MODELING ENERGY STORAGE SYSTEMS IN ELECTRICITY MARKETS

Zejneba TOPALOVIĆ[1], Reinhard HAAS[2]

Nevertheless of many countries globally signing the Paris Agreement and pledging to achieve net-zero emissions in coming years, the recent development of these established targets are not satisfying. Emissions from CO2 from energy and industry have increased by 60% when compared to the signed United Nations Convention on Climate Change in 1992 [1]. COP26 Climate Change Conference in Glasgow in November 2021., concluded that higher ambition is needed along with the strong implementation of climate pledges. Emissions decrease is conducted with the implementation of renewable generation in power systems. The intermittent nature of wind, sun, and other renewable energy sources, brings new challenges for operating and dispatching power systems. Electricity markets are in the need of new technologies since renewables change the merit-order curve making distortions as negative electricity prices, or threatening the energy stability. These obstacles can be overcome with energy storage systems. This paper analyses costs of different types of energy storage systems as flexible tools for daily dispatching of energy systems that consist of thermal and wind power plants. Currently, there are over 182 GW of installed energy storage power capacity worldwide (Fig.1), while pumped hydro is still the leading storage technology. Along with the new investments and research, other storages such as hydrogen cells and batteries are emerging as well. In Austria, the installed storage power capacity of 18 pumped hydro storage power plants is 4,7 GW. These are substantially applicable as bulk energy services for an electric energy time-shift, that is arbitrage. One electrochemical energy storage, ViZn Z20 Zinc Redox Flow Battery is operational since 2013., used as a solar reserve.

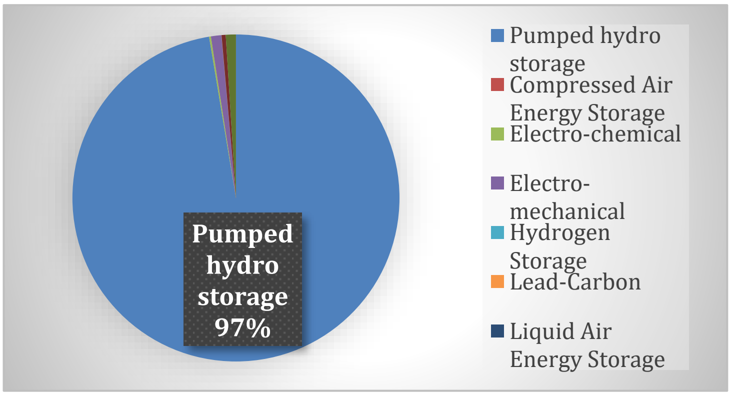


Figure 1 Installed storage power capacities, source: Global Energy Storage Database, accessed June 2021.

Austrian generation mix shows different needs for storage during winter and summer. In winter (Fig.2), fossil gas generation covers most of the demand, hence with the hydro generation, there is enough amount of energy to be stored. During the summer (Fig. 3), with high wind generation and high solar penetration in the grids, at the times of the peak demand, there is a scarce generation, that could be covered with the energy storage systems.

Modeling storage systems requires new strategies in electricity markets since energy storage systems can be used as bulk, distributed, or user-side systems.

Method

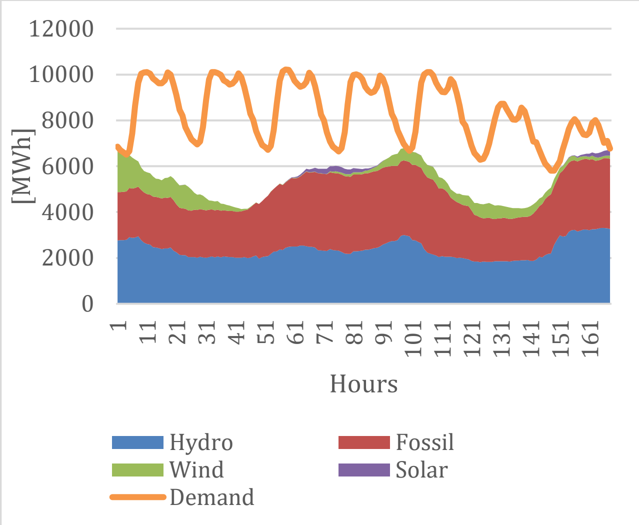
The method of approach is based on mixed-integer quadratic programming. Daily economic dispatch of thermal and wind generation portfolio is modeled in software tool GAMS, alongside battery energy storage. Generation of wind and thermal power plants is assumed based on analyzed data in Austria generation mix. History load and generation data for two scenarios: winter and summer are used. Main

