COMPARATIVE ANALYSIS OF THE ENVIRONMENTAL INTERACTION FOR VARIOUS CONFIGURATIONS OF POWER MACHINES

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Abstract: *The paper presents a comparative analysis of the interaction with the environment of two classes of structures of electrical machines and, respectively, of two magnetic field distributions within the electrical machine: radial – specific to classical electrical machines - and axial – specific to special low output machines. The analysis undertaken combined – in its turn – two approaches: simulation of the interaction with the environment in a specific software interacțiunii cu mediul ambiant într-un mediu de programare specific (PDE-ase) and, respectively, the experimental analysis on electrical machines manufactured inline or assembled in a laboratory.*

Keyword*: electrical machines, permanent magnets, interaction electrical machine - environment*

I. Introduction

Electrical machines have been around for over 120 years, but it was only lately that the problem of their interaction with the environment was raised, due to two reasons:

- the existence of a high number of electrical machines both by manufacture diversifying and by extending the use of these machines into home and office appliances;
- creation of multiple connections between various subsystems equipped with electrical machines, as a result of modifying the concepts and strategies on feeding, command and control of great integrative systems for various applications demanded by the global economy.

Increasing the degree of complexity of electrically powered systems, a drastic reduction of the space in which various electromagnetic modules are placed, call nowadays for an analysis on the degree on which the electrical machine – as a force system of the electrically powered chain – may trouble the environment, may jam the very functioning of the command modules and may generate, through the intermediary of parasite couplings made by the electromagnetic field radiated outside – perturbing signals both for technical systems close by, and for the biotic system.

Such a study needs – in its turn – defining new concepts (specific pollutant factors), measurement of parameters specific for parasite couplings between the electrical machine and the perturbing elements in the environment, visualizing reciprocal influences between electromagnetic systems belonging to different classes of capacities and powers etc. Part of these aspects are approached in this paper firstly intended to be an introduction in this new and fascinating field of the interaction of electromagnetical systems with the environment, in general, and of the interaction between the electromagnetical system themselves in particular.

II. Comparative analysis of the interaction with the environment of the electrical machines

II.1.Comparative analysis developed by simulation

Although it is evident that any electromagnetic system radically influences the environment, it is difficult to quantify the degree of this influence. To firstly visualise if an electrical machine, placed near another system developing its own field (either an apparatus or a biotic system), may influence the functioning of the other system (the wellness in the case of the biotic system), we shall further present the results of the simulation of such an interaction using the software environment PDE-ase (a bidimensional and electromagnetic field software).

To simplify the analysis, the electrical machine is modelled considering that smooth armatures (without slots), and at the border of each armature (external of the rotor and, respectively, internal of the stator) there is a power shell. Also, for a simple approach, it was chosen the case of a continuous power machine (I = ct). The power intensities within the power machine – responsible for the magnetic field development – are high and, implicitly, the developed fields are high, at any rate higher than those pertaining to another system placed near the power machine. Again, for a simpler analysis, it was preferred the study of a „device-device" interaction, where the interfered system (power machine representing the interfering system) is a ironless core coil.

In fig. 1 is represented the integration area for the problem under analysis in the case in which the machine alone is present in the environment (the interaction element is absent, that is the interfered system). For this case, in figures 2, respectively, 3 are presented the magnetic flux density distribution and the surface of the magnetic vector potential. It was noticed that, in the absence of an interaction element, the power machine may be considered annon-interfering element of the environment in what concerns the external emission of the magnetic field developed internally (on the stator side it was considered a field current of 1 A, and on the rotor side a current of 10 A, the ferromagnetic cores made of electric steel with $\mu_{r\max} = 5000$, and the shell made of cast iron with $\mu_{r\max} = 200$).

