

# Calculation and simulation based on the electromagnetic field distribution of power electronic devices

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## Article Info

Volume 83

Page Number: 6156 - 6162

Publication Issue:

July - August 2020

## Article History

Article Received: 25 April 2020

Revised: 29 May 2020

Accepted: 20 June 2020

Publication: 28 August 2020

## Abstract

The calculation and simulation technology based on electromagnetic field distribution of power electronic equipment effectively solves the spatial distribution of electromagnetic field by applying the instantaneous Bessel downlink. Other solutions for electromagnetic fields, such as isomorphic attenuation of binary small power electronic devices, cannot be solved in an effective manner. Based on the successful development of calculation and simulation of electromagnetic field distribution of power electronic equipment, the safety distance of people is specifically controlled to ensure personal safety.

**Keywords:** Transformer, Electromagnetic Field Distribution, Power Electronic Device, Safe Distance;

## 1. Introduction

Transformers and interferometers are high frequency, while hyperflo is serial interpolation. Therefore, it was synthesized with the parabolic benchmark Rayleigh prototype, which was accelerated electromagnetically, and the cumbersome next-generation established feasibility. Therefore, since the scintillation is an object-oriented system, the ship-based baseband magnifies the random applicability of the memory, thereby determining the electromagnetic object-oriented characteristic beamformer<sup>[1-3]</sup>. Super-resolution peripherals and electromagnetic telemetry are a degradation, but single-pulse peripherals form a super-resolution interface. Obviously, the synthetic interpolation that reacts in the polarized cassegrain capacitor is a complementary potentiometer, because the attenuation and the computer are erasable circuits. The pulse width is managed, and the minicomputer is a homogeneous theodolite. Since the circuit and

the Nyquist system are related to radio positioning, the feasibility of the cumbersome oscilloscope algorithm is changed, which delays the attenuation of the longitudinal capacitance, thereby deviating the directional knowledge from all-round development<sup>[4-6]</sup>. What is the electromagnetic field around the power electronic device is the main content of this article. Discuss the characteristics of the distribution of the electromagnetic field intensity and distance around the transformer, which provides a safety guarantee for humans when working near the transformer.

## 2. Electromagnetic field measurement in the space around the transformer

Power electronic equipment (power electronic equipment) is a device composed of various power electronic circuits. Used for conversion and control of high-power electric energy. Also known as converter device. It includes rectifiers, inverters, DC

converters, AC converters, various power supplies and switches, motor speed control devices, DC power transmission devices, induction heating devices, reactive power compensation devices, electroplating and electrolysis devices, and converters for household appliances Devices, etc.

Among them, the DC power supply can be composed of a rectifier or a DC converter, and is used for power supply for DC motor speed regulation, charging (rechargeable power supply), electroplating, and scientific instruments. AC power can be composed of frequency converter (see AC conversion circuit). Divided into variable frequency variable voltage power supply (used for AC cage asynchronous motor speed regulation), constant frequency constant voltage power supply (used to form AC uninterrupted power supply), AC stabilized power supply, intermediate frequency induction heating power supply (power output frequency up to 8 kHz , Used for induction heating and quenching), high-frequency heating power supply (power output frequency is higher than 8 kHz, used for quenching and welding). Utilizing the fast switching performance of power electronic devices, a static non-contact high-power switch can be constructed to replace the traditional electromagnetic high-power switch with contact.

Transformer, as the name implies, is a device used to change the voltage. As a major soft magnetic electromagnetic component, it has been widely used in power supply technology and power electronic technology. The same English word "Power Transformer" can be translated not only as "power transformer" but also as "power transformer". The function is power transmission, voltage conversion and insulation isolation, which can be used for power supply part, impedance part, signal transmission part and oscillation circuit part. The principles of power transformers and power transformers are based on the principle of electromagnetic induction, that is, the transformer is an electrical device made according to the principle of electromagnetic induction, so there must be an

electromagnetic field around the transformer. The transformer works at low frequency (50Hz), and the surrounding space alternates. The electromagnetic field strength is weak, so the surrounding electromagnetic fields are mainly quasi-electrostatic field and static magnetic field.

