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RESEARCH ARTICLE

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COMPUTER ANALYSIS OF MAGNETIC DEVICES OF INFORMATION CONTROL SYSTEMS AUTOMATICS

***Ismibeyli, R.E. and Gunbataliev, E.Z.**

Azerbaijan Technical University

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ABSTRACT

In the paper the possibility of computer analysis of quite complex magnetic devices used in information control systems by one of the numerical methods, by the method of secondary sources, is considered. The proposed calculation algorithm allows the use a variety of computing systems and this can significantly reduce the complexity of the process and allow virtually less error. In this case, it is possible to effectively apply this method for wider range of various magnetic elements and devices of information control systems automatics.

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INTRODUCTION

Existing various mathematical methods for calculating applied technical problems stipulates wideuse of computer technology, which promotealgorithmization of these calculations, significant reduction in labor-intensiveness and a decrease in error. From this point of view, in order to calculate quite complex problems as magnetic elements and devices of automatics of control systems, various numerical methods meet these goals. One of these numerical methods is the method of secondary sources [1-7].

This method allows to completely algorithmize the calculation process based on the application of computing technology and at the same time to determine of magnetic elements and devices the flow distribution, electric and magnetic parameters of thes elements on each *i*- th elementary area. In this connection we consider calculation of magnetic elements and devices by the method of secondary sources (MSS)

Calculation of magnetic elements and devices by the method of secondary sources: According to the method of secondary sources, calculation of electromagnetic system is considered in the form of the system of integral equations by which secondary sources of the field are determined in the form: a) density of fictitious magnetic charges (σ_M : δ), density of eddy currents δv. Having determined secondary sources, distribution of electromagnetic field is determined, and knowing electromagnetic fielddistribution at each point of the considered magnetic system, integral characteristics of the given devices are determined by the known relations. According to (195), calculated integral equations have the form:

***Corresponding author: Ismibeyli, R.E.,**
Azerbaijan Technical University.

$$\sigma_M(Q)+\alpha_m \oint_{S_\Phi} \sigma_M(M)\left(\frac{\overrightarrow{rQ_m}\overrightarrow{nQ}}{2\pi rQ_m^3}-\frac{1}{S_\Phi}\oint_{S_\Phi}\frac{\overrightarrow{rQ_H}\overrightarrow{nQ}}{2\pi rQ_m^3}\right)=d\overrightarrow{S_m}=$$ ....(1.1)

$$=-\mu_0\lambda_M\int_{V_K}\vec{\delta}(M)\frac{\overrightarrow{rQ_m}\overrightarrow{nQ}}{2\pi rQ_m^3}d\overrightarrow{V_\mu}-\mu_0\lambda_M\int_{V_K}\overrightarrow{\delta_b}(M)\frac{\overrightarrow{rQ_m}\overrightarrow{nQ}}{2\pi\, rQ_m^3}d\overrightarrow{V_\mu}$$

$$\vec{B}(Q)=\frac{\mu_0}{4\pi}\int_{V_K}\frac{\vec{\delta}(M)rQ_m}{rQ_m^3}d\overrightarrow{V_M}-\frac{\mu_0}{4\pi}\int_{V_K}\frac{\left[\overrightarrow{\delta_b}(M)\overrightarrow{rQ_m}\right]}{rQ_m^3}d\overrightarrow{V_M}-$$

$$-\frac{1}{4\pi}\oint_S\frac{\sigma_H(M)rQ_m}{rQ_m^3}dS_M$$ ....(1.2)

$$\sigma(Q)+\oint_S\sigma(M)\left(\frac{\overrightarrow{rQ_m}\overrightarrow{n_a}}{2\pi\, r^3 a_M}-\frac{1}{S}\oint_S\frac{\overrightarrow{rQ_m}\overrightarrow{n_Q}}{rQ_m^3}d\overrightarrow{S_M}\right)=\frac{j\omega}{2\pi}\int_V\vec{B}(M)\frac{\left[\overrightarrow{rQ_m}\overrightarrow{n_Q}\right]}{rQ_m^3}dV_m$$ ....(1.3)

$$\delta_b(Q)=\frac{j\omega\gamma'\gamma_0}{4\pi}\int_V\frac{\left[\overrightarrow{rQ_m}\vec{B}(M)\right]}{rQ_m^3}dV_m-\frac{\gamma'\gamma_0}{4\pi}\oint_S\sigma(M)\frac{\overrightarrow{rQ_m}}{rQ_m^3}dS_m$$ ....(1.4)

where $rQ_M=(X_M-X_Q)\vec{i}+(Y_M-Y_Q)\vec{j}+(Z_M-Z_Q)\vec{k}$ isthevectorofdistancebetweenthepoint *Q*,wherethe values of the desired value are determined, and the point *M*, where the source is located;

