UDC 621.311[iii]

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ENHANCED CONTROL OF AUTONOMOUS POWER SUPPLY PROCESS FOR INTERNAL COMBUSTION ENGINE

(SOURCE ENERGY EFFICIENCY IMPROVEMENT BY INTERNAL GASES)

The use of generators with converters allows, depending on the load of the network, to regulate the speed of the internal combustion engine, thus increasing the overall efficiency of the system and reducing fuel consumption as a whole. However, it must be noted that the optimal operation of the internal combustion engine is possible at a certain engine speed. A decrease in the engine speed leads to a deterioration in the filling of the fuel-air mixture and the exhaust of the engine, beside an intake of exhaust gases into the intake manifold and the ejection of part of the combustible mixture into the exhaust pipe. We present in this paper the general idea of creating a control system for an autonomous power source based on an internal combustion engine and an inverter. The expediency of adjusting the opening and closing angles of the valves of an internal combustion engine that works as a source of mechanical energy of an autonomous source of electrical energy is proved. By using this system we could reduce unit costs by 2 times when generating electric energy. After seeing the gas distribution diagram of the internal combustion engine, the dependence of the change in the opening and closing angles of the intake and exhaust valves on the power of an autonomous energy source is proposed.

Key words: autonomous energy source, efficiency, gas distribution system, electromagnetic valve

Introduction. In the almost majority of providing reliable energy supply in cases of external power grid accidents, autonomous energy sources based on internal combustion engines remain. The volume of electricity production in 2017 by autonomous stations is within 6.5 million kWh, with about 5% of total production volume [1]. The main element of autonomous energy sources is the kind of fuel used to generate thermal energy from chemical: diesel, gasoline, gas. However, the principle of the chemical energy to mechanical converter and its design generally remains similar in basic terms: two or four-stroke cycle, crank mechanism, cylinder, piston, valves etc. Second in importance for autonomous energy sources based on an internal combustion engine is the principle of converting mechanical rotational energy into electrical energy. Depending on network load, The use of generators with inverters allows to regulate the rotational speed of the internal combustion engine, thus reduce fuel consumption and increase the overall efficiency of the whole system. Using the proposed scheme allows saving more than half of the total amount of fuel [2-4].

Anyway, it should be noted that the optimum performance of the internal combustion engine is possible at a certain engine speed [4]. This is evident from the internal combustion engine efficiency diagrams that have a domed shape with a maximum at 2500-3500 rpm depending on the design. Reducing the engine speed leads to a deterioration of filling fuel-air mixture and engine exhaust, which is followed by exhaust gases into the manifold intake and the part ejection of the combustible mixture into the exhaust pipe. Energy losses in case of these effects can reach up to 20%, which significantly reduces the inverter usage effect in electricity generation.

Through analysis of existing generators demand and own practice, the authors have focused on generating units based on a single-cylinder, four-stroke gasoline internal combustion engine among a wide range of standalone generators, and that depends on things such relatively low cost of this generating units compared to diesel generators and the minimum required power to operate powerful household appliances, which averages 2.2 kW. It must be noted that synchronous generators without inverter still the most widespread autonomous source of electrical energy, the feature of which is the constant speed of the engine's crankshaft without power regulation possibilities. So, to improve the autonomous power sources energy efficiency with inverter based on gas distribution mechanism regulation is an urgent scientific task.

Purpose and objectives of the research. The purpose of this study is to determine the operation algorithm and parameters of the control system of an autonomous source of electric energy with an internal combustion engine by controlling the gas distribution of an internal combustion engine in order to increase the overall efficiency.

And some its objectives are the formulation of the scientific (scientific and technical) problem, the definition of the object, subject and purpose of the study, analysis of the state of the problem solution on the materials of domestic and foreign publications (including periodicals), justification of the objectives of the study.

Research materials and results.

Review of scientific sources: In the design analysis of autonomous energy sources on internal combustion engine basis, it should be noted the main components: engine, generator, inverter (Fig. 1).

