

Virtual Laboratory of Electric Motor in the Discipline of "Electrical Engineering and Electronics"



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Virtual Laboratory of Electric Motor in the Discipline of "Electrical Engineering and Electronics" ²

For several years, a purposeful work has been carried out at the Department of Diagnostic Information Technologies at the National Research University MPEI to create a set of electronic educational resources for the discipline Electrical Engineering and Electronics for the preparation of bachelors in the non-electrical fields for three institutes:

Institute of Thermal and Nuclear Energy (ITNE);

Institute of Energy Efficiency and Hydrogen Technologies (IEEHT);

Institute of Power Engineering and Mechanics (IPEM).

The discipline's work program includes the section "Electric machines", the study of which provides for laboratory work. At the department there are laboratory stands with electric machines, on which laboratory work is carried out in order to research and study by students the operational properties of electric machines. However, these laboratory stands are expensive, require constant monitoring and repair, and equipment quickly becomes obsolete.

List of designation:

VLW — virtual laboratory work;

EM — electric motor;

DCM — DC motors;

IM — induction motor;

TSM — three-phase synchronous motor;

CM — computer model.

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VIRTUAL LABORATORY OF ELECTRIC MOTORS

To improve the quality and effectiveness of the educational process, the Department developed VLW on EM, which provide the following features:

- to conduct experiments that are not possible on a real stand (for example, in emergency conditions or with overloads of EM);
- expand the range of research tasks, conduct experiments that are impossible in the laboratory due to the lack of the required special electrical devices and measuring instruments (for example, fast dynamic processes and unstable modes, experiments with changing the frequency of the supply voltage);
- provide individual work of students and high-quality verification of results;
- automate the processing of experimental information, speed up the experiment and increase its accuracy;
- receive and display on the computer screen in visual form significantly more complete information about the parameters, properties, characteristics and modes of the EM than can be obtained from measuring instruments at the laboratory stand;
- to promote the student's independent work by providing an alternative research program;
- use modern means of processing information and control results;
- generate a document - an electronic report on the results of laboratory work.

VLW developed by DCM, IM и TSM. Each VLW has two types of software: a modeling program interface and a laboratory work interface.

Virtual Laboratory of Electric Motor in the Discipline of "Electrical Engineering and Electronics" 4

Simulating the operation of a three-phase asynchronous motor

1

Rated power (kw): 3

Rated Speed (r / min): 2900

Mains voltage (V) (circuit - Y): 380

Network Frequency (Hz): 50

Nominal Efficiency (%): 84

Rated power factor: 0,88

Multiplicity of the max. mom: 3

Multiplicity of starting torque: 2

Equivalent moment of inertia: 0,1

2

Connection diagram: Star, Triangle

Engine design: Rotary rotor, Short-circuited

Select options from the database / Run engine simulation

Clear options / Continue process simulation

Clear charts / Complete process simulation

Exit from the program

4

Values of operational parameters

f(Hz) = 50	t(s) = 1,37
Glidle = 0,033	n(r/min) = 2901,18
Pm(w) = 3030,68	Mm(Nm) = 9,88
Pe(w) = 3538,04	Mr(Nm) = 9,98
Effic (%) = 85,64	Rd(Ohm) = 0,00
U(V) = 380,00	I(A) = 6,12
S(VA) = 4025,64	cos(phi) = 0,88