σ_M is the surface density of the fictitious magnetic charge (source of the field of magnetization of magnetic charges);

$\lambda_M=\frac{\mu_i'-\mu_l'}{\mu_i'+\mu_l'}$ is constant;

$\mu_i',\ \mu_l'$ are relative magnetic permeabilities at the beginning and at the end of the area;

S_Q is the surface of the magnetic core;

V_K is the volume of magnetizing coils;

$\vec{\delta}$ is the current density in the magnetization core (primary source);

$\overrightarrow{\delta_b}$ is the density of eddy currents (secondary source);

σ is the source of harmonic charge function;

γ' is the relative conductivity of medium;

γ_0 is the conductivity of homogeneous unbounded medium.

The considered integral equations (1.1-1.4) determine mathematical model of electromagnetic field in piecewise-homogeneous conducting and ferromagnetic field. According to [1], the algorithm for solving the written equations is represented in the following way:

1. Assuming $\overrightarrow{\delta_b}=0,\ \overrightarrow{\sigma_M}=0$, determine $\overrightarrow{B_0}$ accordingto(1.2).
2. Knowing $\overrightarrow{B_0}$ by the magnetization curve of the material $B=f(H),\ \overrightarrow{H_0}$, we determine and then $\mu_0'=\frac{B_0}{H_0}$.
3. Solveequation(1.3) for $\vec{B}=\overrightarrow{B_0}$, having determined the distribution $\sigma^{(1)}$.
4. Solveequation(1.4) i.e.determine $\overrightarrow{\delta_b}^{(1)}$.

5. Solveequation(1.1) i.e. having determined $\sigma_M^{(1)}$.

The given steps of the algorithm are repeated until the iterative processconvergesi.e. $\vec{B} = \overrightarrow{B_0} + \overrightarrow{B^{(1)} + \cdots}$.

With the convergence of the iterative process, the magnetic flux is determined at each $i-$th area according to the relation:

$$\Phi_i = \frac{1}{4\pi}\oint_L \sigma(M)\frac{\left\lfloor r\overrightarrow{Q_m V}\right\rfloor}{rQ_M\left(rQ_M - r\overrightarrow{Q_m V}\right)}\overrightarrow{dS_m}\overrightarrow{dl_Q} \quad \text{...(1.5)}$$

The solution of the written integral equations (1.1.-1.4) is realized by the method of successive approximations. The written expressions are reduced to the solution of a linear integral equation of the form

$$\sigma(Q) + \frac{\lambda}{2\pi}\oint_S K(Q,M)\sigma(M)dS_m = f(Q) \quad \text{...(1.6)}$$

where $K(Q,M) = \frac{r\overrightarrow{Q_m}\overrightarrow{n_Q}}{rQ_m^3} - \frac{1}{S}\oint_S \frac{r\overrightarrow{Q_m}\overrightarrow{n_Q}}{rQ_m^3}dS_m$ is the equation core;

$\sigma(Q)$ is an unknown (desired) function,

$f(Q)$ is a free member,

j is a numerical parameter.

Ifwedividetheentireclosedsurfaceofintegration S into n rather small areas of square ΔS_j centered at the points, $M_j (j = 1,2,\ldots,n)$, then the integral contained in expression (1.6), may be represented in the form of the finite sum of integrals in areas ΔS_j.

$$\oint_S K(Q,M)\sigma(M)dS_m = \sum_{j=1}^n \int_{\Delta S_i} K(Q,M)\sigma(M)dS_m \quad \text{...(1.7)}$$

Assuming that on elementary areas the function $\sigma(M)$ is constant and equals the value $\sigma(M_j)$ at the point M_j, we obtain the following approximate expression for the integral (1.6):

$$\oint_S K(Q,M)\sigma(M)dS_m \approx \sum_{j=1}^n G(Q,M_j)\sigma(M_j) \quad \text{...(1.8)}$$

$$G(Q,M_j) = \int_{\Delta S_i} K(Q,M)\sigma(M)dS_m \quad \text{...(1.9)}$$

Havingsubstituted (1.8) in (1.6) we obtain the equality:

$$\sigma(Q) + \frac{\lambda}{2\pi}\sum_{j=1}^n G(Q,M_j)\sigma(M_j) = f(Q) \quad \text{...(1.10)}$$