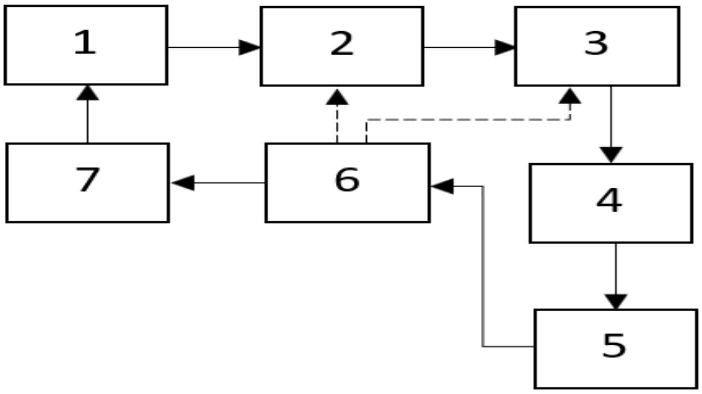

Figure 1 - Control scheme for autonomous power source based on the internal combustion engine and inverter.

1 - internal combustion engine; 2 - generator; 3 - inverter; 4 - a wattmeter, which is connected to 6 - the microcontroller via an Analog-to-Digital converter - 5, is used to control the energy source power consumption. For more precise parameters control of the standalone generator elements, it is possible to use existing channels that connect the microcontroller to the generator and inverter.

In determining the optimal control effects on system elements it is necessary to establish the features of their operation under different load separately.

In researched system, the internal combustion engine is the least energy efficient element. The efficiency of four-stroke internal combustion engines at the optimum speed and load is within 45% (50%) of diesel engines and 39% for gasoline. At the same time (Fig. 2), analyzing the graphs [5], the changes in the power efficiency factor for the internal combustion engine should be noted a significant (up to 30%) drop with a sharp increase in specific fuel consumption (up to 500%) [6, 7].

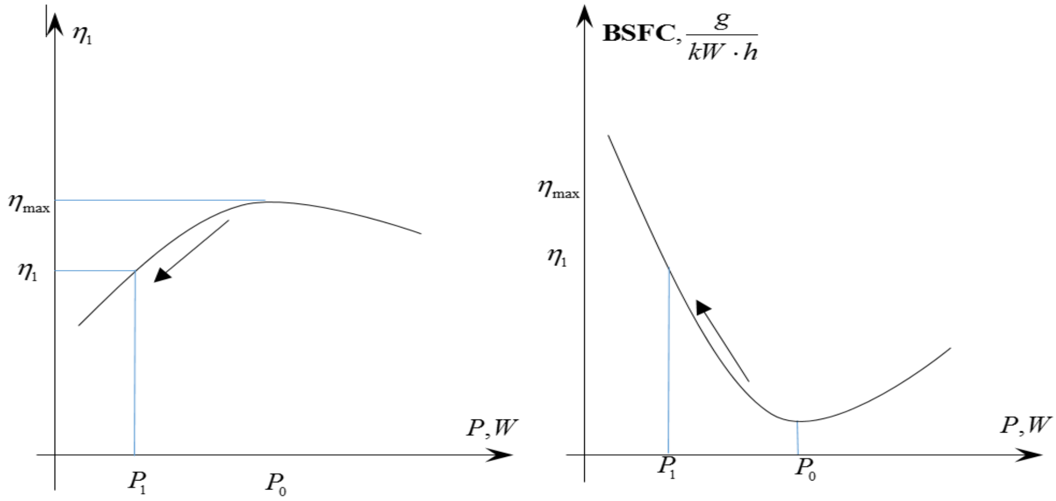

Figure 2 - Charts of efficiency and BSFS changes.

The reasons for this phenomenon are a several negative effects that accompany the process of reducing the engines rotational speed. The basic include deterioration of the cylinder gas filling, reducing turbulence with the release of the charge part in the cylinder intake system during the delay after closing the intake valve after NMT. Putting stop to this phenomenon is possible by regulating the time and height of valve opening, namely narrowing cycles with late opening and early closing of valves without overlapping [8].

At Figure 3, a typical diagram of the internal combustion engine gas phase distribution at nominal speed is presented. The diagram shows the overlap of the exhaust and intake corners areas by the magnitude of the inlet open and outlet close valves. The value of the angles is selected from the condition of obtaining maximum torque and efficiency of the engine [9]. One of the possible options for avoiding these negative phenomena is to minimize the angles of intake opening and closing of the exhaust valves (Fig. 3b) while reducing engine speed.

