UDK 621.3.067

NUMERICAL MODEL OF LENZE 530 SERIES DC DRIVE WITH NEGATIVE VOLTAGE FEEDBACK IN MATLAB

I.M. GOLODNY**, Ph.D (Tech)**
J.M. LAWRINENKO**, Ph.D (Tech)**
National University of Life and Environmental Sciences of Ukraine
A. TOROPOV**, Ph.D (Tech)**
"CIT Altera" Ltd.

Model of electric DC thyristor voltage regulator Lenze 534 with negative voltage and armature feedbacks and electromechanical characteristics research results are presented.

Transition process, semiconductor voltage converter, feedback, P-regulator electromechanical characteristics, the model.

The authors published a series of articles in which recommendations about obtaining of information about work in transients of regulated electric drive based on modern semiconductor voltage converters including DC drives Lenze 530 Series are presented. Research of natural characteristics is recommended to make based on computer models of the system MatLab. Converters work with negative armature voltage feedback (IxR-compensation) or speed tachometer voltage feedback [3]. In [2] a model of electric thyristor voltage regulator Lenze 534 and negative feedback on the speed and results of investigations of the electric drive are presented.

This paper is devoted to modelling of electric Lenze controller 534 and the negative armature voltage feedback.

Aim of paper - to provide reliable performance of DC drive with semiconductor voltage converter Lenze 530 Series at transient processes in MatLab system computer models with a significant reduction of time and reduce material costs.

Materials and research methods. Analysis of driving performance was based on the theory of electric drive using a computer model of the system MatLab.

Research results. Dual circuit system "thyristor voltage converter - motor" with negative feedback from current and voltage armature is shown in Fig. 1. By introduction in to the system of current feedback the limitation of current and torque and by armature voltage - speed automatic stabilization are achieved.

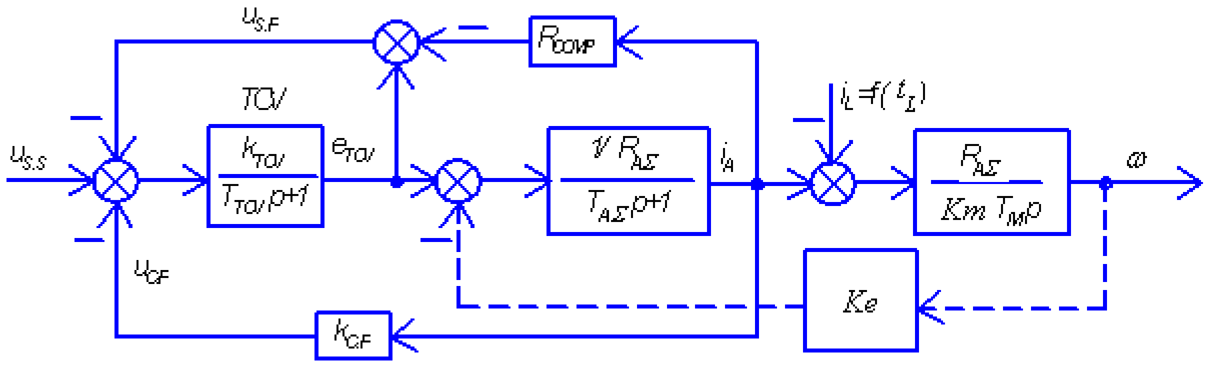


Fig. 1. Dual circuit structural diagram of "TCV-DC motor" system with negative feedback for the current and armature voltage:

$u_{S.S}$ – speed signal setpoint; $u_{S.F}$, $u_{V.F}$ – feedback signals by speed and armature voltage; $u_{C.F}$ – current feedback signal; R_{COMP} – compensation resistance; $R_{A\Sigma}$ – total resistance of armature circuit; TCV– thyristor voltage converter; k_{TCV} – TCV gain; k_e– electrical constant of DC motor; k_m– mechanical constant of DC motor; $k_{C.F}$– current feedback gain; T_{TCV}, $T_{A\Sigma}$ – electromagnetic time constants of TCV and armature current; T_M – electromechanical time constant; e_{TCV} – EMF of thyristor voltage converter; i_A, i_L – instantaneous value of the circuit armature current and current, that is proportional to the load of the working machine; t_L – instantaneous value of load torque; p – Laplace operator.

