DETERMINATION OF ELECTRIC AND ELECTRO-MECHANIC CONVERTERS' PARAMETERS

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Abstract – *The paperwork presents the principles of determination of the inductance of the electric and electro-mechanical converters' windings applying the" finite element" method. The method reduces the difficult calculus usually used to determine the above mentioned parameters.*

Keywords – *Flow/ flux, inductance, winding, magnetic lines, electric power*

1. INTRODUCTION

The massive penetration of calculus technique in the research and study of electric and electro-mechanical converters brought about better knowledge of the processes involved in these devices.

Special programs were created in order to give solutions to problems related to the magnetic field concentrated in the magnetic system and extended into the area of the converter's clothing.

The paperwork illustrates the finite element method (FEM) that is used in the process of obtaining the panels of the magnetic field in the case of static electric devices [1, 2] (transformers), as well as of rotating electric devices, herein referred to as electric and electro-magnetic converters.

2. PARAMETERS DETEMINATION METHOD

Using the FEM one can distribute the magnetic flow in section P (Fig. 1) parallel to its closing lines and determine the values of magnetic field flux and inductions in point a_1, b_1, c_1, a_2, c_2, b_2, arbitrarily chosen on the intersecting lines of planes P_1 and P_2 with plane P. Consequently, Φ and B magnetic field parameters may be determined in any point of the magnetical field closing planes P_1 and P_2 . The mutual and dispersive inductances of this transformer may be determined on the basis of these parameters.

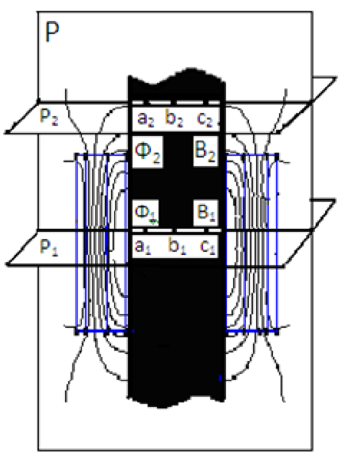

Fig. 1 - Magnetic field parameters determination

Fig. 2 presents the transversal section of a transformer with the primary winding and 2 and 3 secondary windings mounted on the pillars of the magnetic system 1. The magnetic system and the 2[nd] and 3[rd] windings of the transformer are built in reasonable scale so that magnetic field may be obtained in case of no-load running/ back play/ empty running. For the 3[rd] opened secondary winding one has to introduce in the data base the value of the no load running magnetizing force, which has been previously calculated or recommended in the special technical journals:

$$F_m = W_1 I_\mu$$

where W_1 - no. of primary winding's loops

I_μ - magnetizing current

The magnetizing force produces the main magnetic field flux

$$\Phi_m = \frac{F_m}{R_m} \tag{1}$$

And the magnetic circuit resistance

$$R_m = \frac{F_m}{\Phi_m} = \frac{l}{\mu_{FE} S} \tag{2}$$

Where S- transversal section of the column

$$\mu_{FE} = \frac{B_m}{H_m} \tag{3}$$

Increasing the values of B and H one may obtain the values of permeability of magnetic iron material in case of variation of no load running current between (0.02-0.1) I_n limits.

Value of the total magnetic field flux

$$\Psi_m = W_1 \Phi_m \tag{4}$$

The ration between total magnetic field flux and magnetizing current I_μ represents the mutual inductance L_m produced by Ψ_m flow.

$$\frac{\Psi_m}{I_\mu} = L_m \tag{5}$$

Under no load running the clustered magnetic filed flux closes through magnetic field core and the stray flux is very low, in fact is missing.

Table 1 Steel 1411

Size	B_m, T	I_1, A	I_2, A
Value	1.52	12	0
Parameter	W_1	W_2	δ , mm
Value	236	56	0.2

Under no load running the clustered magnetic filed flux closes through magnetic field core and the stray flux is very low, in fact is missing.

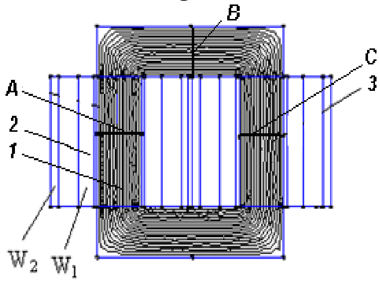

Fig. 2 - Magnetic field panel under no load running

We determine the values of the magnetic filed flux in sections A and B (Fig. 2).
The difference between these values represents the stray flux:

$$\Phi_{\sigma 10} = \Phi_A - \Phi_B \cong 0 \quad (6)$$

The accuracy in determining the extremely low values of the stray flux depends on the FEM applied in this respect.

Further on, the values of the magnetic inductance and the no load running current are presented in the case of transformer with W_1 primary winding and W_2 secondary winding. The value of the gaps formed under pairing of the magnetic system core tray is replaced with an equivalent value equal to **δ**.

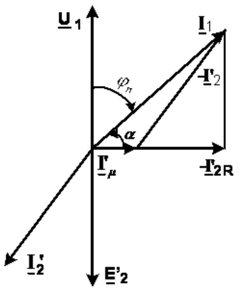

Fig. 3 - Simplified phasor diagram

The mutual and dispersion inductances may be calculated in the case of load running, too: out of the simplified vector diagram (Fig. 3), the reactive components of the no load currents are determined, while the nominal power factor is known from the secondary winding. It results that angle α is equal to 90-φ_n. The current from the secondary winding and the corresponding magnetizing force is determined using the following:

$$I_2^{'} = \sqrt{I_1^2 + I_\mu^2 - 2I_1 I_\mu \cos\alpha}$$
$$F'_2 = \sqrt{(F_1)^2 + F_\mu^2 - 2F_1 F_\mu \cos\alpha} \quad (7)$$

The value of the primary and secondary windings currents are introduced in the computer on the basis of simplified diagram and then one determines the reactive component of the no load current and the secondary winding current that produce the magnetic field flux.

