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IMPROVE OF OVERHEAD POWER LINES MAGNETIC FIELD MITIGATION EFFICIENCY BY COMBINED ACTIVE AND PASSIVE CONTOURS SHIELDING

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Problem of improving of efficiency of *overhead power lines magnetic field mitigation by combined active and passive contours shielding and reducing system sensitivity to uncertainty and changes in system parameters considered. Design of combined active and passive* shielding *reduced to solving the geometric inverse problem of magneto-quasi-static's based on vector game solution with vector payoff calculated based on Maxwell equations solution in a quasi-stationary approximation using COMSOL Multiphysics software. Vector game solution calculated based on particles multi-swarm optimization algorithms from Pareto optimal solutions set taking into account binary preference relations. During design of combined active and passive* shielding *number and spatial arrangement coordinates of active compensating windings and passive contours, as well as currents and phases in active compensating windings calculated. The computer simulation and experimental research of combined active and passive contours* shielding *for improving* of *overhead power lines magnetic field mitigation* efficiency *presented.* References 3, figures 2.
Keywords: overhead power lines, magnetic field, combined active and passive contours shielding, computer simulation, experimental research.

Introduction. Protecting public health from the biological impact of the man-made electromagnetic field of electric power facilities has a high social significance and is an extremely relevant and important task in improving the quality and life expectancy of the population. Many residential buildings located in close proximity to high-voltage power lines (PL), so that magnetic field (MF) level significantly exceeds modern sanitary standards. Currently, research is being intensively carried out all over the world and various systems for power frequency MF active shield (AS) being implemented [1]. Passive shields (PS) have a significantly lower shielding factor (SF) than AS, therefore PS often used as a supplement to AS so that combined active and passive shield (CAPS) various design used simultaneously [2]. In works [1, 2] PL currents considered known and do not change over time, however, actual current values have daily, weekly and seasonal changes, so designed system must be robust.

The aim of this work is development of method for design of combined active and passive contours shielding means for improve of overhead power lines magnetic field mitigation and reducing system sensitivity to uncertainty and changes in system parameters

Problem statement. MF source is PL wires currents. Magnetism direct problem is MF generated by PL wires calculation. Mathematical modeling of electromagnetic field in general case comes down to solving a boundary value problem for system of Maxwell partial differential equations [1]. An intermediate position between a constant field and a rapidly changing field occupied by so-called quasi-stationary field – an electromagnetic field in which study displacement currents neglected in comparison with conduction currents. From this approximation it follows that quasi-stationary MF at any given moment in time is completely determined by distribution of electric currents at the same moment in time and found from this distribution in exactly the same way as is done in magnetostatics.

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Consider MF direct problem – calculating the initial MF generated by PL. Let's set the amplitudes and phases of the power frequency currents in PL wires. Let us introduce a vector of parameters of the initial uncertainties of CAPS design problem with components of initially known inaccurately and change during system operation. Then initial MF vector calculated as the sum of MF vectors generated by all PL wires.

Now consider MF geometric inverse problem for CAPS. It is necessary to calculate the number, spatial locations and geometric dimensions of compensation windings, as well as the amplitude and phase of the currents in the compensation windings of CAPS, so that with the help of these windings a compensation MF generated opposite to original MF, generated by PL wires.

Introduce required parameters vector for the CAPS design problem with components compensation windings geometric dimensions values as well as amplitudes and phases of AS compensation windings currents [1, 2]. Then resulting MF vector calculated as sum of MF vectors generated by all Pl wires, all AS compensating windings wires and all PS contours.

Solution method. CAPS design problem comes down to solving a vector game in which necessary to find the minimum of payoff game vector on required parameters vector but the maximum of the same payoff game vector on uncertainty parameters vector. Payoff game vector is nonlinear vector functions of required parameters vector and of uncertainty parameters vector and calculated by COMSOL Multiphysics software.

To calculate vector game solution from Pareto-optimal solutions set multi-swarm stochastic multi-agent optimization algorithm used based on particles swarm collective intelligence to globally optimal value find [3].

Based on binary preferences relationships when minimizing the induction level of the resulting MF at one point in shielding space and increasing MF level at another point in this space due to undercompensation or overcompensation of original MF, one can choose solution that minimizes the maximum MF level at all considered points of shielding space.