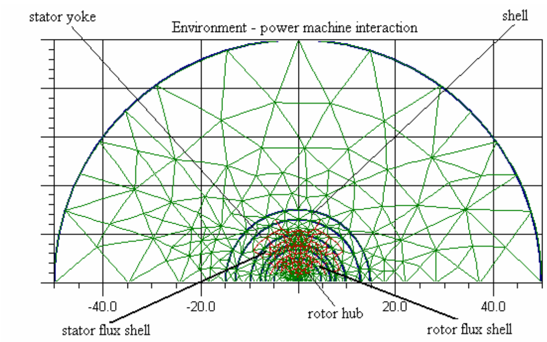

Fig. 1. The integration area in the absence of environment interaction element

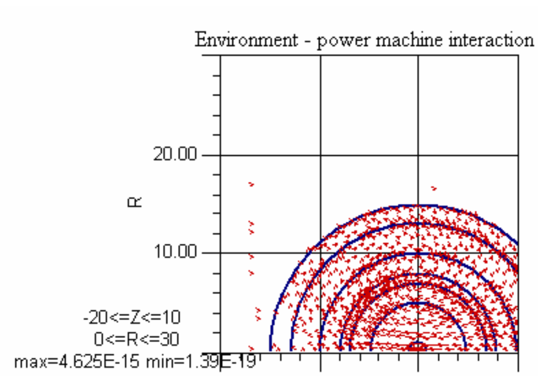

Fig. 2. Distribution of the flux density vector

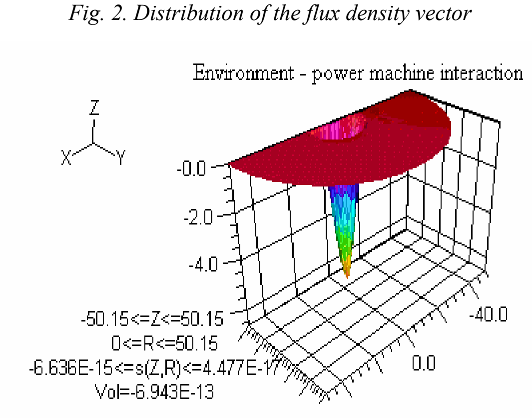

Fig. 3. Distribution of the magnetic potential vector

In the case in which an additional element with own field appears within the environment (a coil without ferromagnetic core in which is emitted a current of 0,1 A) the integration area in presented in fig. 4.

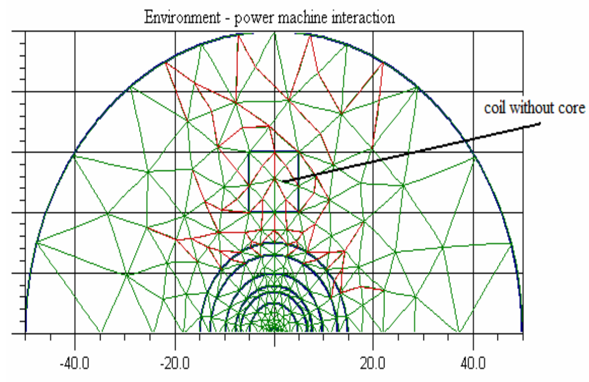

Fig. 4. The integration area in the presence of environment interaction element

The distribution of the magnetic flux density and the variation of the magnetic vector potential, in this case, are presented in fig.5, respectively 6.

