

MATHEMATICAL MODELLING OF THE INDUCTION MOTOR TYPE 4A355M4U3 SQUIRREL-CAGE ROTOR ELEMENTS BREAKING BY USING THE MULTISIM SOFTWARE

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Introduction. Induction motors (IM) with squirrel-cage (SC) rotors form a significant part of alternating current motors – converters of alternating current electric energy into mechanical energy of motor shaft rotation. Simplicity of design and cheapness of production, and also existence of the convenient in programming frequency converters defined almost all-around application of the IM with a SC rotors in industrial electric drives. According to statistical researches, one of the most common reasons of the IM with the SC rotors failures is the damage of the squirrel cage. Thus, the research of this IM element by the methods of mathematical modelling is an important scientific task.

Damages of the squirrel-cage are detected mainly during major repairs. High periodicity between repairs doesn't allows to define the defects of the squirrel-cage in time, which quite often leads to the operation of the IM with breakouted rods or other damages. During the operation of the IM with the damaged squirrel-cage increases the power consumption, currents in the elements of the squirrel-cage and in general – the vibrations of the IM, it effects on the duration of the operation of bearings and a thermal state of the IM. The problems with the rotor when starting the IM also can be observed in [2]. Thermomechanical stresses that occur in the IM during the start, determine the degree of the heating of the squirrel-cage. To estimate the magnitude of the currents in the elements of the squirrel-cage, which are the primary source of its heating, it is necessary to calculate them in special programs. Multisim is the one of these programs. Articles [3, 4] show the examples of usage the Multisim program to determine the currents in the rotor winding by calculating the electrical circuit of the rotor of an electric motor. Fig. 1 shows three-dimensional model of the squirrel cage of the researched IM type 4A355M4U3

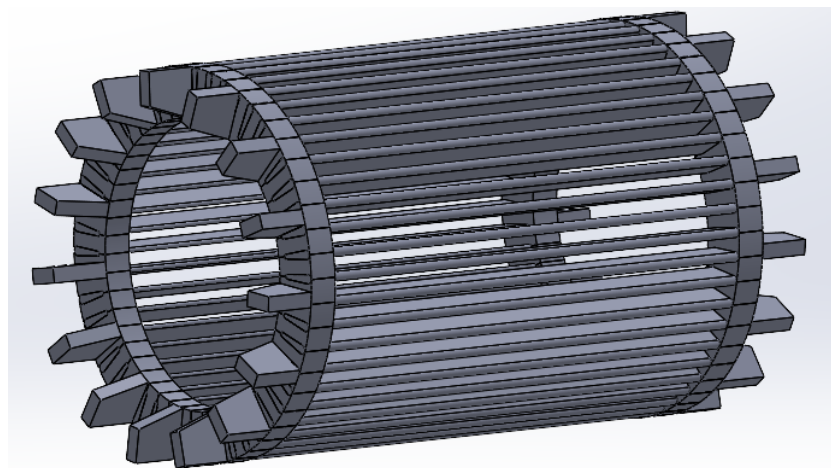


Figure 1 – Three-dimensional model of the squirrel cage of the IM type 4A355M4U3

The purpose of the research. To create and calculate the equivalent circuit of the squirrel-cage of the IM for researching the distribution of the currents in its elements with the absence and presence of its damage in the form of the breakout of the rods on the example of the motor type 4A355M4U3.

The results of the research. The equivalent circuit of the squirrel-cage was created in the National Instruments Multisim software environment, as this software has a number of advantages over other similar systems. For example, the numbering of elements is automatic when copying them, which is very convenient when working with circuits with a large number of similar elements. Also, the advantages of this software include easy usage, small size, and the ability to transfer numerical research results in the form of the tables to Microsoft Office. The algorithm of creation the equivalent circuit of the rotor is the following.

Open National Instruments Multisim software, in the element's library find the following elements:

- RESISTOR
- DC_POWER

Then, place them as shown in fig. 2.