Current feedback gain $k_{C.F}$ is determined from maximum voltage of speed $u_{S.S}$ and maximum (starting) current output:

$$k_{C.F} = \frac{u_{S.S}}{\lambda_I I_N}, \quad (1)$$

де λ_I – allowable multiplicity of starting current; I_N – rated current of the motor.

EMF stabilization of TCV is achieved by supplying of negative feedback coherent signal $u_{V.F} = e_{TCV} - i_A R_{COMP}$ to the input of adjustment speed signal. Changing of R_{COMP}, we can regulate feedback gain value. When load is increases the voltage at motor connectors is decreases due to losses at armature circuit. This increases the voltage drop across the resistance R_{COMP}, the signal from which is subtracted from the

e_{TCV} and consistently applied to the input $u_{S.S.}$. The output voltage of TCV is automatically increased.

According to structural diagram of the electric drive (Fig. 1) we can write the following equations of electromechanical characteristics with negative feedback of current and armature voltage:

$$\begin{cases} k_{TCV}[u_{S.S} - (e_{TCV} - i_A R_{COMP}) - k_{C.F} i_A] = (T_{TCV}\, p + 1) e_{TCV}, \\ e_{TCV} - k_e \omega = R_A (T_{A\Sigma}\, p + 1) i_A; \end{cases} \tag{2}$$

After the transformation equations (2) we obtain the expressions of dynamic electromechanical and mechanical characteristics of electric drive:

$$\omega = \frac{k_{TCV} u_{S.S}}{k_e[(T_{TCV}\, p + 1) + k_{TCV}]} - \\ - \frac{R_A[(T_{TCV}\, p + 1) + k_{TCV}](T_{A\Sigma}\, p + 1) + k_{TCV} k_{C.F} - k_{TCV} R_{COMP}}{k_e[(T_{TCV}\, p + 1) + k_{TCV}} i_A; \tag{3}$$

$$\omega = \frac{k_{TCV} u_{S.S}}{k_e[(T_{TCV}\, p + 1) + k_{TCV}]} - \\ - \frac{R_A[(T_{TCV}\, p + 1) + k_{TCV}](T_{A\Sigma}\, p + 1) + k_{TCV} k_{C.F} - k_{TCV} R_{COMP}}{k_e k_m[(T_{TCV}\, p + 1) + k_{TCV}} t_L. \tag{4}$$

When $p = 0$, equation (3) and (4) are the equations of static electromechanical and mechanical characteristics:

$$\omega = \frac{k_{TCV} u_{S.S}}{k_e (k_{TCV} + 1)} - \frac{R_A (k_{TCV} + 1) + k_{TCV} k_{C.F} - k_{TCV} R_{COMP}}{k_e (k_{TCV} + 1)} i_A; \tag{5}$$

$$\omega = \frac{k_{TCV} u_{S.S}}{k_e (k_{TCV} + 1)} - \frac{R_A (k_{TCV} + 1) + k_{TCV} k_{C.F} - k_{TCV} R_{COMP}}{k_e k_m (k_{TCV} + 1)} t_L. \tag{6}$$

Stiffness of the mechanical characteristics in the closed system depends on the feedback gains, namely from coefficients $k_{C.F}$ i R_{COMP}. So, at $R_A(k_{TCV}+1)+k_{TCV}k_{C.F}= k_{TCV}R_{COMP}$ characteristics has infinite rigidity $\beta=\infty$, and at $R_A(k_{TCV}+1)+k_{TCV}k_{C.F}<k_{TCV}R_{COMP}$ – has a positive rigidity $\beta>0$.

DC Drive model in MatLab (Fig. 2), which consist of TCV Lenze 543, DC motor MI32 314-02 and negative armature voltage and current feedbacks, was created. Specification is given at [2].

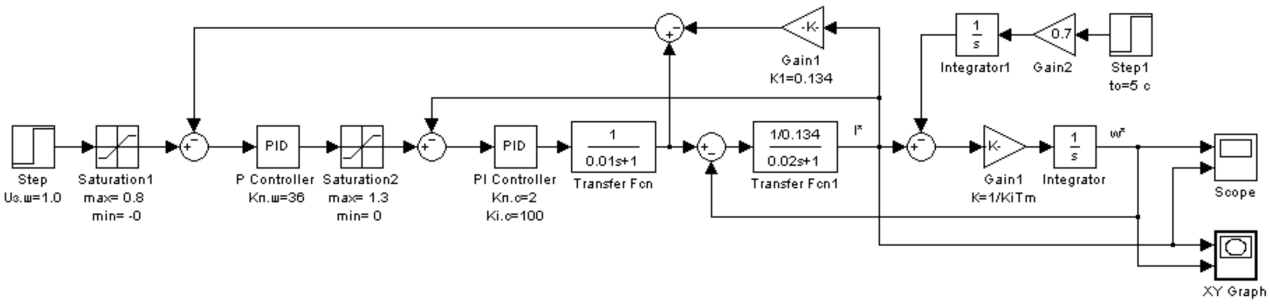


Fig. 2. Numerical model of DC drive with negative armature current and voltage feedbacks