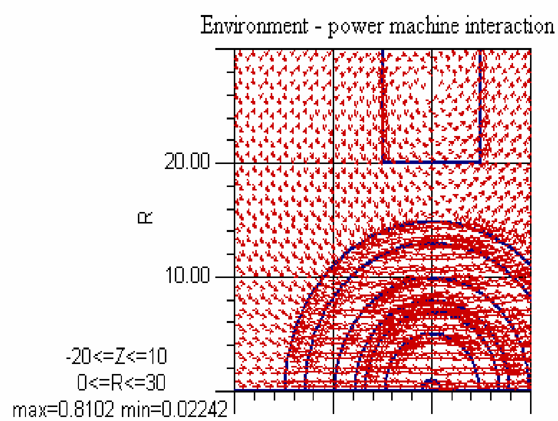

Fig. 5. Distribution of the flux density vector

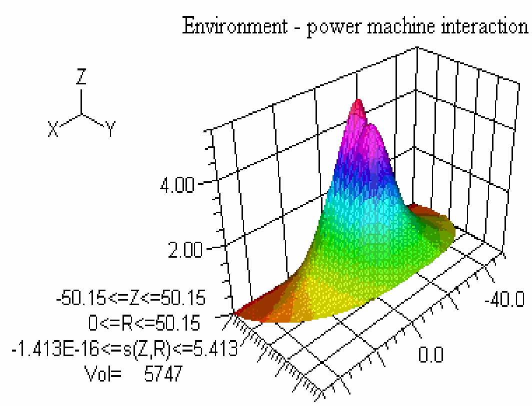

Fig. 6. Distribution of the magnetic potential vector

To perform the comparative analysis– with the asssistance of the PDE-ase software – it was also visualized the interfering effect on the environment of a synchronous machine excited with permanent magnets (with axial distribution of the magnetic field and double electrical gap). The integration area for the chosen machine for our analysis in presented in figure 7.

Due to its symmetrical shape, the machine is presented in transversal section and on one quarter. The environmental interaction element is still a ironless core coil.

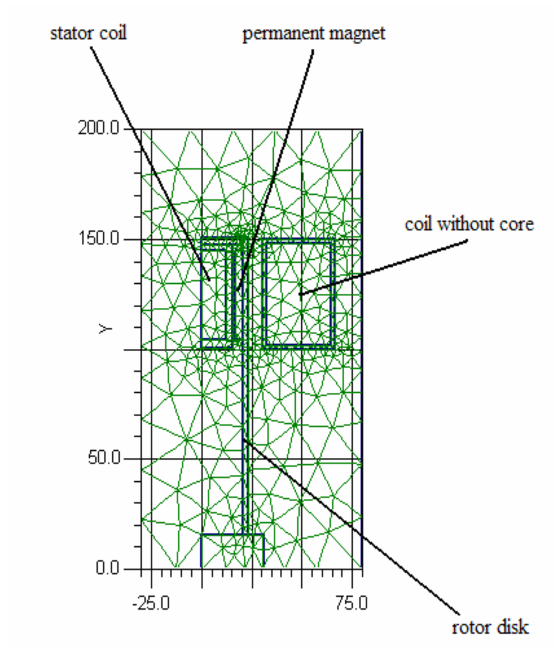

Fig. 7. The integration area – for a synchronous machine with permanent magnets, with double airgap - in the case in the presence of the environmental interaction element

The obtained results – in what concerns the distribution of the magnetic flux and the variation of the magnetic vector – are presented in figures 8, 9, respectively 10,11.

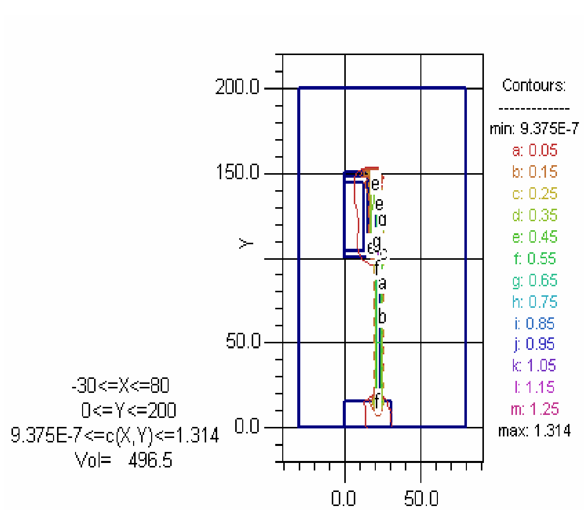

Fig. 8. The distribution of the magnetic flux in the absence of the interaction element

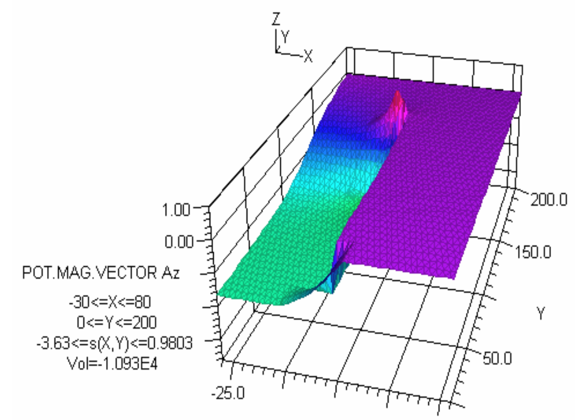

Fig. 9. The distribution magnetic vector potential in the absence of the interaction element