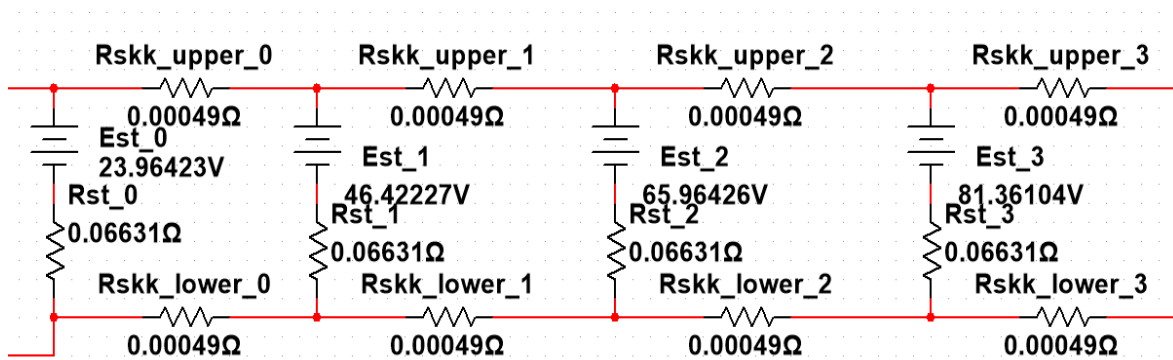


Figure 2 – Fragment of the squirrel-cage rotor equivalent circuit

where, $R_{skk_upper} = R_{skk_lower}$ – resistance of the segments of the short-circuited rings, Est - electromotive force (EMF) of the rod, R_{st} - resistance of the rod. The calculation of these parameters was performed by using the algorithm described in article [1].

Fragments of the circuit that belong to different rods must be connected in parallel, and the last fragment must be connected to the first and the whole circuit must be grounded.

To set a numerical value of the parameter, double-click on the name of its variable and enter the value of a parameter in the “Value” tab, for example for Est (Fig. 3):

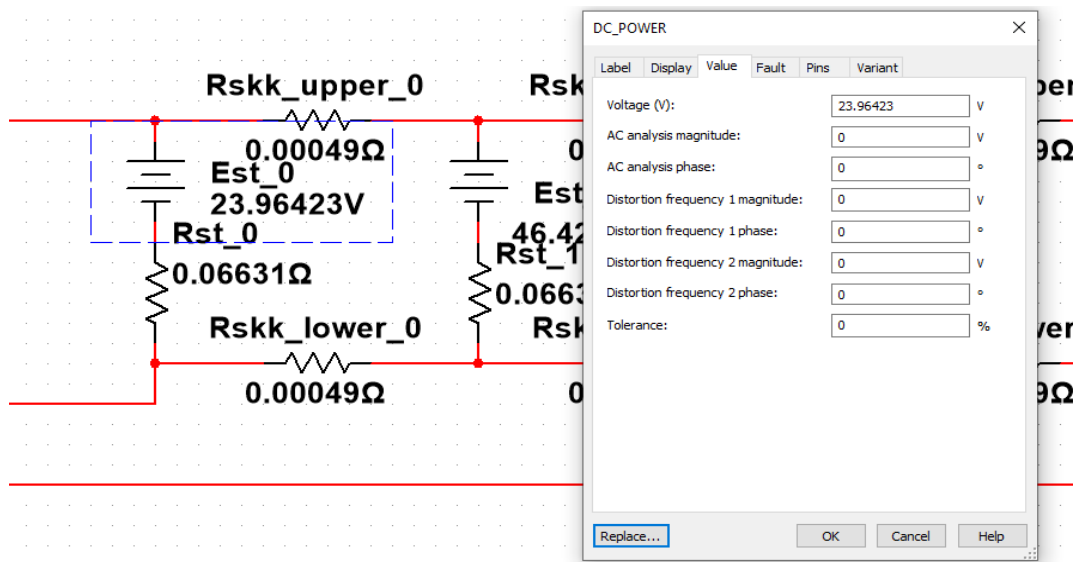


Figure 3 – Setting the EMF value for the 1st rod

Setting of the other parameters is the similar to the previous one.

Fig. 4 shows a complete equivalent circuit of the squirrel-cage rotor in the nominal operation mode without any damage.

