

The choice of electricity storage systems to optimize the load curve. Case studies

Alegerea sistemelor de înmagazinare a energiei electrice pentru optimizarea curbei de sarcină. Studiu de caz

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Abstract. *The European Commission's (EC) policy to phase out fossil fuels from the energy system has forced the reconfiguration of electricity systems (ESS) as a result of the large-scale introduction of renewable energy systems (RES). Achieving these objectives while ensuring energy security must lead to a balanced energy mix capable of ensuring an energy price that can be borne by end consumers, a goal that can be achieved by installing energy storage systems.*

Key words: storage, energy, wind, photovoltaic, RES, energy security, cost

1. Introduction

Population growth, excessive urbanization, and the emancipation of the population have led to the development of a society based on consumption, determining the development of the means of production and the increase in energy consumption. Access to energy resources depends largely on technical, economic, political, cultural, geographical and military circumstances, highlighting the concept of energy poverty. [1-3].

The 1973 oil crisis highlights for the first time the energy vulnerability, including that of rich countries, and practically determines the start of research into renewable energy conversion systems. [1,4]. The attention of researchers, decision-makers, investors and last but not least, users has turned to energy sources capable of ensuring long-term sustainability. Research has been intensified into the use, in addition to waterfalls, of other renewable energy sources (RES): wind, solar, geothermal, tidal and biogas energy [5]. In the early 1980s, important research centers in Romania, under the coordination of the Research Center of the Traian Vuia

Polytechnic Institute in Timisoara, started a large-scale project to exploit the wind potential on Semenic Mountain [1,6].

Experts discuss the issue of depletion of energy resources but also the increase in greenhouse gas emissions (GHG). Thus, the end of the 20th century and the beginning of the 21st century mark the beginning of actions against global warming by reducing GHGs [2,3].

Even though Romania has the possibility of using a diversified range of primary energy resources (oil, natural gas, coal, hydropower, nuclear energy and renewable resources), in the current energy context, this sector is not immune to problems. În Fig. 1 este reprezentată evoluția producției de energie electrică pe surse de energie primară în perioada 2017-2050 [7].

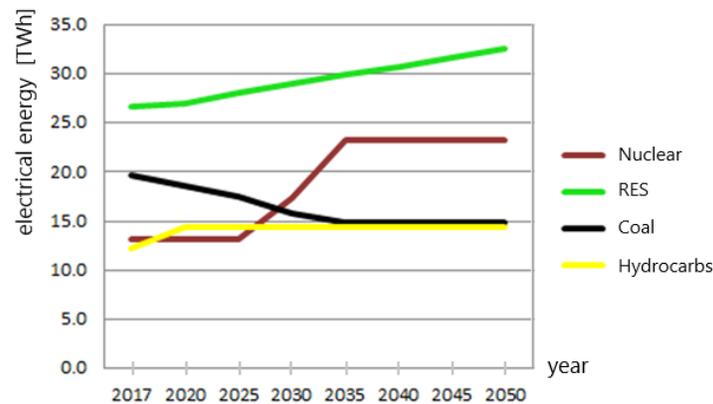


Fig. 1 Evolution of electricity production based on primary energy sources

On the other hand, in Fig. 2 it can be seen that a carbon-neutral Europe relies on solar and wind energy. Offshore wind technologies will become the most important source of electricity in the EU by 2040, complementing other renewable sources leading to a fully decarbonised energy system [8].

