UDC 621.3.01 **doi: 10.20998/2074-272X.2018.2.06**

B.I. Kuznetsov, T.B. Nikitina, I.V. Bovdyj, A.V. Voloshko, E.V. Vinichenko, B.B. Kobilyanskiy

DEVELOPMENT AND INVESTIGATION OF LAYOUT OF ACTIVE SCREENING SYSTEM OF THE MAGNETIC FIELD GENERATED BY GROUP OF OVERHEAD TRANSMISSION LINES

Purpose. Development and field experimental research of layout of the single-circuit active screening system of the magnetic field generated by group of high voltage transmission lines in residential area is given. Methodology. Mathematical model of magnetic field, generated by group of high voltage transmission lines in residential area, based of the experimental values of magnetic field flux density in given points on the basis of optimization problem solving is improved. The objective of the synthesis of the single circuit active screening system is to determine their number, configuration, spatial arrangement, wiring diagrams and compensation cables currents, setting algorithm of the control systems as well as the resulting value of the magnetic flux density at the points of the protected space. Synthesis of the full-scale model of active screening system is reduced to the problem of multiobjective nonlinear programming with constraints in which calculation of the objective functions and constraints are carried out on the basis of the Maxwell equations solutions in the quasi-stationary approximation. The problem is solved by a stochastic multiswarm multi-agent particles optimization. Results. The single-circuit active screening system synthesis results for reduction of a magnetic field generated by group of high voltage transmission lines in residential area is given. Field experimental researches of the single-circuit active screening system of the magnetic field generated by group of high voltage transmission lines in residential area with various control algorithms is given. Originality. For the first time out the development and field experimental studies of the single-circuit active screening system of the magnetic field generated by group of high voltage transmission lines in residential area are carried out. Practical value. Practical recommendations on reasonable choice of the spatial arrangement of compensating cables of single-circuit active screening systems of the magnetic field generated by group of high voltage transmission lines is given. Results of field experimental investigations of the single-circuit active screening system of the magnetic field generated by group of high voltage transmission lines in residential area are given. References 12, figures 5.

Key words: **overhead transmission lines, power frequency technogenic magnetic field, layout of single-circuit active screening system, field experimental investigations.**

Разработан макет одноконтурной системы активного экранирования магнитного поля, создаваемого в жилом помещении группой ЛЭП. Пространственное расположение и геометрические размеры компенсирующей обмотки, а также параметры регуляторов определены на основе решения задачи многокритериальной оптимизации. Проведены полевые экспериментальные исследования макета системы с разомкнутым и замкнутым управлением. Показано, что эффективность системы при разомкнутом и замкнутом управлении примерно одинаковая и составляет более 4 единиц. Приведены результаты сравнения экспериментальных и расчетных значений индукции магнитного поля в зоне экранирования. Показано, что экспериментальные и расчетные значения индукции магнитного поля отличаются не более чем на 20 %. Библ. 12, рис. 5.

Ключевые слова: **воздушные линии электропередачи, магнитное поле промышленной частоты, макет одноконтурной система активного экранирования, полевые экспериментальные исследования.**

Introduction. The flux density of the magnetic field (MF) of the power frequency outside the guard zones of high voltage power transmission lines (TL) in some cases exceeds the boundary permissible level of 0.5 μT [1], which poses a threat to the health of the population and requires taking certain measures to reduce MF of the existing TL in line of cities of Ukraine. Economically the most suitable for Ukraine are [2] methods of active contour screening of operating TL realizing by means of active screening systems (ASS) [3-10].

Analysis of existing active screening systems. In [10], a method for the synthesis of the ASS of the MF was developed, and in [11] experimental studies of the ASS layout with a different number of compensating windings and MF sensors operating according to various control algorithms were carried out [8, 9]. With respect to the geometric dimensions of real systems, these layouts are manufactured on a scale of 1 to 10, which causes additional errors in the layout of the ASS, caused, in particular, by the finite dimensions of the MF sensors commensurate with the dimensions of the compensating windings of the layout. In addition, studies of ASS layouts were carried out for MF, generated by a single TL. In this connection, the problem arises of verification of the synthesis method [10] of the ASS of the MF, created by a group of TL, on a full-scale ASS layout.

The goal of the work are development and field experimental investigations of a full-scale layoot of a single-circuit active screening system of a magnetic field created by a group of overhead transmission lines in residential premises.