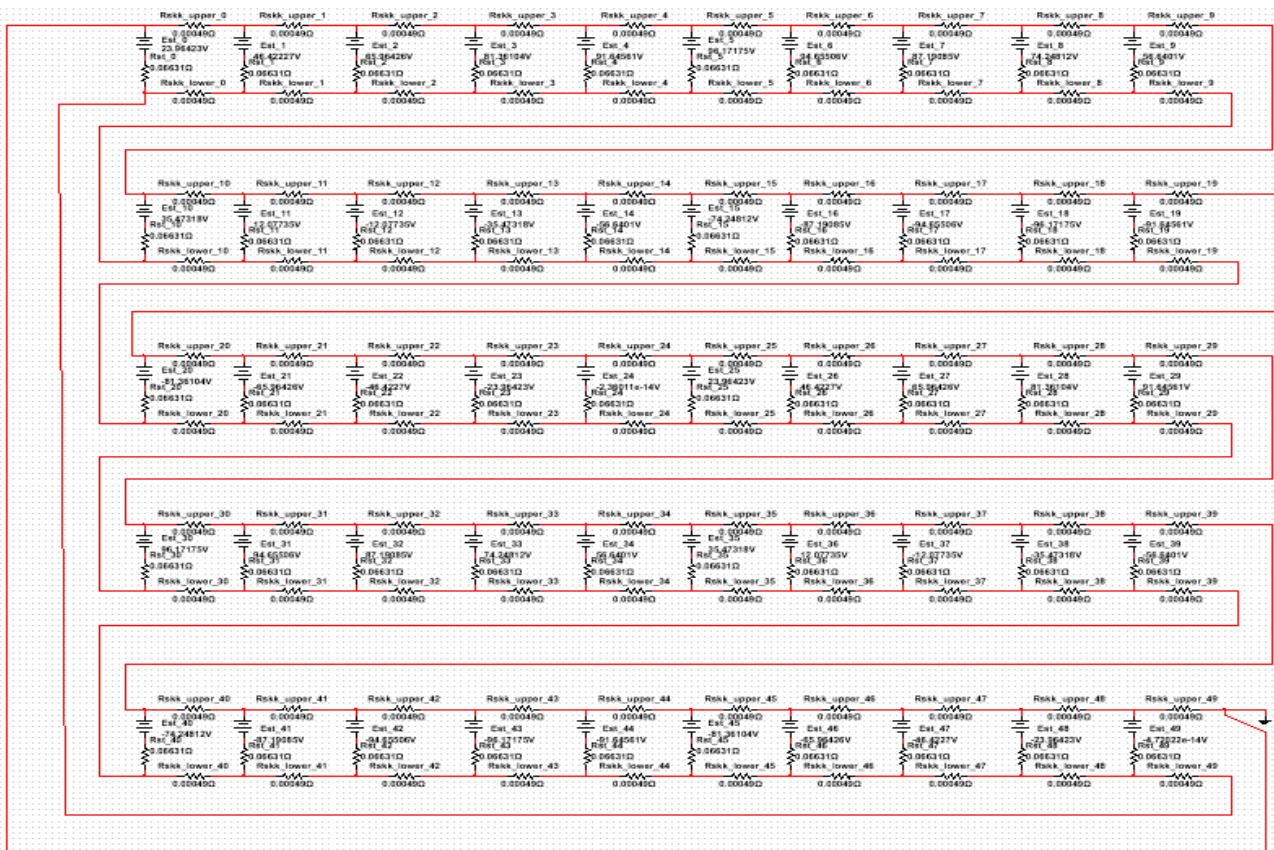


Figure 4 – Complete equivalent circuit of the squirrel-cage rotor

After creating the equivalent circuit, on the top panel of the operation window, select "Simulate" and click "Run". Then choose the variables that will be shown as a result and get the calculated values of the currents in the form of the table (Fig. 5).

File Edit View Graph Trace Cursor Legend Tools Help

DC Operating Point DC Operating Point

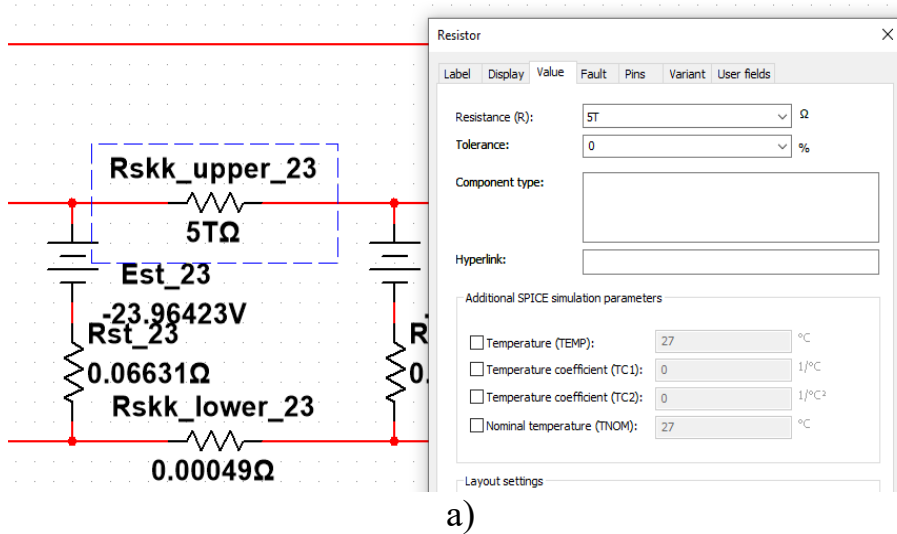
Неповрежденный клетка DC Operating Point Analysis

