MATHEMATICAL MODEL OF CIRCUITS SYSTEM OF RAILWAY AUTOMATION AND TELEMECHANICS

Astanaliev Elmurod Tursunali ogli

"Department of Automation and telemechanics of Tashkent state transport university" master's student,

Tashkent state transport university

Abstract: The article provides information on effective relay contact schemes and their opening and closing condition. To compose the equations of independent circuits, the currents of the circuits are used. In the digraph, the scheme of rotation is marked by five directions.

Keywords: railway automatics and telemechanics, resistors, capacitors, diodes, transistors, transformers, chokes, electronic circuits, relays.

Modern modeling environments are not efficient enough for modeling relay-contact systems of railway automation and telemechanics (SRAT). At the same time, these tools are in a sense the pinnacle of modern development of numerical methods. They are widely used for modeling both radio engineering circuits and other dynamic systems.

The number of modern compressed units can reach several thousand. Modeling such complex systems taking into account transient processes leads to the need to compose systems of high-order nonlinear differential equations. The formation of such systems of differential equations presents significant difficulties with a large number of elements. This article proposes a modified version of the method for mathematical modeling of complex multi-element compressed-air units, originally developed for electrical circuits.

The proposed version of the method is based on the representation of elements in the form of multipoles with complex internal connections described by a special quasi-diagonal matrix - the matrix of codes. This variation of the method makes it possible to significantly simplify the process of forming systems of nonlinear differential equations describing the processes in the SRAT.

In SRAT, circuits of both direct and alternating current are used, therefore the modeling method should allow modeling such circuits taking into account the main characteristics of the elements included in the composition. Circuit elements can be resistors, capacitors, diodes, transistors, transformers, chokes, electronic circuits, relays.

Consider the simplest signaling circuit shown in Fig. 1 and consisting of only two relays with one pair of contacts for closing in each relay.

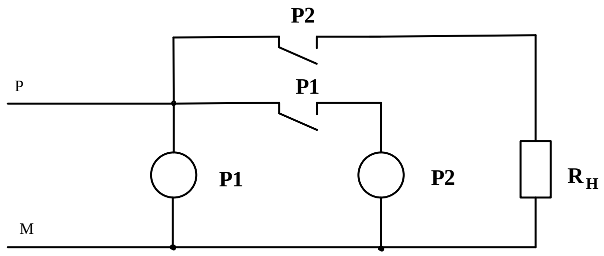


Fig.1. Relay contact schema

When power is applied, relay P1 is triggered and, with its own contact, supplies voltage to relay P2, which, in turn, closes the circuit to the load R_H with its contact.

For further analysis of such a circuit, an equivalent circuit is drawn up, shown in Fig. 2. The relay coil is replaced by a serial LR - circuit, taking into account the coil capacity. The relay contacts are replaced by a resistor, which changes its resistance depending on the current flowing through the relay coil. This takes into account the opening current of the rear contacts of the relay and the closing current of the front contacts, as well as the closing current of the rear contacts and the opening of the front contacts of the relay are unique for a particular type of relay.

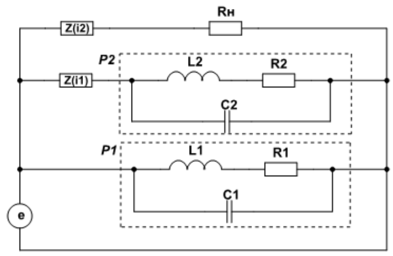


Fig.2. Schema of equivalent relay contact circuit

According to the equivalent circuit, a directed graph (digraph) of the circuit is compiled, shown in Fig. 3. The branches of the reference tree (in the figure they are marked with bold lines) of the digraph by numbers from 1 to 5 correspond to the following elements of the equivalent circuit:

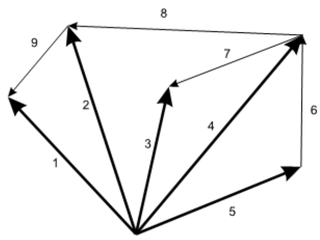
1st branch: resistor R2,

2nd branch: capacitor C2,

3rd branch: resistor R1,

4th branch: capacitor C1,

3rd branch: resistor R_H.



The chords of the digraph numbered from 6 to 9 (in the figure are marked with thin lines) correspond to the elements:

6th: relay contacts P2,

7th: coil inductance of 1st relay L1,

8th: relay contacts P1,

9th: coil inductance of 1st relay L2 ,.

The number of chords in the digraph corresponds to the number of independent circuits in which the flowing currents will be hire, and in which the sum of the voltages across the elements is zero (Kirchhoff's second law). The number of branches of the reference tree of the digraph corresponds to the number of vertices, the sum of the currents in which obeys the first Kirchhoff's law.

To compose the equations of independent circuits, the currents of the circuits are used.

In the digraph, the pivot tree is marked with five thickened branches. The figure shows that the digraph has 5 vertices, 9 arcs, and 4 independent contours, which are formed by chords numbered 6, 7, 8, 9.

Below are presented in matrix form the equations of independent contours for the graph in Fig. 3.

$$\begin{pmatrix} 0 & 0 & 0 & -1 & 1 & 1 & 0 & 0 & 0 \\ 0 & 0 & -1 & 1 & 0 & 0 & 1 & 0 & 0 \\ 0 & -1 & 0 & 1 & 0 & 0 & 0 & 1 & 0 \\ -1 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} u_1 \\ u_2 \\ u_3 \\ u_4 \\ u_5 \\ u_6 \\ u_7 \\ u_8 \\ u_9 \end{pmatrix} = 0 \qquad (1)$$

The index in the stress notation (column vector) corresponds to the numbers of branches (5 elements u_1,…, u_5) and chords (4 elements u_6,…, u_9).

The number of lines in the matrix corresponds to the number of contours (chords), with the first line describing the connections in the first independent contour, which includes the sixth chord, the second line - the second contour and the 7th chord, etc. fourth line fourth contour - 9th chord. The number of columns corresponds to the total number of edges in the graph: the first column is the 1st edge,…, the fifth column is the 5th edge. The elements of the first five columns of the matrix (the numbers of these columns correspond to the branches of the reference tree are:

- zero if the corresponding chord is not incident of this branch;
- units, ate incidental and oriented according to the branch;
- minus one, incidental and oriented opposite to the branch.

The last four columns of this matrix represent the identity matrix and describe the chords of the digraph.

In folded form, the equations are written as follows:

$$CY = [C_b E_c] \begin{bmatrix} Y_b \\ Y_c \end{bmatrix} = 0 \qquad (2)$$

where C_b - is a matrix-block of branches, E_c - is a unit, Y_b - is a vector of branch voltages, Y_c - is also for chords.

The resulting four equations

$$\begin{cases} -u_4 + u_5 + u_6 = 0 \\ -u_3 + u_4 + u_7 = 0 \\ -u_2 + u_4 + u_8 = 0 \\ -u_1 + u_2 + u_9 = 0 \end{cases} \quad (3)$$

obtained by multiplying the matrix by the stress vector, express the second Kirchhoff's law for stresses in the circuits. The independence of the equations of independent contours follows from the fact that each equation contains the stress of only one chord. Similarly, you can make up the equations for the currents of nodes.

Graph theory methods can be used to derive nonlinear differential equations for voltages or currents, and the formalization of such an apparatus for systems formed by multipoles leads to very simple methods for calculating the coefficients of these equations. The possibility of expanding the method for a multi-contact electromagnetic relay by representing its model in the form of a matrix of codes is shown.

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