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Influence of the Air Gap of Hybrid Systems with Magnetic Flux Modulation

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Abstract— **Influence of air gap in the main magnetic path is studied in a hybrid system with magnetic flux modulation. The constant magnetic flux is generated by permanent magnets and additional magnetic field is applied to the system by externally power supplied coils.**

Index Terms—**Computer simulations, Magnetic flux modulation, Permanent magnet**

I. Introduction

ELECTRICITY in nowadays has a major role in people's daily lives. Its rational use through the more efficient devices contributes to reducing the negative impact on nature, which undoubtedly occurs when electrical energy is generated. This is one of the main reasons why scientists are constantly looking for new technologies to produce electricity, and to make devices that use the least amount of electrical energy. To reduce the amount of electrical energy used by a device, both the develop of new materials and new constructive solutions contribute. Conceptually new solutions are also often applied. Such devices are so-called hybrid systems with magnetic flux modulation. Their principle of operation is based on the switching of the magnetic flux of a permanent magnet (PM) on different paths in a magnet core, using pulsed coils. The idea of such devices is not new, as can be seen from patents of the twentieth century in [1-4].

In [5] a magnetic system based on changed of PM flux of an open magnetic path is described. Alternating voltage is used to power the magnetized coil in this system. The patent application from [6] is for a magnetic modulation system called by the authors “Motionless electromagnetic generator”, that is with closed magnetic path. They already made several prototypes of their system to demonstrate the working principle. Detailed system description and experimental results can be found in [7]. Different methods to change the PM flux are described in [8]. Based on that, the author of the patent described a parallel path magnetic technology generator [9]. In [10] a special construction of toroidal transformer is shown. The main advantage of that construction is that the flux passing primary coil and the secondary coil are different. A working example of system that use PM magnetic flux modulation is demonstrated in [11].

The main drawback to the realization of many of these ideas is the lack of available magnetic materials with appropriate characteristics, but the continuous development of these materials and the emergence of new ones lead to constant research into new constructive variants and testing of generally known ones using new magnetic materials. The main objective of a hybrid electromagnetic system with magnetic flux modulation (HEMSMM) is to control the magnetic flux of the permanent magnet to achieve a coefficient of performance (COP) greater than 1. Here is the time to specify that COP is different from the device's performance. Efficiency, as is well known, is defined as total useful output divided by total energy input from all sources. On the other hand, COP can be defined as total useful output divided by total energy input to the system added from external source. As an example, if a system has input (external) power of 50 wats and active environment of the system add 150 wats more, then the total input is 200 wats, but only 50 wats are from external source. Now if we suppose that the system has 50% efficiency, then the useful output power will be 100 wats. This makes it clear that the system has 50% efficiency, but COP = 2.

II. Studied Constructions

A previous research by the authors is published in [12], where a HEMSMM is modelled and studied. In the present paper a construction that can be named as double framed transformer with build in permanent magnets in outside magnetic frame is presented. By the computer simulation made with COMSOL Multiphysics software [13], air gap influence over the characteristics of the system is studied. Mainly three configurations of the construction are modelled. Difference between them is in number and position of the air gaps. In Fig. 1 main geometry parts of the studied construction configurations are shown. They are:

1 - Ferromagnetic frame 1;
2 - Ferromagnetic frame 2;
3 - Input (control) coils;
4 - Output (signal) coil;
5 - Permanent magnets.

