

O. S. Yandylyskiy, Dr. Sc. (Eng.), Prof.; A. A. Marchenko, Cand. Sc. (Eng.); V. S. Guliy

MODELING OF WIND TURBINE CONTROL SYSTEM AND OPTIMIZATION OF REGULATOR PARAMETERS

System of linear differential equations for modeling of automatic regulation of angular velocity of wind turbine rotor, taking into account the impact of wind velocity, power of loading and regulation delay time is suggested. Optimization of PID regulator coefficients, using object-oriented library of non-linear systems of Matlab environment which enables to determine the parameters of regulator, that meet the requirements of optimality criterion, is carried out.

Key words: automatic regulation, mathematic model, optimization, modeling, wind power unit.

Introduction

Wind power units (WPU) are alternative sources of energy and investigations carried out in this sphere, are very urgent, due to constant growth of the price for fuel.

The aim of the paper is the development of mathematical model for the forecast of angular velocity of generator rotor, angle of incidence of the blade, taking into consideration the change of power of consumed electric energy and modeling of automatic control system of regulation with constant delay, optimization of PID (proportionally-integral differential) regulator parameters.

Presentation of main material of research

Functional diagram of wind power unit, as the object of regulation, is shown in Fig. 1., where the following symbols are used: $V(t)$ – wind velocity; $a(t)$ – angle of blade rotation relatively axle; $M_T^B(t)$ – torque, created by the blade; $M_K^R(t)$ – total torque, created by the rotor of WPU, $\omega_G(t)$ – angular velocity of electric generator rotor rotation; $I_l(t)$ – electric generator load current.

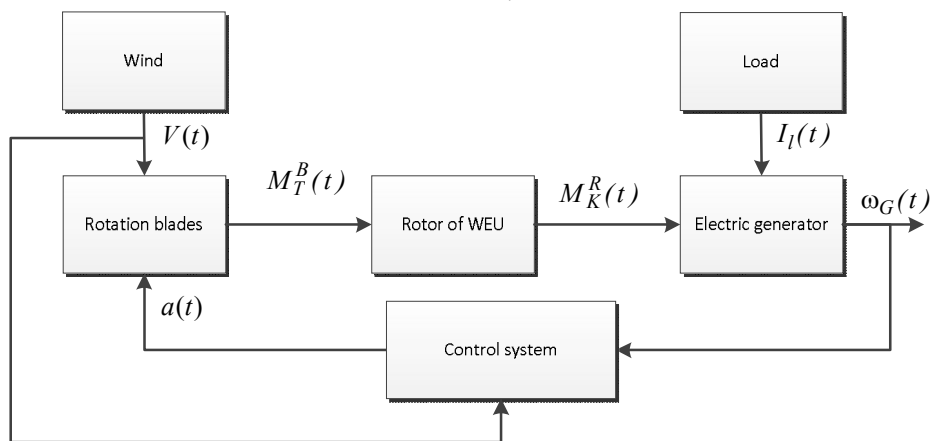


Fig. 1. Functional diagram of regulation object

General view of differential equation of the wind turbine [1]:

$$J \cdot \frac{\partial \Omega}{\partial t} = M_T - M_r,$$

where J – given moment of inertia; M_T – torque ; M_r – moment of resistance.

Total torque equals:

$$M_T = 0.04 \cdot \frac{V^2}{\alpha} \int_{r_0}^R r \partial r = 0.04 \cdot \frac{V^2}{\alpha} (R^2 - r_0^2) = 0.02 \frac{V^2}{\alpha} R^2$$

The system of differential equations with constant coefficients for the system of automatic control has the form [2]:

$$\begin{cases} \frac{\partial \Delta \Omega}{\partial t} - 0.00008 \cdot \Delta \Omega = 0.000001 \cdot \Delta V - 0.0000002 \cdot \Delta \alpha - 0.0000005 \cdot \Delta P \\ \frac{\partial \Delta \alpha}{\partial t} = (\Omega_t - \Omega_n) \cdot J \end{cases}$$

where $\Delta \Omega$ – increment of the value of angular velocity of generator rotor on time interval of consumed electric energy power forecast; ΔV – increment of wind velocity; $\Delta \alpha$ – angle of incidence increment of the blade; ΔP – active power increment; Ω_t – factual value of angular velocity; Ω_n – nominal value of generator angular velocity.