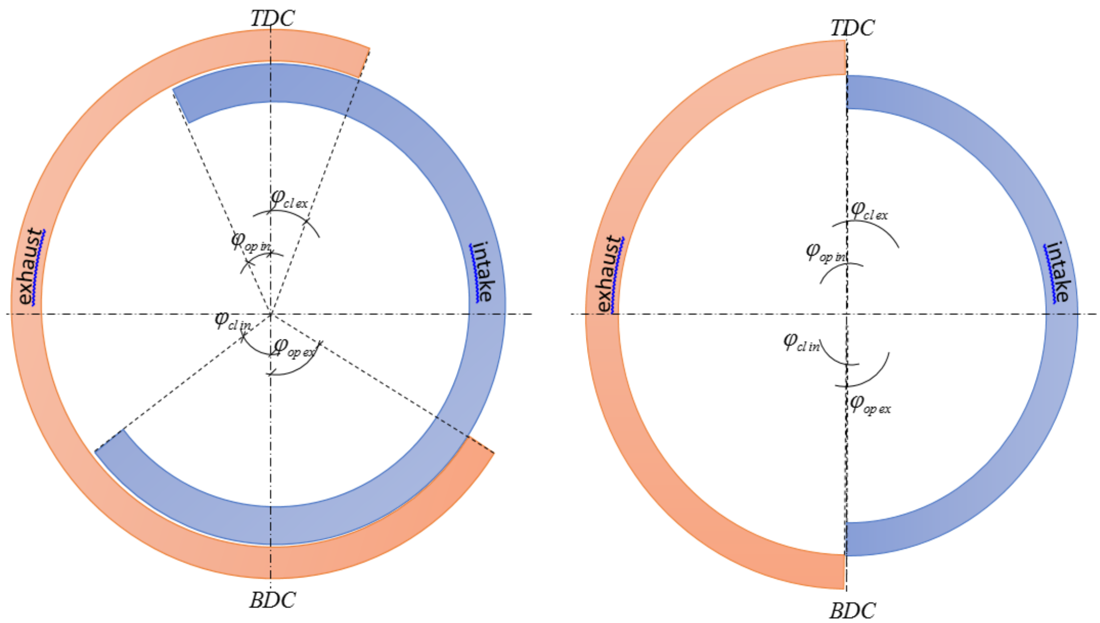

Figure 3 - ICE phase diagrams: a - rated speed; b - minimum speed.

To set the angles of the inlet valves opening and closing from the power level, a system of linear equations is proposed:

$$\varphi_{op\,in}(P)=\frac{\varphi_{op\,in}}{P_0-P_1}(P-P_1);\quad (1)\qquad \varphi_{op\,ex}(P)=\frac{\varphi_{op\,ex}}{P_0-P_1}(P-P_1);\quad (2)$$

$$\varphi_{cl\,in}(P)=\frac{\varphi_{cl\,in}}{P_0-P_1}(P-P_1);\quad (3)\qquad \varphi_{cl\,ex}(P)=\frac{\varphi_{cl\,ex}}{P_0-P_1}(P-P_1).\quad (4)$$

The implementation of the proposed program of controlling the gas distribution of the internal combustion engine of the autonomous power source is possible within the use of special actuators of the gas distribution mechanism. Mechanical, hydromechanical, and electric actuators are common. Further, amongst these types of actuators, high-performance provides by electromagnetic one due to the slow movement of the valve in the cam and hydraulic actuator [10, - 12].

Description of research methods:

Let's define the main engine's parameters of the exhaust valve motion process under an electromagnet action (fig. 4). When moving the valve 2 down the electromagnet 1 must develop a force equal to the total resistance from spring 3 action, from gases action and inertia forces. In the general case, the equation of motion of the valve follows:

$$m_v\frac{d^2z}{dt^2}+\vec{F}_1+\vec{F}_2+\vec{F}_{em}=0 \qquad (5)$$

where m_v – valve weight with the anchor.