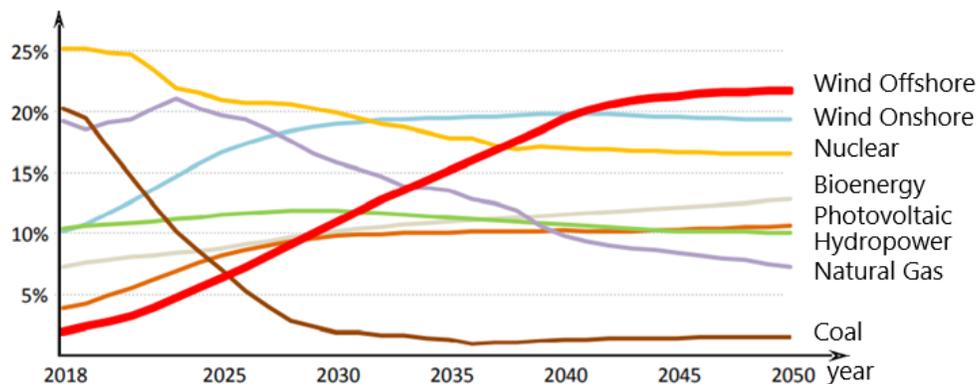


Fig. 2 Electricity production quotas in the EU according to the technologies used, in the scenario SDD [8]

The achievement of the objectives imposed by energy strategies at European level must be accelerated so that through the diversification of energy sources, energy security and an energy price that can be borne by end consumers are ensured.

2. Analysis of the National Energy System during the period 01.04.2025-21.04.2025

The announcements made by the Ministry of Energy proposing measures to support investments in new renewable electricity generation capacities [9,10] will increase the number of prosumers Table. 1, registered in the records of the National Energy Regulatory Authority (ANRE) [11]. All this confirms the trend towards the widest possible use of electricity from RES.

Table 1

Situation of the number of prosumers on 31.11.2023 versus 31.11.2024 [11].

Individual prosumers (IP)		Legal entity prosumers (PJ)		Total number of prosumers	
2023	2024	2023	2024	2023	2024
92569	172546	14432	22357	107001	194903

Analyzing the energy mix in the National Energy System (SEN) Fig.3, during the period 01.04.2025- 23.04.2025, its inability to ensure the energy needs was found, the positive balance is greater than the negative balance. It is worrying that with few exceptions Romania imported energy both on weekends and weekdays, Fig.4.

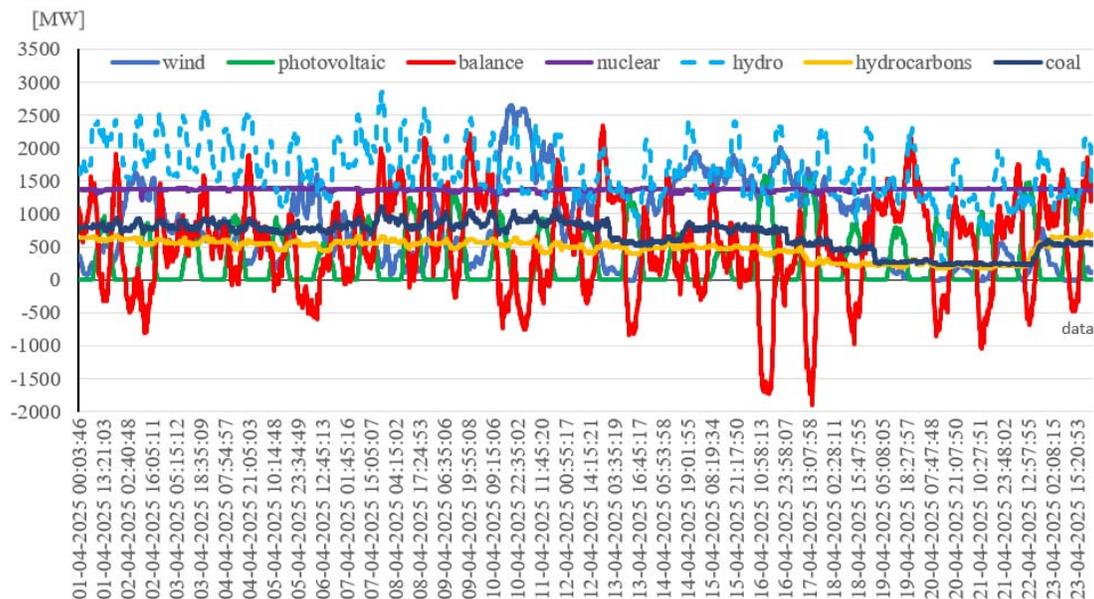


Fig. 3 Energy mix in the period 01.04.2025- 23.04.2025 [12]

