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Computer Model of Diagnosing a Diesel Generator

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ABSTRACT: When using a diesel generator for energy supply of continuous technological processes, an important task is to ensure reliable operation of the diesel engine. To measure the parameters of the engine, various sensors are used, which are located on its main nodes. Based on the use of sensor readings, control and diagnostic algorithms are built. To provide the possibility of carrying out a diagnostic procedure, there is a need to build a mathematical model of a diesel engine with the possibility of its operation in real time.

KEYWORDS: computer model, mathematical model of a diesel engine, Simulink model, computational stability, diagnostics of a diesel generator.

I.INTRODUCTION

When using a diesel generator for energy supply of continuous technological processes, an important task is to ensure reliable operation of the diesel engine. One of the ways to improve the reliability of a diesel engine is to monitor the main operating parameters during its operation. In order to measure the parameters of the engine, various sensors which are located on its main nodes are used. Based on the use of sensor readings, control and diagnostic algorithms are built. Since the vast majority of engine parameters change over time, a promising approach to the organization of diagnostic algorithms is to use a mathematical model of the engine in order to obtain reference values of the parameters, which are further compared with those coming from the sensors. The most informative modes of operation of a diesel engine, from the point of view of diagnostics, are its launch and moments of abrupt load changes, so the diagnostic process is carried out both at the beginning of the diesel generator and during its operation by artificially throwing (if possible, dropping) the load. So, to provide the possibility of carrying out a diagnostic procedure, it becomes necessary to build a mathematical model of a diesel engine with the possibility of its operation in real time.We will consider as a simulation object a diesel generator with an automatic control system. It contains the following components: generator, mechanical and thermodynamic systems of the engine, fuel supply equipment, hydraulic servo amplifier, pulse-width converter, electronic controller, sensors of the hydraulic booster output and shaft speed (Fig. 1).

II. METHODOLOGY

In order to build a mathematical model, we make the following assumptions: the thermodynamic system and fuel supply equipment can be represented by linear differential equations; the discrete nature of the processes in these systems can be neglected, since the cut-off frequency of the system is not less than an order of magnitude lower than the frequency of the flashes in the cylinders (taken into account as a pure delay); the mechanical system is considered as a concentrated mass; backlash and "dry" friction are small and have no significant effect.

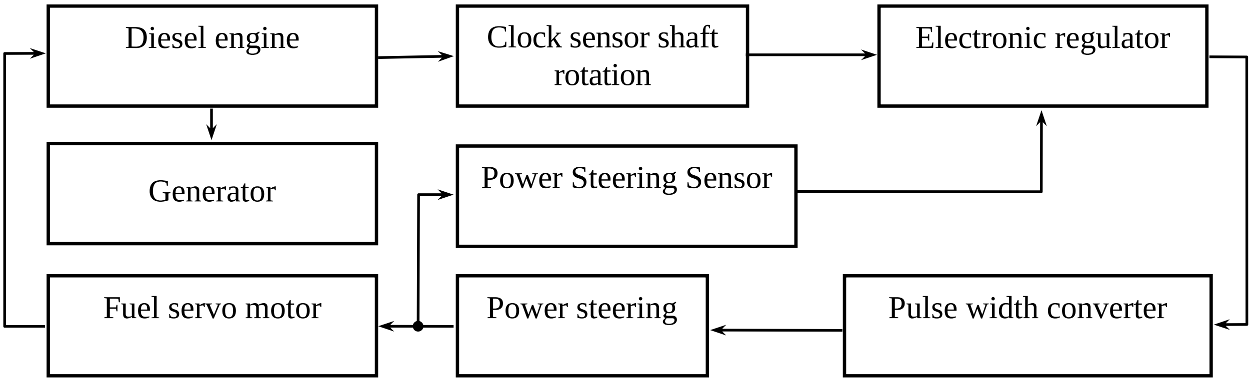

Fig. 1. Structural diagram of a diesel generator

Taking into account the accepted assumptions, the mathematical model of a diesel engine is described by a system of equations in the following operator form