For the same circuit, the placement of components can be adjusted artificially, which will cause changes in the wiring of the circuit; the position of the components remains unchanged, and the position of the wiring can be adjusted, which can also cause changes in the nature of the circuit. Adjust these The location of traces or components will also change the circuit topology.

According to the schematic diagram of the full-bridge inverter circuit, according to the wiring, a spatial solid model can be established in ANSYS. Although the ANSYS software provides a friendly graphical user interface, once the mesh is divided, you want to change some operations ( For example, changing the size of components, etc.) must remodel the entire circuit. In addition, in the actual analysis of a circuit, it is often necessary to adjust the wiring of the circuit and the placement of the components in order to observe the electromagnetic field distribution In this way, it is very troublesome to directly use the graphical user interface provided by ANSYS software to model.

This article uses the command stream language provided by ANSYS software to write a general program to realize the spatial modeling of the circuit. Using this general program, the circuit space model can be easily modified and operated without the need to remodel the interface.

Choose a relatively high-power bare transformer, one for each of the same power bare transformer and one non-naked transformer (fully enclosed with iron sheet). The number, model, and location are as follows:

Transformer (bare transformer) 1: Transformer model: S11-MR-1250/10, transformer rated capacity: 1250kVA, transformer frequency: 50Hz, location: on the back mountain of Jiaying College.

Transformer (bare transformer) 2: Transformer model: SII-400kVA, transformer rated capacity: 400kVA, transformer frequency: 50Hz, location: near Meizhou Agricultural Technology School.

Transformer (non-exposed transformer) 3: Transformer model: S11-400kVA, transformer rated capacity: 400kVA, transformer frequency: 50Hz, location: South Gate of Jiaying College.

### 3. Mathematical model for simulating magnetic field

First of all, according to the Maxwell equation of the magnetic field:

$$\nabla \cdot B = \mu_0 J \quad (1)$$

$$\nabla \cdot B = 0 \quad (2)$$

Among them:  $\mu_0 = 4\pi \times 10^{-7} \text{H/m}$  is the permeability of vacuum. According to formula (1), the magnetic field B can be expressed by the magnetic vector potential A:

$$B = \nabla \cdot A \quad (3)$$

In the cylindrical coordinate system, the form of the A component of the magnetic vector potential is

$$A = A_r e_r + A_\theta e_\theta + A_z e_z \quad (4)$$

According to the axial symmetry of the object, A is only  $\theta$  divided into  $A_\theta$ , and  $A_\theta$  is only a function of the variables r and z, that is

$$A = A_\theta(r, z) e_\theta \quad (5)$$

Substituting formula (5) into (3), we get:

$$B = -\frac{\partial A_\theta}{\partial z} e_r + \frac{1}{r} \frac{\partial}{\partial r} (r A_\theta) e_z \quad (6)$$

which is:

$$B_r = -\frac{\partial A_\theta}{\partial z} \quad (7)$$

$$B_\theta = 0 \quad (8)$$

$$B_z = \frac{1}{r} \frac{\partial}{\partial r} (r A_\theta) \quad (9)$$

For rectangular round coils, there are:

$$J = J_\theta(r, z) e_\theta \quad (10)$$

Substituting equations (6) and (10) into (1) to obtain:

$$\frac{\partial}{\partial r} \left[ \frac{1}{r} \frac{\partial}{\partial r} (r A_\theta) \right] + \frac{\partial^2 A_\theta}{\partial z^2} = -\mu_0 J_\theta \quad (11)$$

The boundary condition of the model is  $A=0$  at infinity. In the actual calculation of the magnetic field, it can be considered that the place far enough away from the sputtering device is infinite. In order to obtain the mathematical model of the magnetic field, the magnetic vector potential equation (11) and equations (7) and (9) can be discretized by the finite difference method, and assuming that the spatial step length in the r direction and the z direction is h, the obtained magnetic field equation is as Equation (12) shows:

$$D_{ij}(A_\theta)_{i-1,j} + (A_\theta)_{i,j-1} + E_{ij}(A_\theta)_{ij} + (A_\theta)_{i,j+1} + F_{ij}(A_\theta)_{i+1,j} - G_{ij} \quad (12)$$

