


Fig.3 Busbars model

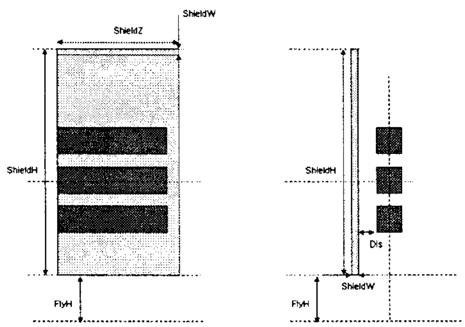
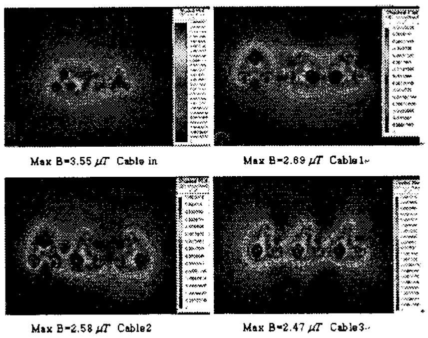


Fig.4 Definition of design variables of busbars.

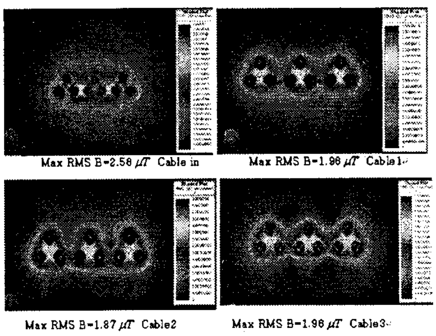
Table 1. Dimension and performance changes of shield plate

	Optimized shield	Initial shield	without shield
Variable	**Optimized Shield**	Initial shield	Without Shield (criterion)
FlyH (mm)	6	400	-
ShieldH (mm)	1524	1350	-
ShieldW (mm)	10	5	-
Dis (mm)	45	50	-
ShieldZ (mm)	986	1000	-
Weight(kg)	20.34	17.60	0
RMS|B| (μT)	0.0052	0.0102	0.0219

From Table I, it is noted that there are differences between dimensions of the initial and the optimized shield plates in terms of the length, width and distance and so on. The distance between the plate and busbars is smaller to improve the shielding effect (i.e. increase electromagnetic interaction between the plate and busbars). This gives better performance of SE compared to the initial design.



(a)Flux density distributions at ω_t=0



(b)Time-average flux density distributions

Fig.5 Flux density distributions around power cables

2.3 Analysis and discussion

The flux density distributions around the power cables are shown in Fig. 5, where the maximum value of B fields and the root mean square value around power cables are presented. The contour illustrates relative magnitude of the fields at a certain phase angle.

The comparison of flux density distributions along the y-axis from 0.5 m to 3 m are shown in Fig.6. Cablel yields lowest field values among the four different cable combinations. From the viewpoint of time-average value, it is concluded that Cablel is the best choice from the combinations considered here.

The flux density distributions are compared before and after optimization of the shield plate in Fig. 7. The optimized plate produces apparently lower stray field value around the busbars. Fig. 8 shows flux density distributions around the busbars with the initial and optimized shield plates, respectively. The same field range from 0.0150 μT to 0.0055 μT are applied to Fig. 8.

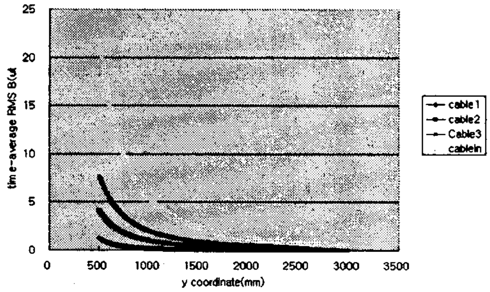
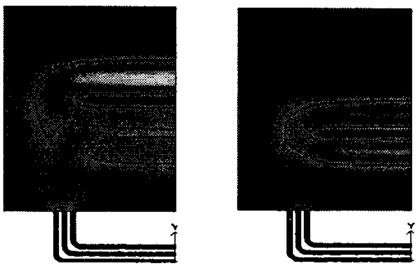
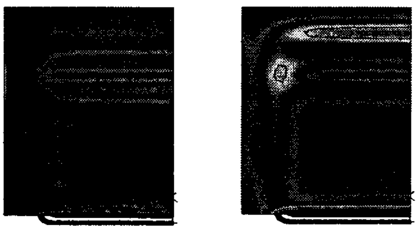


Fig.6 Flux density distributions along the y-axis from 0.5 m to 3 m

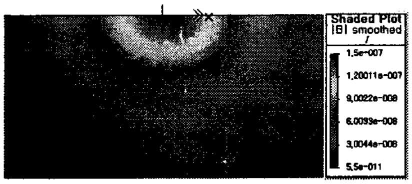


(a)Initial shield

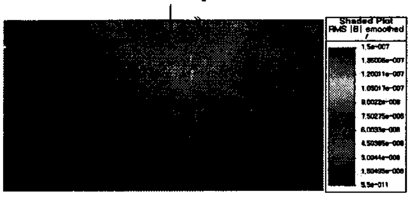


(b)Optimized shield

Fig.7 Eddy current distributions on the side plate



(a)Before optimization



(b) After optimization

Fig.8 Magnetic flux distributions on the measurement plane

3. Conclusions

In this paper, using 2D/3D finite element analysis and evolutionary strategy, ELF magnetic fields from power cables and busbars are mitigated. The configuration of Cablel is the lowest magnetic field than others by comparing four different arrangements of power cables. SE factor of optimized shield is improved 49% more than one of initial model with evolutionary strategy.

All of results are easily and suitably applied to real case due to considering real conditions in optimization process. And these results could be the fundamental material for reducing ELF field in the future.

Acknowledgement

This work was supported by the Korea Science and Engineering Foundation(KOSEF) grant funded by the Korea government(MEST) (No. R01-2008-000-105 22-0).

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