Expression(1.10) forthepoints Q_i the centers of the areas ΔS_i, $(i = 1,2,\ldots,n)$ is written in the form of the system of linear algebraic equations:

$$\sigma(Q_i) + \frac{\lambda}{2\pi}\sum_{\substack{i=1\\ j=1}}^n G(Q_i,M_j)\sigma(M_j) = f(Q_i)\; i = 1,2,\ldots,n \quad \text{...(1.11)}$$

$$G(Q_i,M_j) = \int_{\Delta S_i}\left(\frac{r\overrightarrow{Q_m}\overrightarrow{n_Q}}{rQ_m^3} - \frac{1}{S}\oint_S \frac{r\overrightarrow{Q_m}\overrightarrow{n_Q}}{rQ_m^3}dS_m\right)dS_M, \quad \text{...(1.12)}$$

that satisfy the values of the desired $\sigma(Q_i)$ function at the points dS_M.

The $n-$thorder system (1.12) is written in the form:

$$\sum_{j=1}^n a_{ij}\sigma_j = f_i i = 1,2,\ldots,n \quad \text{...(1.13)}$$

or in the vector matrix form

$$\vec{A}\vec{\sigma} = \vec{f} \quad , \qquad (1.14)$$

where $\sigma_j = \sigma(M_j)$ are the components of $n-$dimensional vector $\vec{\sigma}$, $f_i = f(Q_i)$ are the components of $n-$dimensional vector $\vec{f}$, a_{ij} are the elements of the matrix A.

The $n-$thorderexpression (1.14) is solved by the method of block iterations that allows more economical use of computer-on-line storage.

Thematrix A isdividedinto p^2 rectangular cells $\overrightarrow{A_{ij}}\,(i = 2,3,\ldots, p)$. Dimension of rectangular matrices $\overrightarrow{A_{ij}}$ equals $(m_i x, m_j)$,where $\sum_{i=1}^{p} m_i = n$. The $n-$dimensional vectors $\vec{\sigma}$ and $\vec{f}$ are divided into p vectors $\vec{\sigma}_i$ and $\vec{f}_i$ of dimension m:

$$\vec{\sigma} = \{\overrightarrow{\sigma_1}, \overrightarrow{\sigma_2}, \ldots, \overrightarrow{\sigma_i}, \ldots \overrightarrow{\sigma_p}\} \qquad (1.15)$$

$$\vec{f} = \{\overrightarrow{f_1}, \overrightarrow{f_2}, \ldots, \overrightarrow{f_i}, \ldots \overrightarrow{f_p}\} \qquad (1.16)$$

Then the system (1.14) will be equivalent tothe systems

$$\vec{A}\vec{\sigma} = \vec{f}\; i = 1,2,\ldots, p \qquad (1.17)$$

each of order m_i .

The iterative process is constructed in such a way that at each step p systems are solved by the prime method and the order of each systems is less than n .

Having set the initial approximation of vectors $\sigma_i^{(0)}$ $(i = 2,3,\ldots, p)$ we determine $\overrightarrow{\sigma_i^{(1)}}$, solving by the primary method the first one from the systems (1.17) of m_i $-$order:

$$\overrightarrow{\sigma_i^{(1)}} = \overrightarrow{A_{11}^{-1}}\left(\vec{f}_1 - \sum_{j=2}^{p} \overrightarrow{A_{11}^{-1}}, \overrightarrow{\sigma_j^{(0)}}\right), \qquad (1.18)$$

where $\overrightarrow{A_{11}^{-1}}$ – is a matrix inverse to square matrix $\vec{A}$.

