*electrochem*

MDPI

*Editorial*

# Advances in Electrochemical Energy Storage Systems

**Qi Zhang [1,2,*], Wenhui Pei [3] and Xudong Liu [4,5]**

[1] School of Control Science and Engineering, Shandong University, Jinan 250061, China
[2] State Key Laboratory of Automotive Simulation and Control, Jilin University, Changchun 130022, China
[3] School of Information Science and Electrical Engineering, Shandong Jiaotong University, Jinan 250357, China; peiwenhui4452@163.com
[4] College of Automation, Qingdao University, Qingdao 266071, China; xudong19871982@163.com
[5] Shandong Key Laboratory of Industrial Control Technology, Qingdao 266071, China
* Correspondence: zhangqi2013@sdu.edu.cn

The large-scale development of new energy and energy storage systems is a key way to ensure energy security and solve the environmental crisis, as well as a key way to achieve the goal of "carbon peaking and carbon neutrality". Lithium-ion batteries are widely used in various energy storage systems, new energy vehicles, electric and unmanned vehicles, etc. According to data in 2022 from the Ministry of Industry and Information Technology of the People's Republic of China, the output of lithium-ion batteries in China was 324 GWh in 2021, a year-on-year increase of 106%; the total output value of the lithium battery industry exceeded CNY 600 billion [1]. The battery and energy storage industry has become a major national demand and the main economic battlefield in the future.

Electrochemical energy storage systems are composed of energy storage batteries and battery management systems (BMSs) [2–4], energy management systems (EMSs) [5–7], thermal management systems [8], power conversion systems, electrical components, mechanical support, etc. Electrochemical energy storage systems absorb, store, and release energy in the form of electricity and apply technologies from related fields such as electrochemistry, electricity and electronics, thermodynamics, mechanics, etc. Energy storage systems can eliminate the difference between the peaks and valleys in power demand between day and night and play a role in smooth power output, peak and frequency regulation, and reserve capacity. According to the 2021 Data released by the research institute Huajing Industry Re-search Institute in 2022, the cumulative installed capacity of pumped hydro storage accounted for 90.3% of the operational energy storage projects around the world by the end of 2020, second only to pumped storage (90.3%). Other energy storages are molten salt thermal energy storage, compressed air energy storage, and flywheel energy storage, all of which account for only 2.2% in total [9]. Due to the advantages of cost-effective performance, unaffected by the natural environment, convenient installation, and flexible use, the development of electrochemical energy storage has entered the fast lane nowadays.

Standards are developed and used to guide the technological upgrading of electrochemical energy storage systems, and this is an important way to achieve high-quality development of energy storage technology and a prerequisite for promoting the development of energy storage marketization. Considering the importance of electrochemical energy storage systems, as shown in Table 1, five national standards in China have been released in 2017–2018 which are all under centralized management by the National Technical Committee 550 on Electric Energy Storage of Standardization Administration of China (SAC/TC550), and eleven new national standards are being drafted, which were planned during 2021–2022. The purpose of the new national standard is to add to or replace the existing national standards. It should be pointed out that the names of these standards all contain the keyword "electrochemical energy storage system/station". Thus, the importance of electrochemical energy storage systems is self-evident.



**Citation:** Zhang, Q.; Pei, W.; Liu, X. Advances in Electrochemical Energy Storage Systems. *Electrochem* **2022**, *3*, 225–228. https://doi.org/10.3390/electrochem3020014

Received: 15 April 2022
Accepted: 19 April 2022
Published: 21 April 2022

**Table 1.** Five national standards released during 2017–2018 in China.

| Standard Number | Standard Name | Release Time | Implementation Time |
|---|---|---|---|
| GB/T 36547-2018 | Technical rule for electrochemical energy storage system connected to power grid | 13 July 2018 | 1 February 2019 |
| GB/T 36545-2018 | Technical requirements for mobile electrochemical energy storage system | 13 July 2018 | 1 February 2019 |
| GB/T 36548-2018 | Test specification for electrochemical energy storage system connected to power grid | 13 July 2018 | 1 February 2019 |
| GB/T 36558-2018 | General technical requirements for electrochemical energy storage system in power system | 13 July 2018 | 1 February 2019 |
| GB/T 34120-2017 | Technical specification for power conversion system of electrochemical energy storage system | 31 July 2017 | 1 February 2018 |

Electrochemical energy storage systems have become a hot topic worldwide. The "energy storage" and "energy storage systems" were used as the search term in IEEE Xplore, and the number of publications (including Conferences, Journals, Early Access Articles, Magazines, Books, and Standards) in this discipline has increased steadily within the last few years. As shown in Figure 1, the number of publications with both "energy storage" and "energy storage systems" accounts for more than 50% of their respective totals since 2015. As shown in Figure 2, since 2018, the number of publications has remained at more than 5000 per year, with a maximum of 5793 in 2021, and is expected to reach more than 5000 in 2022, considering that there are 940 publications already so far in 2022 (Data acquisition time ends on 13 April 2022).