5

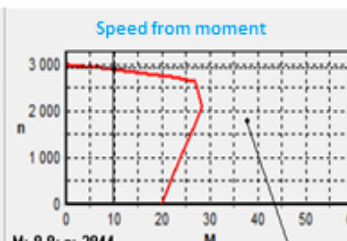
Vmod, U, V, F, Hz, M, Nm, Rd, Ohm

100, 380, 50, 9,88, 0

Ist = 35,05 A
MSt = 19,76 Hm
Mn = 9,88 Nm

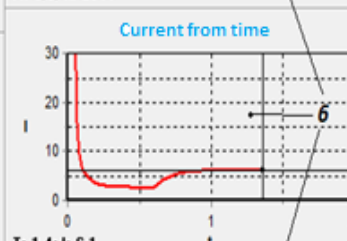
6

Speed from moment



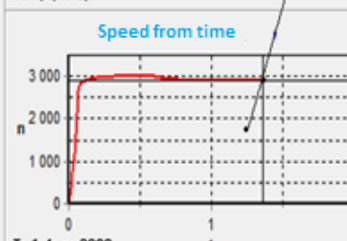
M: 9,8; n: 2944

Current from time



T: 1,4; I: 6,1

Speed from time

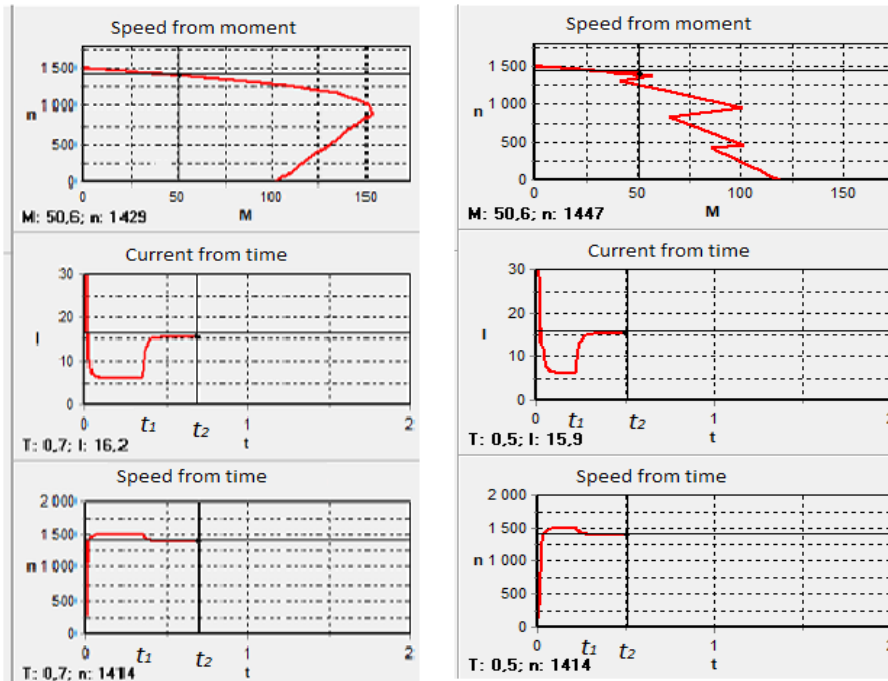


T: 1,4; n: 2899

View of the main window of the computer model of IM: 1 - area for setting source data; 2 - area for setting the phase connection diagram of the stator windings and rotor design; 3 - control area; 4 - display area of the current values of the main operating parameters; 5 - area for adjusting operational parameters; 6 - display area of graphical dependencies.

MODELING IM

As an example, left figure and right figure shows the dependency graphs obtained by simulating the starting processes of the IM with a squirrel-cage rotor (left figure) and with a phase rotor (right figure) without load (0-t₁), then the motor is loaded with a rated torque (t₁-t₂).



Virtual Laboratory of Electric Motor in the Discipline of "Electrical Engineering and Electronics" ⁶

COMPUTER MODEL FEATURES

CM allows you to explore the following modes of operation IM:

- Start: direct connection to the electrical network; at low voltage; switching stator windings from a triangle to a star; using a starting rheostat in the phase rotor circuit.
- Changing the moment of resistance on the shaft.
- Speed control: by changing the voltage of the power source; change in voltage frequency; the inclusion of an adjustment resistor in the phase rotor circuit.

State registration certificates received for EM simulation programs.

CM for DCM and TSM are constructed in a similar way and allow to study the main operational properties of EM.

Virtual Laboratory of Electric Motor in the Discipline of "Electrical Engineering and Electronics" 7

LPL No. 3. Operational properties of three-phase asynchronous motors. About

Enter your data

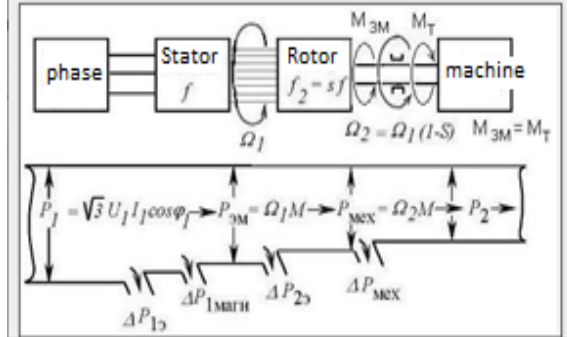
Student :*

Group :*

Group list number (1..30) Record ?

Job Option Number:

1. Objectives of work >
2. Preparation for work. >
3. Work task. >
4. Methodical instructions. >
5. The protocol of the results of work. >



The diagram illustrates the operational properties of a three-phase asynchronous motor. It shows the flow of power from the stator to the rotor and then to the machine. The stator is connected to a three-phase supply (phase) and has a frequency f and angular velocity Ω_1 . The rotor has a frequency $f_2 = sf$ and angular velocity $\Omega_2 = \Omega_1(1-s)$. The mechanical power developed in the rotor is $P_{2M} = \Omega_1 M$ and the mechanical power developed in the machine is $P_{2MEX} = \Omega_2 M$. The total mechanical power developed is $P_2 = P_{2M} + P_{2MEX}$. The diagram also shows the power losses in the stator ($\Delta P_{1\sigma}$), rotor (ΔP_{1MEX}), and machine ($\Delta P_{2\sigma}$).

VLW Interface Programs was made in the JAVA 2 language in the Integrated Application Development Environment NetBeans (IDE). They allow you to provide a complete individuality of tasks and independent work of the student.

Each VLW contains: goals of work, preparation for work, work assignment, guidelines for performing work, protocol of results. To go to the corresponding section, press the button to the right of the section name.

Virtual Laboratory of Electric Motor in the Discipline of "Electrical Engineering and Electronics" 8

2. Preparation for work.

2.1 ... 2.3. They are carried out at home according to the description of the work and presented to the teacher.

