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PROSPECTS FOR THE DEVELOPMENT OF PEAK LOAD COVERAGE TECHNOLOGIES IN UKRAINE

Summary. *The article presents the results of a review of the development prospects for peak load coverage technologies in Ukraine. It is noted that traditional technologies will remain dominant in the near future. Innovative approaches related to energy storage systems, load management, and virtual power plants using renewable energy sources will eventually become an important source of flexible capacity. The importance of developing hybrid systems based on internal combustion engines, gas turbines, and renewable energy sources is also emphasized.*

Key words: *energy system, peak loads, demand response, renewable energy sources, energy storage.*

Peak loads, caused by many factors such as climate, social, economic, weather, and others, are of great importance for the stable and reliable operation of the Ukrainian energy system.

The Strategy for the Development of the Unified Energy System of Ukraine until 2035 specifies the need to achieve at least 10% of the system's peak load in flexible capacity, which requires the introduction of at least 1.5–2.0 GW of additional flexible peak capacity [1].

Ensuring peak load coverage in Ukraine requires a combination of traditional and innovative technologies. Traditional technologies primarily include thermal power plants as the basis for peak reserve, gas turbines, hydroelectric power plants, and pumped storage plants. Innovative technologies include battery systems (ESS – Energy Storage Systems), demand-side management (DSM), virtual power plants (VPP), and others. Flexible thermal power plants, pumped storage capacity, internal combustion engines, and gas turbines will play a leading role in the short term. Over time, innovative technologies will form the foundation for creating a future flexible and adaptive resource.

As for thermal power plants, despite their limited maneuverability due to equipment inertia, they will remain an important source of flexible capacity for some time. Internal combustion engines and gas turbines, given their many advantages, will also retain their importance as key elements of peak generation. Internal combustion engines will be used for systems with high flexibility requirements and for urban microgrids due to their superior performance under dynamic loads and rapid response to power changes. Gas turbines will be used primarily in stable modes or in high-capacity combined heat and power plants. However, in the future, the emphasis will be on more environmentally friendly alternatives, such as gas turbines running on biomethane or hydrogen, hybrid gas turbine systems, and battery storage systems. Mobile electric modules based on internal combustion engines and gas turbines will also see further development.

Regarding the future implementation of internal combustion engines and gas turbines, the greatest potential lies in the southern and eastern industrial regions, the Zaporizhzhia, Dnipropetrovsk, and Kharkiv regions, as well as large cities in Central Ukraine [2, 3]. Furthermore, the implementation of modular gas turbine or gas piston units is advisable for remote areas with low population density, particularly the Carpathian region and some regions of Polesia [4].

As part of the implementation of new energy modernization programs through international donor mechanisms, active expansion of cogeneration projects using internal combustion engines and gas turbines is projected in more than 15 regions of Ukraine by 2030 [5].

Hydroelectric and pumped storage power plants are highly effective at covering peak loads due to their high flexibility, and the availability of high-capacity pumped storage power plants is critical for system balancing. Therefore, the construction of new pumped storage power plants and the modernization of existing ones are long-term and strategic objectives. In the context of developing peak-handling capacity based on hydroelectric power plants, the creation of mini-

hydroelectric power plants combined with energy storage systems also deserves attention.

As for innovative peak-handling technologies, one of the most promising areas is the use of energy storage battery systems (ESS). These are characterized by response times in the millisecond range and can be deployed anywhere in the grid. Given this, battery storage systems are highly effective for localized peak shaving and ensuring system stability. For example, 50-100 MW modules can be widely used at sites housing solar and wind power plants.

The importance of developing energy storage systems is also highlighted by the development of a special program by NEC Ukrenergo [6].

The innovative approach of load management (DSM), which enables influencing consumer behavior to smooth out peaks, remains important. Demand-side management tools such as time-differentiated tariffs, peak-hour load reduction programs, and night-time consumption accumulation will be further developed. The potential for implementing DSM is demonstrated by research conducted by the German International Cooperation Agency GIZ, which found that just 100 of the largest consumers could provide 300–400 MW of flexible load reduction.