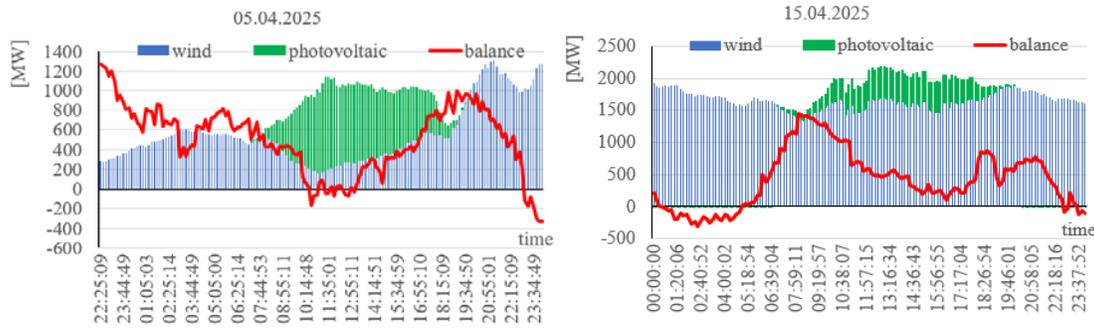


Fig. 4 SEN operation on 05.04.2025 and 15.04.2025 [12]

Even though the installed power in the NES increased by 4.52% in 2025 compared to 2024 [23], from a technical point of view, the failure to ensure the load curve, except for solar and wind systems, was due to the operation of classic conversion systems at 30.96% of the installed power [12], Table 2.

Table 2

Installed powers in NES [11,12]

Energy source	Installed capacity in 2024 [MW]	Installed capacity in 2025 [MW]	Average power charged in SEN in April 2025 [MW]
Wind	3026.91	3091.31	801.56
Photovoltaic	1626.74	2334.75	311.23
Hydropower	6639.06	6687.78	1658.78
Coal	2762.20	2762.20	676.18
Hidocarbs	2684.43	2727.38	468.38
Nuclear	1413.00	1413.00	1368.40
Biomass	106.27	106.27	69.00

At the same time, it is noted that adopting only measures to increase the installed photovoltaic and wind power cannot ensure the ever-increasing demand for energy. Measures are required to improve the efficiency of coal-fired thermal power plants either by adopting Ultra-Supercritical (USC) technology or CO₂ Capture and Storage (CCS) technologies [14], or by supplementing nuclear capacity [15] and electrical energy storage systems [16]. Practically, the optimization of hybrid energy systems that integrate RES is only possible by installing energy storage systems. All the more the storage systems are necessary for the optimization of small prosumer systems, which must be able to store the energy produced in favorable climatic conditions and return it to cover the load peaks during the day or when the production of renewable systems is not possible.

3. Electricity storage systems

The choice and sizing of electrical energy storage systems must take into account the nature and amplitude of fluctuations in the NES, the energy storage time,

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the operating duration, the size of the storage system and, last but not least, the possibility of storing energy in natural environments or environments that do not generate electrotechnical waste.

Except for electrical and electrochemical storage systems, storing electrical energy with mechanical systems involves converting it into another form of energy. The classification of electrical energy storage systems is shown in Figure 5 [16].

