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Modern Techniques to Test the In Load Operation of a DC Motor with Separate Excitation Using an Acquisition and Data Processing System

Florica Novacescu, Daniel Velcea, and Eugen Raduca

Abstract. The utility of this paper is to experimentally determine the in load operation characteristics and the mechanic characteristic of a direct current engine through the use of an acquisition and data processing system. In this paper we proposed to check the operation process of a DC motor with separate excitation using an acquisition and data processing system, through which we determined the operation characteristics of this engine, because the operation process of the direct current engine with excitation derivation can be observed through the medium of the operation characteristics. Data acquisition involves gathering signals from measurement sources and digitizing the signal for storage, analysis, and presentation on a PC. Data acquisition (DAQ) systems come in many different PC technology forms for great flexibility when choosing your system. Scientists and engineers can choose from PCI, PXI, PCI Express, PXI Express, PCMCIA, USB, Wireless and Ethernet data acquisition for test, measurement, and automation applications. There are five components to be considered when building a basic DAQ system: transducers and sensors, signals, signal conditioning, DAQ hardware, and driver and application software.

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Key words and phrases. Acquisition and data processing system, transducers and sensors, operation characteristics, mechanic characteristic, DC motor.

1. Introduction

Data acquisition begins with the physical phenomenon to be measured. This physical phenomenon could be the temperature of a room, the intensity of a light source, the pressure inside a chamber, the force applied to an object, or many other things. An effective DAQ system can measure all of these different phenomena.

A transducer is a device that converts a physical phenomenon into a measurable electrical signal, such as voltage or current. The ability of a DAQ system to measure different phenomena depends on the transducers to convert the physical phenomena into signals measurable by the DAQ hardware. Transducers are synonymous with sensors in DAQ systems. There are specific transducers for many different applications, such as measuring temperature, pressure, or fluid flow.

Different transducers have different requirements for converting phenomena into a measurable signal. Some transducers may require excitation in the form of voltage or current. Other transducers may require additional components and even resistive networks to produce a signal. Sometimes transducers generate signals too difficult or too dangerous to measure directly with a DAQ device. For instance, when dealing with high voltages, noisy environments, extreme high and low signals, or simultaneous signal measurement, signal conditioning is essential for an effective DAQ system.

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Signal conditioning maximizes the accuracy of a system, allows sensors to operate properly, and guarantees safety. It is important to select the right hardware for signal conditioning. Signal conditioning is offered in both modular and integrated forms. Signal conditioning accessories can be used in a variety of applications including: amplification, attenuation, isolation, bridge completion, simultaneous sampling, sensor excitation, multiplexing.

This paper consists of two major parts. The first part of paper presents some theoretical notions referring to the electrical machines, acquisition and data processing system, transducers and sensors, sampling and quantization of signals and to the programming medium LabVIEW. In the second part of this paper presents the practical acquisition of data necessary to increase the operation characteristics and the mechanic characteristic of the direct current engine with separate excitation.

2. Generalities regarding the direct current engine with excitation derivation

The operation process of the direct current engine with excitation derivation can be observed through the medium of the operation characteristics which are represented in the relations: (1), (2) and (3):

$$n = f(P_2) \tag{1}$$

$$M_2 = f(P_2) \tag{2}$$

$$\eta = f(P_2) \tag{3}$$

where the useful power P_2 is an independent variable, for the supply tension, the excitation current and the resistance of the rotor circuit are constant and n, M_2 and η represent the revolution, the useful mechanic torque and the efficiency.

For the electric drives, the mechanic characteristic is also presented $n = f(M)$.

For the direct current engine with (separate) excitation derivation, the operation characteristics are given in figure 2.

In figure 2 the rate of the characteristic given by the equation (1) is represented by one of the curves 1, 2, 3.