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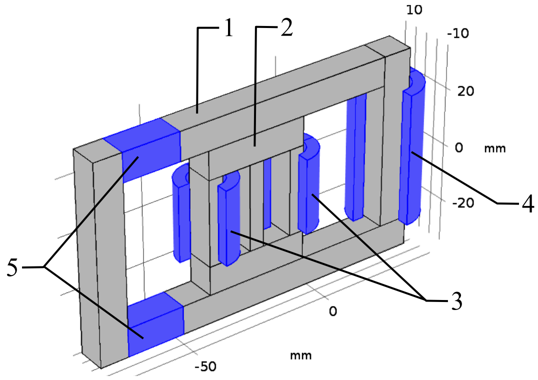
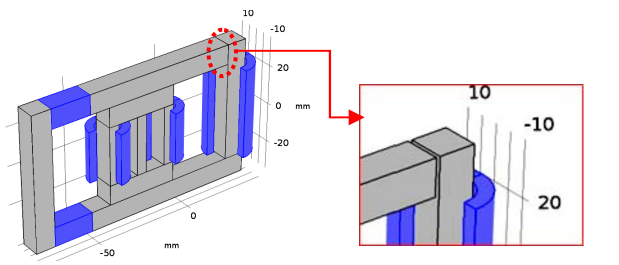
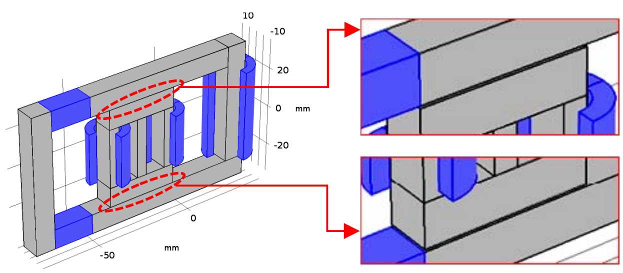


A) Configuration V1.1 – no air gap



B) Configuration V1.2 – one air gap in outer magnetic core



C) Configuration V1.3 – two air gaps between outer and inner magnetic cores

Fig. 1. Main geometry construction and studied configurations of HEMSMM

III. Computer Simulation

COMSOL Multiphysics software is used for computer modelling, where coupled electric circuit -electromagnetic field problem is solved. For all studied constructions, the parameters of input and output coils are defined. The input coils are fed by pulse power source from an electric circuit. Different power modes can be achieved by changing the parameters of electric pulses. Inductance and active resistance of the coils are achieved from electromagnetic field interface and are directly employed in electric circuit. An active load is connected to the output coil.

The computer modelled HEMSMM are solved in two steps:

- First, a stationary task with respect to the electromagnetic field is solved. In this step the electric circuit does not participate. Results for the electromagnetic field due to permanent magnets have been obtained;
- In the second step, a time-dependent task is solved, where as an initial condition the results for the electromagnetic field obtained in the calculation of step 1 is taken in account. In addition, the coils here are connected to the electric circuit shown in Fig. 2 and modeled in the same computer model. Power pulses from sources V1 and V2, whose parameters are shown in Fig. 3, are used to supply input coils of the system. An active load R3 is connected to the output coil L3.

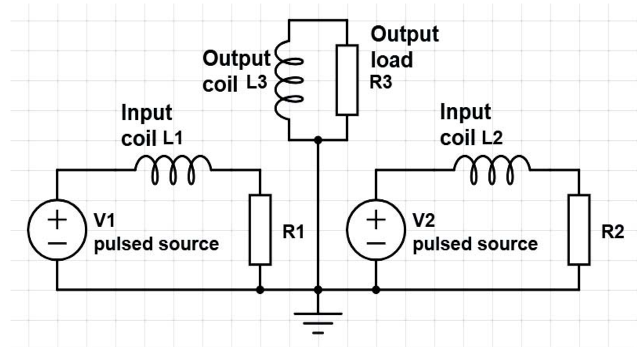


Fig. 2. Electric circuit used in the computer simulations

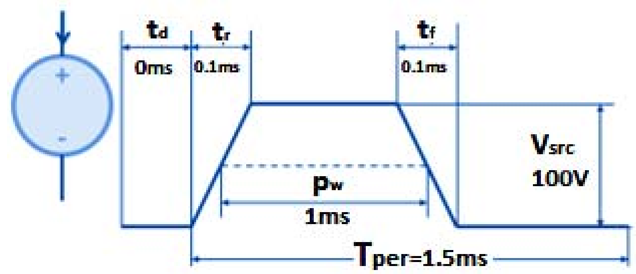


Fig. 3. Parameters of power pulses from V1 and V2 sources that are used to supply input coils

In Fig. 4 the *B-H* curve of the used ferromagnetic material for the magnetic frame 1 and 2 is presented.