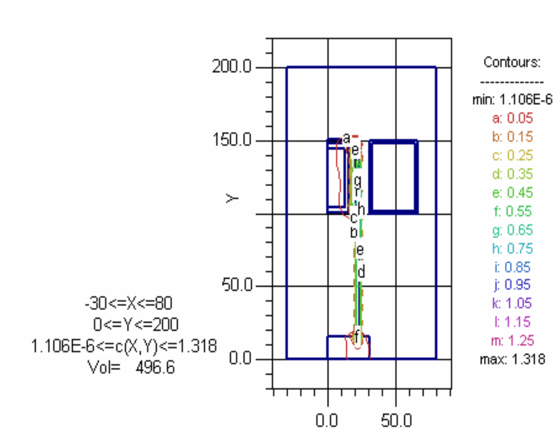

Fig. 10. The distribution of the magnetic flux in the presence of the interaction element

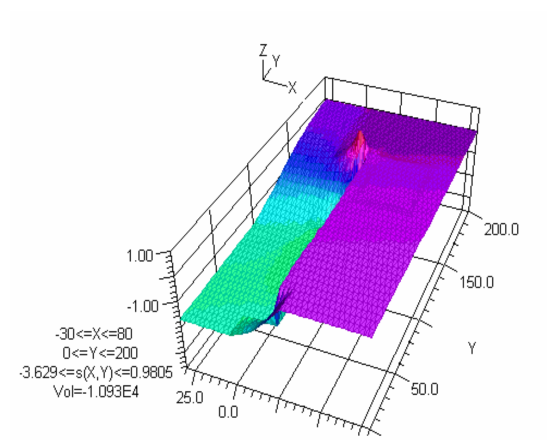

Fig. 11. The distribution magnetic vector potential in the presence of the interaction element

The results obtained by simulation prove that an electromagnetical system (electrical machine), regardless their spacial configuration, have a powerful effect on the immediate environment, thus the new integrative system obtained by inter-coupling the electrical machine and the perturbed element is shown to have a high potential (fig.6).

II.2. Comparative analysis developed experimentally

In what concerns the interaction of the electrical machine with the environment while lenghty functioning, the experimental analysis, also developed to respond to the demands of this study, has highlighted few very important issues that are presented as follows.

Such an analysis was done on two classes of alternating current machines:

- one asynchronous machine, functioning as an engine, with $P_N = 0{,}55 kW$, classical build;
- one synchronous machine with permanent magnets, functioning as a generator, with $S_N = 0{,}375 kVA$.

The analysis was aimed at visualizing the electromagnetic interactions of electrical machines with the environment. The monitored field parameters were: $\overline{E}$ - field intensity and $\overline{B}$ - magnetic induction. Visualisations were done for two distinct statuses of the electrical machine shaft: idle rotor (machine disconnected from the power supply but used after a prior recently operation), respectively, rotor in motion (disconnected machine).

Check ups have been performed with the support of a measurement device specialized in visualizing electric and magnetic fields, that is TRIFIELD METER Model 100XE (USA).

Measurement results are presented in the following table.