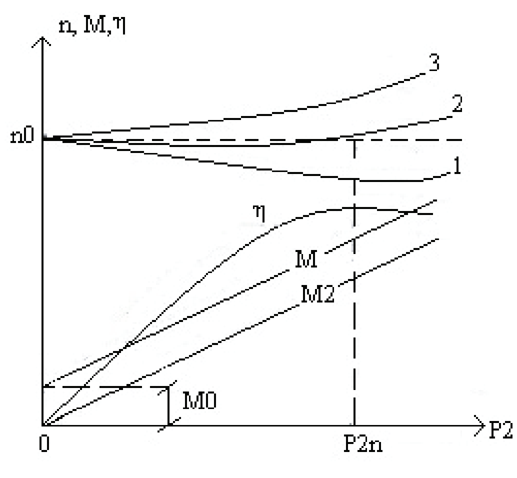

FIGURE 1. The operating characteristics of DC motor with excitation derivation

The theoretical mechanical characteristic is represented in figure 2.

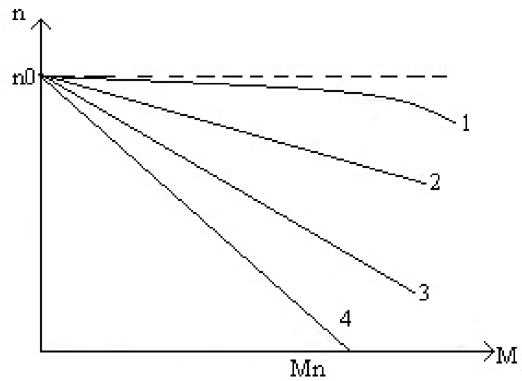

FIGURE 2. The mechanical characteristics of the direct current engine with excitation derivation

In figure 2, n_0 and M_n represent the revolutions of no-load work and respectively the nominal mechanic torque, in consequence characteristic 1 represents the natural mechanic characteristic and the characteristics 2, 3, 4 are the artificial mechanic characteritics.

3. Transducers and Sensors

Having in view that a large part of the measures to be acquired are non-electric and the transmission, memorizing and processing medium is electric, we use transducers which transform the non-electric values in electric values.

Measuring a value supposes first of all its detection. The sensitive elements which detect the values to be measured are called sensors. The sensor has the role to detect the value to be measured x(t) applied to its input and to convert it in another physical value, having the same nature or another nature, $y_{int}(t)$, which can be easily measured, most frequently electrically, the value thus obtained at the sensors output is applied to the input of the adapting and processing circuit (adapter). The conversion of the input value in output value to sensors is based on the physical and chemical effects.

The transducer can have in its construction several sensors capable to achieve the conversion of the value to be measured in an electrical value indirectly through many intermediate stages until the achievement of the final output value y(t).

The transudcer is a conversion element which transforms a non-electric value in a value which can be electrically evaluated.

The unit composed of the sensitive element (the sensor) and the adaptation elements (circuits) and the processing elements (conditioning the signals) is called *transducer.*

4. Acquisition and Data Processing Systems

The data acquisition systems are complex systems of monitoring some processes in which usually intervene several physical values. They achieve the assay through some adequate transducers of analogical and numerical signals (according to the nature of the transducer), having the aim of memorizing, transmitting or processing the acquired information, monitoring and control of terrestrial, naval or aerial traffic.

An ADPS (acquisition and data processing system) can contain only the channel of picking and processing data about the observed values or it can also contain (control) reaction links through which we can act upon the controlled values.

The channel of picking - processing signals contains: transducers and sensors which transform any value in electric signal, the signal processing system, in which the basic electric signal is changed in a signal convertible in a numeric code, the signal quantifying system which realizes the array of signal samples and the analogue - digital conversion, the computer which takes over the basic data through the standardized interface .

The computer leads the whole process of acquisition, memorizes data, displays the basic data and the processed data, receives commands from the operator. The computer immediately processes the input data (in real time) or makes calculations on the memorised data. Through an adequate interface the computer can communicate the selected data to other computers of similar hierarchic rate or to the strong leading and surveillance computers or to receive instructions from other computers (generated data).