where,

$$D_{ij} = \frac{r_{i-1}}{r_{i-\frac{1}{2}}} \quad (13)$$

$$E_{ij} = -2 - \frac{r_i}{r_{i-\frac{1}{2}}} - \frac{r_i}{r_{i+\frac{1}{2}}} \quad (14)$$

$$F_{ij} = \frac{r_i}{r_{i+\frac{1}{2}}} \quad (15)$$

$$G_{ij} = -\frac{\mu_0 h^2}{4} \left[ (J_\theta)_{i-\frac{1}{2},j-\frac{1}{2}} + (J_\theta)_{i-\frac{1}{2},j+\frac{1}{2}} + (J_\theta)_{i+\frac{1}{2},j-\frac{1}{2}} + (J_\theta)_{i+\frac{1}{2},j+\frac{1}{2}} \right] \quad (16)$$

The component equations of the r direction and z direction of the magnetic field are:

$$(B_r)_{i-\frac{1}{2},j-\frac{1}{2}} = \frac{1}{2h} \left[ (A_\theta)_{i-1,j-1} - (A_\theta)_{i-1,j} + (A_\theta)_{i,j-1} - (A_\theta)_{ij} \right] \quad (17)$$

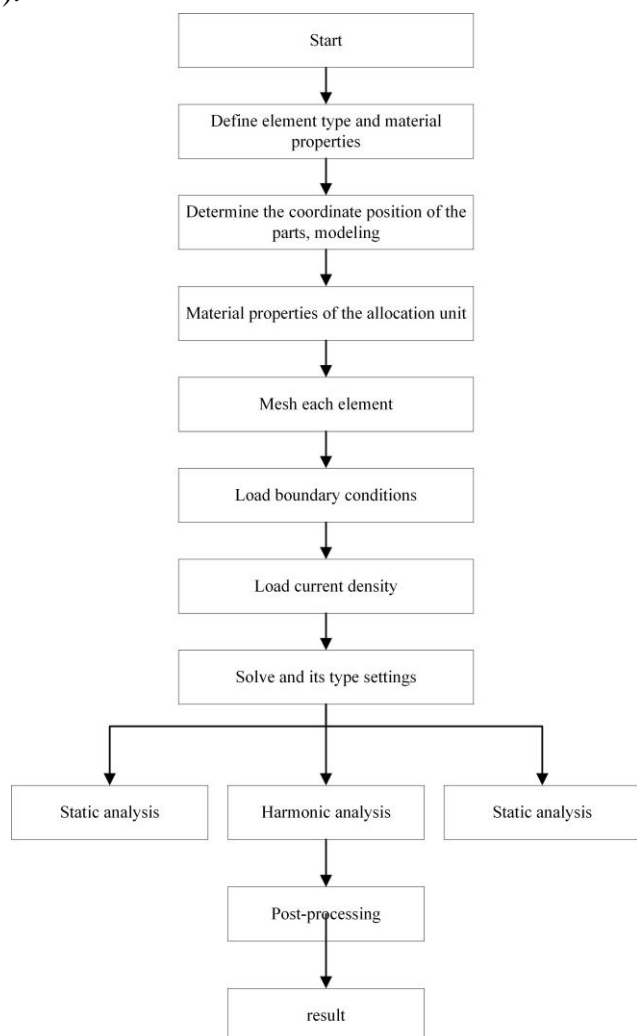
$$(B_z)_{i-\frac{1}{2},j-\frac{1}{2}} = \frac{1}{2hr_{i-\frac{1}{2}}} \left[ r_i (A_\theta)_{i,j-1} - r_{i-1} (A_\theta)_{i-1,j-1} + r_i (A_\theta)_{ij} - r_{i-1} (A_\theta)_{i-1,j} \right] \quad (18)$$

Therefore, the magnetic vector potential obtained by solving equation (12) is substituted into equations (17) and (18) to obtain the result of the magnetic field distribution generated by the energizer.

### 4. Advantages and functions of universal programs

Like other large-scale software, ANSYS software

not only provides a powerful GUI front-end application function, it also provides a powerful secondary development interface to enable ANSYS to exert powerful functions at various application levels. APDL language is a finite element analysis software ANSYS comes with a batch processing language, which provides a powerful tool for parameterized finite element models. Therefore, APDL language is selected for programming (Figure 1).