[1] Institute of Energy Systems and Electrical Drives, TUWIEN, Gußhausstraße 25 – 29/E37003 1040 Vienna Austria, +43 1 58801-370303, +43 1 58801-370397, zejneba.topalovic@student.tuwien.ac.at, https://eeg.tuwien.ac.at/
[2] Institute of Energy Systems and Electrical Drives, TUWIEN, Gußhausstraße 25 – 29/E37003 1040 Vienna Austria, +43 1 58801-370303, +43 1 58801-370397, haas@eeg.tuwien.ac.at, https://eeg.tuwien.ac.at/

objective for energy storage systems to participate in electricity markets optimally, is to maximize the profitability of dispatching the analyzed system, as in equation:

$$Profit = \sum_{t=1}^{24} Ci,t * Pi,t - \sum_{t=1}^{24} Cpwt - \sum_{t=1}^{24} Cpesi \ ,$$

where Ci,t is the price in energy market offered at hour t, Pi,t is offered power from the generation unit i at hour t, Cpwt and Cpesi are the operating costs of wind facility and energy storage system.



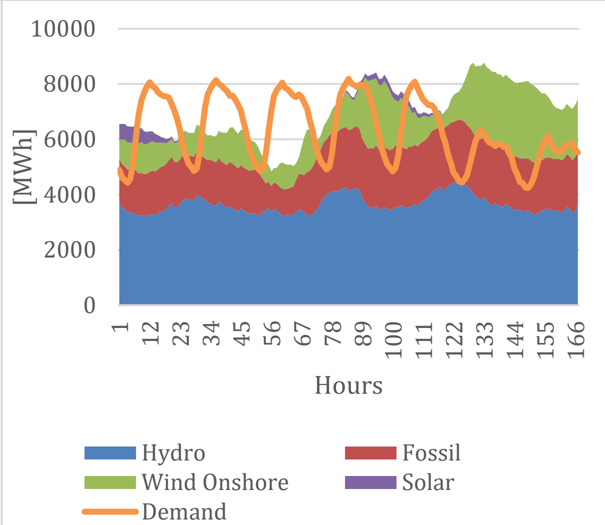


Figure 2 Generation in winter week 20.1.2020.-26.1.2020. *Figure 3 Generation in summer week 10.8.2020.-16.8.2020.*

Results

Results show the optimal operation of these plants with minimum costs of storage. Analysis showed that with proper dispatching, energy storage systems can be a valuable market player and factor for further penetration of renewables in the grids. Figure 4 shows that installed batteries alongside wind power plants are effectively providing flexibility options, covering the gap in wind generation.

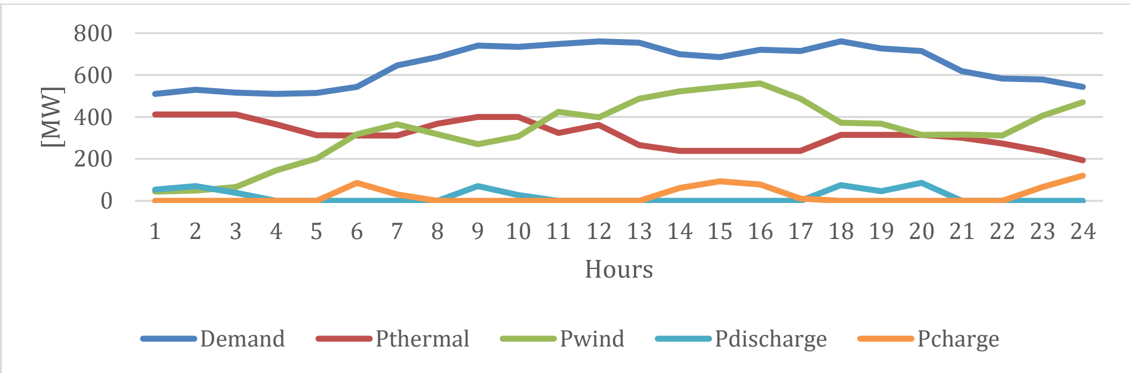


Figure 2 Economic daily dispatch with battery energy storage

Conclusions

This analysis provides us with conclusions:

- energy storage is an inevitable tool for further renewable implementation in power systems.
- With adequate economic dispatching, energy storage can be a feasible solution for overcoming challenges with wind and solar generation's intermittent nature.
- With higher electricity market prices, energy storage systems installations are more justified and hence optimal dispatching of these technologies should be considered.

References

[1] Net-zero by 2050 A roadmap for the Global Energy Sector, International Energy Agency report, May 2021.