Simulation results. Consider CAPS design to increase the efficiency MF reduction generated by single-circuit PL with wires triangular arrangement in one-story old house. In CAPS design process spatial location coordinates of 16 conductors of multi-circuits PS calculated. Spatial location coordinates of AS two compensation windings, as well as the currents and phases in these AS windings also calculated. Unlike work [2] in this work spatial location coordinates of 16 contours of multi-circuit PS calculated as vector game solution.

The layout of PL, AS compensating windings and PS multi-circuit passive screen shown in Fig. 1.

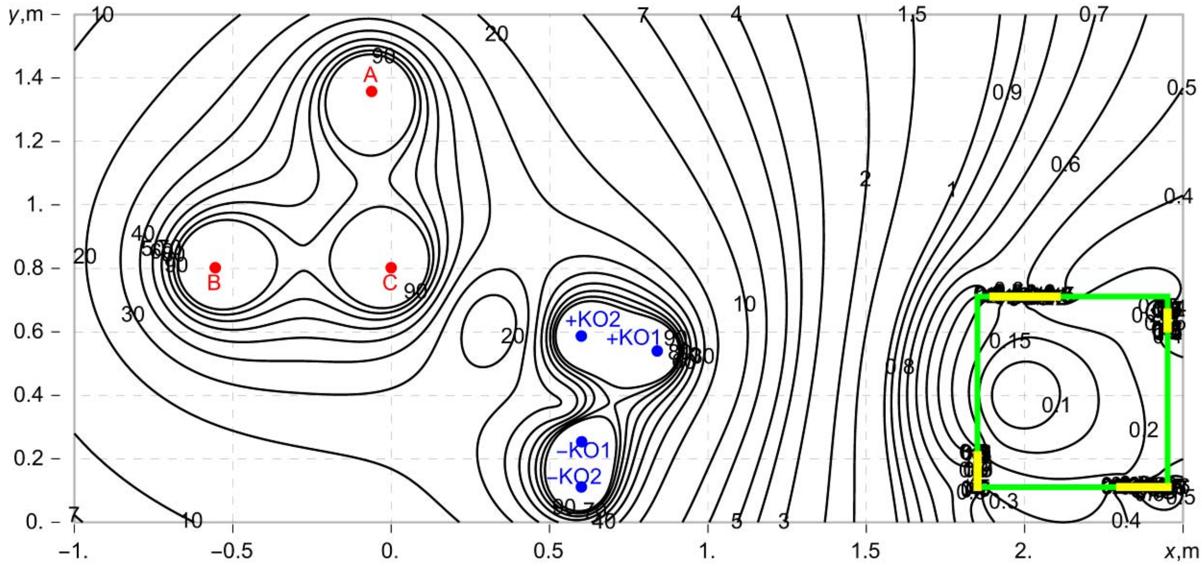


Fig. 1

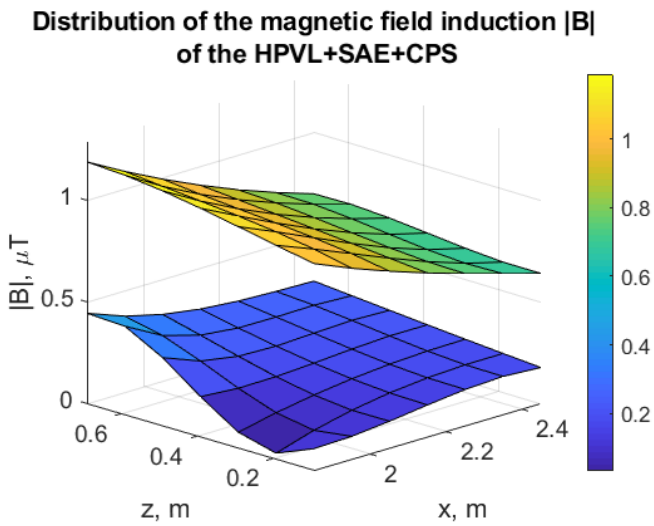
In MF distribution characteristic areas of stress concentration at 16 conductors locations of multi-loop PS. Minimum level of the resulting magnetic field in central part of the shielding space is 0.1 μT.

