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Electromagnetic Field Influence upon the Electroenergetic System of the Ship

It is presented a global evaluation criterion of the perturbation magnetic field of a volume, which presents interest. It is determined the medium volume density of the magnetic field energy in the interested volume and correspond the medium value of the electromotive force (e.m.f.) which is induced in a single winding. The medium value of the e.m.f. is considered to be an evaluation criterion of the electromagnetic compatibility.

1. Introduction

Any coil, from electromagnetic system, made by an alternative current creates around it a magnetic field, which generates bad effects to the electronic equipment.

The global evaluation of the dispersion magnetic field, created by the diversity of the electromagnetic systems establish the calculus relation for the dispersion magnetic field ant finds out the medium volume density of the field energy in volume which presents interest.

For the justification of a generalised relation for the calculus of the dispersion magnetic field [2], we will start with 2 examples used frequently in technique applications: the transformers and the engine asincrone.

In specialised texts [2,3] we meet mathematics models for the calculus of the dispersion field, which associates to the real transformer on equivalent system of conductors or winding traversed by alternative current.

We presented the results obtained, for the moonfaced transformer in column, with cylindrical coils, equivalent transformer from the point of view of the dispersion magnetic field, with a winding, placed in air, with the ray equal to the medium ray of the primary coil traversed by equivalent alternative current with amplitude $N_1 \cdot I_{m10}$, where N_1 is the number of windings of the primary coil and I_{m10} is the amplitude of the current strength unloaded. The calculus and the measurements are made in points on the axe of the equivalent winding, in which the values of the magnetic induction are maxims.

2. Mathematical relations in the non-steady state

It was calculated the magnetic induction in axe of the equivalent winding to a distance R>>a from the center of the winding, obtained expressed:

$$b_R(t) = \frac{\mu_0 \cdot N_1 I_{m10} \cdot a^2}{2R^3} \sin \omega t \quad , \tag{1}$$

where a is the ray of the equivalent winding.

In (1) we have the amplitude of the magnetic induction:

$$B_m = \frac{\mu_0 \cdot N_1 I_{m10} \cdot a^2}{2R^3} \tag{2}$$

The use of the relation (2) is not desirable, because of the difficulties in establishing the values of I_{m10} and the ray a.

We use a relation based on the measurements of the magnetic induction in reference point, placed on the axe of the equivalent winding, to a distance $R_0 < R$ from the centre of the winding.

The amplitude of the magnetic induction in the reference point are expression:

$$B_{0m} = \frac{\sqrt{2}\, N_1 I_{10} \cdot a^2 \cdot \mu_0}{2R_0^3}, \tag{3}$$

From expression:

$$\frac{B_m}{B_{0m}} = \left(\frac{R_0}{R}\right)^3 \quad , \tag{4}$$

Resulted:

$$B_m = B_{0m}\left(\frac{R_0}{R}\right)^3, \tag{5}$$

So, if we measure the value B_{0m} in a reference point on the axe of the equivalent winding for a moonfaced transformer we can calculate the value of the magnetic induction in any point with $R > R_0$, from the axe.

The verification of the relation (5) was realised by the measurements of a column moonfaced transformer with cylindrical coil with the parameters: S_n=2,5 KVA, U_{1n}=220 V, U_{2n}=24 V, I_{10}=0,82 A, N_1=245, N_2=32, f_n=50 Hz, a=0,055 m.

It was considered from the reference point R_0=0,207 m, and the calculus of the value of the medium induction was $B_{0med}=2\cdot 10^{-4}$ T. It was verified the relation (5) for different values $R>R_0$, and the results are mentioned in table 1.

Table 1

R(m)		0,335	0,535	0,735	0,935	1,135
Measured values	B_{Rmed}	48	12	4,5	2,1	1,2
Calculated values	B_{Rmed}	47,18	11,58	4,66	2,16	1,23

We see that between the measured values and the calculated ones is a good approximation. Marking the measurements for more moonfaced transformers we see that the values B_{0med} measured in the axe of the equivalent winding at the same distance R_0=0,207 m, one different, and from de point of view of the dispersion field, the moonfaced transformer is similar to a magnetic dipole.

The dispersion magnetic field created by three-phase transformers, with star connected coils, at great distance R >> D, where D is the distance between the lateral columns, has the same reaction of a dipole.

For the asynchronous engine we use a calculus relation of the dispersion magnetic field, which has acceptable results is:

$$B_m = B_{0m}\left(\frac{R_0}{R}\right)^{3/2} \qquad (6)$$

where B_{0m} is the value of the magnetic induction measured at the distance R_0 from the geometric centre of the electric machine, and B_m is the unknown value for the distance R >R_0.

For example, we have a asynchronous engine with the parameters: P_n=7Kw, U_n=380 V, n_n=1460 r/min, cos φ = 0,84, f_n=50 Hz.

If we measure the medium values of the magnetic induction on the surface of a semicylinder which includes the electric machine, we see that the values do not remains the same but remains similar.