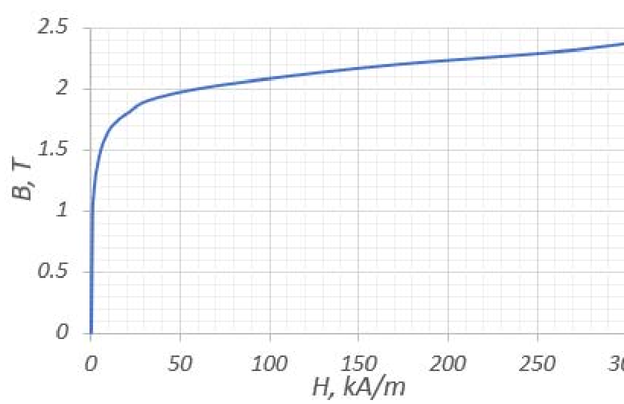
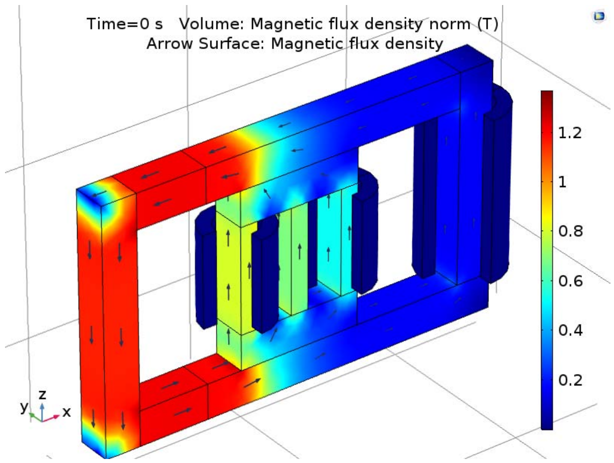
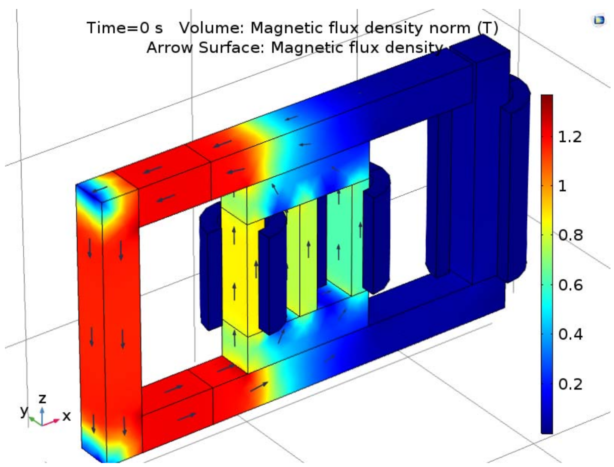


Fig. 4. *B-H* curve of used ferromagnetic material in the modelling

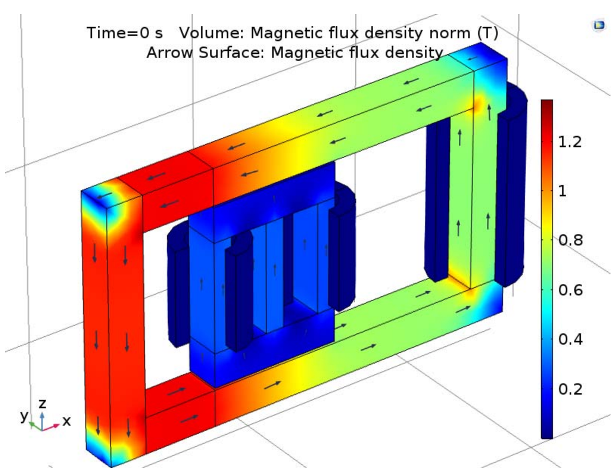
In Fig. 5 and 6, magnetic flux density distribution of some of the modelled constructions are shown. As can be seen the air gap significantly change the path of the magnetic flux produced from the permanent magnets. By power feeding the input coils, the magnetic flux changes its path which produce signal to the output coil.