Input parameters of the model are given in relative units. To convert them from relative units to the real it is need to multiply obtained results with the corresponding baseline values U_N, I_N, R_N and ω_0.

In present model block "Transfer Fcn" models link of armature motor with T_A = 0.02 s and gain of $1/R_A^*$, and block "Transfer Fcn1" models link of voltage thyristor converter with T_{TCV}= 0,01 s. Block "Integrator" and block "Gain" with coefficient K=1/$k_I T_M$ implement the equation of drive motion. The load current is formed by blocks "Step1 ", "Gain2" with coefficient K_2= 0,7 and "Integrator1" as the integral from continuous signal.

To achieve high accuracy of speed control was necessary to simultaneously control armature current (torque). For this purpose subordinate control system with certain standard settings is used.

The basis of the first circuit is a PI controller, TCV and armature winding of motor, covered by negative feedback of armature current. Usually the current controller is adjusted at technical optimum. However, according to the theory of automatic control [3] it is required that the transfer function of controller had the form:

$$W_{C.R}(p) = \frac{T_{A\Sigma} p + 1}{T_{TCV}\, p}. \qquad (7)$$

According to (7) the gains of current regulator are next:

- integral gain coefficient

$k_{I.C}$=1/T_{TCV}= 1/0,01= 100;

- proportional gain coefficient

$k_{P.C}=T_{A\Sigma}/T_{TCV}$= 0,02/0,01= 2.

The external circuit with armature voltage negative feedback is adjusted at technical optimum and contains a proportional regulator too. Coefficients are taken from transfer function of controller [1, 4]:

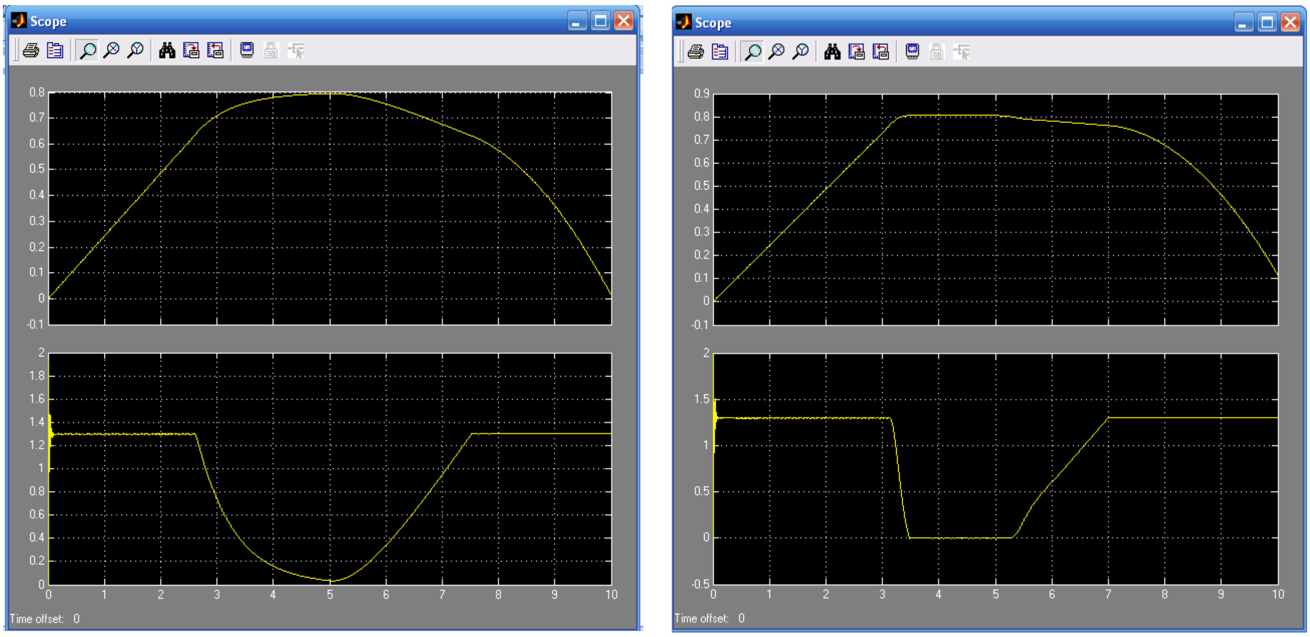
$$W_{I.R}(p)=\frac{T_M}{2T_{TCV}}. \tag{8}$$

