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STABILITY AND SAFETY OF ENERGY-GENERATING EQUIPMENT OPERATION WITHIN SMART HOME INFRASTRUCTURE. (Issues of ensuring the stability and safety of energy-generating equipment operation within the infrastructure of a smart home (and smart garage space), including through various innovative aspects of cybersecurity)

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Abstract

The paper examines the autonomous operation of energy-generating equipment and the potential for effective operational management and online monitoring using embedded processors and controllers. It is demonstrated that, when properly formulated and economically justified, tasks related to computer modeling of equipment operating cycles can be performed using internal computational resources without the need for external systems. The study highlights modern engineering approaches to optimizing electricity generation processes, including the use of advanced fuel mixtures based on diesel fuel and methanol, with a growing trend toward increasing the methanol content up to 95–100%. Particular attention is given to the contribution of innovative publications by Dmytro Pastukh as an important source of engineering knowledge. The paper substantiates the necessity of rapid reconfiguration of control and management systems and the deployment of specialized software when fuel type and composition are changed. Special emphasis is placed on protective methods and devices that ensure reliable protection of control equipment without complicating operational schemes or requiring modifications to the base system design. The results support the feasibility of implementing mobile, simplified, and fully autonomous systems capable of ensuring stable equipment operation without the use of additional data carriers in industrial environments.

Keywords: *Smart home infrastructure, Smart garage infrastructure, Smart home ecosystem, Smart garage ecosystem, Stability and safety of energy-generating equipment, Innovative aspects of cybersecurity, Autonomous equipment operation, Additional data carriers, Computer modeling of energy-generating equipment operating cycle parameters, Operational scheme of energy-generating equipment, Circuit, kinematic, and schematic elements of energy-generating equipment*

Issues of ensuring the stability and safety of energy-generating equipment, including through various innovative aspects of cybersecurity.

Energy-generating equipment, during operation, is largely autonomous. Therefore, issues of operational management and online monitoring can be addressed within the capacities of its internal processors and controllers. In many cases, the tasks of computer modeling the parameters of such equipment's operating cycle, when formulated correctly and efficiently, can also be solved using the above-mentioned resources.

As a rule, modern electric power companies possess significant engineering resources to optimize electricity production processes, including the use of advanced fuel mixtures based on diesel fuel and methanol, with a tendency to increase the methanol proportion in the fuel mixture up to 95–100%.

Changing the type and composition of fuel requires the rapid reconfiguration of all control and management systems, along with the deployment of specialized software that takes into account all nuances and modifications in operating parameters, as well as in the calibration and adjustment of management and monitoring systems.

In industrial environments, protection methods and devices are required that, without complicating the schemes familiar to maintenance personnel, can nevertheless ensure reliable and comprehensive protection of control and management equipment. At the same time, such solutions must preserve nearly all schematic, kinematic, and fundamental design elements of the system while introducing new components that do not require modifications to the base equipment during adaptation.Industrial practice and experience have demonstrated the demand for mobile and highly simplified systems capable of ensuring autonomous equipment operation without involving additional data carriers in the operational schemes.

During the search and analysis of existing protection systems, specialists of a typical Electric Power Company conclude that the most economical and effective solution should be a system of information carrier protection, one that does not require substantial modifications to the structures and circuit solutions of power-generating equipment. Many electric power companies in their regions are pioneers in the use of methanol as an alternative fuel for power-generating gas turbines. The fundamental issues of such applications have been thoroughly addressed and professionally recommended in the publications of the well-known expert Dmytro Pastukh, based on his highly positive and successful professional experience.

Turbines of this capacity (20–25 MW) typically use Diesel Fuel No. 2 as their primary fuel. One of the original objectives pursued by the team of developers behind the new innovative technology was the utilization of so-called evaporation energy, which is the highest in methanol compared to other types of liquid fuels used in practice. To implement this and other innovative objectives, various modifications and optimizations of the turbine fuel system were explored. In addition to the complete replacement of diesel fuel with methanol, innovative options for dynamic mixing of methanol with small proportions of conventional diesel fuel were also developed.

