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CHALLENGES IN IMPROVING THE CONTROL QUALITY OF DIESEL-GENERATOR SETS IN AUTONOMOUS ELECTRIC POWER SYSTEMS

The reliability of autonomous electric power systems (AEPS) directly affects the safety and operational efficiency of facilities such as remote industrial sites, emergency infrastructure, and ships. Gas-diesel generator

sets (GDGS) have power ratings from 315 kW to 750 kW and are frequently used in AEPSSs, which also include shipboard power systems. The use of natural gas instead of diesel fuel, as shown in [1, p. 4], is more economical and reduces the cost of electricity. In addition, GDGS produce lower carbon dioxide emissions, which makes their use more environmentally friendly [2, p. 11].

The overall power quality, reliability, and energy efficiency of an AEPS largely depend on the control quality of the GDGS. Despite their advantages, one of the major drawbacks of gas-diesel generator operation is rotational speed instability, which negatively affects the generated power quality. The instability of the gas-diesel engine speed may be caused by various factors, including fuel quality, particularly low calorific value, as shown in [3, p. 8], and structural features of the gas-diesel engine. Frequency instability causes voltage fluctuations at the output of semiconductor power converters. In solving the problems of small-ship demagnetization, it is necessary to ensure a reliable process of generating high-quality electric power. Demagnetization systems are often powered by shore-based networks, where gas-diesel generator sets serve as the source of electricity. Therefore, improving the control quality of GDGS is an essential step toward enhancing the overall stability and energy efficiency of such systems.

When several GDGS units operate in parallel under a common load, the instability of rotational speed leads to unequal power sharing and oscillations of active power between generators. In [4, p. 374], a special device for active power distribution among generators is proposed, based on monitoring the rotor angular positions and the torques on the shafts of the prime movers. However, due to voltage frequency instability caused by engine speed fluctuations, the synchronization process can take a long time, which is critical in overload conditions when additional power must be introduced quickly. One possible solution is the use of fuzzy logic in the generator synchronization system, as proposed in [5, p. 3220]. Nevertheless, the technical solutions presented in [4, 5] do not address the issue of improving the control quality of the gas-diesel engines themselves.

Improving gas-diesel engine control by managing the fuel mixture composition was considered in [6, p. 2]. However, the drawback of this approach is that installing additional and costly equipment to control the mixing of natural gas and diesel fuel is not always technically feasible, and the proposed method is intended for low-power diesel engines (up to 5 kW). Another possible approach is to optimize the coefficients of the speed controller, as shown in [7, p. 136], but this study did not account for the nonlinear characteristics of the gas-diesel engine, and the proposed solution ensures stable operation only under constant load.

The problem of voltage frequency instability in isolated (autonomous) power stations, caused by fluctuations in the speed of diesel generator prime movers, is also noted in [8, p. 35]. However, the optimization methods

discussed in [8] mainly aim to reduce electricity generation costs, fuel consumption, and CO₂ emissions. Numerical models for investigating combustion processes in dual-fuel hydrogen-natural gas (HNG)/diesel engines are also known, allowing simulation under various load and gas composition conditions. However, those models mostly focused on thermal processes rather than control quality.

In Ukraine, the use of GDGS units in AEPs to provide power during emergency situations has become highly relevant. This is due not only to the rising cost of diesel fuel but also to the availability of an extensive gas pipeline network, which allows GDGS units to be installed closer to consumers. In AEPs operation, the load constantly varies, and therefore, for each operating mode, the regulator settings must be optimized to ensure high-quality control.

Improving the control quality of gas-diesel generator sets not only enhances power reliability but also directly contributes to energy efficiency. Stable operation of GDGS units minimizes fuel overconsumption, reduces mechanical wear, and ensures optimal use of fuel resources, which is essential for achieving energy-saving goals in industrial and municipal energy systems.

A review of the literature shows that insufficient attention has been paid to the problem of improving the rotational speed stability of GDGS units. To address this issue, detailed studies of the static and dynamic characteristics of generating units based on experimental data are needed, as well as the development of appropriate measures and hardware/software tools to ensure stable operation of gas-diesel generator sets over a wide load range. The proposed approach to improving GDGS control stability allows reducing fuel consumption and carbon emissions without costly hardware upgrades. This makes the research relevant for energy-saving and low-emission operation of autonomous and distributed power systems used in industrial and municipal applications. The obtained results provide a foundation for developing advanced control strategies for hybrid and distributed power systems, supporting the transition toward more sustainable and resilient energy infrastructures.

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