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THE IMPACT OF RENEWABLE ENERGY SOURCES ON THE FORMATION OF PEAK LOADS

Summary. *This paper presents the results of an examination of the problem of covering peak loads in Ukraine's energy system in the context of Russia's full-scale invasion of Ukraine. Information is provided on the characteristics of these loads and their changes as a result of the war. The corresponding challenges associated with the integration of renewable energy sources into Ukraine's energy system are analyzed. The analysis concludes that the problem of covering peak loads in Ukraine's energy system has become increasingly pressing, given the increase in these loads for a number of different reasons.*

Key words: *renewable energy sources, peak loads, energy system, peak load coverage, energy storage.*

Introduction. The efficient functioning of the energy system largely determines economic development and ensures a comfortable life for the population. One of the critical challenges to the state of the energy system is peak load, which should be considered not only as a technical phenomenon but also as a socioeconomic marker [1].

The generation and coverage of peak loads in Ukraine has specific characteristics that have changed significantly over time, particularly since Russia's full-scale invasion of Ukraine. Systematic attacks on major generation and transmission facilities in the spring of 2024 resulted in the loss of a significant portion of the power's maneuvering capacity, making the problem of

peak loads particularly acute. Addressing this issue requires the introduction of additional flexible peak capacity and a fundamental review of approaches to effectively forecasting, covering, and smoothing peak loads.

A large number of works have been devoted to various aspects of the problem of peak load management, for example [2–16]. This review aims to examine the impact of renewable energy sources on the formation of peak loads in the Ukrainian power system.

Aim.

The aim of this paper is to analyse a number of issues related to peak load generation in the context of their dependence on renewable energy sources.

Peak load management and renewable energy sources.

The integration of renewable energy sources into Ukraine's power system is significantly changing the structure of consumption and generation, affecting peak loads. Table 1 shows the installed capacity of renewable energy sources in 2014 and 2024, according to the Ministry of Energy. Solar generation appears to be dominant, with a capacity of 1,006 MW in 2014 and a decrease to 782 MW by 2024. Wind power system capacity has remained unchanged over the past 10 years (299 MW) and is significantly lower than solar power.

Table 1

**Installed capacity of renewable energy sources (MW) in Ukraine in 2014
and 2024 according to the Ministry of Energy**

Renewable energy sources	2014 year	2024 year
Solar power system, MW	1006	782
Biogas, MW	6	9
Wind power system, MW	299	299
Total, MW	1311	1090

Table 2 presents data on changes in the generation structure in the Ukrainian power system caused by renewable energy sources and the corresponding resulting effects.

Table 2

The influence of renewable energy sources on the formation of peak loads in the energy system of Ukraine

Structural changes	A change in the traditional daily load curve, manifested in an increase in generation during the day and a decrease in the evening	Formation of so-called “artificial” or “pseudo-peaks” alongside classical peaks	Random and unpredictable fluctuations in generation due to seasonal and weather instability	Asymmetry of generation due to territorial concentration of renewable energy sources (mainly in the southern regions of Ukraine)
Resulting effects	Increase in the amplitude of daily load fluctuations	Switching on conventional generation at sunset to compensate for the absence of a solar power system and the limitation of renewable energy sources, provided that the grid cannot accommodate excess generation	Frequent changes in the direction of power flows in main networks and sharp fluctuations in power due to cloud cover, changes in wind speed, etc.	Local network congestion, especially when subject to restrictions due to unexpected military action or damaged infrastructure

The growth of installed renewable energy capacity has led to a change in the traditional daily load curve, resulting in increased generation during the day and a decrease in the evening. Consequently, the amplitude of daily load fluctuations has increased [19].

The integration of renewable energy sources into the Ukrainian energy system has led to the formation of so-called “artificial” or “pseudo-peaks” alongside classical peaks, namely: a peak in which traditional generation is switched on at sunset to compensate for the lack of solar power and a peak in which renewable energy sources are limited when the grid cannot accommodate excess generation.

Important characteristics of renewable energy sources include their seasonal and weather instability, which leads to random and unpredictable fluctuations in generation. This, in the absence of the necessary storage capacity, is due to frequent changes in the direction of power flows in transmission networks and sudden power fluctuations due to cloud cover, changes in wind speed, and the like [20]. Another characteristic of renewable energy sources is generation asymmetry due to their territorial concentration in the southern regions of Ukraine, which creates localized network overloads.

The stated requirements related to the integration of renewable energy sources into the energy system of Ukraine require an active response and coordinated development of relevant mechanisms.

Conclusions. This article analyzes several aspects of peak load coverage in the Ukrainian power system. The impact of renewable energy sources integrated into the Ukrainian power system on peak load generation is examined. It is noted that the growth in installed capacity of renewable energy sources has led to increased daily load fluctuations, the formation of "artificial" or "pseudo-peaks" alongside traditional peaks, generation asymmetry due to the spatial concentration of renewable energy sources, and other factors.

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