	Variable	Operating point value
1	I(RSKK_LOWER_0)	4.36383 k
2	I(RSKK_LOWER_1)	3.79706 k
3	I(RSKK_LOWER_2)	2.99170 k
4	I(RSKK_LOWER_3)	1.99836 k
5	I(RSKK_LOWER_4)	879.46147
6	I(RSKK_LOWER_5)	-294.70051
7	I(RSKK_LOWER_6)	-1.45035 k
8	I(RSKK_LOWER_7)	-2.51486 k
9	I(RSKK_LOWER_8)	-3.42136 k
10	I(RSKK_LOWER_9)	-4.11287 k
11	I(RSKK_LOWER_10)	-4.54597 k
12	I(RSKK_LOWER_11)	-4.69342 k
13	I(RSKK_LOWER_12)	-4.54597 k

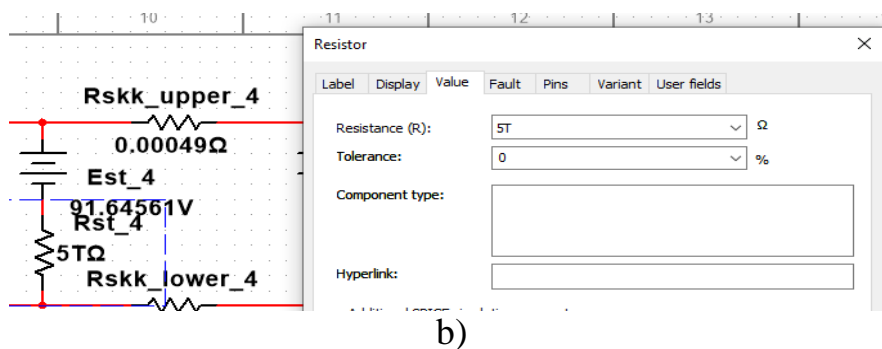
Figure 5 – Calculated values of the currents of the equivalent circuit

Then, for the convenience of the further calculations, you can export the obtained values to Excel. In the "Tools" tab, click "Export to Excel". After that, opens the file with the results in Excel. Then save the file in the location you have selected.

Simulation of the breakout of the rods or segments of the short-circuited ring is carried out by the increasing their resistance to 5 TOhm (Fig. 6).



a)



b)

Figure 6 – Modelling of the breakout of the squirrel-cage rotor elements in Multisim:
a) segments of the short-circuited ring; b) rods.

As the results of the simulation, were obtained the current distributions in different elements of the squirrel-cage with the presence and absence of the damage. In particular, fig. 7 shows the distribution of the currents in the rods of the squirrel-cage in the nominal operation mode for the following options: the absence of the damage, damage of 3 rods and damage of 3 segments of the short-circuited ring.

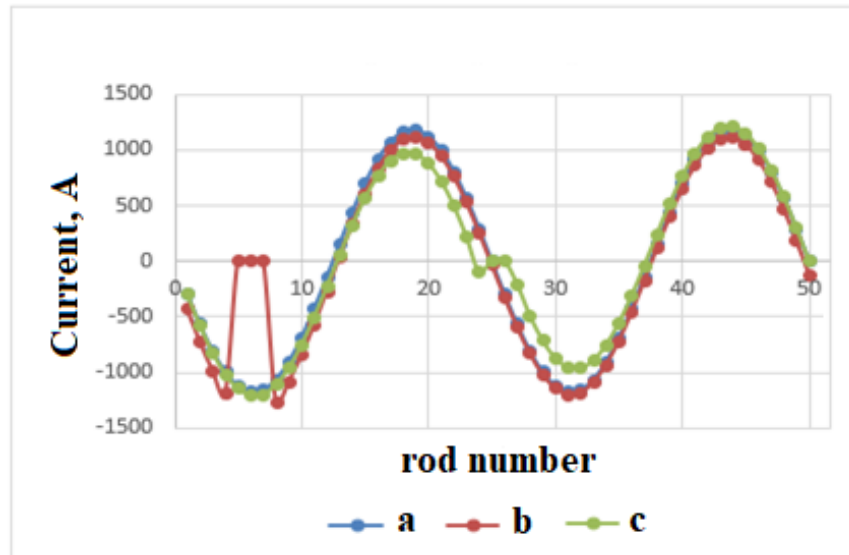


Figure 7 – Distribution of the currents in the rods of the squirrel-cage in the nominal operation mode for the following options: a) the absence of the damage, b) damage of 3 rods and c) damage of 3 segments of the short-circuited ring.

Conclusions. This article shows the algorithm of creation and calculation of the equivalent circuit of the IM rotor and the further modelling of its damages by using the National Instruments Multisim software on an example of the IM type 4A355M4U3. These algorithms are quite simple to use and allow you to conduct the researches on the distribution of the currents in the elements of the squirrel-cage rotor in different operation modes of the IM. It is worth to note that these algorithms could be used to carry out researches on any type of the IM with the SC rotor.

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