Then from the second system of (1.17) the m_2 order first approximation $\overrightarrow{\sigma_2^{(1)}}$,

$$\overrightarrow{\sigma_2^{(1)}} = \overrightarrow{A_{22}^{-1}}\left(\vec{f}_1 - \overrightarrow{A_{21}}\overrightarrow{\sigma_1^{(1)}} \sum_{j=3}^{p} \overrightarrow{A_{2j}^{-1}}, \overrightarrow{\sigma_j^{(0)}}\right). \qquad (1.19)$$

Forthe $i-$value of the first approximation of the vector $\overrightarrow{\sigma_i^{(1)}}$, we have:

$$\overrightarrow{\sigma_i^{(1)}} = \overrightarrow{A_{ii}^{-1}}\left(\vec{f}_i - \sum_{j=1}^{i-1} \overrightarrow{A_{ij}}\overrightarrow{\sigma_j^{(1)}} - \sum_{j=i+1}^{p} \overrightarrow{A_{ij}}, \overrightarrow{\sigma_j^{(0)}}\right) i = 1,2,\ldots p \qquad (1.20)$$

where $\overrightarrow{A_{ii}^{-1}}$ is a matrix inverse to the matrix $\overrightarrow{A_{ii}}$ – of order m_i.

Theapproximationofthe $k-$th step of the iterative process is:

$$\overrightarrow{\sigma_i^{(k)}} = \overrightarrow{A_{ii}^{-1}}\left(\vec{f}_i - \sum_{j=1}^{i-1} \overrightarrow{A_{ij}}, \overrightarrow{\sigma_j^{(k)}} - \sum_{j=i+1}^{p} \overrightarrow{A_{ij}}, \overrightarrow{\sigma_j^{(k-1)}}\right) i = 1,2,\ldots p. \qquad (1.21)$$

Information about geometry of magnetic core, magnetizing coils (sizes, width, thickness, length) the basic magnetization curve enter in the form of the approximating function $B(H) = aH^b(1+cH)$ for electrical steel ЭА-1 the values of constants $a = 0{,}99483$, $b = 0{,}123398$, $c = 000092$. The magnetization curve may be given in the form of a table $B = f(H)$.

The values of densities of currents of sources, square ofthe magnetic core surface are set up. Volume and surface of magnetic elements and devices, and also volume of magnetization coils is divided into n number of rectangular areas. The flow distribution value is determined in the centre of these areas and in a such a way we obtainthe dependence $\Phi_i = f(N)$, where N is the number of the points (of the centers of the i – threctangular areas of magnetic elements). The coordinates of these points are determined with respect to the given system of coordinates and enter into the memory of a computer. Implementation of the program of calculation of magnetic elements and devices is perfomedaccording to block – diagram of the calculation program (Fig. 1). Description of the given block-diagram of the calculation program if given in table 1.

2. Description of block – diagram of the calculation program of magnetic elements and devices by the method of secondary sources (MSS).

1. Initial data are set up;
N isthe number of elementary segments in the contour l;
X_1, Y_1 are the coordinates of the location point of the first given charge (current),
X_2, Y_2 are the coordinates of the location point of the second given charge (current),
MAG isa sign equal to 0 in the case of an electric field and to 1 in the case of magnetic field;
KZ isthe number of the versions of the problem and equals the number given by magnetic permeability of medium inside and outside the contour l .

2. The number of the points M of the contour l is calculated.
3. The arrays $X, Y, D, A, B, C, CP, R2M, CIN$ are calculated.
4. The coordinates of extreme points of segments X_i, Y_i are entered.
5. Organization of the input cycle of coordinates X_i, Y_i, changing from 1to i through 1.
6. $LK = 0$ – perimeter of the contour l of approximated segment is calculated.
7. The distance between the points by $X - YA_i$ and $Y - YA_i$ the distance D_i between them are calculated.
8. $LK = \sum D_i,\ A_i = \frac{A_i}{D_i}, B_i = \frac{B_i}{D_i}, X_i = (X_{i+1} - X_i)/2$ are calculated.
9. Organization of calculation cycle /7-8/ changing from i to 1 up to N.
10. Setup El with respect to magnetic permeability of medium inside and outside the contour l .
11. Calculation of L parameter λ, / LI parameter/.
12. Calculation of $R3 = 0$.
13. Verification of the condition $MAG = 1, T = 1,\ TA = 1$, if it is fulfilled, then $R3 = L \cdot L1 / LK$
14. Calculation of $R = L \cdot D_M / LK,\ R1 = 0$
15. Verification of the condition $T = 1$, if it is fulfilled, then $RI = R$
16. Verificationofthecondition $K = M$, if it is fulfilled, pass to block 19.
17. Calculationof G_{KM} – coefficients of the system of algebraic equation.
18. Unconditional jumpto block20.
19. Calculation of C_{KM} for $K = M$.
20. Organization of calculation cycleof the coefficients of the K – thline of the system of algebraic equations /1.21/ changing m from 1 to N.
21. Calculation of $R2$.
22. Verificationofthecondition $TA = 1$, if it is fulfilled, pass to block 24.
23. Calculationof $R2$
24. Calculationof CP_K – coefficientsoftheright side of the K – thline of the system of algebraic equations.
25. Organizationofcalculationcycleofall K – lines of the coefficients of the system of algebraic equation and right sides changing K from 1 to N.
26. Solving the system of linear algebraic equations by the Gauss method.
27. Calculationof $RB_i = 0$
28. Calculationof $RB_i = RB_i + CP_k \cdot D_k$.
29. Organizationofcalculationcycle changing K from 1 to N
30. Printing RB_i
31. Organizationofcalculationcyclefor $TA / TA = 1$ when only one of the first given field source is active and $TA = 2$ when both sources are active, changing TA from 1 to 2 through 1.