A) Magnetic flux density of configuration V1.1



B) Magnetic flux density of configuration V1.2



C) Magnetic flux density of configuration V1.3

Fig. 5. Magnetic flux density of the system, when coils are not energized

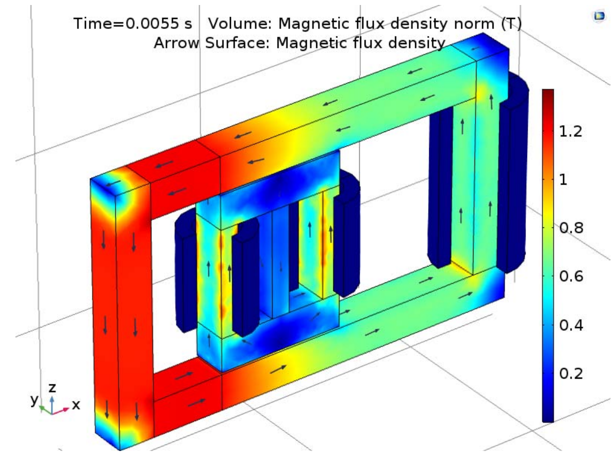


Fig. 6. Magnetic flux density of configuration V1.3, when coils are energized

IV. Results from Simulations

In Fig. 7 and Fig. 8 input electric power applied to the modelled systems is shown. Because of the closer position of the permanent magnets to the input coil 1, the magnetic flux through the two input coils is not equal for configurations V1.1 and V1.2, which also leads to the differences in the input powers in Fig. 7. This is not the case with configuration V1.3 in Fig. 8, where an air gap is existing between the ferromagnetic frame 1 and 2.

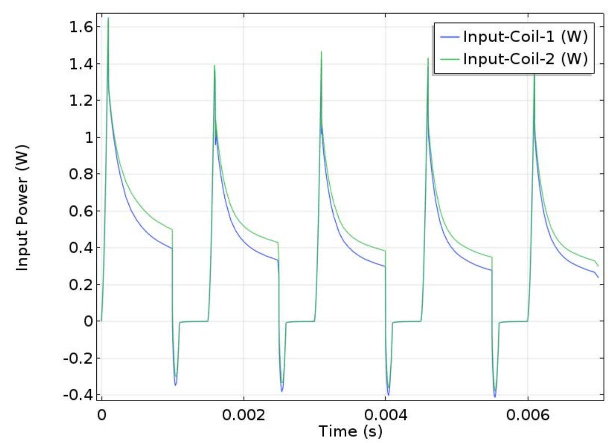


Fig. 7. Input power for configurations V1.1 and V1.2

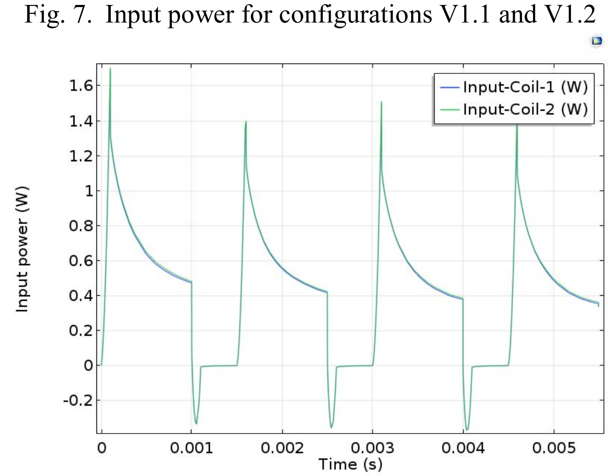


Fig. 8. Input power for configuration V1.3

In Fig. 9 voltage and current through one of the input coils are shown. Output power for some of the studied configurations is presented in Fig. 10 and Fig. 11. The output power decreases with each subsequent input impulse until it reaches an established operating mode. Setting an input pulse only after the system has reached its original state would increase the output power.