Time evaluation mathematical model of the motor of pitch angle drive blade switch on, taking into account wind velocity change and consumed power will have the following form:

$$T_{sw.P} = t_1 + \left(\left(\ln \left(1.3 - 0.3 \frac{V_1}{V_0} \right) + \ln \left(1.3 - 0.3 \frac{P_0}{P_1} \right) \right) 0.001 \cdot J - t_{const.t.} \right);$$

Taking into account PID regulator [3], the system of linear differential equations with constant coefficients for automatic regulation with delay argument can be written as:

$$\begin{cases} \frac{\partial \Delta \Omega}{\partial t} - 0.00008 \cdot \Delta \Omega = 0.000001 \cdot \Delta V - 0.0000002 \cdot \Delta \alpha - 0.0000005 \cdot \Delta P \\ \Delta \alpha_{t-T_{sw.}} = \left(K_P \Delta \Omega + K_I \int_t \Delta \Omega \partial t + K_D \frac{\partial}{\partial t} \Delta \Omega \right) J \end{cases}$$

Fig. 2 shows *Matlab* simulink-model of automatic regulation realized on the basis of this system of equations.

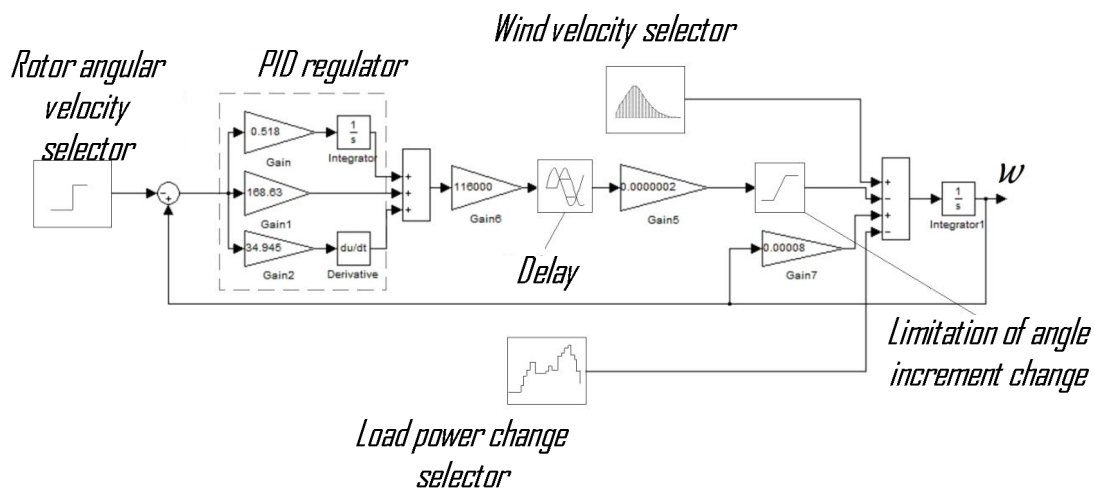


Fig. 2. Simulink-model of the system of automatic control of angular velocity of generator rotor regulation генератора

We will perform optimization of PID regulator parameters. For this purpose we apply Наукові праці ВНТУ, 2014, № 1

optimization tool NCD Output (Nonlinear Control Design) [4].

Proceeding from initial estimates, the process of optimal parameters of system PID regulator search is presented graphically. First the graph, that corresponds to initial conditions of optimization is derived (Fig. 3). If in the course of computations such value of variable that completely corresponds to optimality criterion is obtained, then the computation process automatically stops (Fig. 3, line 1), at $K_c = 168.63$, $K_i = 0.518$, $K_D = 34.945$ for the given case of disturbance.