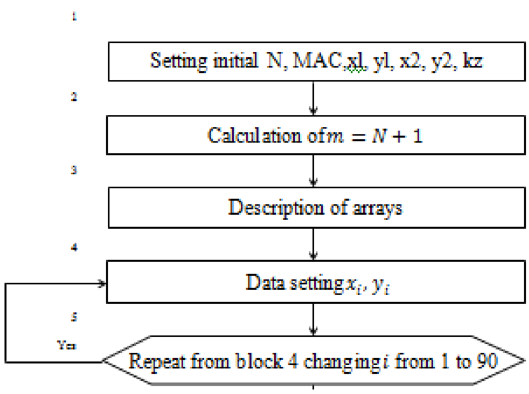
32. Organizationofcalculationlevelfor $T/T=1$when solving the transformed equation $TA=3$when solving untransformed equation changing $T$from 1 to 3 through 2.
33. Organizationoftheimpus cycle of magnetic permeability changing $K1$ from 1 to K through1.
34. End.

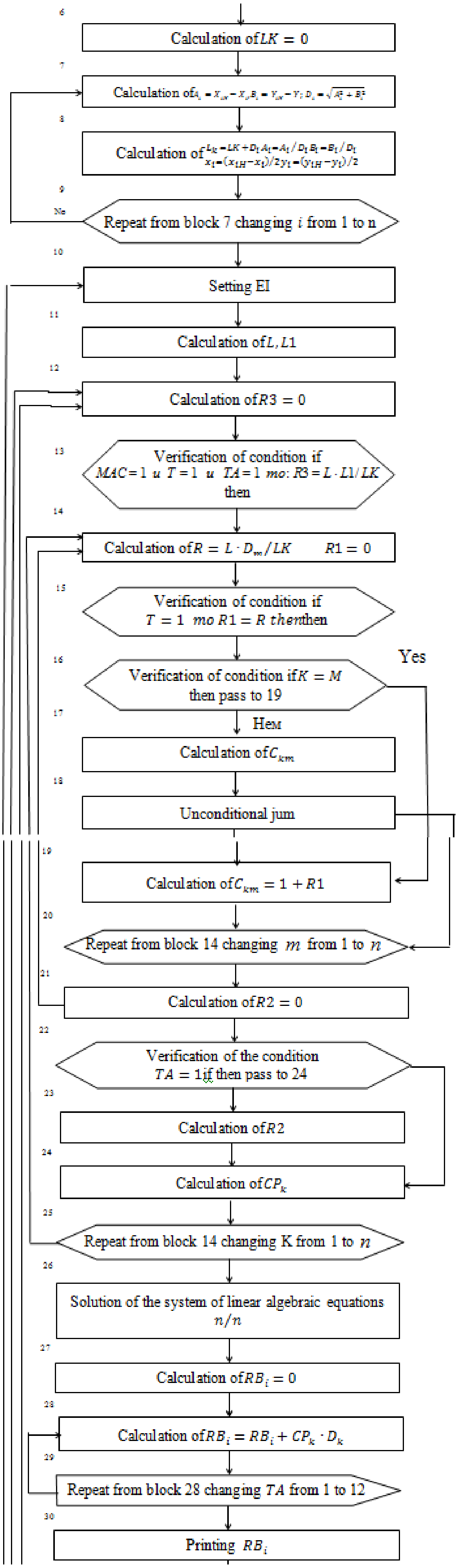
Calculation of flow distribution electrical parameters of the magnetic element of power relay was performed by the given block-diagram of calculation program by MSS (Fig. 2) of the table (1-2).