$$\left.\begin{aligned}
&p\omega_{\text{Д}} = K_{\text{ДГ}}(m_{\text{Д}} - m_{\text{Н}});\\
&(T_{\text{ТС}}^2 p^2 + 2\xi_{\text{ТС}} T_{\text{ТС}} p + 1)m_{\text{д}} = K_{\text{ТС}} g;\\
&(T_{\text{ПА}}^2 p^2 + 2\xi_{\text{ПА}} T_{\text{ПА}} p + 1)g = K_{\text{ПА}} e^{-\tau_0 p} h;\\
&(T_{\text{СП}} p + 1)h = -K_{\text{СП}} S,
\end{aligned}\right\} \qquad (1)$$

Where $\omega_{Д}$, $M_{Д}$ - the angular velocity and the torque of the shaft of the diesel engine, respectively; m_{H} - load moment; g, h, S - the output coordinates of the fuel supply equipment and the hydraulic servo amplifier, respectively; $K_{ДГ}$ - total drive to the shaft of the moment of inertia of the diesel engine and generator; $T_{TC}, T_{ПА}, T_{СП}$ - time constants of the thermodynamic system, fuel supply equipment and hydraulic servo amplifier, respectively; τ_0 - delay, where $(\tau_0 = 2\pi / \omega_{Д} z + 0,27 / \omega_{Д})$ - the number of cylinders; z - damping coefficients of the thermodynamic system and fuel supply equipment; $\xi_{TC}, \xi_{ПА}$ - transmission coefficient of the hydraulic servo amplifier.

The link of delay with transfer function $W_1(p) = Y(p) / X(p) = e^{-p\tau_0}$ is given in the form of an equivalent Volterra integral operator:

$$y(t) = \int_0^t \delta(t - \tau) x(t) d\tau, \quad (2)$$

where $\delta(x)$ - impulse transient response.

The shaft speed sensor is described by an inertial link with a transfer function, where $W_2(p) = \dfrac{K_4}{T_{\text{ДЧ}} + 1}$.

The electronic controller model consists of a proportional link with a transmission coefficient K_1 and a forcing link, with a transfer function $W_3 = \dfrac{T_\omega p}{T_4 p + 1}$, connected in parallel. Parameter values are: $K_1 = 1$; $T_\omega = 0.1 \div 0.5c$; $T_4 = 0.0001\,c$.

The model of the power steering output unit consists of connected in parallel proportional link with a transmission coefficient K_2, and a boost link, with a transfer function $W_4(p) = \frac{K_{ДГП}}{T_{ДГП}p+1}$, where

$$K_2 = 0,2 мм \cdot c^{=1};\ K_{ДГП} = 0,005 \div 0,8\ мм^{-1};\ T_{ДГП} = 0,01 \div 0,08\ c$$

The parameters of a diesel engine are as follows: $K_{ДГ} = 31,96;$.

In order to be able to calculate the reference mode parameters at the control points of the diesel system, it is advisable to carry out the model decomposition according to the physical principle (Fig. 2). The model is synchronized with a real object by using the signal from its shaft speed sensor. Points A - D are control.

Since the system consists of dissimilar elements, in constructing its model, we will use various ways of mathematical description: for the diesel engine and pulse-width converter - Volterra integral operators; for sensors of shaft speed and output of the hydraulic booster, electronic controller, hydraulic booster, fuel servomotor - transfer functions.