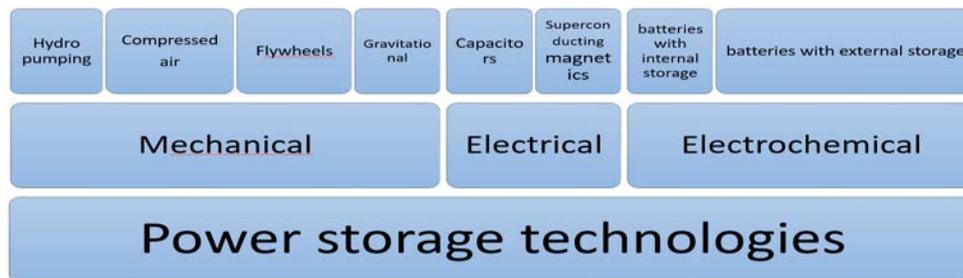


Fig. 5 Tehnologii de înmagazinare a energiei

In Fig. 6 shows the electrical energy storage systems ordered according to the power density (kW/kg), the energy density (kWh/kg) that it can store, but also according to the time in which the system can return the stored electrical energy to the SEN [5].

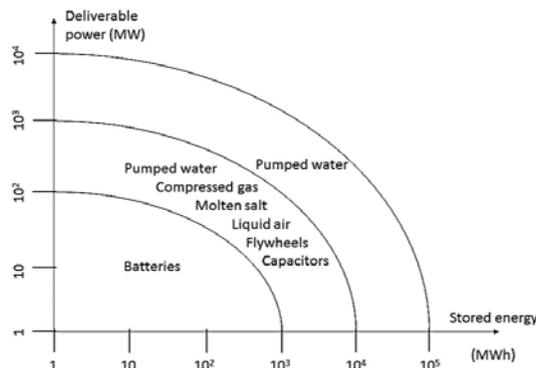


Fig 6 Systems of electrical energy storage [17]

The time in which an energy storage system returns the necessary energy can be in the order of seconds, minutes, hours, days, and the factors that influence the ability to return the stored energy are power density and energy density.

Mechanical energy storage systems are based on the transformation of kinetic and/or gravitational energy into electrical energy. Mechanical energy storage can be achieved in simple or complex systems, where the primary source can be water, compressed air, pressurized gases, thermal energy, etc. [18]. These systems have the advantage of qualitative and quantitative regulation of the NES, being able to return large amounts of energy in a very short time. The main electrochemical storage technologies presented in Fig. 7 refer to the storage of electrical energy in batteries, capacitors/supercapacitors and fuel cells, representing storage solutions in areas where

there are no storage possibilities in natural environments [1,16]. The electrochemical storage solution is compact, easy to install with fast charge/discharge cycles and is recommended for prosumers, but can also be adopted for large-scale RES systems.

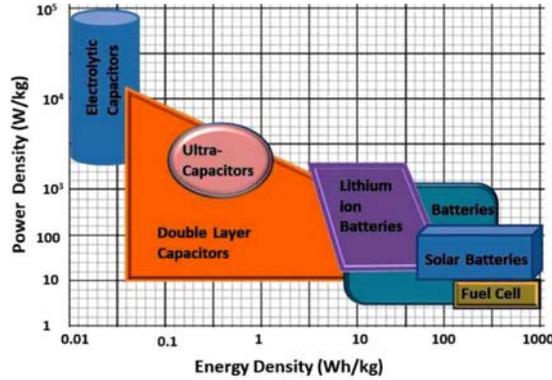


Fig. 7. Electrochemical storage systems [1]

3. Considerations regarding improving energy balance

The sizing of the storage system for the period analyzed in Fig. 8 must take into account the nominal voltage, maximum power, stored energy and the time in which it is stored and returned.