The control channel is presented in all the acquisition and data processing systems and through its medium it is achieved an optimal leadership adapted to the process whose characteristic values were gathered. This channel contains: the computer which emitted the values assigned of the controlled values, the signal transmission block which contains signal channels through which the transmission of the commands is realised according to the protocols of (specific) transmission, processing the commands which usually also contains the digital-analogical conversion, performance elements which perform the correction actions of the controlled values.

5. Sampling and Quantization of Signals

The numeric signals are obtained by taking at a certain moment the values of analogic signals and the conversion of these samples into numeric sequence.

Sampling means to take the values of the analogic signal at different concrete moments in time.

Quantifying represents the attribution of a numeric code to a value from an infinite set of values.

The way to choose the values for N,f_e,Δt takes into account the theorem of sampling according to which a signal can be reproduced from its samples if only the frequncy of samples is at least two times larger than the maximum frequency of the spectrum, that is:

$$f_e \geq 2 \cdot f_m \tag{4}$$

Thus, $f_{emin} \cong 2 \cdot f_m$ .In LabView $f_{emin} \cong 10 \cdot f_m$.
The number of samples in a period is:

$$N_p = \frac{f_e}{f_m} \tag{5}$$

It is recommended that: $N_{min} = (5 \div 20)N_p$.
The duration of sampling is: $\Delta t = \frac{N}{f_e}$, and the number of samples in the time interval, Δt, is: $N = f_e \cdot \Delta t$

6. The programming medium LabVIEW

In the framework of the acquisition and data processing system, the programming medium has the role to take over and process the information received from the digitizer (acquisition board), it fulfills the following functions: it controls and commands the whole acquisition system, it takes over the digitized values gathered through a communication line, it restructures the signal in the samples (digital-analogue conversion), it determines certain values characteristic for the signal (amplitude, peak value, etc), it performs a soft filtering of the signal, it performs a Fourier analysis (spectral), it performs different arithmetical operations (addition, multiplication, radical, integration, differentiation, etc).

The LabView medium is in fact a graphic programming language in which the code is not written as text but with the use of pictographs. The programs (applications) performed with LabView are called virtual instruments because they reproduce the operation of real instruments such as: ammeter, voltammeter, oscilloscopes, ohmmeter, multimeter, etc.

A *virtual instrument* can be summarily described as being made up of two different windows which are connected.

The Front Panel - defines the graphic interface with the user or what the user will see on the computer screen; it is an interface which contains graphic representations for buttons, cursors, switches, graphics, etc, these representations being similar with those of the real instruments. This interface user (front panel) is built using controls and indicators. By controls, the user introduces or up-dates the values of the input data (Get type objects), and the indicators are used in order to display the results of the processing (Say type objects). If the virtual instrument is regarded as virtual sub-instrument (thus, as sub-routine), then the controls correspond to the input formal parameters and the indicators are the formal output parameters. The controls are: revolving buttons, push buttons, scales and other input mechanisms and the indicators are: graphics, LEDs and other output displays.

The Block Diagram - retains the code of the program and it defines the functionality of the virtual instrument being realised under the form of a diagram of data flows with symbols and connections between symbols. This contains the functions of the virtual instrument. Programming an application in LabVIEW is done on the data flow principle using the "G" graphic language. The graphical symbols are connected as in a block scheme. This block scheme constitutes the program of the application.

7. The practical acquisition of data necessary to increase the operation characteristics and the mechanic characteristic of the direct current engine with separate excitation.

The operation of the engine is monitored through the operation characteristics which represent the dependences: $n = f(P2)$, $M2 = f(P2)$, $\eta = f(P2)$, for the tension of rotor suply, the resistance of the rotor circuit, where n is rotation, $M2$ is mechanic torque, η is efficiency and $P2$ is mechanic power.