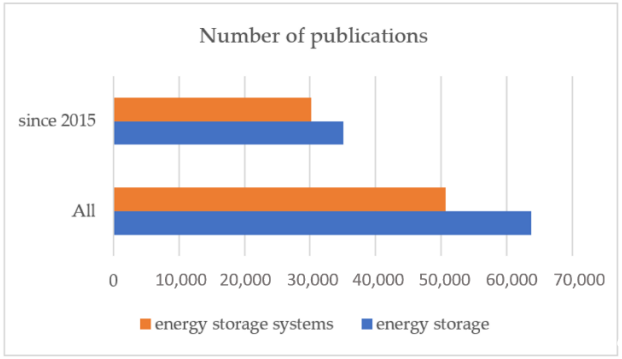


**Figure 1.** The number of publications in IEEE Xplore with "energy storage" and "energy storage systems" as the search term.

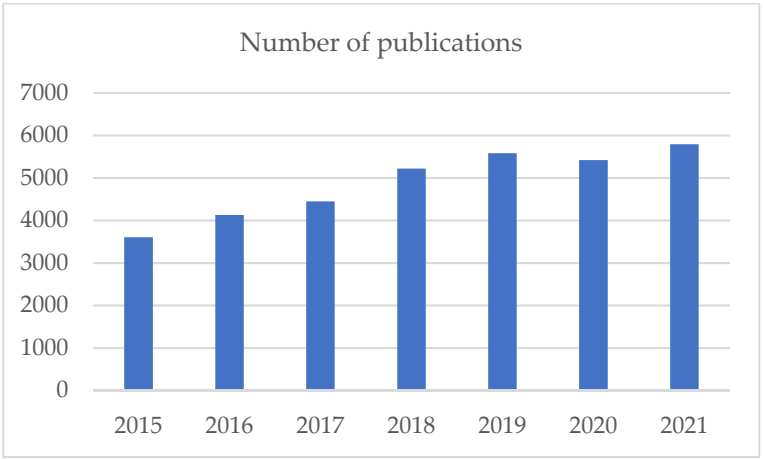


**Figure 2.** The number of publications on energy storage within the last seven years.

Despite a series of recent research progress, the technology still has a lot of room for improvement. The main challenge lies in developing advanced theories, methods, and techniques to facilitate the integration of safe, cost-effective, intelligent, and diversified products and components of electrochemical energy storage systems. This is also the common development direction of various energy storage systems in the future. Therefore, there is an urgent need to investigate new strategies and promising approaches for electrochemical energy storage systems. With this Special Issue, we aim to provide an overview of recent advances in electrochemical energy storage systems and their applications in different fields. A further aim of this Special Issue is to contribute to advances in modelling, estimation, management, optimal design and control, and applications of electrochemical energy storage systems and related devices and components [10–15].

Potential topics include, but are not limited to, the following:

- Electrochemical materials for energy storage batteries;
- Technologies of the intelligent battery management system (BMS);
- Power conversion systems for electrochemical energy storage systems;
- Energy management of electrochemical energy storage systems;
- Optimized design and control of electrical components for energy storage systems;
- Thermal management of electrochemical energy storage systems;
- Optimized control of power electronics and power drives;
- Vehicle-to-grid and energy storage systems-to-grid;
- Technologies of electric vehicles and unmanned vehicles.

**Author Contributions:** All authors contributed equally to this work. All authors have read and agreed to the published version of the manuscript.

**Funding:** This research was funded by Shandong Provincial Natural Science Foundation, grant number ZR2020QF059, ZR2021MF131; Projects of Shandong Province Higher Educational Science and Technology Program, grant number J18KA348, J18KA330, J18KB144; Foundation of State Key Laboratory of Automotive Simulation and Control, grant number 20181119.