Development of the layout of a single-circuit ASS. Fig. 1 shows the layout of a group of TLs generating MF, the flux density of which must be reduced in residential premises (hereinafter «in the screening zone»).

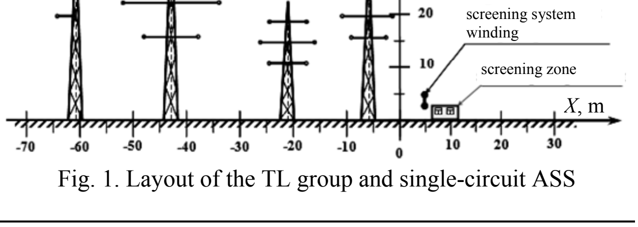

Fig. 1. Layout of the TL group and single-circuit ASS

The initial MF in the screening zone is generated by two double-circuit 110 kV TLs (TL-1 and TL-2), a two-circuit 330 kV TL (TL-3) and a single-circuit 330 kV TL (TL-4). Fig. 1 also shows the zone in which the MF is to be screened. On the basis of experimental studies, it was found that in the screening zone, the MF has an insignificant polarization [12], which makes it possible to use a single-circuit ASS with one compensation winding. In the synthesis of the ASS layout, constraints on the geometric dimensions and the location of the supports of its compensation winding were taken into account.

Fig. 2,*a* shows the calculation scheme of the layout of the single-circuit ASS, screening zone and compensating winding.

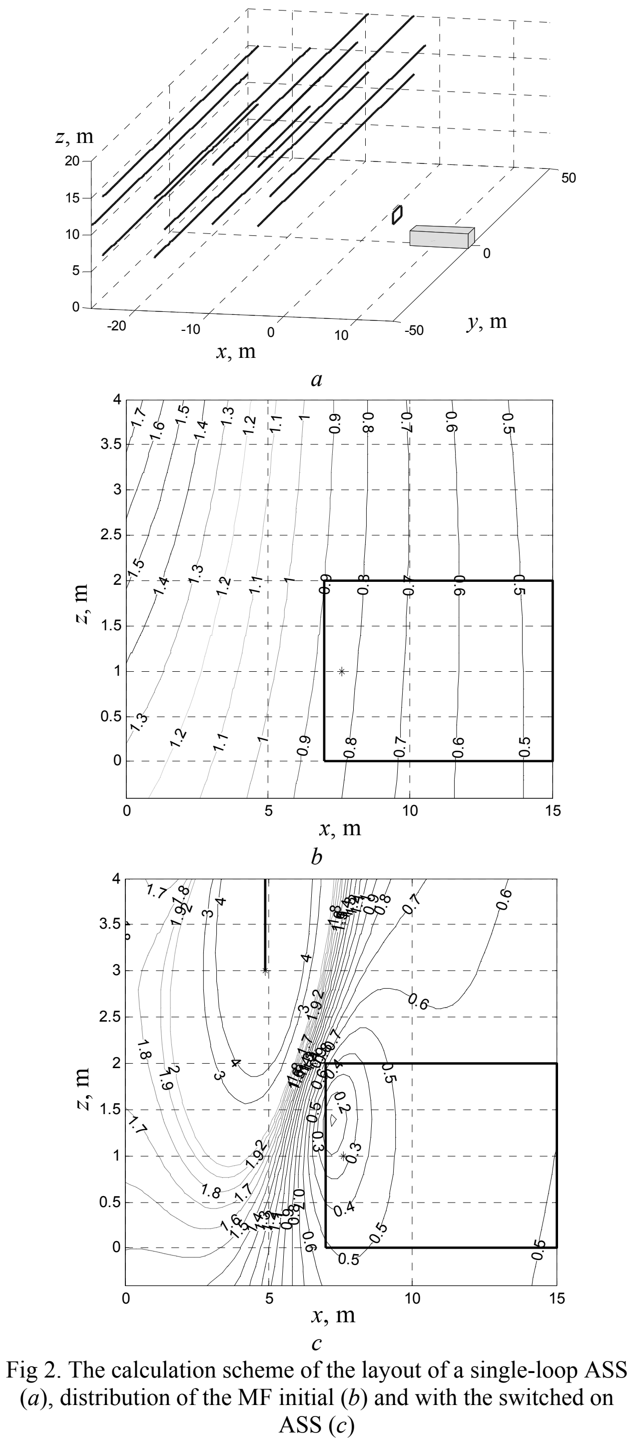

Fig 2. The calculation scheme of the layout of a single-loop ASS (*a*), distribution of the MF initial (*b*) and with the switched on ASS (*c*)

Fig. 2,*b* shows the distribution of the flux density of the initial MF, created by a group of TL, and Fig. 2,*c* – flux density distribution of MF with switched on ASS. The initial flux density of the MF in the space under consideration is 0.9 μT, and with the switched on ASS, the level of the flux density of the magnetic field does not exceed 0.4 μT.