In order to determine these in load operation characteristics, the mounting in figure 4 was achieved and used:

As load for the engine, it was used a generator of direct current with separate excitation and a stand of light bulbs mounted in parallel to the terminal of the generator which were in turn switched on, thus, modifying the value of the load.

The following values were acquired: tension of rotor supply, excitation current, rotor current (load current), mechanic torque, excitation tension and the engine revolution.

There were directly acquired the excitation tension and tension of rotor supply using the channels *ai3* and *ai0* of the tension module *SCXI-1125* foreseen with the terminal block *SCXI-1313* used for the extension of the measurement field.

For the acquisition of the excitation current and the rotor current there were used two (T.C. noted) current transducers 3A of *LEM* type which were connected to the channels *ai1* and *ai2* of the same module *SCXI-1125*, choosing tension as measured value, but in order to obtain the current a conversion scale was introduced which has the form: $i = 4.8u - 12$.

For the measurement of the revolution, it was used a transducer of incremental revolution T.n. type *Elcis Encoder* which was connected to the rotor axis. The output of the transducer where we obtain a pulse for every complete revolution. Thus, the frequency of the revolutions is exactly the revolution expressed in rot/s. This is measured on the channel *ai0* of the module *SCXI-1126* which is a converter frequency-tension. The value obtained was multiplied by 60 in order to obtain the revolution in rot/min.

For the measurement of the torque we used a torque transducer of type *transducer techniques* which has TEDS (Transducer Electronic Data Sheet) and is 22,6 Nm (200 inch lbs.). It is compatible with the module *SCXI-1520* foreseen with the connector terminal block conector *SCXI-1314T*. The maximal revolution is 7000rpm. It is connected in line through shaft key. The bridge is supplied with 10V at an intern source of the module SCXI-1520.

The torque transducer measures in fact the tangential strains produced by the torque resistant to the surface of the transducer axis which are directly proportional with the torque. Thus, we use four tensorezistive stamps mounted in Wheastone bridge. The link with the exterior is achieved with 4 collecting rings mounted on the transducer axis and insulated, on each one there is a brush. At two of them the supply diagonal of the bridge is connected and the supply tension is provided by the module SCXI-1520 with the connector block SCXI-1314T and the other two rings are connected to the indicating diagonal where the imbalance tension is obtained which is directly proportional with the torque to be measured.

In order to obtain these characteristics, two virtual instruments were achieved: one for the data acquisition and their writing in a text file and the second virtual instrument is for reading the data in the text file and the achievement of the necessary processing which has the front pannel for the visualisation of the resulted operation characteristics.

The data acquisition is done with the help of the function *DAQ Assistant* presented in the block diagram in Figure 5. This function allows the selection and denomination of channels on which the data acquisition is done and the establishment of the type of acquired signal (ex: current, tension, frequency, etc) on each channel.

The 6 simultaneously acquired signals are separated using *Select Signals* and for each signal using *Amplitude and Level Measurements* determining the average value, thus, elminating the disturbances, as shown in Figure 5.

The acquired measures are written in a text file with the help of the function *Write to Measurement File* for a subsequent use of these ones in the virtual instrument achieved for the data reading from the text file and achieving the necessary processings which has the front pannel in order to visualize the operation characteristics.

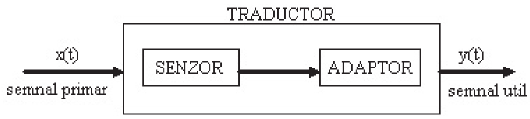

FIGURE 3. The general scheme of a transducer

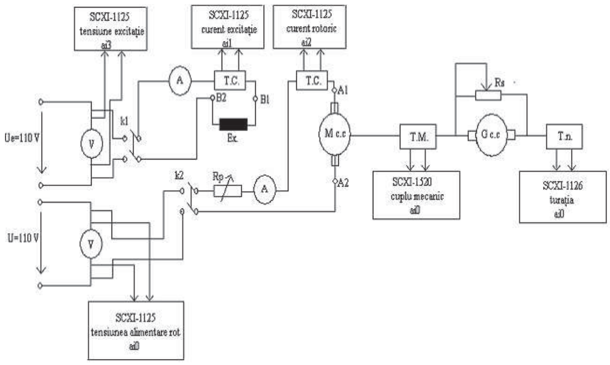

FIGURE 4. The electric sheme of the mounting achieved for the in load operation of the direct current engine with separate excitation (derivation)