Table 1. Errors of calculation of flow distribution in the areas of magnetic element of power relay (fig.2) (number of nodes 38)

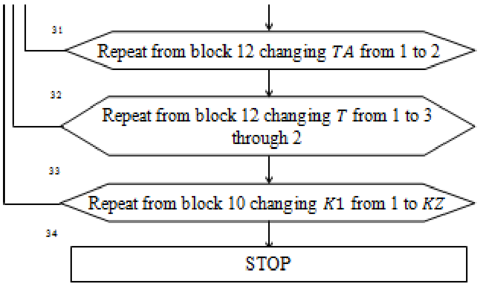
Number of topological areas	Experimental values of magnetic flux $\lvert\Phi_i\rvert\ 10^{-5} B\delta$	Calculation values of magnetic flux $\lvert\Phi_i\rvert\ 10^{-5} B\delta$ by the method of secondary sources	Calculation errors /Exp./-/Calc./ Exp. 100% by the method of secondary sources
1	4,473	4,741	-5,992
2	5,245	5,062	3,489
3	3,768	3,885	-3,105
4	3,617	3,793	-4,866
5	3,820	3,674	3,822
6	4,365	4,215	3,436
7	9,213	9,579	-3,973
8	4,225	4,094	1,101
9	3,586	3,475	3,095
10	3,652	3,850	-5,422
11	3,661	3,784	-3,360
12	4,905	4,665	4,893
13	4,663	4,396	5,115
14	1,504	1,599	-5,964
15	2,438	2,355	3,404
16	2,235	2,369	-5,996
17	2,007	2,073	-3,288
18	3,983	3,475	5,975
19	1,184	1,255	-5,997
20	0,906	0,858	5,298
21	2,122	2,249	-5,985
22	3,755	3,638	3,116
23	0,959	0,905	5,631
24	1,114	1,078	3,232
25	1,817	1,926	-5,999
26	2,135	2,070	3,044
27	2,208	2,077	5,933
28	1,626	1,547	4,859
29	0,251	0,239	4,781
30	0,254	0,240	5,512
31	0,220	0,212	3,536
32	0,218	0,211	3,211
33	0,202	0,194	3,960
34	0,179	0,173	3,352
35	0,262	0,271	-3,435
36	0,280	0,270	3,571
37	0,177	0,184	-3,955
38	0,175	0,169	3,429

Block-diagram for calculating magnetic elements and devices by MSS





Calculation of LK = 0
Calculation of A_i = X_iH − X_i, B_i = Y_iH − Y_i, D_i = √(A_i² + B_i²)
Calculation of L_k = LK + D_i, A_i = A_i / D_i, B_i = B_i / D_i, x_i = (x_iH − x_i)/2, y_i = (y_iH − y_i)/2
Repeat from block 7 changing i from 1 to n
Setting EI
Calculation of L, L1
Calculation of R3 = 0
Verification of condition if MAC = 1 и T = 1 и TA = 1 то: R3 = L · L1/ LK then
Calculation of R = L · D_m / LK R1 = 0
Verification of condition if T = 1 то R1 = R thenthen
Yes
Verification of condition if K = M then pass to 19
Нет
Calculation of C_km
Unconditional jum
Calculation of C_km = 1 + R1
Repeat from block 14 changing m from 1 to n
Calculation of R2 = 0
Verification of the condition TA = 1if then pass to 24
Calculation of R2
Calculation of CP_k
Repeat from block 14 changing K from 1 to n
Solution of the system of linear algebraic equations n/n
Calculation of RB_i = 0
Calculation of RB_i = RB_i + CP_k · D_k
Repeat from block 28 changing TA from 1 to 12
Printing RB_i