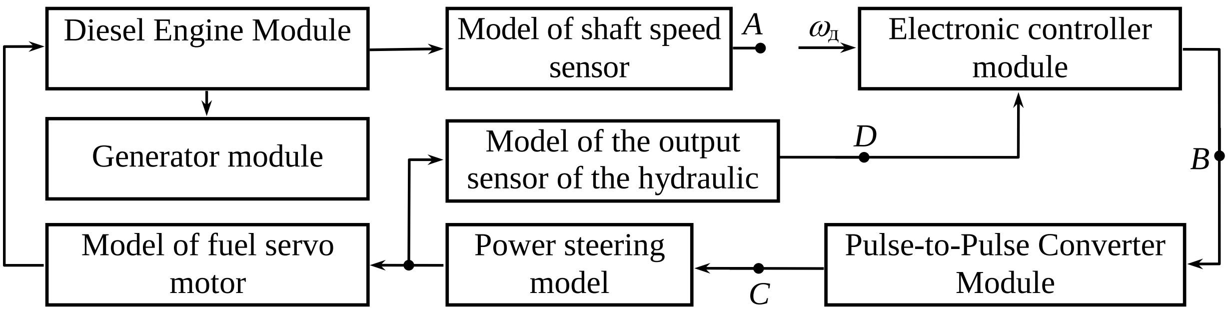

Fig. 2. Block diagram of a diesel generator model

The use of an integrated macromodel to describe the dynamics of a diesel engine is due to the presence of a delay link in its structure, and for a description of a pulse-width converter, the presence of signals described by functions with discontinuities of the first kind.

For the numerical implementation of the structural model, we use blocks of Volterra integral operators and standard Simulink blocks (Fig. 3). The kernels of integral operators are found by differentiating the transient characteristics of the corresponding subsystems or analytically. The diesel engine subsystem consists of two series-connected blocks of integral operators. The first block implements the model (2), and the second one is the Volterra integral operator:

$$y(t) = 3,26\int_0^t (e^{-6(t-\tau)}\cos(31,05(t-\tau)) - 5,06e^{-6(t-\tau)}\sin(31,05(t-\tau)) - \\ -e^{3,13(t-\tau)}\cos(7,26(t-\tau)) + 22,03e^{3,13(t-\tau)}\sin(7,26(t-\tau)))x(\tau)d\tau. \qquad (3)$$

The subsystems of the hydraulic booster sensor (Fig. 4) and the electronic controller (Fig. 5) are implemented using standard simulink-blocks.