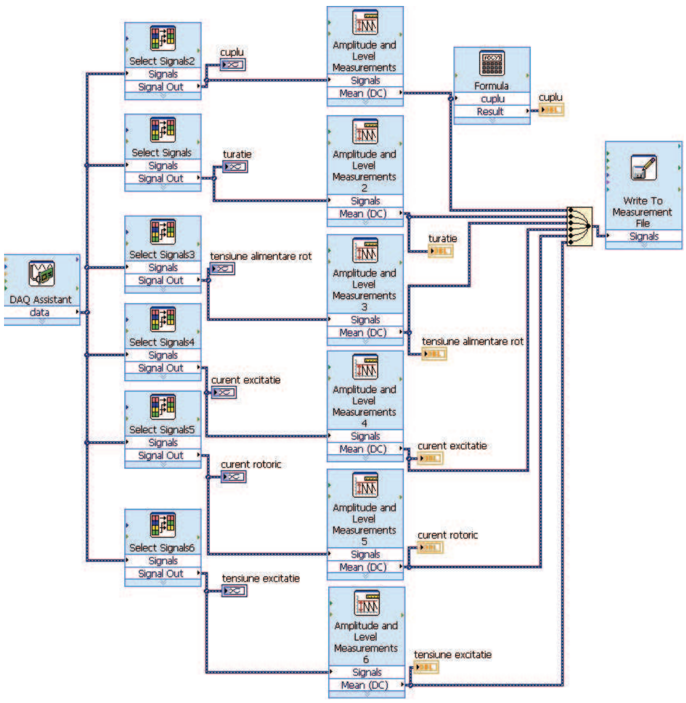

FIGURE 5. The block diagram of the virtual instrument achieved for the acquisition measures necessary for the increase of the in load operation characteristics and the mechanic characteristic

Because the two tensions are taken from a rectifier, we can observe that they are not perfectly constant but they are pulsating because at the rectifier output we obtain a pulsating signal, but due to the fact that the pulses are low, it is considered that the respective signal is constant, thus, the currents will also be pulsating. The torque is almost constant and the torque records maximal and minimal values increasing suddenly up to a certain value and oscillating lightly around the respective value after that it drops to a minimal value and oscillates around that value.

In the block diagram of the virtual instrument achieved for the reading of data presented in Figure 7 the data in the text file were read and they were written using the block diagram in Figure 5, after that some data were selected and the electric power was calculated with relation (6) where U_e represents the excitation tension, I_e represents the excitation current, U - the rotor supply tension and I - the current of rotoric supply,

$$P_1 = U_e \cdot I_e + U \cdot I \tag{6}$$

the mechanic power using relation (7) where: M_2 - mechanic torque in shaft and n - the rotor revolution,

$$P_2 = M_2 \cdot \frac{\Pi \cdot n}{30} \tag{7}$$

and efficiency :

$$\eta = \frac{P_2}{P_1} \tag{8}$$

and then we achieved the graphics which present the operation characteristics of the engine.

The reading of the text file where they were written is done with the help of the function Read From Measurement File.

The signals are selected using the function Select Signals and the calculations are done using the formulas (6), (7) and (8) using the function Formula.

The graphic visualization of the characteristics is possible due to the use of the functions Build XY Grph at whose output a graphic indicator is connected.

The function Build Table allows the writing of results in a table.

