Journal of ELECTRICAL ENGINEERING, VOL 66. NO 7/s, 2015, 18-21

MODELLING AND SIMULATION OF THE POSSIBLE EM RADIATION OF THE POWER SUPPLY TOWARDS THE SYNCHRONIZED AND BLDC MOTORS

Josef Blažek

The contribution examines questions of the possible radiation of electromagnetic energy from the power wires of various types of electric motors. The emphasis is put on the modelling, simulation and analysis of the possible wires radiation which is supplied by the power modern BLDC motor and synchronized motor with permanent magnets. The QuickField software was used for the examination of the electromagnetic energy radiation and deployment of the magnetic fields in the close zone of the wires, this software enables to connect modelling of electric circuit with the modelling of space deployment of the electromagnetic fields of the selected parts of the solved electric circuit. There were examined more variants of power supply with wires in different geometrical arrangement such as symmetric or asymmetric, spatial or linear. The results of modelling and simulations are described in the contribution. The assumptions have been confirmed, it means that relatively small areas arisen between wires, for example near connectors or looser local arrangement of connected wires are becoming the radiator due to relatively high power supply as well as their frequency (PWM regulation approximately 8 – 32 kHz). In the near future, we are going to focus on the real measurements and the possibilities of detection of the given radiation sources.

Keywords: BLDC motor, electromagnetic field, wire of electric supply, modelling and simulation

1 INTRODUCTION

Terrorism and other illegal crimes have begun to be the real threat by using the small UAV (Unmanned Aerial Vehicles), so called drones, that are now used in many civil applications and despite some issues there are processes for their integration into the controlled airspace [1]. Different types of copters with the electric drive are the most available and they also have very good flight characteristics.

The contribution examines questions of the possible radiation of electromagnetic energy from the power wires of various types of electric motors. The emphasis is put on the modelling, simulation and analysis of the possible wires radiation which is supplied by the power to modern BLDC (brushless DC) motor and synchronous motor with permanent magnets [2,3,4]. Results of modelling and simulations are described in the contribution. There were examined more variants of power supply with two and three wires, line and space arrangements.

2 THEORY

Three-phase synchronous permanent magnet motors and BLDC motors in particular are modern drives for small UAVs. The article examines the magnetic field in the space around the power wires. This magnetic field is given by geometrical configuration of the conductors and the electric currents that through these pass. Power supply of the engines is three-phase harmonic or is created by the switching inverters as shown in Fig.1. In the case of synchronous machines is the total current at any time equal to zero. In the case of BLDC motors is the dominant rule that each pair in the active phase conducts the same current but in opposite direction. This is shown in Fig. 1 as well.

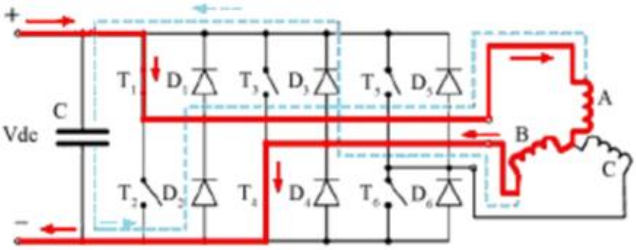

Fig. 1. Invertor BLDC [5]

Electric current to the motor windings is fed to the drivers in different geometric configurations. For example, the controller output conductors can be configured as in Fig. 2.

Fig. 2. Controller output wires on the arm of UAV

3 MODELING AND SIMULATIONS

For the modelling and simulation we used the Quick Field (QF) program. We exploit the fact that the version of "stu-

* University of Security Management in Košice, Kukučínova 17, 040 01 Košice, Slovakia; josef.blazek@vsbm.sk

ISSN 1335-3632 © 2015 FEI STU

dent" program allows complete analysis of models assembled in the professional version.