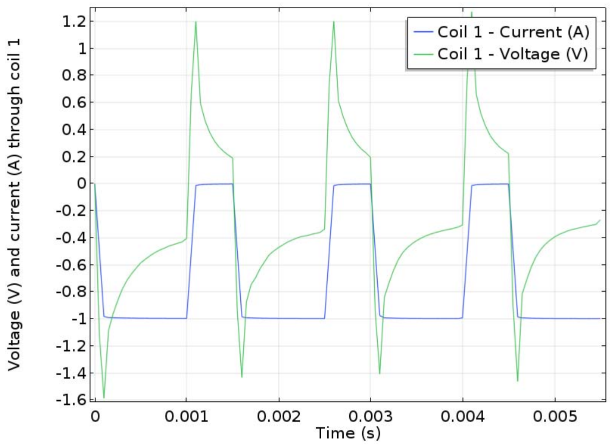


Fig. 9. Voltage and current through one of the input coils

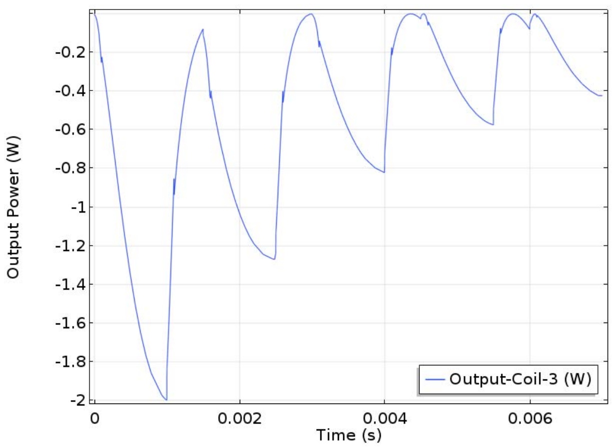


Fig. 10. Output power for configuration V1.2 – one air gap in outer magnetic core

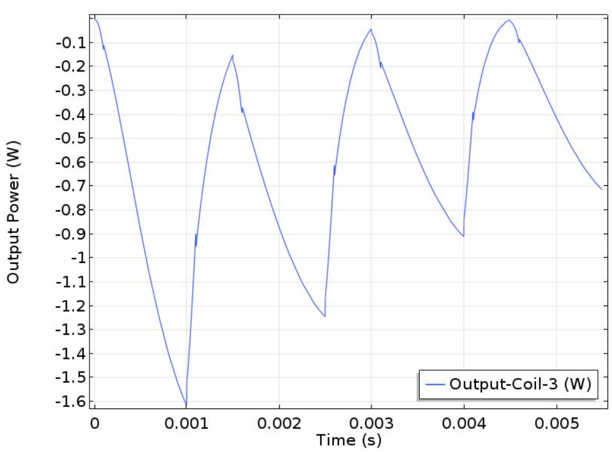


Fig. 11. Output power for configuration V1.3 – two air gaps between outer and inner magnetic cores

V. CONCLUSION

The obtained results have shown that the air gap in HEMSMM, when power impulses with certain characteristics are used, can lead to an improvement in the characteristics of the respective construction. The air gap also contributes to making it easier to control the flux of permanent magnets. This is because it is not necessary to give a backward impulse to the input coils to realize a return flow to its original magnetic path. Using advanced ferromagnetic materials with better characteristics will further enhance the efficiency of the device.

The computer models made possible for a deeper analysis of such constructions, as well as preliminary assessment of a construction and its improvement before its realization. The future development of the models involves the development of electrical circuits in which the impulses supplied to the input coils are realized using key-operated transistors. This will bring computer models closer to real-life experiments and make it possible to set different operating modes.

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