In Figure 8 it is presented the operation characteristic $\eta = f(P_2)$. It is observed that the efficiency increases as the mechanical power increases.

In Figure 9 the operation characteristic is represented and it is given by the relation $n = f(P_2)$. We observe that the revolution remains almost constant until the mechanical power exceeds the value of 500W when the revolution begins to decrease lightly because the value of the load increases and the engine must develop a higher power which leads to the decrease of the revolution.

In Figure 10 it is represented the operation characteristic of the direct current engine given by the relation: $M2 = f(P2)$. We observe that the mechanic torque increases almost linearily with the increase of the mechanical power.

The values of the acquired measures are given in Table I and these confirm the graphical results previously presented.

It is common for the direct current engines to have also the mechanical characteristic given by the relation: $n = f(M_2)$.

In order to determine this characteristic a virtual instrument was built which has its blcok diagram in Figure 11. The data necessary for the increase of the mechanical characteristic are read from the same text file from which we have also read the data necessary for the increase of the operation characterstics of the direct current engine.

The mechanic characteristic is a line if the excitation flow is constant. In the proximity of the nominal load the flow decreases a little due to the saturation, the revolution decreases even more, its variation according to the torque deviating from a line, fact which results from the front pannel of the virtual instrument achieved for the determination of the mechanic characteristic of the direct current engine which contains a mechanic characteristic.

From Figure 12 it results that the revolution remains aproximately constant until the mechanic torque exceeds the value 3Nm, moment when the revolution starts to visibly decrease.

8. Conclusions

The scheme is not complex which is an advantage to use in various applications. The presented solution is flexible and can be applied to a broader range of engine models with a minimum level of knowledge. We note that all starting characteristics mentioned in the work correspond with theoretical data, which means that both data acquisition and processing were performed with high precision.

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(Florica Novacescu) Faculty of Engineering Eftimie Murgu University, Resita, Romania
E-mail address: f.novacescu@uem.ro

(Daniel Velcea) Faculty of Engineering Eftimie Murgu University, Resita, Romania
E-mail address: d.velcea@uem.ro

(Eugen Raduca) Faculty of Engineering Eftimie Murgu University, Resita, Romania
E-mail address: e.raduca@uem.ro

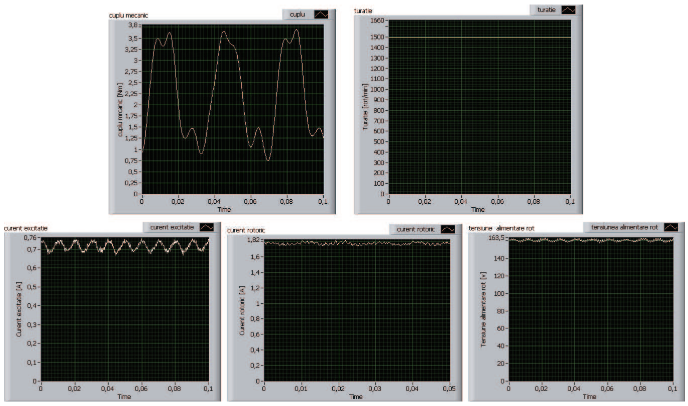


FIGURE 6. The front panel of the virtual instrument achieved for the acquisition of the measures necessary to the increase of the operation characteristics of the direct current engine with excitation derivation