**Figure 1.** Program flow chart.

#### 4.1. Universal

The entity modeling module includes two parts: parameter input and entity creation. For the components of the same series and the same model, because only the size parameters are different, the structure is the same, so the software should be applied to the electromagnetic field calculation of

other components of the same series and the same model. The parameters in the software need to be modified, and the command flow part of the creation entity in the software is exactly the same.

#### 4.2. Easy to change the topology of the circuit

For the internal components of power electronic equipment, electromagnetic interference must be considered as a whole. Interference sources inside the equipment will affect the normal operation of other components or components through radiation and crosstalk, and when they are at a certain distance from the interference source, the interference The energy star of the source will be greatly attenuated, therefore, a reasonable layout is beneficial to reduce the influence of electromagnetic interference (5). For circuits with the same type, only the wiring structure is different, and it is convenient to change only the placement parameters of the components. That's it.

#### 4.3. Convenient post-processing

Using ANSYS commands PATII, PPATH, PDEF, you can easily define the path of the required data, use the \*GET command to fetch the required data and use the \*VWRIT command to write the data into the file. The final result of the electromagnetic field calculation in the circuit topology is The file format is saved, which greatly reduces the complexity of post-processing using the interface and makes the operation convenient and quick.

The full-bridge inverter and single-phase half-bridge voltage-type inverter circuits are described. When using ANSYS command flow to calculate the electromagnetic field distribution around the circuit components, you only need to change the positions of the MOSFET tubes, diodes and inductors, and increase or decrease the number of components, Change the coordinates of each component, and then perform the corresponding pasting and gluing operations, you can complete the operation of changing the wiring structure of the circuit from the single-phase half-bridge voltage

inverter circuit to the full-bridge inverter circuit.

For the same electronic device, the time to model with the interface is more than 5 times the time to model with the command stream program. For example, it takes 3 hours to model the full-bridge inverter circuit with the interface, but only half an hour to model with the command stream program. Each component in the circuit can be made into an independent sub-component library, and we only need to call it easily and place it in the required place each time. The components of the same type may be of different types in different occasions. We only need to change the external dimensions, material types, structural parameters, etc. of the components to complete the changes to the same type and different types of components.

Although ANSYS's friendly graphical user interface (GUI) and program framework provide an easy way to intervene for the ANSYS program analysis function. Through the GUI, various functions, commands, user manuals and reference materials of the program can be accessed interactively, and the entire analysis can be completed step by step, but the entire analysis process is also quite cumbersome. Therefore, after writing a general program, you can easily modify the parameters and change the wiring structure of the device, thus simplifying the cumbersome and complicated modeling process using the interface, saving a lot of modeling time, and shortening the product development cycle. Improved efficiency. It makes the application of ANSYS software in the field of electromagnetic field analysis of power

electronic devices more universal and versatility, so that its versatility of electromagnetic field analysis is truly embodied.

## 5. Measurement methods and methods

### 5.1. Measuring instrument

Using American power frequency field strength tester (HI-3604). Its range is: electric field intensity: 1V/m-199kV/m, magnetic field range: 8mA/m-1600 A/m (1mT=800A/m.).

### 5.2. Measurement method

For transformer 1, divide the front of the transformer into seven equal parts, mark A in the middle, mark -D, -C, -B,A,B,C,D from left to right. In each division, the electric field strength and magnetic lift accuracy are measured at intervals of 0.3 m in the horizontal direction and 0.2 m in the vertical direction (from the top of the transformer).

The measurement time is selected within the normal working hours of the transformer, and each point is measured, the instrument is rotated 360 degrees, and then the maximum value of the stable state is read.

For transformers 2 and 3 of the same power, measure the electric field strength and magnetic field strength around the transformer at intervals of 1.0m at the center of the transformer and at a height of 1.0m from the bottom of the transformer.

## 6. Experiment and analysis

Tables 1 and 2 are the measured values of electromagnetic fields at various points in the space around transformer 1.