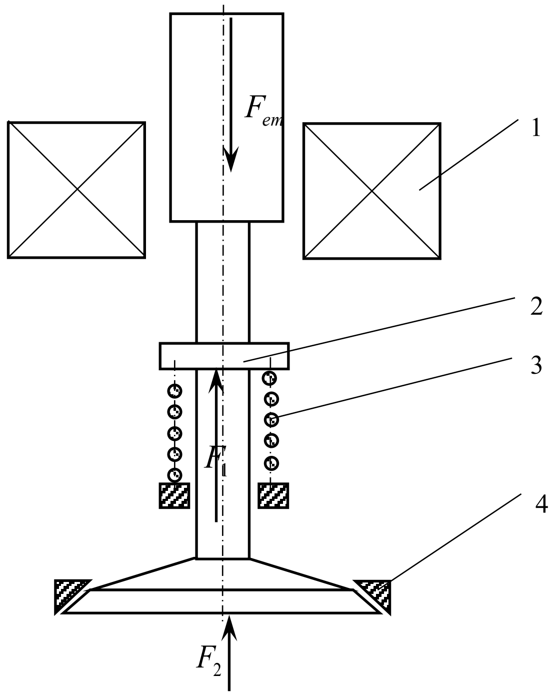

Figure 4 - Scheme of the engines exhaust valve forces action:1 - electromagnet; 2 - valve; 3 - spring; 4 - valve seat

Spring resistance: $F_1=F_1'+cz$ (5)

F_1' - Preliminary force of a spring compression; c - spring stiffness.

The resistance force from the action of compressed gases depends on the moment and height of the valve opening. The value of the initial pressure corresponds to the end of the expansion stroke and for the case of the gasoline engine is $p_1=0,3-0,4MPa$. Further movement of the valve is accompanied by a rapid drop in pressure to $p_2=0,03-0,04MPa$. The valve closes when it is rarefied $p'=0,035-0,045MPa$.

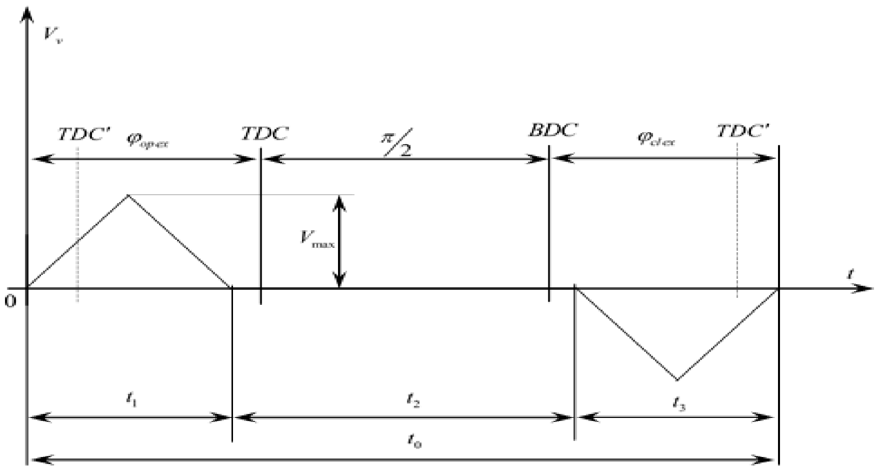

Figure 5- Tachogram of engines exhaust valve movement when exposed to an electromagnet. The opening and closing times of the valve in modern cam driven engines depend on the specified cam profile and in some cases may be equal to the total valve travel time. Assume a fixed value of the angles $\varphi'_{op\,ex}, \varphi'_{cl\,ex}$ at which the exhaust valve will fully open to height h. Valve opening and closing time:

$$t_1 = \frac{\varphi'_{op\,ex}}{\omega}; \qquad t_2 = \frac{\varphi'_{cl\,ex}}{\omega}. \tag{7}$$

acceleration:

$$a_1 = \pm 4h\left(\frac{\omega}{\varphi'_{op\,ex}}\right)^2; \; a_1 = \mp 4h\left(\frac{\omega}{\varphi'_{cl\,ex}}\right)^2. \tag{8}$$

resistance force from the compressed gases action and dilution:

$$F_2 = \frac{\pi D^2}{4}\frac{(p_1 - p_2)}{t_1}t; \; F_2' = \frac{\pi D^2}{4}p' \tag{9}$$

Conclusion.

1. The general theory of a control system for autonomous power supply based on an internal combustion engine and inverter is shown in the work. The workability of operating internal combustion engine opening and closing angles adjusting as a source of mechanical energy of an autonomous electricity source has been confirmed. Utilization of this system permits to reduce specific costs by 2 times in generating electricity.

2. The diagram of the internal combustion engine phase gas distribution (Fig. 3, a) for the conditions of minimum energy production is proposed. Based on the diagram the angles dependence of opening and closing of the inlet and outlet valves on the capacity of the autonomous energy source (1-4) is offered.

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СЕКЦІЯ 5.
ІНЖЕНЕРНА ЕКОЛОГІЯ ТА РЕСУРСОЗБЕРЕЖЕННЯ