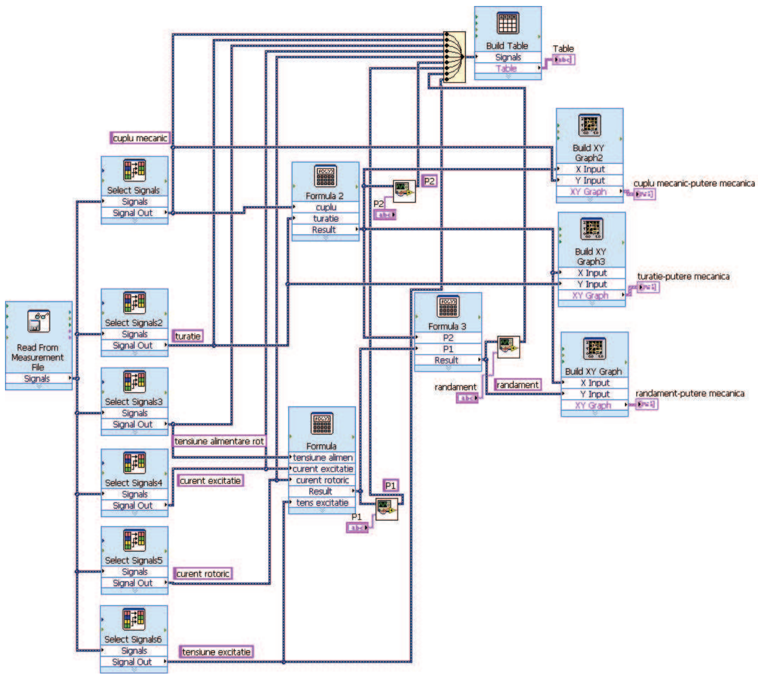


FIGURE 7. The block diagram of the virtual instrument achieved for the determination of the operation characteristics of the direct current engine

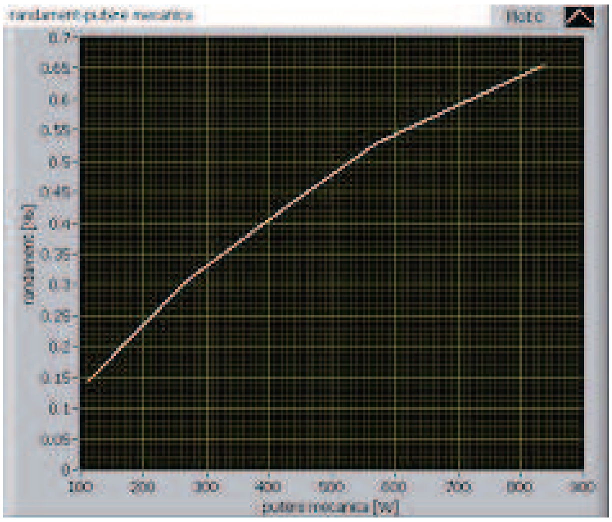


FIGURE 8. The characteristic given by the efficiency according to mechanic power

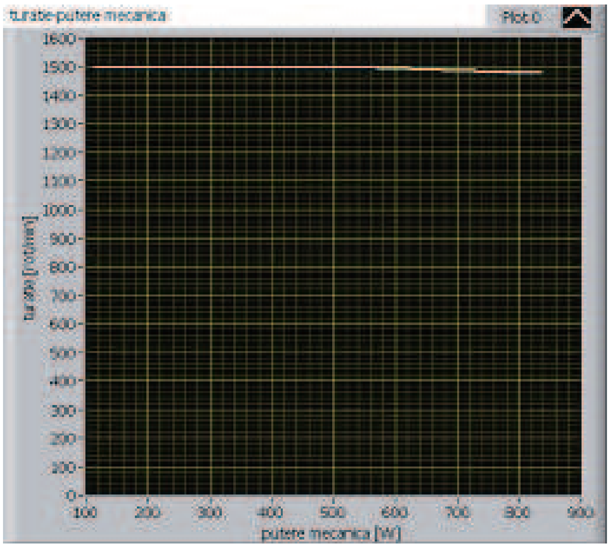


FIGURE 9. The operation characteristic represented by the speed according to the mechanic power