**Institutional Review Board Statement:** Not applicable.

**Informed Consent Statement:** Not applicable.

**Data Availability Statement:** Not applicable.

**Acknowledgments:** The guest editors express their gratitude to the authors for their contributions to this Special Issue and the journal *Electrochem* for their support during this work.

**Conflicts of Interest:** The authors declare no conflict of interest.

## References

1. Department of Electronic Information. Ministry of Industry and Information Technology of the People's Republic of China. In *Operation of Lithium-Ion Battery Industry in 2021*; Department of Electronic Information: Beijing, China, 2022.
2. Zau, A.T.P.; Lencwe, M.J.; Chowdhury, S.P.D.; Olwal, T.O. A Battery Management Strategy in a Lead-Acid and Lithium-Ion Hybrid Battery Energy Storage System for Conventional Transport Vehicles. *Energies* **2022**, *15*, 2577. [CrossRef]
3. Zhang, Q.; Li, Y.; Shang, Y.; Duan, B.; Cui, N.; Zhang, C. A Fractional-Order Kinetic Battery Model of Lithium-Ion Batteries Considering a Nonlinear Capacity. *Electronics* **2019**, *8*, 394. [CrossRef]
4. Shang, Y.; Zhang, Q.; Cui, N.; Zhang, C. A Cell-to-Cell Equalizer Based on Three-Resonant-State Switched-Capacitor Converters for Series-Connected Battery Strings. *Energies* **2017**, *10*, 206. [CrossRef]
5. Wang, J.; Li, D.; Lv, X.; Meng, X.; Zhang, J.; Ma, T.; Pei, W.; Xiao, H. Two-Stage Energy Management Strategies of Sustainable Wind-PV-Hydrogen-Storage Microgrid Based on Receding Horizon Optimization. *Energies* **2022**, *15*, 2861. [CrossRef]
6. Ouramdane, O.; Elbouchikhi, E.; Amirat, Y.; Le Gall, F.; Sedgh Gooya, E. Home Energy Management Considering Renewable Resources, Energy Storage, and an Electric Vehicle as a Backup. *Energies* **2022**, *15*, 2830. [CrossRef]
7. Zhang, Q.; Fu, X. A Neural Network Fuzzy Energy Management Strategy for Hybrid Electric Vehicles Based on Driving Cycle Recognition. *Appl. Sci.* **2020**, *10*, 696. [CrossRef]
8. Huajing Industry Research Institute. *2022–2027 China Portable Energy Storage Industry Development Monitoring and Investment Strategic Planning Research Report*; Huajing Industry Research Institute: Wuxi, China, 2022.

9. Zhu, C.; Zhang, J.; Wang, Y.; Deng, Z.; Shi, P.; Wu, J.; Wu, Z. Study on Thermal Performance of Single-Tank Thermal Energy Storage System with Thermocline in Solar Thermal Utilization. *Appl. Sci.* **2022**, *12*, 3908. [CrossRef]
10. Tavares Nascimento, V.; Martinez-Bolaños, J.R.; Morales Udaeta, M.E.; Veiga Gimenes, A.L.; Riboldi, V.B.; Ji, T. Energy Storage System Design in the Light of Multisource Solution from a Viability Analysis. *Designs* **2022**, *6*, 38. [CrossRef]
11. Xiao, G.; Chen, Q.; Xiao, P.; Zhang, L.; Rong, Q. Multiobjective Optimization for a Li-Ion Battery and Supercapacitor Hybrid Energy Storage Electric Vehicle. *Energies* **2022**, *15*, 2821. [CrossRef]
12. Lee, W.; Chae, M.; Won, D. Optimal Scheduling of Energy Storage System Considering Life-Cycle Degradation Cost Using Reinforcement Learning. *Energies* **2022**, *15*, 2795. [CrossRef]
13. Fu, X.; Zhang, Q.; Tang, J.; Wang, C. Parameter Matching Optimization of a Powertrain System of Hybrid Electric Vehicles Based on Multi-Objective Optimization. *Electronics* **2019**, *8*, 875. [CrossRef]
14. Pei, W.; Zhang, Q.; Li, Y. Efficiency Optimization Strategy of Permanent Magnet Synchronous Motor for Electric Vehicles Based on Energy Balance. *Symmetry* **2022**, *14*, 164. [CrossRef]
15. Uwineza, L.; Kim, H.-G.; Kleissl, J.; Kim, C.K. Technical Control and Optimal Dispatch Strategy for a Hybrid Energy System. *Energies* **2022**, *15*, 2744. [CrossRef]