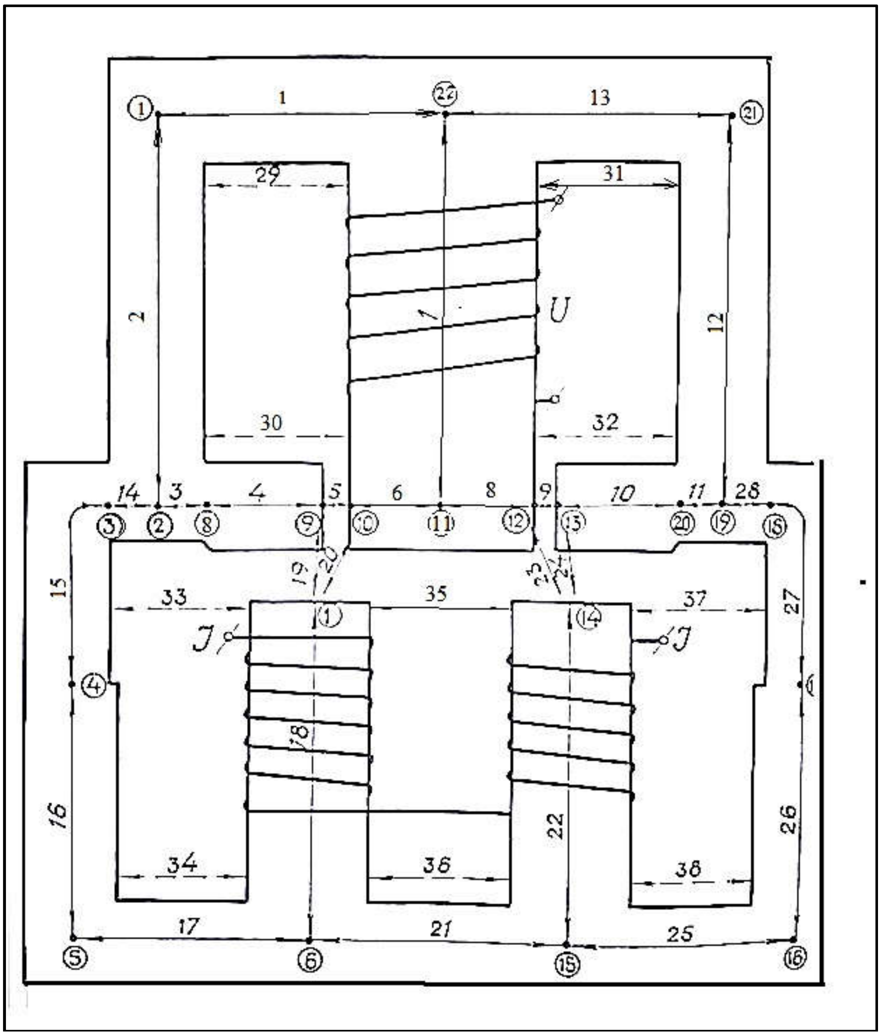


Fig. Magnetic element of power relay divided into areas

Conclusions

1. Calculation of magnetic elements and devices of automatics of control systems allows completely to analyze the calculation process.
2. Based on the suggested algorithm, the flow distribution and also electric, magnetic parameters of rather complex magnetic elements and devices are determined byi elementary areas.
3. The suggested calculation algorithm significantly reduces the labor -intensiveness of the process and also rater virtually reduce the error of calculation with respect to experimental data.
4. The finite element method, as one of various numerical methods allows widespred use of calculating systems for calculating different complex magnetic elements and devices with regard to specificity of these elements with giving rather effective value of calculation.

REFERENCES

1. TozoniO.B.Method of secondary sources in electrical engineering.M.Energia 2005, 296 p.
2. RozenblattM.A.Magnetic elements of automatics and computing technology.M.Nauka1994, 768 c.
3. PirogovA.I., ShamaevYu.M.Magnmetic cores for automation and computing technology devices.M.Energia, 1993, 264c.

4. Kusko A., Wroblewski T. Computer aided design of magnetic curcuits. Research, Mong. N55. The MIT Press Cavbridge, Massachusetts, USA 1998, 367p.
5. VidyasagerM.New directions of research in nonlinear system theory.Proc. of the IEEE. v. 74, №78, 1996, p.5-41
6. E.G.Ismibayli, I.V.Islamov, R.Sh.Abdullayev. Numerical simulation and experimental investigation of rectangular waveguide electrical field taking into account nonlinear means. American Journal of Engineering Research (AJER), e-ISSN:2320-0847 P-ISSN:2320-0936. v.5, issue 5, p.38-45 www.qjer.org.
7. E.G.Ismibayli, I.V.Islamov, Y.G.Gaziyev. Simulation of electromagnetic field formicrowave rectangular wave-guide to circular in transition devices.Intern.journal of Engineering Sciences and Research Technology IJESRT 5(3), march 2016, ISSN:2277-9655, www.ijesrt.com

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