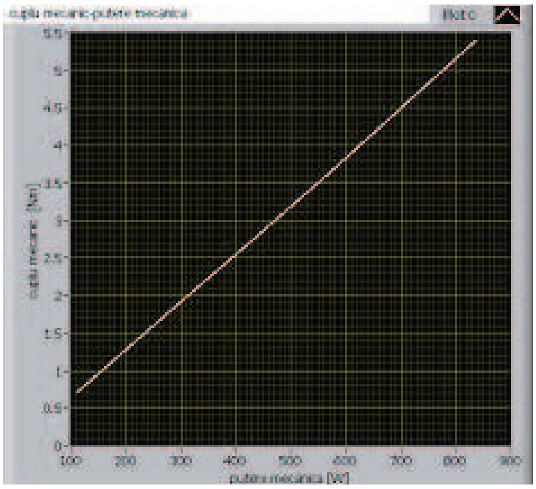
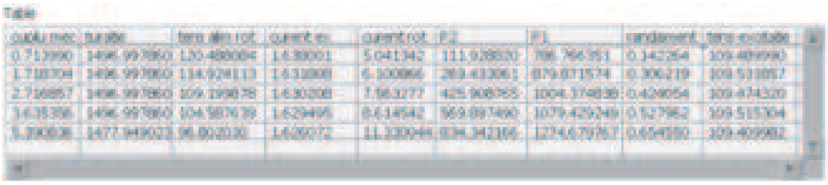


FIGURE 10. The operation characteristic represented by the mechanic torque according to the mechanic power



Table

cuplu mec	turatie	tens alim rot	curent ex	curent rot	P2	P1	randament	tens excitatie
0.713990	1496.997860	120.488084	1.630001	5.041342	111.928820	786.766351	0.142264	109.409990
1.718704	1496.997860	114.924113	1.631000	6.100866	269.433061	879.071574	0.306219	109.533857
2.716857	1496.997860	109.199878	1.630200	7.563277	425.908765	1004.374838	0.424054	109.474320
3.635356	1496.997860	104.587639	1.629495	8.614542	569.897490	1079.429249	0.527962	109.515304
5.390836	1477.949023	96.802030	1.626072	11.330044	834.342166	1274.679767	0.654550	109.409982

FIGURE 11. Tabel 1

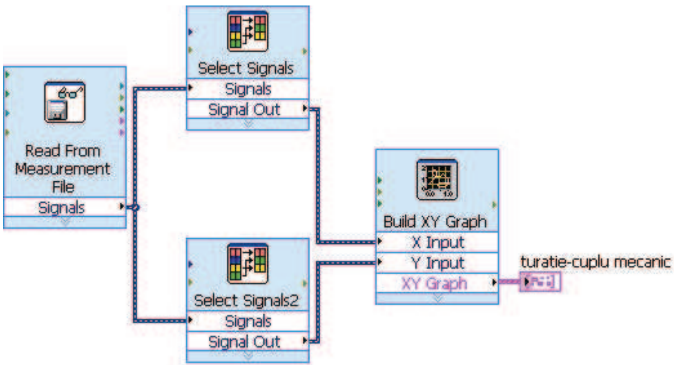


FIGURE 12. The block diagram of the virtual instrument achieved for determining the mechanical characteristic

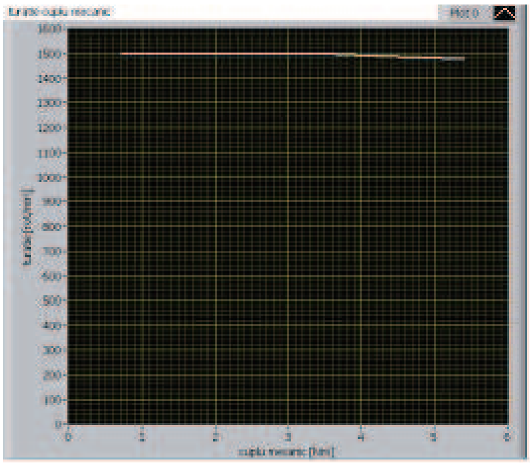


FIGURE 13. The front panel of the virtual instrument achieved for determining the mechanical characteristic