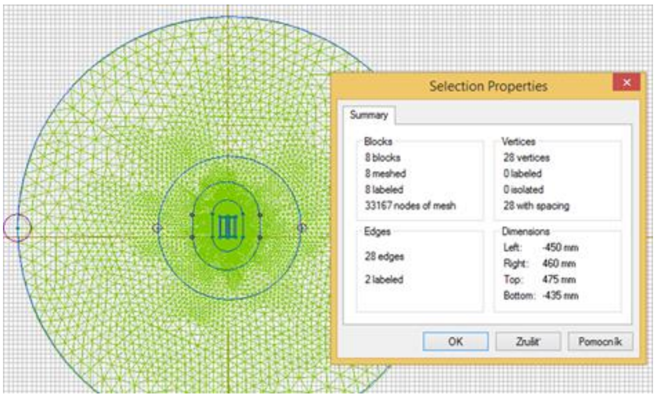

Fig. 3. Geometry model of the pair copper bars – professional QF, [6]

A good qualitative analysis are possible for a number of own geometric models which we developed in Quick Field student version.

The model of the electrical circuit in the QF, as the three-wire power supply is shown in Fig. 4. The magnetic field is modelled on the portion of the wires - as linked on the model by indexes A, B, C.

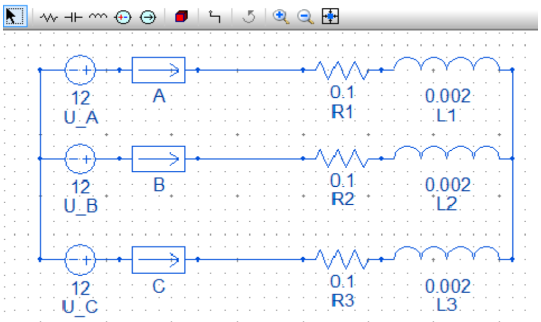

Fig. 4. Model of the triple wire electrical circuit

4 EXPERIMENTS AND RESULTS

4.1 Twin wire supply

The fundamental case for analysing the electromagnetic field around the conductor is the geometrical configuration of the pair. The wires are close together. Currents have identical value but their direction is reversed. The geometric model from the QF professional version was taken from [6]. Our own analysis allowed us to do this. The detailed mesh is shown in Fig. 3. For quantitative analysis, the field values must be scaling of 1:100. Selected results of analysis options are shown in Figure 5 to 8. Fig.5 documents that even tight pair emits electromagnetic fields in its surroundings.

The selected basic parameters of the field for case analysis are outlined in the graphs on the following figures. The *x*-axis is defined by the selected line on Fig. 5. When AC power is applied, we can also choose to view a specific phase diagram or use the maximum and effective values. Generally it is known the fact that the electromagnetic field is proportional to the electrical current. This allows us to apply the results of basic analysis also for radiating of drivers with real currents of BLDC motors with PWM.

