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APPROACHES TO COVERING PEAK LOADS IN THE UKRAINIAN POWER SYSTEM

Summary. *This paper examines the implementation of traditional and innovative approaches to covering peak loads in the Ukrainian power grid. Specifically, it analyzes the use of peak-load generating capacity, energy storage systems, smart grids, and demand-side management, as well as the integration of renewable energy sources into the power grid, combined with energy storage systems or virtual power plants. It is noted that, in the short term, traditional approaches will have certain advantages over innovative ones.*

Key words: *peak load coverage, renewable energy integration, peak generation capacity, energy storage systems, smart grids, demand response*

For the efficient operation of Ukraine's energy system, the most critical issue is peak loads. The country's coverage of these peak loads is subject to certain challenges, constantly changing due to the constant attacks of the aggressor state, Russia [1-5] .

The issue of covering peak loads has technological, economic, regulatory, and other aspects. The main areas of addressing these loads include:

- use of peak generating capacity (peaking units);
- use of energy storage systems (ESS — Energy Storage Systems);
- integration of renewable energy sources into the power grid in combination with energy storage or virtual power plants (VPP);
- application of smart grids (Smart Grids) and demand management DSM (Demand Side Management).

Regarding the use of peak generating capacity, the main ones in Ukraine include thermal power plants, combined heat and power plants, hydroelectric power plants, and pumped storage power plants. Table 1 provides information on the dynamics of changes in the installed capacity of these energy facilities. As can be seen, the most widespread use of thermal power plants in Ukraine is their relatively short start-up time, load flexibility, and the possibility of centralized control. However, this technical solution has certain disadvantages:

high specific fuel consumption, significant CO emissions, and dependence on imported gas [6].

Table 1

Installed capacity of nuclear power plants, thermal power plants, combined heat and power plants, hydroelectric power plants, pumped storage power plants in Ukraine in 1991, 2014, and 2024 according to the Ministry of Energy of Ukraine

Years	Installed capacity *N*, MW				
	Nuclear power plants	Thermal power plants	Combined heat and power plants	Hydroelectric power plants	Pumped storage power plants
1991	13835	20807	4960	4580	236
2014	13835	17659	4528	4586	1510
2024	7835	14137	4019	4235	1510

Gas turbine units and internal combustion engines are widely used to cover peak generation. Their main advantages include: fast start-up—cold start-up within 5–10 minutes for gas turbine units and 1–5 minutes for internal combustion engines; compactness and mobility; low capital costs compared to the high ones in thermal power plants or pumped storage power plants—600–1200 euros/kW for gas turbine units and 400–800 euros/kW for internal combustion engines; the ability to operate on various types of fuel, etc. Limitations of using gas turbine units and internal combustion engines include, first and foremost, low efficiency at partial loads and high generation costs. Thus, the average cost of 1 kWh produced by an internal combustion engines in Ukraine in 2023 reached 6–9 UAH/kWh under short-term operation conditions. In addition, the use of gas turbines and internal combustion engines in densely populated areas due to noise and harmful emissions is only possible with proper sound insulation and purification of these emissions.

Examples of the use of gas turbines in industry include enterprises such as ArcelorMittal Kryvyi Rih, Zaporizhstal, and others, where backup gas turbines with a capacity of 1 to 15 MW were used to cover their own peak loads.

Internal combustion engines are widely used, particularly in critical infrastructure facilities. Thus, in 2023-2024, internal combustion engines were purchased en masse for hospitals, water utility pumping stations, regional power company dispatch systems, etc. According to the Ministry of Health of Ukraine, more than 300 key medical institutions were equipped with backup internal combustion engines with a capacity of 50 to 500 kW to ensure continuous operation during rolling blackouts [7].

As for cogeneration units, they can be upgraded to a partially flexible mode. Specifically, this requires increasing the level of automation, implementing bypass control, and using heat buffer tanks [8].

Hydroelectric power plants, especially pumped storage hydroelectric power plants, play a vital role in meeting peak loads. The latter are characterized by fast response times (reaching full power in 2-5 minutes), environmentally friendly energy production, a wide load range, the ability to maintain frequency inertia, etc. Factors hindering the use of pumped storage hydroelectric power plants include their high construction costs (up to $2-2.5 million per MW) and geographic limitations, which require the ability to create reservoirs with the required elevation changes.

An innovative peak load coverage segment is the battery energy storage system (ESS) using lithium-ion batteries, hybrid storage, and hydrogen technologies. Key advantages of ESS include the ability to regulate frequency (primary/secondary frequency response), stabilize voltage, smooth out fluctuations in renewable energy sources, and provide peak shaving services (peak shaving) etc.

The implementation of energy storage system (ESS) in Ukraine is in its early stages. In 2023, DTEK commissioned Ukraine's first industrial-scale energy storage system with a capacity of 1 MW/2.25 MW per year in Energodar, integrated with renewable energy sources [9]. This year, Japan provided four storage units, each with a capacity of 4 MW, as part of its assistance to Teplokommunenergo in Odessa. However, Ukraine has significant potential for ESS development. According to the Ministry of Energy's plans, the total ESS capacity should reach at least 500 MW by 2030 [10].

Smart grids and demand-driven management (DSM) form the basis of a peak load management approach that involves reducing or shifting loads without increasing generation. This approach is implemented through the implementation of ACKOE and AMI systems for metering and pricing, flexible tariffs with time differentiation (day/night, hourly pricing), and remote consumer management (DSM).

The potential of the above-mentioned approach is being realized to a very limited extent in Ukraine. However, there are isolated examples of pilot programs implementing AMI in Kyiv, Dnipro, and Lviv, demonstrating the technical feasibility of scaling these solutions [11].

As noted, renewable energy sources combined with storage or virtual power plants (VPPs) can be used to cover peak loads. The VPP concept involves combining a number of small-scale renewable energy sources, energy storage, and load-shedding consumers into an energy cluster. The implementation of this flexible and adaptive peak load covering resource in Ukraine is just beginning. One example is the first VPP pilot project, based on a network of 45 households with energy storage, which was implemented in 2024 in the Kyiv region.

The approaches to covering peak loads discussed above require further development, particularly given that these loads tend to increase due to climate change, the electrification of various sectors of the economy, the increasing share of renewable energy sources, etc.

Conclusions. This paper presents an analysis of the characteristics of traditional and innovative approaches to peak load coverage. It explores the advantages and limitations of the following key approaches to peak load coverage: peaking units; energy storage systems (ESS); integration of renewable energy sources into the grid, combined with energy storage units or virtual power plants (VPP); smart grids; and demand-side management (DSM).

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