Shielding factor (SF) calculated value in central part of shielding space is more than 10 units. CAPS makes it possible to reduce initial MF in a significantly larger area of the shielding space compared to using only AS.

Experimental results. Let us now consider the results of experimental studies of CAPS. In Fig. 2, *a* shown CAPS control system. In Fig. 2, *b* shown PS multi-circuit PS. In Fig. 2, *c* shown the experimentally measured initial MF and resulting MF with CAPS. MF minimum value in small shielding space with CAPS is 0.1 μ*T*. Experimentally measured SF maximum value is also more than 10 units. Comparison of the results of calculated and experimentally measured initial and resulting MF magnetic fields with CAPS differ by no more than 20 %.

a

b



c

Fig. 2

Conclusion. For the first time the method for design of combined active and passive contours shield for improving of efficiency of overhead power lines magnetic field mitigation and reducing system sensitivity to uncertainty and changes in system parameters development.

Combined active and passive shielding design reduced to solving the geometric inverse problem of magneto-quasi-static's based on vector game solution with vector payoff calculated based on Maxwell equations solution in a quasi-stationary approximation using COMSOL Multiphysics software. Vector game solution calculated based on particles multi-swarm optimization algorithms from Pareto optimal solutions set taking into account binary preference relations.

Number and spatial arrangement coordinates of active compensating windings and passive contours, as well as currents and phases in active compensating windings calculated during design of combined active and passive shielding.

Result of computer simulation and experimental research of combined active and passive contours shielding for improving of efficiency of overhead power lines magnetic field mitigation and reducing system sensitivity to uncertainty and changes in system parameters presented.

The main advantage of using combined active-passive screen is that it can be used to reduce the level of the initial magnetic field over a much larger area of the shielding space compared to using only an active screen.

Conflict of interest. The author of the article declares no conflict of interest.

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ПОКРАЩЕННЯ ЕФЕКТИВНОСТІ ОСЛАБЛЕННЯ МАГНІТНОГО ПОЛЯ ПОВІТРЯНИХ ЛІНІЙ ЕЛЕКТРОПЕРЕДАЧІ ЗАСОБАМИ КОМБІНОВАНОГО АКТИВНОГО ТА ПАСИВНОГО КОНТУРНОГО ЕКРАНУВАННЯ

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Вступ. *Розглянуто проблему підвищення ефективності ослаблення магнітного поля в житлових будинках від повітряних ліній електропередачі комбінованими активними та пасивними контурними екранами.* ***Мета.*** *Розробка методу проектування комбінованих активних і пасивних контурних екранів задля підвищення ефективності ослаблення магнітного поля повітряних ліній електропередачі та зменшення чутливості системи до невизначеності і змін параметрів системи.* ***Методологія.*** *Проектування комбінованих активних і пасивних контурних екранів зводиться до розв'язання геометричної оберненої задачі магніто-квазістатики на основі рішення векторної гри з векторним виграшем, який розраховується на основі рішень рівнянь Максвелла в квазістаціонарному наближенні за допомогою програмного забезпечення COMSOL Multiphysics.* ***Оригінальність.*** *Рішення векторної гри розраховується на основі алгоритмів багаторойової оптимізації частинок із множини Парето-оптимальних рішень з урахуванням бінарних відношень переваг. Під час проектування комбінованого активного та пасивного контурного екрану розраховують кількість і координати просторового розташування активних компенсуючих обмоток і пасивних контурів, а також струми й фази в активних компенсуючих обмотках.* ***Результати.*** *Представлено комп'ютерне моделювання та експериментальне дослідження застосування комбінованого активного та пасивного контурного екрану задля підвищення ефективності ослаблення магнітного поля, яке генерується одноколовою повітряною лінією електропередачі із трикутним розташуванням проводів в одноповерховому будинку старої забудови. Під час проектування комбінованого активного та багатоконтурного пасивного екранів розраховано координати просторового розташування 16 контурів пасивного екрану та двох компенсаційних обмоток, а також струми та фази в цих обмотках активного екрану*. Бібл. 3, рис. 2.

Ключові слова*:* повітряні лінії електропередачі, магнітне поле, активне та пасивне контурне екранування, комп'ютерне моделювання, експериментальні дослідження.

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