Peak load coverage using renewable energy sources in combination with storage or virtual power plants also holds promise. In the context of the emergence of new types of peak loads caused by the integration of renewable energy sources into the energy system, modernizing peak load forecasting systems using artificial intelligence and satellite data is becoming increasingly important [7].

The development of hybrid systems based on internal combustion engines/gas turbines and renewable energy sources is of significant interest, reflecting one of the key trends in the global energy sector. This so-called hybridization offers a number of well-known advantages, such as optimization of

operating costs through load balancing, reduction of overall CO₂ emissions, and so on.

The goal of peak load coverage using the above approaches is to ensure the necessary amount of capacity activation to meet demand while minimizing costs, reducing emissions, and maintaining system reliability [9, 10].

This article examines the prospects for applying only the basic approaches to peak load coverage, which does not exhaust the range of possible technological solutions.

Conclusions

This paper analyzes the prospects for developing peak load coverage technologies in the Ukrainian power system. It is noted that, in accordance with the Strategy for the Development of the Unified Energy System of Ukraine by 2035, it is necessary to achieve at least 10% of the system's peak load in flexible capacity, which means introducing at least 1.5–2.0 GW of flexible capacity. Peak load coverage should be achieved through a combination of traditional and innovative technologies, although in the short term, the primary trend will remain the use of traditional technologies (thermal power plants, gas turbines, hydroelectric power plants, and pumped storage power plants). The importance of developing hybrid systems based on internal combustion engines/gas turbines and renewable energy sources is emphasized, given the undeniable advantages of hybridization.

References

1. Energy Strategy of Ukraine for the period up to 2035 “Security, energy efficiency, competitiveness”. URL: <https://zakon.rada.gov.ua/laws/file/text/58/f469391n10.pdf> (accessed: 20.10.2025).
2. Ustimenko V.I., Kirichenko E.M. Gas turbine units: design, processes, characteristics. Kyiv: Naukova Dumka, 2014. 320 p.

3. Khalatov A.A., Kulishov S.B., Chobenko V.N., Raimov R.I. The use of gas turbine technologies is the key to energy security in Ukraine. *Promelectro «Industrial electrical power engineering and electrical engineering»* 2020. No. 3. P. 10–16. URL: <https://promelektro.com.ua/archive.html> (accessed: 20.10.2025).

4. USAID Energy Security Project. Distributed cogeneration for resilience of critical infrastructure in Ukrainian cities. Kyiv, 2023. URL: <https://www.usaid.gov/ukraine> (accessed: 20.10.2025).

5. National Strategy of Energy Security of Ukraine until 2030. Kyiv: Ministry of Energy of Ukraine, 2022. 45 p.

6. Data transmission system development plan for 2020-2029. URL: <https://ua.energy/wp-content/uploads/2020/04/Plan-rozvytku-systemy-peredachi-na-2020-2029-roku.pdf> (accessed: 20.10.2025).

7. Artificial intelligence in energy: analytical report / Sukhodolya O. M. K.: NISD, 2022. 49 p. DOI: <https://doi.org/10.53679/NISS-analytrep.2022.09>

8. Gülen C. Hybrid Systems. in: Gas and Steam Turbine Power Plants. Applications in Sustainable Power. Cambridge University Press, 2023. P. 233–245. DOI: 10.1017/9781108943475.008.

9. Ghofrani M, Hosseini NN. Optimizing Hybrid Renewable Energy Systems: A Review [Internet]. Sustainable Energy - Technological Issues, Applications and Case Studies. InTech; 2016. DOI: <http://dx.doi.org/10.5772/65971>

10. Giedraityte A, Rimkevicius S, Marciukaitis M, Radziukynas V, Bakas R. Hybrid Renewable Energy Systems — A Review of Optimization Approaches and Future Challenges. *Applied Sciences*. 2025. 15(4). P. 1744. DOI: <https://doi.org/10.3390/app15041744>