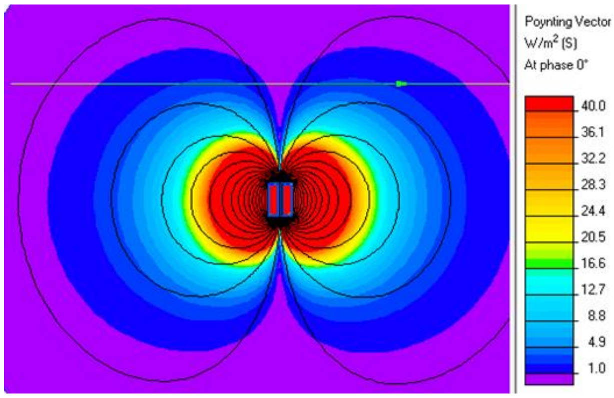

Fig. 5. Absolute value of the Poynting vector

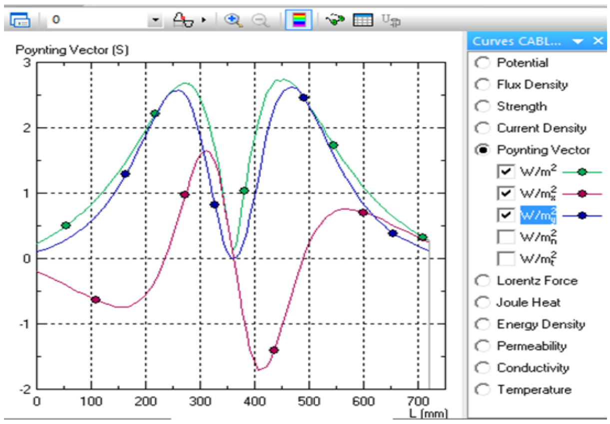

Fig. 6. Poynting vector on the chosen line in Fig. 5

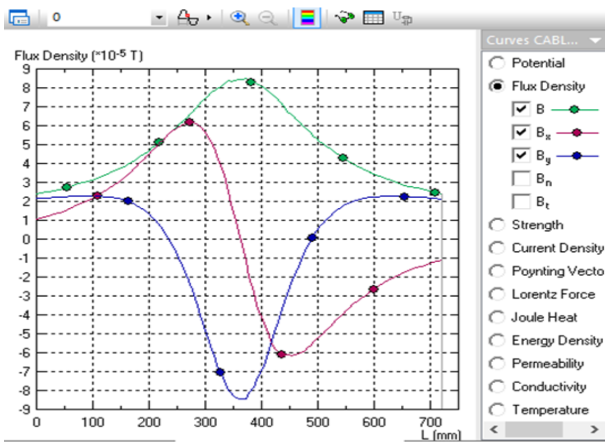

Fig. 7. Flux density on the chosen line in Fig. 5

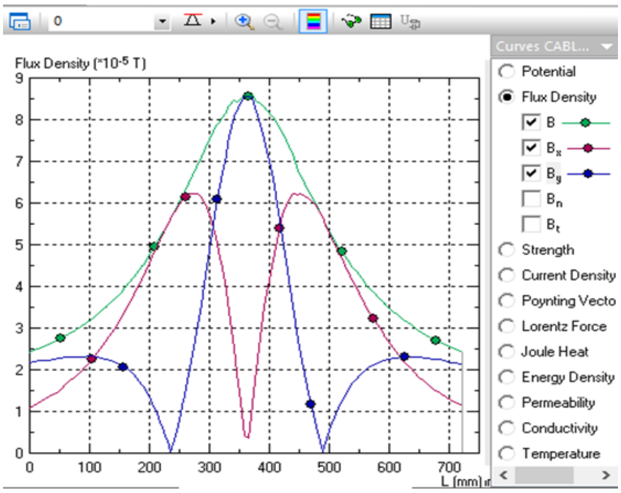

Fig. 8. Flux density – max values on the line

4.2 Triple wire supply

The geometric configuration of supply wires to PM (Permanent Magnets) synchronous and BLDC motors is a triple cable. The geometric model of linear type cable has been made in the QF student version.

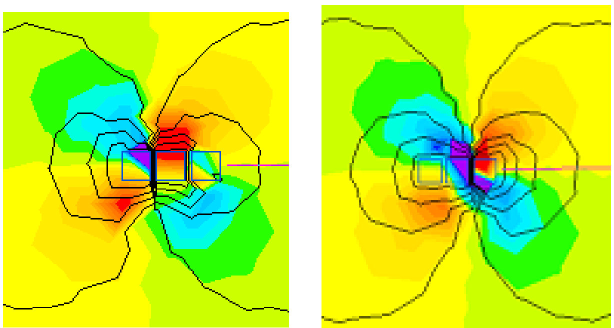

Fig. 9. The shift of the field centre at different apportionment currents in conductors of triple cable

The wires are geometrically configured in a similar situation to the line as in Fig. 2. As envisaged it was shown that the magnetic field does not change its character, see Fig. 9. It is a vibrant field but with displacement of the field midpoint between wires. The results of modelling are applicable for essential qualitative analysis.

Another prime example of the geometric configuration of three-wire line is triangular. The geometric model of this configuration was available in [7]. Selected results of our simulations of the magnetic field are shown from Fig. 10 to Fig. 14.

CONCLUSION

The QuickField software was used for the examination of the electromagnetic energy radiation and deployment of the magnetic fields in the close zone of the conductor wires, this software enables to connect modelling of electric circuit with the modelling of the spatial deployment of the electromagnetic fields of the selected parts of the solved electric circuit.