According to (8) speed regulator gain is:

$$k_{S.R}=0{,}72/(2\cdot 0{,}01)=36.$$

Control of the model is adjusted by “Step” block, which specify the output voltage of TCV. Model has two limiting blocks “Saturation”. “Saturation1” is used for limiting of maximal n_{max} and minimal n_{min} angular speed, “Saturation2” – for limiting of maximal armature current I_{max}. To visualize the electromechanical (mechanical) characteristics “XYGraph” is used, and at the oscilloscope “Scope” trends of angular speed and armature current are observed.

The simulation results of the electric drive work are shown at Fig. 3 and 4.

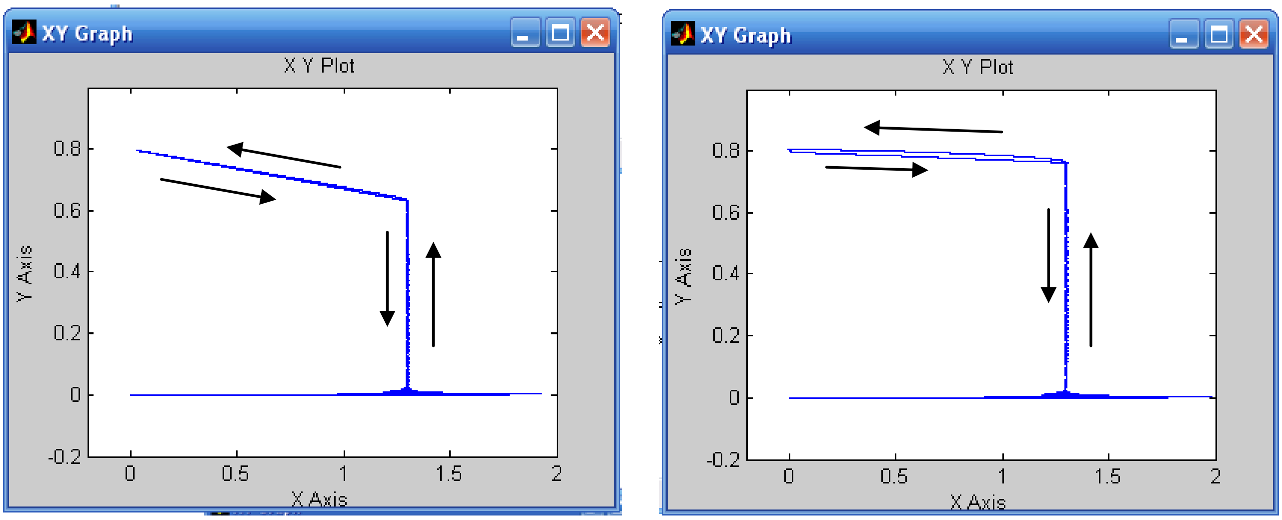


а *б*

Рис. 3. Angular speed (top) and armature current (bottom) transients.

a **–** $\boldsymbol{R_{COMP}}$**= 0,034 p.u.;** ***b*** **–** $\boldsymbol{R_{COMP}}$**= 0,134 p.u.**

The process of the motor work modelled as follows. Motor starts with no-load (Fig. 3), and after 5 s, the load starts to increase. According to adjusted value of speed the limits are set: for the speed up to 0,8ω_0, and for the current up to– 1,3I_N. Numerical model accurately tracks established limits, as shown at Fig. 6. At start when the difference between adjusted and actual speed value is large enough, speed controller switches to "saturation" mode. Herewith current setpoint is constant and we have only armature current control loop. Due to PI-regulator the value of armature current remains constant and angular speed increases linearly (Fig. 6). When P-regulator of angular speed (armature voltage) comes out from «saturation», control system becomes dual-loop with internal current regulation loop and external voltage regulation loop. This increases the rigidity of characteristics, but they become not absolutely rigid because of using of P-regulator. Starting current drops and the system stabilizes the angular speed at adjusted level. When the motor load becomes greater than the critical torque, the motor speed is reduced and the system again switches to stabilize the current.



