A REVIEW OF ENERGY STORAGE SYSTEMS IN ELECTRICITY MARKETS

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Overview

Recent events in power systems, such as negative electricity prices, high fluctuations in electricity market and positive progress of variable generation, have influenced need for energy storage systems. These systems were used firstly as pumped hydro plants, but in recent years new types of storage have been developing, as the technology costs decrease and renewables installations increase. Policy makers have established a roadmap for reaching net-zero emissions by 2050., ensuring clean energy transition which has been questioned since the COVID-19 outbreak. At the beginning of the global pandemic, with the government restrictions and industrial setback, decrease of CO2 emissions occured for the short period of time. Demand drop and high supply of variable generation in the grids, have been challenging for power systems operators, hence energy storage systems are inevitable future flexibility solutions.

Since global energy sector has been under disruptions and has influenced high socio- economic changes, growing number of countries pledge net- zero emissions agreement, towards sustainable and clean energy development. With the Paris Agreement goals for limiting global warming to 1,5 degrees Celsius, many countries are already going towards carbon neutrality ambitious targets. These goals are opening set of new technologies, business opportunities, thus improving economy. Measures taken for the implementation of the set goals and for higher share of renewable generation, are already taken, showing that energy storage systems are becoming new emerging technology as balancing option in the power grids. With projections of new solar by 2050., it is expected for storage market to rise and balance possible price fluctuations.

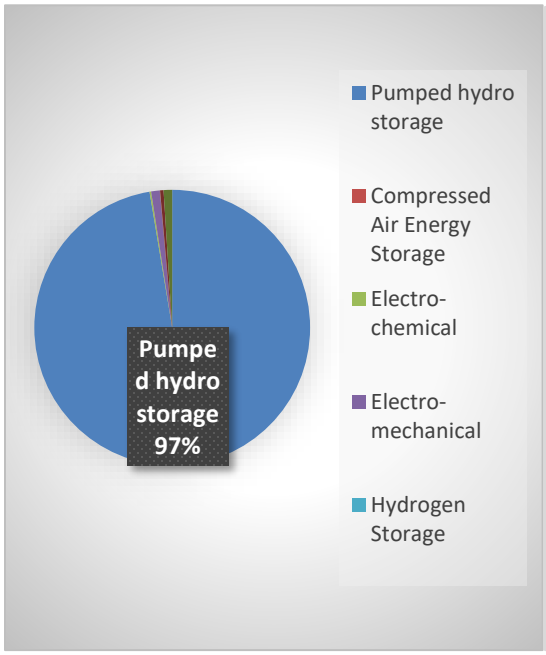

Figure 1Installed energy storage capacities globally [1]

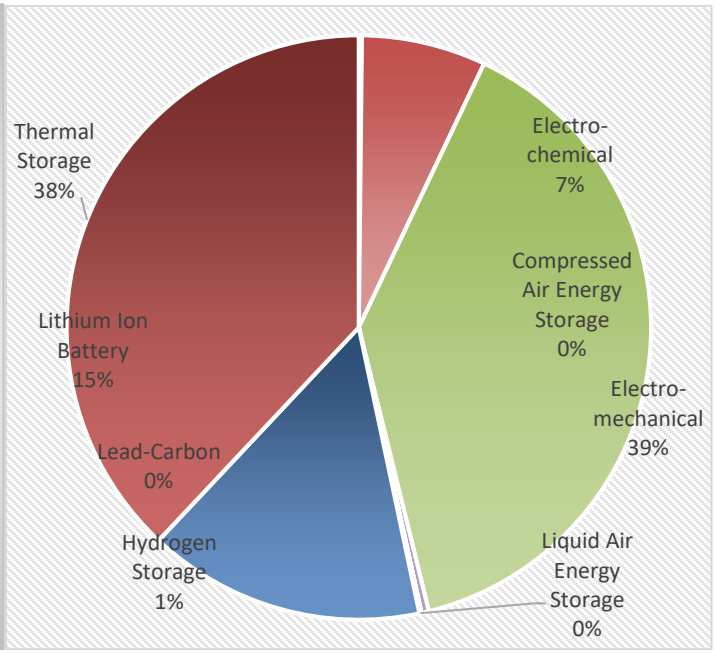

Figure 2 Installed energy storage capacities without pumped hydro storage [1]

Methods

This paper presents energy storage review using method of narrative. Collecting up-to-date research on energy storage technologies, applications, environmental and economic assessment, published in wide range of articles with high impact factor is given. Since, there is an obscure research on relatively new technology such as energy storage, and especially their costs, global databases are used.