Tab. 1

<table>
<tr><td colspan="4">Asynchronous engine $P_N = 0{,}55 kW$</td><td colspan="4">Synchronous generator with MP $S_N = 0{,}375 kVA$</td><td>Rotor status</td></tr>
<tr><td>$E_{ext}[V/m]$</td><td>$B_{ext}[mG]$</td><td>$B_\delta[mG]$ $x\ 10^6$</td><td>SPF x 10^{-7}</td><td>$E_{ext}[V/m]$</td><td>$B_{ext}[mG]$</td><td>$B_\delta[mG]$ $x\ 10^6$</td><td>SPF $x\ 10^{-7}$</td><td>-</td></tr>
<tr><td>1</td><td>5 -10</td><td rowspan="2">6,5</td><td>7,69 – 15,38</td><td>2 -10</td><td>4 -7</td><td rowspan="2">4</td><td>10 – 17,5</td><td>idle</td></tr>
<tr><td>150 - 200</td><td>100
0,5 m away from the body</td><td>153,8</td><td>120 - 150</td><td>100
1 m away from body</td><td>250</td><td>in motion
(the two machines function simulatenousy, so they have coilings that are run thorough by power)</td></tr>
<tr><td>$E_{ext}[V/m]$</td><td>$B_{ext}[mG]$</td><td>$B_\delta[mG]$ $x\ 10^6$</td><td>SPF x 10^{-7}</td><td>$E_{ext}[V/m]$</td><td>$B_{ext}[mG]$</td><td>$B_\delta[mG]$ $x\ 10^6$</td><td>SPF $x\ 10^{-7}$</td><td>-</td></tr>
</table>

Asynchronous engine $P_N = 0{,}55kW$				*Synchronous generator with MP* $S_N = 0{,}375kVA$				*Rotor status*
100 *in 2 circumstances:* *- at 2 cm, the measurement device being parallel to the machine axis;* *- at 2 cm, the measurement device being perpendicular to the machine axis.*	*100* *in 2 circumstances:* *- at 5 cm, the measurement device being parallel to the machine axis;* *- at 10 cm, the measurement device being perpendicular to the machine axis.*	*6,5*	*153,8*	-	-	*4*	-	*in motion* *(only the asynchronous engine is connected to the power supply, thus it can function by itself)*

III. Conclusions

As a result of our analysis the following conclusions can be drawn:

- when within the immediate vicinity of the electrical machine there is an apparatus (system) that develops a field of the same nature with the one of the machine, then the interaction machine-environment is very strong. This is why, in these circumstances, we may say that the electrical machine is a perturbing system for the environment.

Thus, it can be defined, measuring the vlue of the magnetic inductuion found outside the electrical machine, on the direction on which it is obtained the highest value of this parameter due to security reasons concerning the observer – a specific polluting factor that might quantify, for a given power, the influence of the electrical machine on the environment. The value of this specific polluting factor can determined by applying the following equation:

$$SPF_{elmg} = \frac{B_{ext}}{B_{\delta}} \tag{1}$$

where: B_{ext} - is the value of the magnetic induction measured outside the machine (as presented above);

B_{δ} - is the value of the induction in the machine electrical gap (stated by the designer and, if needed, measured by the manufacturer).

High values for this factor will surely point to adopting urgent measures, in order to reduce the effect of the electromagnetic perturbation of the machine on the environment.

- the electromagnetic perturbations of the operating electrical machines on the environment are important (to these add the perturbations of thermal nature tat occur as a result of the losses developed within the electrical machines and, certainly, the sound perturbations – linked to electromagnetic and mechanical noise). It is important to notice that the perturbations of thermal nature diminish once with the decrease of the coilings number that are run through bu the power, and with the mass of ferromagnetic core. This fact gives again an advantage for the version of electrical machine assembled within the Laboratory of Electrical Machines within the Faculty of Electrical Engineering and Electronics (synchronous, with permanent magnets);

- both magnetic and electric fields are developed around electrical machines. These fields have low values for static machines, comparable for the two classes of machines under analysis;

- the electric field - during the operating process proper – it is more intense for classical machines (with ferromagnetic core and coilings) and lower for those with permanent magnets and without statoric flux concentrator (as is the synchronous machine excited with permanent magnets);

- the magnetic field - during the operating process proper – is strong on relatively big distances outside the electrical machine. Moreover, it maintains at high values in the case of the permanent magnet machines, and at double distances as compared to classical machines that d not have permanent magnetizing. From the point of view of the interaction with the environement, such a such a particularity is of course a disadvantage for the machine excited with permanent magnets;

- it is remarkable the fact that the values of the magnetic field outside the electrical machine (for the classical machine of asynchronous type) varies differently with the distance for two directions of the quadrant, wras the electrical field remains unchanged.

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