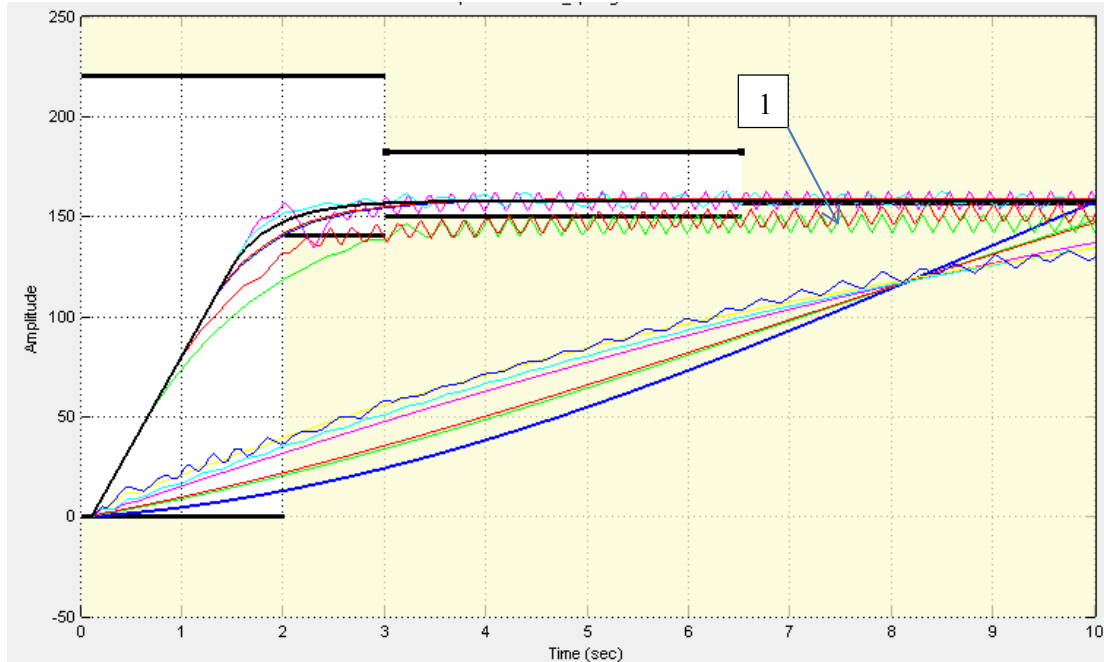


Fig. 3. Graph, corresponding to the initial conditions of optimization

Fig. 4 presents the combined regulation graph of angular velocity of generator rotor with delay $t_{del} = 0.1$ s, $t_{del} = 0.2$ s, $t_{del} = 0.25$ s and $t_{del} = 0.3$ s.

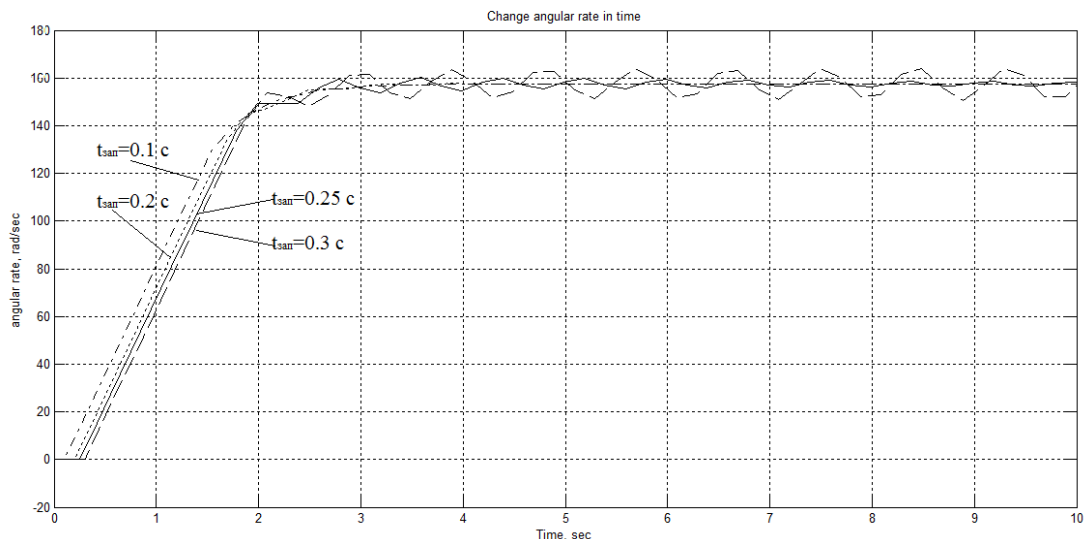


Fig. 4. Graph of generator rotor angular velocity regulation with delay

Conclusions

For efficient control of wind turbine in the process of wind velocity change in greater or smaller side it is necessary to calculate the time of pitch drive motor start. Considerable increase of the delay leads to greater regulation and, as a result, to oscillations of voltage and power, generated by WEU.

REFERENCES

1. Кривцов В. С. Невичерпна енергія: підручник. Кн. 2. Вітроенергетика / Кривцов В. С., Олейников А. М., Яковлев А. І. – Харків: Вид-во Нац. аерокосмічного ун-ту. «ХАІ», Севастополь: Севастополь. нац. техн. ун-т, 2004. – 519 с.
2. Буяльский В. И. К вопросу оценки параметра времени включения двигателя привода питча для ветротурбины USW56–100 / В. И. Буяльский // Вісник СевНТУ Сер. Механіка, енергетика, екологія: зб. наук. пр. – 2010. – Вип. 106. – С. 114 – 119.
3. Резван В. Абсолютная устойчивость автоматических систем с запаздыванием / Резван В.; под. ред. В. А. Якубовича; с доп. А. П. Лихтарникова, В. А. Якубовича. – М.: Наука, 1983. – 256 с.
4. Веремей Е. И. Пособие " Nonlinear Control Design Blockset " [Електронний ресурс] / Е. И. Веремей, С. В. Погожев. – Режим доступу: <http://matlab.exponenta.ru/nonlinecondes/book1/preface.php>.

Yandylskiy Olexandre – Dr. Sc. (Eng.), Professor with the Department of Energy Systems Automation, tel.: (044) 236-41-11.

Marchenko Anatoliy – Cand. Sc. (Eng.), Assistant Professor with the Department of Energy Systems Automation, tel.: (044) 454-93-08.

Guliy Volodymyr – Master student with the Department of Energy Systems Automation. National Technical University of Ukraine «Kyiv Polytechnical Institute».