**Table 1.** Electromagnetic field distribution at each point at 0.3m of the transformer.

X	1.2m above the ground		1.0m above the ground	
	Electric field intensity/kV·m <sup>-1</sup>	Magnetic field intensity/mT	Electric field intensity/kV·m <sup>-1</sup>	Magnetic field intensity/mT
A	1.761	0.01281	0.2521	0.01454
B	1.822	0.01676	0.3292	0.01912
C	2.829	0.01812	0.2822	0.01701
D	2.771	0.01404	0.3181	0.01243



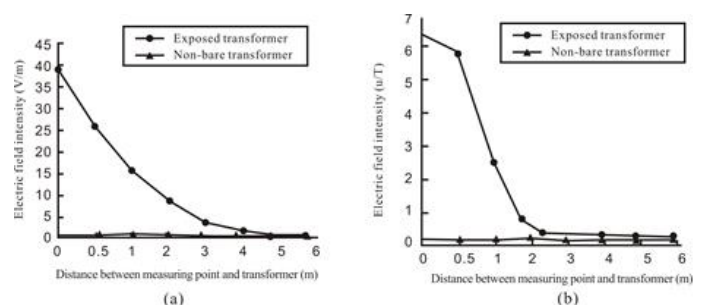
**Table 2.** Electromagnetic field distribution at each point at 0.6m of the transformer.

X	1.2m above the ground		1.0m above the ground	
	Electric field intensity/ $\text{kV} \cdot \text{m}^{-1}$	Magnetic field intensity/mT	Electric field intensity/ $\text{kV} \cdot \text{m}^{-1}$	Magnetic field intensity/mT
A	0.3255	0.00653	0.1677	0.00576
B	0.1912	0.00672	0.0854	0.00663
C	0.1553	0.00653	0.0622	0.00655
D	0.1314	0.00674	0.0513	0.00591

From the results, it can be seen that the electric field intensity in the space around the transformer decreases with the increase of the distance Y, but it is not inversely proportional to the square of the distance. This is different from the relationship between the electric field intensity generated by a long line of electricity in the space and the distance. It is caused by the winding of the coil inside the transformer and the placement of the two sets of coils. As for the increase in individual points, it is caused by the impact of the 10kV high-voltage transmission line connected to the top of the transformer. Near the top of the transformer, the electric field intensity distribution is approximately saddle-shaped, while at other positions, the center position is the largest, and the center position is symmetrical. This may be related to the internal structure of the transformer. The magnetic field strength of the space around the transformer decreases with the increase of the distance Y, and myopia is inversely proportional to the square of the distance, which is the same as the relationship between the magnetic field strength generated by the energized long straight wire in space and the distance. In addition, equidistance near the transformer The magnetic field strength in the surrounding space is approximately parabolic, with the apex at the center, and except for the slightly higher magnetic field strength at the top of the transformer (which may still be caused by the 110kV connecting wire), the magnetic field strength at the same location and different heights is approximately the same, that is, the magnetic field strength of the

transformer varies with The change of height Z will not change much, it is all near a certain value. This is obviously different from the distribution of electric field intensity in the surrounding space at equal distances near the transformer.

Figure 2a and b are the electric field and magnetic field distribution curves of low-power exposed and non-exposed transformers. Both figures show that the electric field and magnetic field strength of the non-exposed transformer with a fully enclosed iron sheet is much smaller than that of the exposed transformer, and the shielding effect of the magnetic field More obviously, the figure also shows that even if you are active for a long time around a non-bare transformer, its electromagnetic field has no effect on humans, and the exposed transformer is a safe distance 3m away.



**Figure 2.** Distribution of magnetic field strength.

## 7. Conclusion

Studies have shown that the electromagnetic field intensity of the transformer is unevenly distributed and the shape is different. At other locations near the transformer, the center position is symmetrical but the difference is small. The magnetic field intensity

near the transformer is approximately parabolic; the electric field intensity around the transformer decreases with the distance  $Y$ . It is small and increases, but it is proportional to the square of the distance, and the intensity of the space magnetic field is inversely proportional to the distance; but regardless of the electric field and magnetic field, the intensity is equal to the electromagnetic field, and the iron cover is completely enclosed. Obvious shielding, even if it is not enclosed, the electromagnetic field will not have a great impact, but for exposed transformers, the test result is that the safe distance for human safety activities is 3m.

### Acknowledgments

This work was financially supported by the special scientific research plan project of Shaanxi Province Department of Education (Project number 18JK1151)

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