Fig. 3 shows the spatio-temporal characteristics (STC) of MF, created by: *1* – a group of TLs; *2* – compensating winding, and *3* – total magnetic field with the system switched on. As can be seen from this figure, in the space under consideration, the initial MF produced by the TL group has a negligible polarization, so that its STC represents a strongly elongated ellipse, and the ellipse coefficient (ratio of the smaller semiaxis of the ellipse to the larger semiaxis) is about 0.4, which is confirmed by the experimental research.

STC of the MF, created by the winding of a single-circuit ASS is a line and, consequently, this MF has no polarization. With this winding, the larger semiaxis of the STC ellipse of the original MF is compensated, so that the STC of the resultant MF remaining after the operation of the ASS is an ellipse with an ellipse coefficient equal to 0.8.

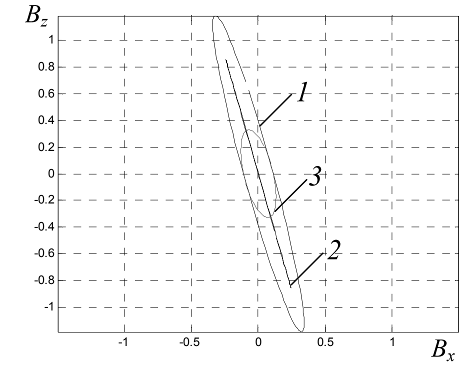

Fig. 3. Spatio-temporal characteristics of the MF created by: a group of TLs (*1*); compensating winding (*2*), and total MF with switched on ASS (*3*)

Implementation of the layout of a single-circuit ASS. The layout of a single-circuit ASS contains [10] one square winding, the upper part of which is located at a height of 5.1 m, and the lower one – at a height of 3.1 m. The winding contains 20 turns and is powered by an amplifier of the TDA7294 type. The inductive sensor is used as the flux density sensor of the MF, and the flux density measurement of the MF is performed by a magnetometer of the EMF-828 type from Lutron. The ASS is powered by an autonomous source.

The winding control system is built on the principle of subordinate regulation and contains an internal current regulator and an external regulator of the flux density of the MF.

Results of field experimental studies of the open-loop single-circuit ASS layout. To realize the open control of the ASS, the MF sensor was installed in the immediate vicinity of the TL wires and at some distance from the screening zone. With the help of such a MF sensor, the flux density of the magnetic field produced by only the TL is measured and, consequently, the output voltage of such a MF sensor is proportional to the current of one of the phases of the TL wire or their superposition. Thus, an indirect measurement of the currents of the TL generating the initial MF is carried out, and the ASS on the basis of such a MF sensor, on the principle of its construction, is open.

Fig. 4 shows the experimental flux density distributions of: *a*) the initial MF, created by the TL group and *b*) – *d*) the total MF with the switched on ASS.

The initial flux density of MF in the space under consideration is 1.15 μT, which is more than twice the boundary permissible level in 0.5 μT [1].