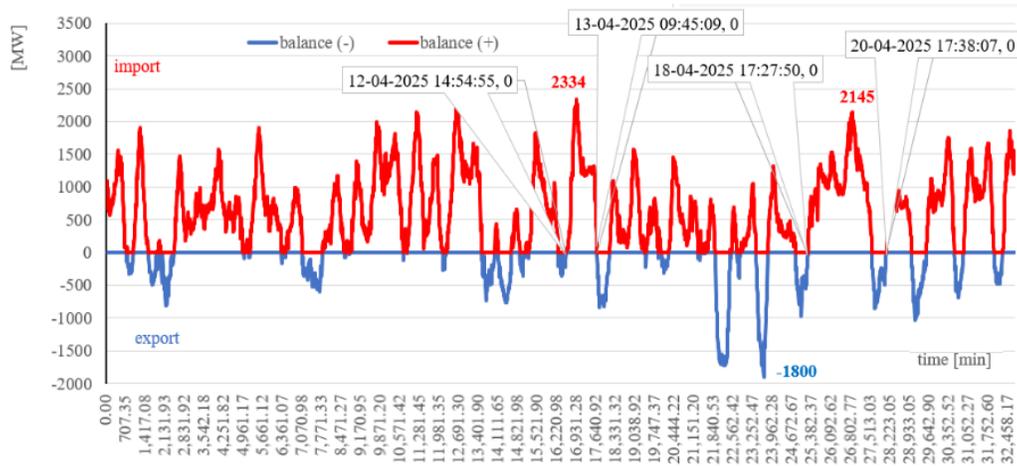


Fig. 8. NES balance in the period 01.04.2025- 23.04.2025 [12]

The value of the imported/exported energy E , in MWh, is obtained with the aid of rel.1:

$$E = \int_{t_1}^{t_2} P dt \quad (1)$$

Where: P is the electrical power in MW; t - time in h

For the period 04/01/2025- 04/23/2025, the energy required to cover the load curve calculated with rel, (1) is 11544MWh, at a maximum power of 2334MW (Fig.8). Assuming that we want to cover the load curve in Fig. 8, in the interval 18-04-2025 17:27:50 to 20-04-2025 17:38:07, i.e. 1128.59MWh with the energy produced up to that moment 1917.75MWh, a 2300MWh electrochemical storage system is proposed, the block diagram of which is presented in Fig. 9.

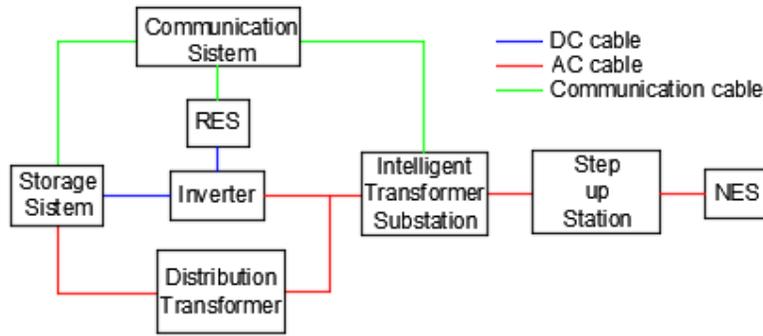


Fig. 9. Block diagram of the storage system

To size the storage system, the technical data sheet of the LUNA2000-4.5MWH-2H1 high-capacity battery, with 4.5MWh and 2h autonomy, was analyzed.. To store the energy produced during the analyzed period, 256 such batteries are required, each containing 104 cells of 280Ah/93.18kWh. Since the nominal power of the battery is 2236kW, peak loads will be covered from another source. The design of the system also involves the design of the site, which must take into account the fact that each unit is containerized, occupies an area of 17.55m² and a volume of 42.78m³. For this reason, attention must be paid to the land areas occupied and to the design of the post-use phase of electrotechnical waste.

3. Conclusions

Without having a clear picture of the unavailability of already installed energy capacities, the inability of the NES to ensure consumption was observed even in the conditions in which there was an increase in installed power from RES compared to the previous year.

Thus, the targets assumed without careful analysis, the abandonment of fossil fuels without re-engineering thermoelectric plants based on the examples of good practices already on the table of the Ministry of Energy by Deloitte Touche Tohmatsu Limited, lead to massive imports of electricity to increase the price of electricity, to instability and energy poverty.

The need for electrical energy storage is accepted in all scientific and engineering circles, even by investors. The authors of this paper, analyzing the worrying situation of the NES, present the advantages of energy storage, but also draw attention to the occupied land areas and the obligation to design the post-use phase of electrotechnical waste.

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