2.4. Your data corresponds to a TAM with a phase rotor of the type:

The phases of the stator windings TAM are connected in a star pattern. Mains voltage 380 V, frequency 50 Hz

P2 kW : n, r/min

Passport data TAM:
КПД, %: cosϕI:

Enter and check the rated design values:

Moment Mn, Nm:	<input type="text"/>	Verify	<input type="text"/>
Electric power P1n, kw	<input type="text"/>	Verify	<input type="text"/>
Stator current I1n, A	<input type="text"/>	Verify	<input type="text"/>
Number of Pole Pairs:	<input type="text"/>	Verify	<input type="text"/>
Glide:	<input type="text"/>	Verify	<input type="text"/>
Rotor Current Frequency f2:	<input type="text"/>	Verify	<input type="text"/>

2.5 ... 2.7. Are carried out at home according to the description of the work and are presented to the teacher:
2.8. The electric circuit of the setup for experiments, which is implemented in the TAD simulation program used below.

VIRTUAL LABORATORY INTERFACE

PREPARATION FOR WORK

After registration, the student enters, upon request, the calculation results at the homework preparation stage corresponding to the number in the group list and checks their values. According to the result of the check, a comment is displayed (Correctly / Not Correctly). The results of the verification are entered into the protocol of results, which the student can open for viewing.

Virtual Laboratory of Electric Motor in the Discipline of "Electrical Engineering and Electronics" 9

3. Work task

3.1. Run the model program with the TAD shortcut

3.2. Select from the catalog and set the type of engine

4A71B2Y3

Perform a direct and rheostatic start (using the starting rheostat) of the induction motor with a phase rotor in the absence of a load on the shaft. Take screenshots of the graphs $n(M)$ for direct and rheostatic launches induction motor .

3.3.1 Determine and record inrush currents and starting torque in direct start, calculate the multiplicity of starting current and starting torque. Enter and check their values:

In1, A:	13	Verify	OK
Mn1, H.M:	7.2	Verify	OK
KIn1:	5	Verify	Error
KMn1:	7	Verify	Error

Take screenshots of the graphs and put them in to protocol

>

To carry out the work task, the computer model of the IM is loaded and the motor type is selected from the database corresponding to the option number.

The main points of the work assignment:

- study of the launch of the IM with squirrel-cage and phase rotor;
- getting of mechanical and work characteristics;
- the study of ways to control the speed.

The interface for each item of the task provides for the verification of the results of the study of IM.

As an example in figure shows one of the items of the working assignment related to the study of the launch of IM with a squirrel-cage rotor, and in next slide by building a natural mechanical characteristic and work characteristics.

Virtual Laboratory of Electric Motor in the Discipline of "Electrical Engineering and Electronics" 1 0

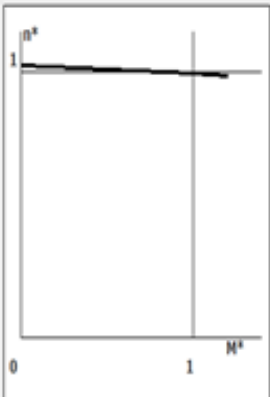
3.4. TAM Features:

To get graphs of performance, re-direct start and, changing the motor torque at rated voltage, get on the model and enter the values of torque, power and speed in the table

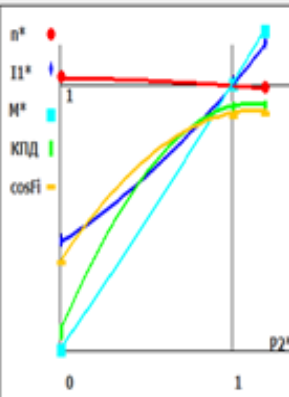
n, об/мин	I/A	M, Н·м	КПД, %	cosϕ	P2, Вт
2998	6	0.02	6.47	0.33	84.3
2901	14.76	24.7	89.7	0.88	7579
2880	16.98	29.64	90.2	0.89	8998

Graphs Y (P2) are plotted in relative values:
 $Y^* = Y/Y_{nom}, P2^* = P2/P2_{nom}$

3.4.1. Natural characteristic of TAM in relative units. V



3.4.2. Work characteristic of TAM in relative units. V



Characteristics are built on the three values of the variables obtained at the CM.

When constructing, the quadratic approximation is applied.

VIRTUAL LABORATORY INTERFACE

PROTOCOL OF WORK RESULTS

Based on the results of the VLW, a results protocol is generated (Fig. 8), which indicates:

- Name of student.
- Group number.
- Date, time of the beginning and end of the work.
- Points received.
- Results:% of correct answers; how many mistakes are made

5. Protocol of the results of work

Student	<input type="text" value="Иванов И.И."/>	Group	<input type="text" value="ТФ-9-13"/>	Student number	<input type="text" value="1"/>
Date	<input type="text" value="1 Март 2020"/>	Start	<input type="text" value="19:03:36"/>	End	<input type="text" value="19:06:17"/>
Points earned	<input type="text" value="10.0"/> из <input type="text" value="100.0"/>	success (%)	<input type="text" value="10.0"/>	Number of errors	<input type="text" value="2"/>
Work	Не завершена				

Thank you for attention!

Speaker's contacts:



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