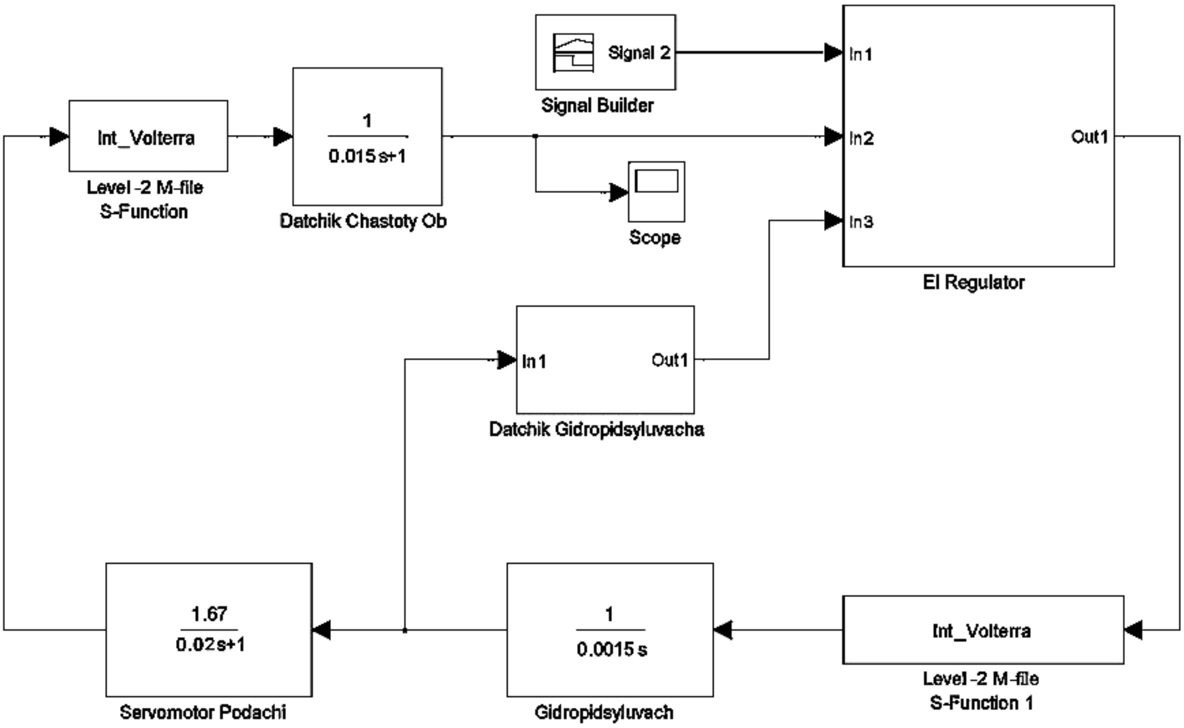

Fig. 3. Simulink model of a diesel engine

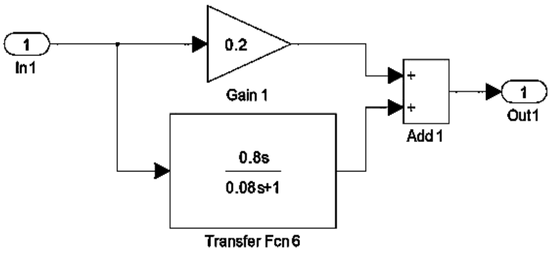

Fig. 4. Simulink model of the power steering sensor subsystem

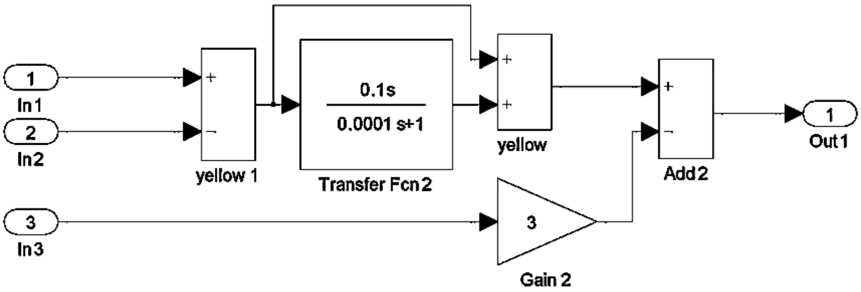

Fig. 5. Simulink model of the electronic controller subsystem

III. EXPERIMENTAL RESULTS

A feature of integral dynamic models, like non-parametric models, is that their construction, as well as periodic refinement, can be carried out on the basis of the obtained transition characteristics of the system links that they represent.

The computational experiments performed showed the model working capacity when modeling the dynamics of the engine start-up (Fig. 6). For the calculations $\omega_Д$ simulink-model with a closed contour ($\omega_Д = A$) is used.