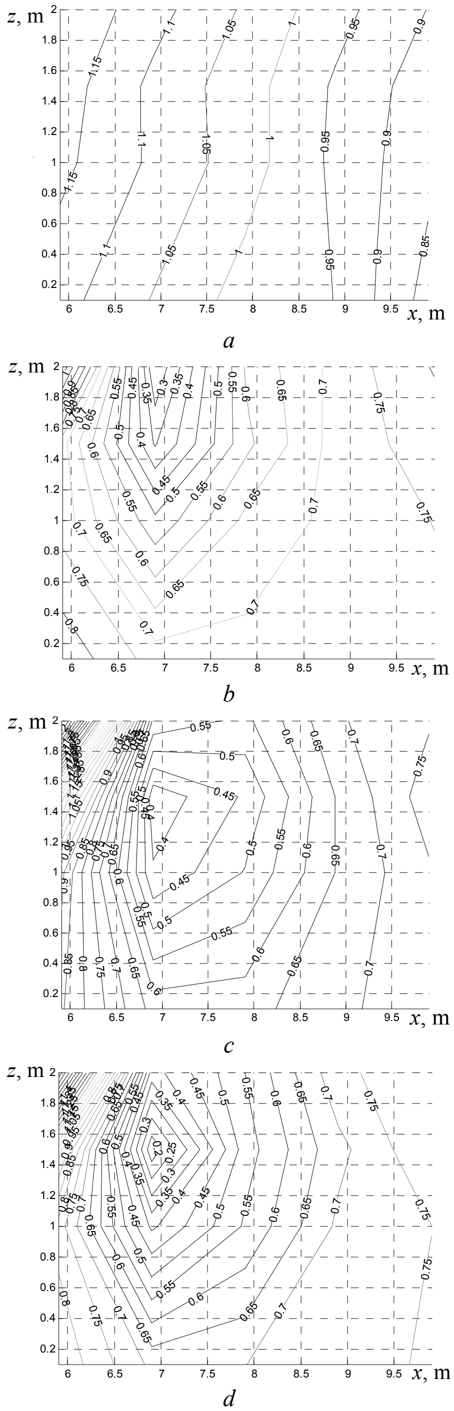

Fig. 4. Lines of equal level of the magnetic flux density module of: *a*) the initial magnetic field produced by the TL group and *b*) – *d*) the total magnetic field with the switched on open ASS

The adjustment of the open ASS was performed in such a way as to minimize the flux density of the MF at a given point in the space where it is necessary to screen the original MF. In particular, Fig. 4,*b* – *d* show the distributions of the total MF with the switched on ASS at its adjustment to different points of the screening zone. Note that in the adjustment points of the ASS, the flux density of the MF has a minimum value, practically the same for any adjustment point, and is 0.2 μT.

Field experimental studies of the layout of a closed single-circuit ASS. To implement closed-loop control, the MF sensor was installed directly in the screening zone.

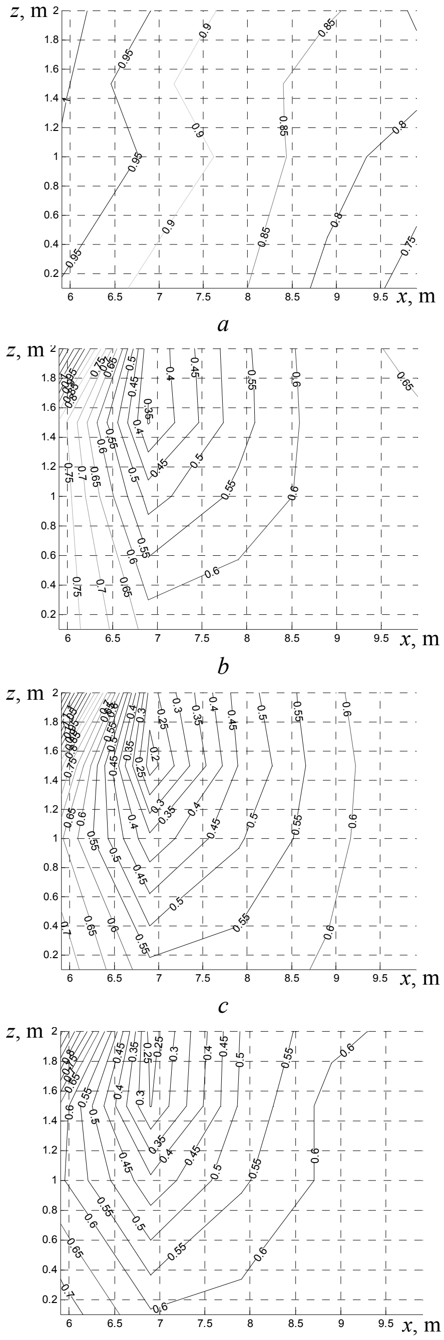

Fig. 5. Lines of equal level of the magnetic flux density module of: *a*) the initial magnetic field produced by the TL group and *b*) – *d*) the total magnetic field with the switched on closed ASS

Here, with the help of such a MF sensor, the flux density of the total MF, created in the screening zone by the wires of the TL and the compensation winding, is measured, and the ASS on the basis of such a sensor becomes closed on the basis of its construction principle.