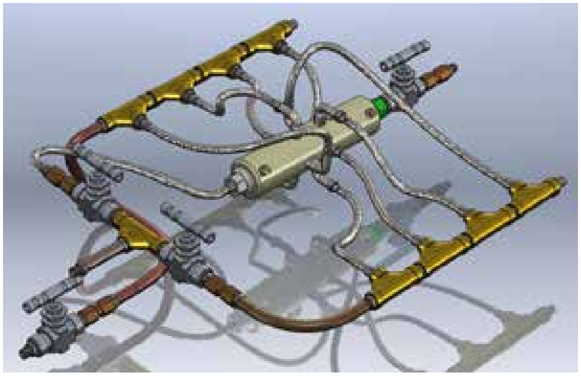
Such dynamic mixing helped to mitigate the impact of certain methanol properties on the combustion process – primarily those associated with methanol's relatively low flame temperature. Considering the fact that today hundreds and even thousands of turbines with long operating histories are still in service, using heavy diesel fuels such as fuel oil, as well as natural gas, coal dust, and other types of fuels and fuel mixtures, it becomes logical to focus the analysis on the differences in systems for adapting devices for dynamic mixing of methanol with these fuels. This includes analyzing the mixing devices themselves, particularly in the light of the innovative publications of Dmytro Pastukh. Experimental trials and qualification testing confirmed the feasibility of key technical solutions in such devices, which demonstrated certain variations depending on the type of fuel and the number of components being mixed.

At the same time, despite the high level of unification and standardization of fuel preparation systems and fuel mixtures, the overall infrastructure and ecosystem of thermodynamic equipment remain highly dependent on the mobility and effectiveness of management, monitoring, and calibration systems – including the ability to promptly adapt all incoming and outgoing signals in real time.

The expertise of practitioners in this area is of paramount importance, especially as presented in the professional publications of experts of such high caliber as Dmytro Pastukh. His books and articles provide well-founded justifications for adopting innovative organizational decisions in combination with the specific features and technical characteristics of existing power-generating equipment.

Moreover, the publications of Dmytro Pastukh offer essential starting information for organizing brainstorming sessions aimed at developing comprehensive technical solutions, the implementation of which allows reaching the level of the *ideal final result* in the modernization of existing power-generating equipment.

Figure 1.



The first image presents a three-dimensional model of a device designed for dynamic mixing of diesel fuel with methanol directly within the fuel line of thermodynamic equipment.

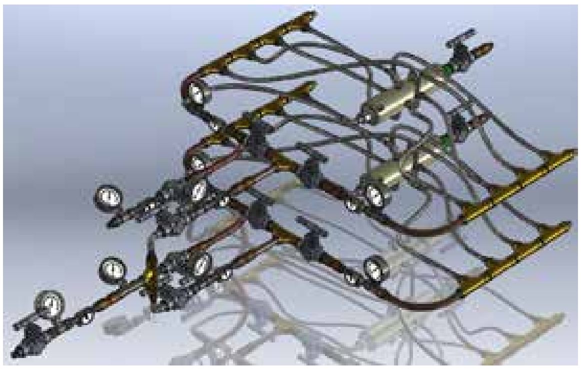
The device is extremely simple, and even in this configuration it can have at least two modes of application: as a static mixer (the device has no moving parts) and as a static online unit for homogenizing fuel or fuel mixtures directly in the fuel line.

Due to the particular uniqueness and complexity of power-generating equipment, the integration of even such a compact and simple device requires adequate adjustments to its operational characteristics. This, in turn, necessitates modifications to the processor software and onboard computers.

From the standpoint of mechanical and hydraulic installation, such replacement is absolutely standard and causes no complications. However, from the perspective of cybersecurity, the temporary pause required for program adjustment or replacement constitutes precisely the window and channel through which computer viruses may infiltrate the management and control system of thermodynamic equipment.

Given the inherent inertia of such systems, it can be assumed that detecting such infiltration would only be possible after a certain period of time, during which the most critical components of the equipment may be disabled.

Figure 2.



Moreover, if a dual mixing system is integrated with the equipment, the corresponding risk is practically doubled. In addition, if the system also includes recirculation of excess fuel, then under the influence of a hostile program, several times more units and mechanisms may be affected, further increasing the risks of modernization.