The present contribution shows the basic situation of the magnetic fields around the conductor in the geometric arrangement of a pair, the linear triple cable and wires in triangular configuration. The results can be applied to the main power BLDC motors and permanent magnet motors.

Magnetic field around the linear array conductors has at AC power supply pulsating character. With good triangular geometric configuration of drivers has the magnetic field particularly rotary character. At the general cable layout geometry at varying rates are applied both two phenomena. In the terms of the best sensing it is necessary to use probes in all *x*, *y*, and *z* axes and then to calculate the magnitude of the field vector.

It appears that on the frequencies of an engine speed and its PWM controlling, the UAV can be localized in close range by sensitive magnetometers and other inductive sensing devices. This will be investigated by further simulations and measurements especially in special anechoic and shielded chambers.

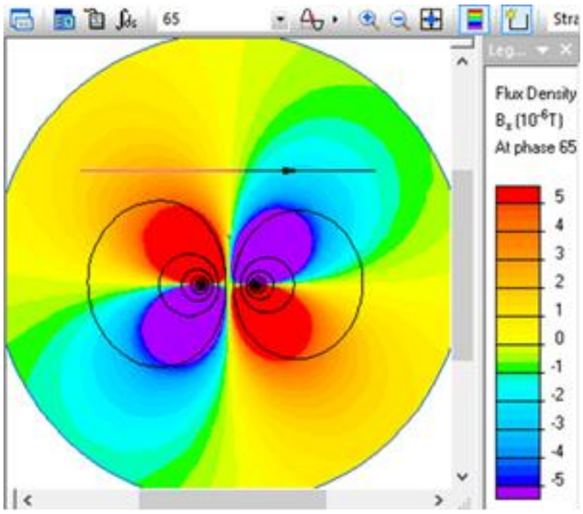

Fig. 10. Triple wire supply, flux density B_x from down wires – phase approx. 60°