Fig. 5 shows the magnetic flux density distributions of: *a*) the initial MF, created by the TL group and *b*) – *d*) the total MF with the switched on enclosed ASS at a different position of the MF sensor. With the help of a closed ASS, the flux density of the MF at the point of installation of the MF sensor is minimized. In this case, the minimum value of the flux density in the three considered variants is 0.2 μT, but the distribution of the magnetic field in the screening zone depends significantly on the position of the MF sensor.

The initial flux density of the MF in the space under consideration is 0.95 μT, and when the closed ASS is switched on, the level of the flux density of the magnetic field does not exceed 0.4 μT.

Note that the efficiency of the closed system depends on the location in the screening zone of the MF sensor. Moreover, with one compensation winding, an important issue is also the spatial orientation of this MF sensor, which ensures the maximum efficiency of a closed system.

In general, a closed ASS minimizes the level of the magnetic field at the location of the MF sensor. Therefore, one of the possible approaches to the problem of determining the location of the MF sensor is its placement at a point in space in which the flux density value of the MF calculated in the synthesis of the ASS assumes a minimum value. In this case, a closed ASS provides the maximum screening efficiency in a given space.

The advantage of a closed ASS is also the possibility of compensating both the external MF, generated by TL, and the internal MF, generated, for example, by household electric appliances located near the screening zone, by electric floors, etc. In addition, when the parameters of a closed ASS change, its efficiency varies insignificantly, i.e. the closed system has more robustness in comparison with the open system. However, with significant changes in parameters, a closed system may lose stability and, therefore, become inoperable. In addition, the measurement of the magnetic field at the point at which the level of the total MF has a minimum value leads to an increase in measurement noise and, consequently, to a deterioration in the efficiency of the closed system operation.

The advantage of an open ASS is the use of an MF sensor located near the TL wires, where the level of the flux density of the initial MF is sufficiently large and, therefore, can be measured with a high signal-to-noise ratio. Therefore, in an open system, the noise level can be substantially smaller than the noise of measuring the MF in a closed system. In addition, in the open system when the parameters of the system are changed, its stable operation is always ensured, although the efficiency of its operation can be reduced due to undercompensation or overcompensation of the initial MF.

A comparison of the results of the MF distribution of the synthesized single-circuit ASS, shown in Fig. 2,*c*, with the experimental MF distributions of the open and closed single-circuit ASS shown in Fig. 4,*b*-*d* and Fig. 5,*b* – *d* showed that they differ by not more than 20 %.

Conclusions.

1. A full-scale layout of a single-circuit system for active screening of a magnetic field created in the screening zone by a group of overhead transmission lines is developed, taking into account the limitations on the spatial arrangement and geometric dimensions of the compensating winding.
2. Field experimental studies of the layout of a single-circuit active screening system of magnetic field with open and closed control algorithms are carried out. It is shown that the efficiency of an open and closed system is approximately the same and is more than 4 units.
3. Comparison of the results of experimental and calculated values of the magnetic field flux density in the screening zone shows that their spread does not exceed 20%, which confirms the adequacy of the developed method for synthesizing the active screening system layout and the possibility of using it for creating real active screening systems.

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Received 15.12.2017

B.I. Kuznetsov[1], *Doctor of Technical Science, Professor,*
T.B. Nikitina[2], *Doctor of Technical Science, Professor,*
I.V. Bovdyj[1], *Candidate of Technical Science,*
A.V. Voloshko[1], *Candidate of Technical Science,*
E.V. Vinichenko[1], *Candidate of Technical Science,*
B.B. Kobilyanskiy[1], *Candidate of Technical Science, Associate Professor,*
[1] State Institution «Institute of Technical Problems of Magnetism of the NAS of Ukraine»,
19, Industrialna Str., Kharkiv, 61106, Ukraine,
phone +380 50 5766900,
e-mail: kuznetsov.boris.i@gmail.com
[2] Kharkov National Automobile and Highway University,
25, Yaroslava Mudrogo Str., Kharkov, 61002, Ukraine,
e-mail: tatjana55555@gmail.com

How to cite this article:
Kuznetsov B.I., Nikitina T.B., Bovdyj I.V., Voloshko A.V., Vinichenko E.V., Kobilyanskiy B.B. Development and investigation of layout of active screening system of the magnetic field generated by group of overhead transmission lines. *Electrical engineering & electromechanics*, 2018, no.2, pp. 36-40. **doi: 10.20998/2074-272X.2018.2.06.**