Results

This paper results in the following:

- Up-to-date research on energy storage technologies, grid applications and economic assessment,
- Review of the energy storage technologies in the whole chain, explaining the impact on the total energy demand,
- Comprehensive energy storage systems review considering technology and feasibility.
- Review of the energy storage costs, as it is presented in the Figure 3.

Type of storage	Capital cost (power based) $/kW	Capital cost(energy based) $/kWh	Charge time	Discharge time	Environmental impact	References
Pumped hydro	2000-4300	5-100	hr-months	1-24hr+	Large	(Das *et al.* , 2018)
	500-4600	5-100				(Koohi-Fayegh and Rosen, 2020)
		12-84				(Olabi *et al.* , 2021)
Compressed air	400-1000	2-120	hr-months	1-24hr+	Large	(Das *et al.* , 2018)
	400-800	2-50				(Koohi-Fayegh and Rosen, 2020)
		4-84				(Olabi *et al.* , 2021)
Flywheel	250-350	1000-14000	s-min	ms-15min	Almost none	(Das *et al.* , 2018)
	300-1000	3000-6000				(Koohi-Fayegh and Rosen, 2020)
		400-800				(Olabi *et al.* , 2021)
Lithium- ion	900-4000	600-3800	min-days	min-hr	Moderate	(Das *et al.* , 2018)
	1200-4000	100-2500				(Koohi-Fayegh and Rosen, 2020)
		900-1300				(Olabi *et al.* , 2021)
Lead-acid	300-600	200-400	min-days	s-hr	Moderate	(Das *et al.* , 2018)
	300-600	200-400				(Koohi-Fayegh and Rosen, 2020)
		60-120				(Olabi *et al.* , 2021)
Nickle-Cadmium	500-1500	400-2400	min-days	s-hr	Moderate	(Das *et al.* , 2018)
	500-1500	800-1500				(Koohi-Fayegh and Rosen, 2020)
		400-2400				(Olabi *et al.* , 2021)
Natrium-Sulfur	1000-3000	300-500	s-hr	s-hr	Moderate	(Das *et al.* , 2018)
	1000-3000	300-500				(Koohi-Fayegh and Rosen, 2020)
		250-537				(Olabi *et al.* , 2021)
Vanadium-Redox	600-1500	150-1000	hr-months	s-24hr+	Moderate	(Das *et al.* , 2018)
	1000-3000	300-500				(Koohi-Fayegh and Rosen, 2020)
	-	-				(Olabi *et al.* , 2021)
Capacitor	200-400	500-1000	s-hr	ms-60min	Small	(Das *et al.* , 2018)
	200-400	500-1000				(Koohi-Fayegh and Rosen, 2020)
	-	-				(Olabi *et al.* , 2021)
Supercapacitor	100-450	300-2000	s-hr	ms-60 min	None	(Das *et al.* , 2018)
	130-515	10000				(Koohi-Fayegh and Rosen, 2020)
	-	-				(Olabi *et al.* , 2021)
Magnetic	200-489	1000-72000	min-hr	ms-8s	Moderate	(Das *et al.* , 2018)
	130-515	1000-10000				(Koohi-Fayegh and Rosen, 2020)
		7157;20000				(Olabi *et al.* , 2021)
Hydrogen	500-10000	15	hr-months	1-24hr+	Small	(Das *et al.* , 2018)
	500-10000	-				(Koohi-Fayegh and Rosen, 2020)
		14-18				(Olabi *et al.* , 2021)
Thermal CES	200-300	3-30	min-days	1-8 hr	Bening	(Das *et al.* , 2018)
	200-300	3-60				(Koohi-Fayegh and Rosen, 2020)
	-	-				(Olabi *et al.* , 2021)

Figure 3 Review of the energy storage costs

Conclusions

Energy storage systems are going to be used more in the light of the renewable generation increase and technology cost decrease. Main concern if the peak of the batteries occurs, are disposable and environmental consequences. In future development of net-zero emissions by 2050, energy storage systems should develop proportionally to the renewable shares in the power systems. Development of the different type of storage systems should be encouraged, not just batteries and pumped hydro storage. Prices are still major limit for wider integration, since Lithium- ion batteries are the most used technology in electric vehicles, but for large – scale storage, they are still expensive. As energy storage systems are main source of flexibility in electricity market, it is expected for storage market to rise and balance possible price fluctuations.

References

[1] Global Energy Storage Database, National Technology& Engineering Sciences of Sandia, LLC (NTESS), https://www.sandia.gov/ess-ssl/global-energy-storage-database/, June, 2021