For the electrical engine considered, to a distance R=0,15 m to wards the carcass of the machine, the measured values are between 18 μT and 24 μT. If we measure, an axe perpendicular on the carcass of the machine placed at the half of its length, in a certain point placed at distance R_0=0,105 m, towards the carcass of the machine, we obtain the medium value of the induction B_0=56 μT.

The results of the measurements made for R>R_0 and the results obtained by calculus (of relation 6), are presented in table 2.

Table 2

R(m)		0,155	0,21	0,26	0,41
Measured values	B_{Rmed}	30	18	13	7,6
Calculated values	B_{Rmed}	30,8	19,7	14,7	7,2

Relation (6) gives the possibility to determinate the dispersion magnetic field with a good approximation.

In practical calculus the values obtained on the axe of measurement which, was selected so that the values obtained to be maximum, are extended for any point on the surface of a sphere with the ray equal to the distance between the measurement point and the perturbation source.

The dispersion magnetic field, created by the electromagnetic systems is to by described with a good approximation by the relation (7):

$$B = B_0 \left(\frac{r_0}{r} \right)^n , \tag{7}$$

where B_0 is the measured value of the induction at the distance r_0 from the perturbation source, r is the distance of the observation point, and n for the real perturbation sources has values between 1,5 – 3.

The field source can be conventionally presented as a equivalent sphere with ray R_0, and on its surface the measured value of the magnetic induction is B_0.

The volume in which we determinate the level of magnetic pollution made by the dispersion field can be equalised with a sphere with the ray R.

The value R in calculus is considered equal with the distances from the geometric center of the perturbation source to the point where it is placed the perturbation equipment.

Considering the conventional model mentioned the medium density volume of the energy of the dispersion magnetic field is:

$$w_{m.med.} = \frac{1}{V} \int_{(V)} \frac{\vec{B} \cdot \vec{H}}{2} \cdot dv = \frac{1}{V} \cdot \frac{B_0^2}{2\mu_0} \cdot r_o^{2n} \int_{(V)} \frac{dv}{r^{2n}} , \tag{8}$$

where V is the volume in which is placed the receptor equipment of the perturbation. With the notification:

$$V = \frac{4 \cdot \pi \left(r^3 - r_0^3 \right)}{3}; \quad \beta = \frac{r_0}{R} << 1; \quad w_0 = B_0^2 / 2\mu_0 , \tag{9}$$

and considering the system of spherical co-ordinates in which $dv = r^2 \sin \varphi dr d\varphi d\theta$ we obtain for relation (8) the expression:

$$\int_{(V)} \frac{dv}{r^{2n}} = \frac{4\pi}{2n-3} \left(\frac{1}{R^{2n-3}} - \frac{1}{r_0^{2n-3}} \right) , \tag{10}$$

and relation (8) becomes:

$$w_{m.med.} = \frac{3w_0}{(2n-3)(1-\beta^3)} \left(\beta^{2n} - \beta^3 \right) , \tag{11}$$

but $w_{m.med.}$ can become:

$$w_{m.med.} = \frac{B_{med}^2}{2\mu_0} \quad (12)$$

where B_{med} is the medium value in the volume considered of the dispersion magnetic induction.

From relation (11) and (12) results:

$$B_{med} = B_0 \left[\frac{3\left(\beta^3 - \beta^{2n}\right)}{(2n-3)\left(1-\beta^3\right)} \right]^{1/2} \quad (13)$$

Relation (13) leads to almost equal values of B_{med} for $1,5 \le n \le 3$. We consider the value n=2 is the armonic medium for this parameter.

Than, we have $\beta << 1$ and n=2, [2] we obtain:

$$B_{med} = \sqrt{3} B_0 \beta^{3/2} \quad (14)$$

We considered $1-\beta \cong 1$ and $1-\beta^3 \cong 1$.

As a evaluation criterion of the pollution level compared to the dispersion magnetic field, we can consider the medium value in the volume of the e.m.f., which is induced in a circular shape with the surface equal to 10^{-4} m^2, placed in the field of medium magnetic induction B_{med} and frequency:

$$U_{e.med.} = 2\pi f \cdot 10^{-4} \sqrt{3} \cdot B_0 \beta^{3/2} \cong f B_0 \beta^{3/2} \cdot 10^{-3}, \ [V/cm^2] \quad (15)$$

In case of influence of more perturbation sources, with the same frequency of work we obtain:

$$U_{e.med.} = 10^{-3} f \left[\sum_k^N B_{0k}^2 \beta^3 \right]^{1/2} \ [V/cm^2] \quad (16)$$

where k=1...N, represents the number of sources.

4. Conclusion

The mathematics models presented do not require ample experimental search and the alternative dispersion magnetic field has great variations at small variations of the ray of the observation point. The magnetic asymmetries which are in the construction of the electromagnetic system require the search of the position of ray r_0 in which the measured value of the dispersion induction is maximum. For the presented method to be applicable is necessary that the purveyor to specify for every electromagnetic system the values r_0 and B_0. In the calculus of the value $U_{e.med.}$ it was considered the influence of the screens for the frequencies of work.

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