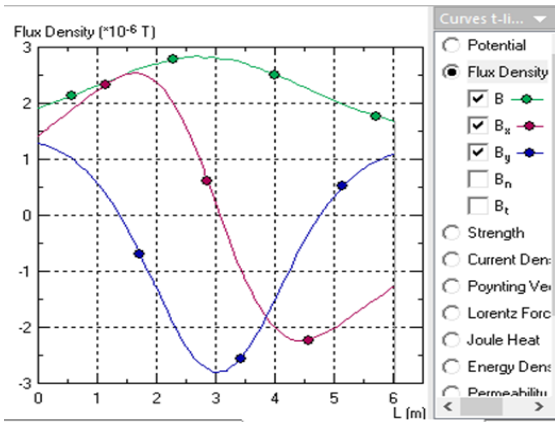

Fig. 11. Flux density B_x on the line from Fig.10

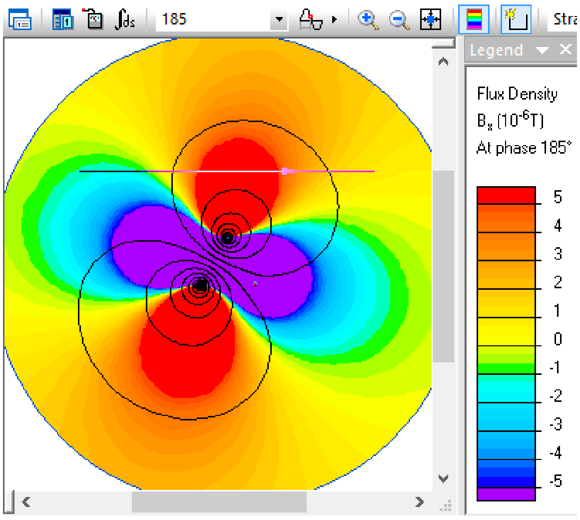

Fig. 12. Flux density for lower left and upper conductor, phase around 180°

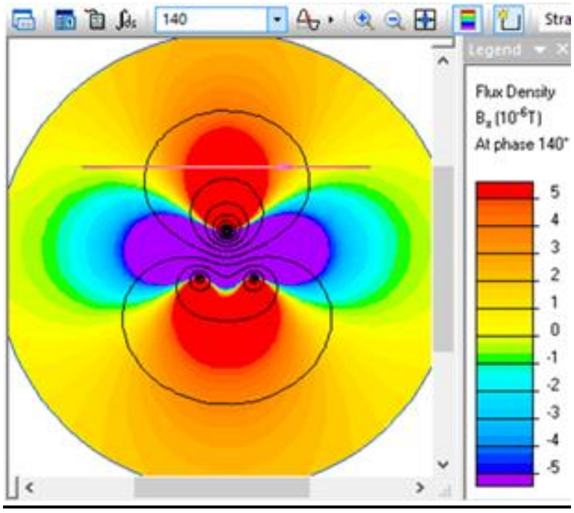

Fig. 14. Flux density B_X if the currents are in all three wires - at phase 140°

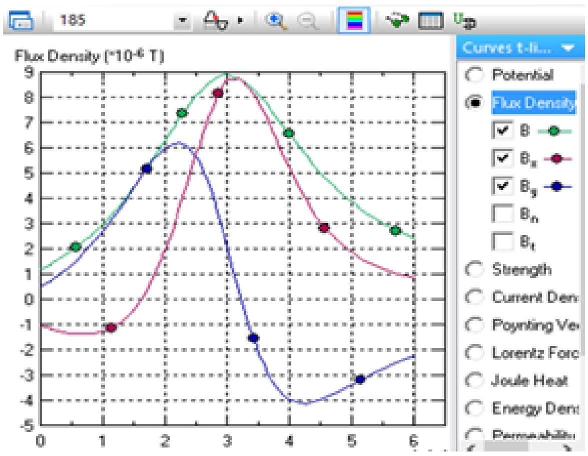

Fig. 13. Flux density B_X on the line from Fig. 12

Acknowledgement

This work was supported by the Scientific Grant Agency of the MESRaS SR and SAS under contract No VEGA 1/0585/15.

REFERENCES

[1] DRAGANOVÁ, K. - LIPOVSKÝ, P.: UAS integration into the controlled airspace. In: Aeronautika 2011 : Intenational Scientific Conference, Košice : LF TU, 2011 S. 1-9. ISBN 978-80-553-0758-9

[2] CHUDIVÁNI, J.: Simulácia synchrónneho stroja s permanentnými magnetmi [Simulation of synchronous machine with permanent magnets]. In: EE časopis pre elektrotechniku a energetiku, Vol. 18. No. 4.. 2012. p 16-18. ISSN 1335-2547 (in Slovak)

[3] YEDAMALE, P. Brushless DC (BLDC) Motor Fundamentals. [online]. 2003[Cit 2015-04-16]. Available: http://ww1.microchip. com/ downloads/en/AppNotes/00885a.pdf

[4] SHAO, J.: Direct Back EMF Detection Method for Sensorless Brushless DC (BLDC) Motor Drives. [online]. Master thesis, Virginia Polytechnic Institute 2003. 72p. [cited 2015-04-16]. Available from:

[5] UHRÍK, M.: BLDC motory a SMPM [BLDC motors and SMPM]. Zborník prednášok z predmetu Elektrické pohony mechatronických systémov. [online]. ELF STUBA 2011. s. 4-29. [Cit. 2015-03-25]. Available at: http://www.kesp.elf.stuba.sk/sk/Pedagogika/EPoMS/PR2-LDC_motory_a_SMPM.pdf

[6] VERKE,.D.: Field distribution around two copper bars. [online] [cited 2015-04-16]. Aavailable at: http://quickfield.com/advanced/copper_bars_magnetic_field.htm

[7] QUICKFIELD EXAMPLES.:3-phase-tranmmission-line. [online] [cited 2015-04-16]. Aavailable at: http://quickfield.com/advanced/3-phase-transmission-line..htm http://scholar.lib.vt.edu/theses/available/etd-09152003-171904/unrestricted/T.pdf

Received 30 November 2015