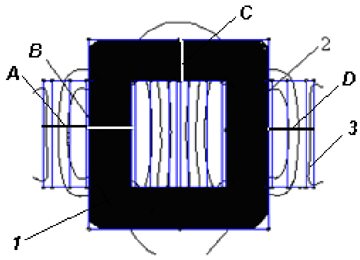

Fig. 4 - Magnetic field panel under load running

Fig. 4 illustrates the one-phase transformer with the same parameters as the one above mentioned. In the magnetic field panel there are presented: the lines of the primary magnetic field closing through the magnetic system and the lines of the dispersion magnetic field closing in the extended area outside the magnetic system. The dispersion and primary fluxes correspond to the values obtained in sections A, B, and C, D respectively.
Table 2 contains the results of the FEM application:

Table 2 Steel 1411

Size	B_n,T	I_1,A	I_2,A
Value	1.46	47	160
Parameter	W_1	W_2	**δ** , mm
Value	236	56	0.2

The results obtained are high, and thus the effective and stray fluxes are determined, as well as the mutual and dispersion inductances:

$$L_{\sigma 1} = \frac{W_1 \Phi_{\sigma 1}}{I_1}; L_{\sigma 2} = \frac{W_2^{'} \Phi_{\sigma 2}}{I_2^{'}};$$
$$L_m = \frac{W_1 \Phi_m}{I_1} = \frac{W_2^{'} \Phi_m}{I_2^{'}}. \quad (8)$$

Fig. 5 illustrates the magnetic field panel used in the determination of the parameters in the case of short-circuit running of the transformer. The inductances above mentioned are calculated using the FEM application corresponding to the high magnetic field fluxes in sections A, B, C, D, as well as to the sizes and values indicated in table 3.

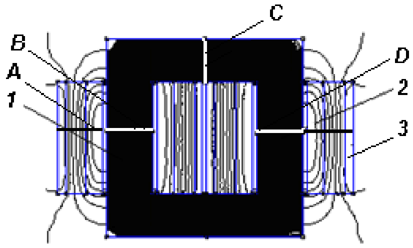

Fig. 5 - Magnetic field panel under short-circuit running

Table 3 Steel 1411

Size	B_n, T	I_1, A	I_2, A
Value	1.13	94	380
Parameter	W_1	W_2	**δ ,** mm
Value	236	56	0.2

The issue of research of the magnetic field in the rotating electrical devices producing direct and alternating current has been significantly important because the magnetic field between the magnetic gaps determine the quality of consumed or produced electric energy, the leakages, yield, the action of torques determined by the superior waves/harmonics and braking or accelerating the rotor.

The modern programs, such as the finite element method (FEM), may be applied also in the thorough study of magnetic field in the electro mechanical converters.

Further on we approach the problem of the distribution of magnetic field flux in the case of co-phasal device with permanent magnets of axial construction [3,4]. Assumptions partially simplifying the research using the FEM have been acknowledged, such as:

- The axial co-phasal rotor device is developed in plane layout
- Permeability of permanent magnets $\mu_m \approx \mu_0$;
- The magnetic system is considered to be non-saturated
- The gap of the co-phasal device is uniform (from the magnetic point of view); the magnetic field is calculated on the basis of basic geometrical sizes and parameters, using the FEM.

It is acknowledged that on the rotor winding's terminals the phasal voltage is applied so that the phasal windings may close the currents under load running producing reactive magnetizing force:

$$F_I = \frac{m_1\sqrt{2}W_1 k_{w1}}{\pi p} I_I \cos\omega t; \qquad (9)$$

unde I_I - curentul fazic al indusului.

The instantaneous values of the currents closed through the phases of the rotor vary as follows:

$$\begin{aligned} i_A &= I_{mA}\cos\omega t; \\ i_B &= I_{mB}\cos(\omega t - \frac{2\pi}{3}); \\ i_C &= I_{mC}\cos(\omega t - \frac{4\pi}{3}). \end{aligned} \qquad (10)$$

The magnetic field flux panel between magnetic gap and the rotor's and armature's yokes is determined by using the instantaneous values of the currents, i.e:

$$(i_A = I_m,\ i_B = i_C = -I_m/2). \qquad (11)$$

Fig. 6 presents the magnetic field lines between the gap and the armature's and rotator's yokes, simultaneously the values of these fluxes are determined in τ, h_{j1}, h_{j2} sections.

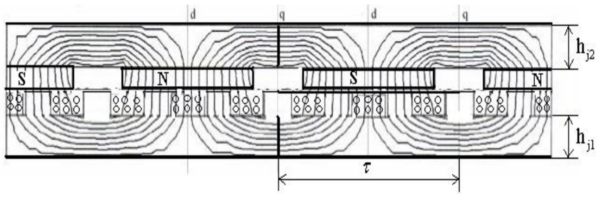

Fig. 6 - The magnetic field of the axial co-phasal device with permanent magnets

Mutual and dispersion magnetic fluxes and their correspondent inductances may be determined according to the method above presented in the case of electrical transformers.

3. CONCLUSIONS

The paperwork highlights on the *finite element method (FEM) program* as a means to determine the electrical transformers' parameters.

The inductances may be determined for all running types of the electrical transformer.

Using the same method the inductive parameters of the co-phasal device with permanent magnets may be determined, under close consideration of the complicated layout of this device/ appliance.

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