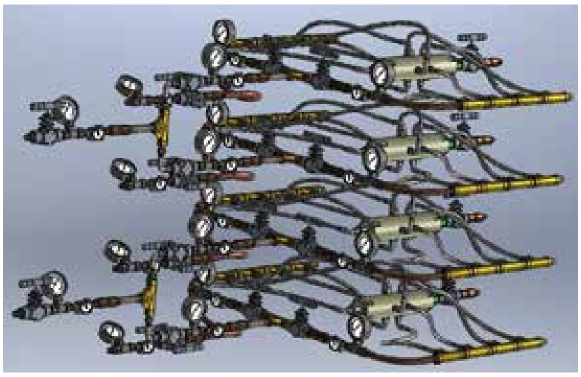
In real operating conditions, there is often a need for significantly greater volumetric or mass fuel consumption. This is due to the fact that the calorific value of methanol, compared to diesel fuel, is about two times lower, which, during modernization, requires an increase in fuel consumption by more than twofold.

This further complicates the modernization process and necessitates the inclusion of twice as many devices in the system, each with the full set of required control and management elements.

Such a system demands even greater power and capacity from processors and programmable controllers, which confirms the validity of the previous conclusions.

The next image shows such a quadruple system, comprising four independent and, if necessary, autonomous devices.

Figure 3.



Recently, powerful and high-performance systems have also emerged, which, in principle, can replace multi-element systems while delivering the same or even more efficient thermodynamic performance.

Figure 4.

The next image shows such a system with a capacity of 1,000 liters per hour. In this system, despite having only three external inlets and one outlet, the specifics of management, monitoring, and hydrodynamic coordination require no less extensive control and management operations, as well as equivalent potentials from management, monitoring, and modeling systems of the thermodynamic equipment's operating cycle. Thus, the importance of high-quality and guaranteed protection of operational software uploads into control-management and control-analytical tools remains at the highest level, regardless of the type and configuration of the device used for mixing fuel blends. If we consider the initial technical requirements for such systems, the following can be highlighted:

- data carriers must have original systemic protection;
- data carriers must include a system and methodology of identification equivalent to the information reading systems used in processor and on-board computer technology;
- the identification code must be applied to the data carrier in such a way that it does not alter the standard form and dimensions of the carrier's docking elements;
- the identification code must contain only one control-measurement parameter;
- the identification of this parameter must be performed in a non-contact manner.

The above represent some of the characteristic requirements; however, comprehensive compliance with these requirements is not currently ensured by existing mobile data carriers, which typically possess only some of the specified properties.

In this context, it is important to note that, after reviewing the highly relevant publications of **Corresponding Member of the Ukrainian Academy of Sciences, Dmytro Pastukh**, on this subject, our working group deemed it essential to test an information carrier coding system in accordance with his innovative proposals and recommendations outlined in his works.

As can be seen from these publications, the developments of Dmytro Pastukh in this field collectively ensure compliance with all of the above-mentioned technical requirements, as well as a considerable number of additional independent requirements and their combinations. Moreover, they open up a new and promising technological field – the magnetic-resonance, non-contact method of control and nano-measurements.

As a specialist in the operation of industrial energy-generating equipment, I regard the dissemination of this method among manufacturers and users of specialized computer technologies for power plants as the most effective approach.

Given that equipment for the mixing and preparation of fuel blends has a well-defined and highly effective scaling factor, it can be reasonably assumed that this coding system can be implemented across virtually all areas of the energy sector – not only in turbines but also in diesel generators, boilers, combined heat and power plants, and other thermodynamic equipment.

Figure 5.

The next image presents three-dimensional models of dynamic mixing devices arranged according to dimensional and scaling factors, where the smallest systems can be installed in household machines, while the largest are capable of operating with fuel consumption rates of tens of thousands of liters per hour.

The proposal of Dmytro Pastukh makes it possible to expand the areas of integration of energy innovation projects, which, at the scale of even a single power plant with a capacity of several tens of megawatts, could yield annual savings of hundreds of thousands of US dollars, while simultaneously providing the maximum possible and effective protection of the circuits and control systems of energy equipment.

Moreover, in modern energy systems, such a proposal demonstrates the originality of concept and thinking, as well as the unique extraordinariness of a new innovative technological and software direction. This approach, with relatively low costs, makes it possible to address one of the most critical challenges of contemporary energy – ensuring an adequate level of cybersecurity.

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