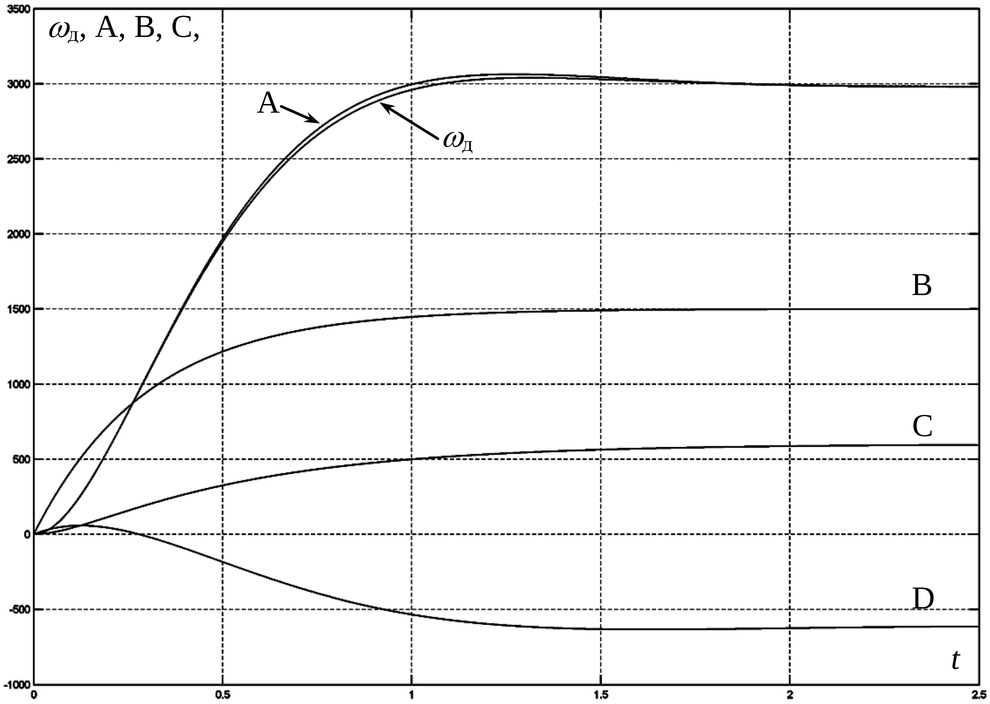

Fig. 6. Modeling the dynamics of a diesel generator when it starts

The study of the noise immunity of the models was carried out at different levels of high-frequency interference [1]. For the original model, even at a noise level of 3%, there is a discrepancy in the computational process, when for a model containing blocks of Volterra integral operators, stability is maintained at a noise level of up to 15%. Fig. 7 shows the simulation results of a diesel generator start-up with a high-frequency noise level of 15% of the signals from the shaft speed sensors and the hydraulic booster output.

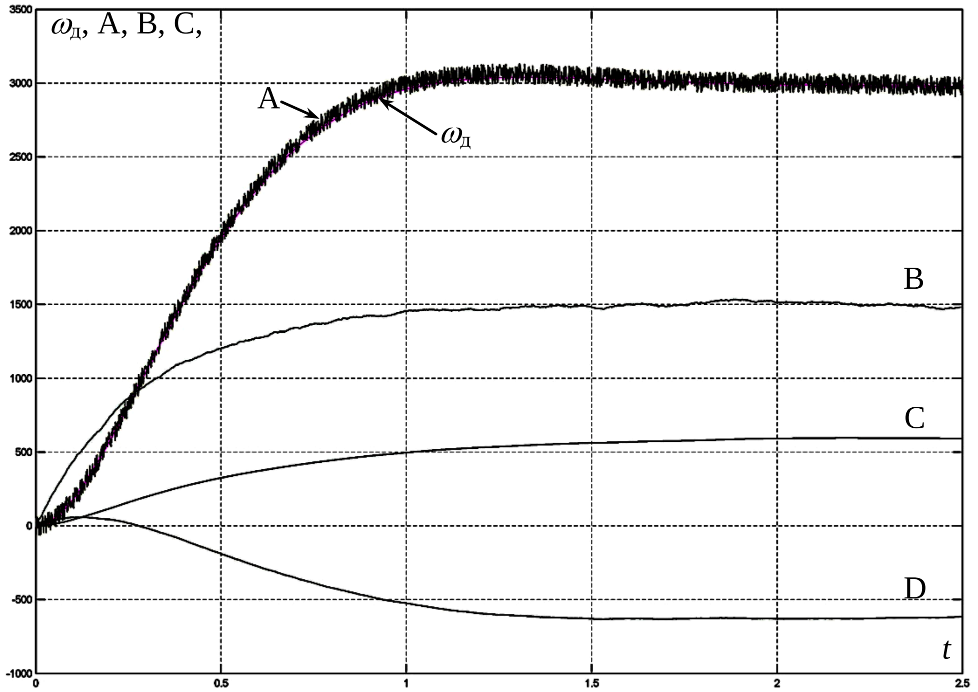

Fig. 7. Modeling the dynamics of a diesel generator with a level of interference on sensors- 15%

IV.CONCLUSION

So, the meaning of replacing individual subsystems with integrated macro models is that the resulting computer model as a whole has increased computational stability as well as less computational complexity than the original model while maintaining the required accuracy, which allows its use in real-time systems with significant levels of high-frequency signals.

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