а *б*

Fig. 4. Electromechanical characteristic of the drive:
***а* – R_{COMP}= 0,034 p.u.; *б* – R_{COMP}= 0,134 p.u.**

There is the following explaining of the obtained electromechanical characteristics (Fig. 4). When starting the motor there is a slight wobble of starting current, then it is held at the maximum allowable level, while the motor speed increases. When the current becomes less than the maximum, angular speed increases linearly up to maximum 0,8ω_0. When the load increases, the reverse process occurs.

At Fig. 4, *b* it is good to see the impact of dynamic moment when over clocking motor (upper curve of electromechanical characteristics).

Simulations performed for two values of feedback gain of armature voltage , determined by resistance R_{COMP} (compensation coefficient). As shown in Fig. 6 rigidity of electromechanical characteristics increases with increasing feedback gains, confirming the theoretical calculations previously presented. Coefficient of compensation in electric drive Lenze Series 530 is adjusted by "I×R" potentiometer.

In Fig. 5 shows electromechanical characteristics which obtained at laboratory equipment. Analysis of graphs confirms the adequacy of the results obtained on the model and at the real drive.

.

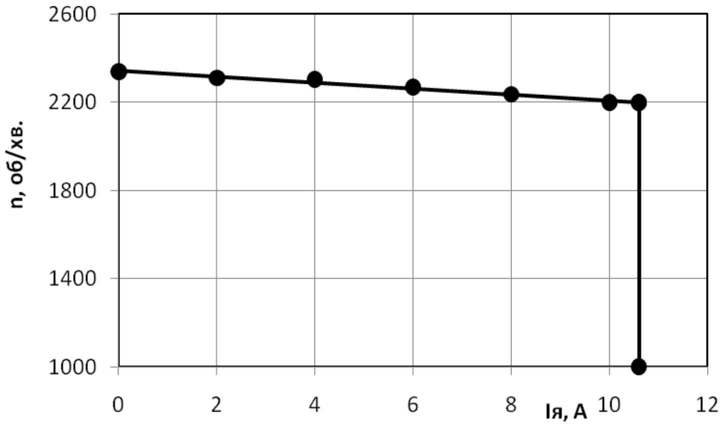


Fig. 7. Electromechanical characteristics, obtained at laboratory equipment (*R_{COMP}*=0,134 p.u.)

CONCLUSIONS

The computer model in MatLab electric with TCV Lenze series 530, which provides limits of the maximal and minimal speed, limit of armature current, stabilization of adjusted speed, regulation of transient time, is created.

REFERENCES

1. German-Galkin S.G. Computer simulation of semiconductor systems in MatLab 6.0: Tutorial. / S.G. German-Galkin. – St. Petersburg: CORONA print, 2002. – 304p. [in Russian].

2. Golodny I.M. Investigation of electric characteristics of DC series Lenze 530 at MatLab model / I.M. Golodny, J.M. Lawrynenko, A.V. Toropov // Scientific Bulletin of NUBiP Ukraine. Series "Technology and Energy at agriculture". – 2013. – Issue. 184, § 1. – p. [in Ukrainian].

3. DC drive Lenze 530 user manual: [Electronic resource]. – Access from http://www.lenze.org.ua/pdf/530_Speed_controllers_1202_EN.pdf.

4. Golodny I.M. Investigation of electric characteristics of DC series Lenze 530 at MatLab model / I.M. Golodny, J.M. Lawrynenko, A.V. Toropov // Scientific Bulletin of NUBiP Ukraine. Series "Technology and Energy at agriculture". – 2013. – Issue. 184, § 1. – p. [in Ukrainian].

Приведена модель электропривода постоянного тока с тиристорным регулятором напряжения Lenze 534 с отрицательной обратной связью по напряжению якоря и результаты исследований электромеханических характеристик.

Переходной процесс, тиристорный преобразователь напряжения, обратная связь, П-регулятор, электромеханическая характеристика, модель.

DC drive model with thyristor voltage regulator Lenze 534 and results of investigations of electromechanical properties are presented.

Transition process, semiconductor voltage converters, feedback, P-controls, electromechanical characteristics, model.