IARJSET

ISSN (Online) 2393-8021
ISSN (Print) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology

3rd-International Conference on Muti-Disciplinary Application & Research Technologies (ICMART-2024)

Geetanjali Institute of Technical Studies

Vol. 11, Special Issue 2, May 2024

Review of Smart Energy Storage System in Indian Context

Dr. Saurabh Tege1, Dr. Vijendra Kumar Maurya[2], Dr. Chintal Patel[3], Rakesh Kumar Jain[4]

Associate Professor Geetanjali Institute of Technical Studies Udaipur Rajasthan INDIA[1,2,3]

Assistant Professor Geetanjali Institute of Technical Studies Udaipur Rajasthan INDIA [4]

Abstract: Smart Energy Storage Systems (SESS) represent innovative energy storage solutions aimed at optimizing the utilization of renewable energy sources like solar and wind by enhancing their integration into the grid. SESS incorporates energy storage, power electronics, and intelligent controls to store and regulate surplus energy generated by renewable during periods of low demand, facilitating its utilization during peak demand periods. This strategy diminishes reliance on conventional power generation, enhances energy efficiency, and mitigates greenhouse gas emissions. Essential components of SESS include batteries, inverters, energy management systems, and monitoring and control systems. The significance of developing and implementing SESS cannot be overstated in transitioning towards a more sustainable energy future. This paper provides an analysis of energy storage systems with the objective of advancing smart energy storage technology and contributing to the realization of a more sustainable and efficient energy landscape

Keywords*:* SESS, Renewable, Smart Controls, Power Electronics etc.

I. INTRODUCTION

Th Smart Energy Storage Systems (SESS) are vital for advancing towards a sustainable and efficient energy future. These systems optimize the integration of renewable energy sources into the power grid by managing and storing surplus energy generated dur-ing low-demand periods, making it available during peak periods. SESS are essential for reducing reliance on conventional power generation, lowering greenhouse gas emissions, and enhancing energy efficiency [1].

A standard SESS includes energy storage components, power electronics, and smart controls. Energy storage units, like batteries and super capacitors, hold excess energy produced by renewable, while power electronics, such as inverters, convert this stored energy into a usable form for the grid. Smart controls, including energy management systems and monitoring and control systems, regulate the energy flow, ensuring its efficient and effective utilization [2].

The advancement and implementation of SESS are pivotal for the expansion of renewable energy and the transition to a more sustainable energy landscape. These systems can be applied in both residential and commercial contexts and have the potential to transform energy usage and management. By enhancing grid reliability and stability and decreasing dependency on traditional power sources, SESS will be instrumental in achieving a more sustainable and efficient energy future for the coming generations. Need of Smart Energy Storage System [3].

The need for Smart Energy Storage Systems (SESS) arises from the increasing demand for renewable energy sources and the need to integrate them into the grid efficiently. The following are some of the key reasons why SESS is necessary [5]

1. Integration of Renewable Energy: Renewable energy sources like wind and solar are significantly influenced by weather conditions, often producing surplus energy when demand is low. SESS helps to store and manage this excess energy for use during peak periods, thus improving the integration of renewable into the grid

2. Grid Stability: SESS helps to improve the stability of the grid by balancing the energy demand and supply. It is step forward for smart grid. This is particularly important during periods of high demand, when conventional power plants may not be able to keep up with the energy demand. The transmission and distribution grid can be stabilized by these energy storage devices by minimizing the difficulty in meeting peak power demand and output power fluctuations.

3. Energy Efficiency: SESS helps to reduce the energy losses that occur during energy transmission and distribution, thus improving energy efficiency.

4. Cost Savings: SESS can reduce reliance on traditional power generation, leading to lower energy costs, especially during peak demand times when energy prices are elevated.

5. Environmental Benefits: SESS helps to reduce greenhouse gas emissions by reducing the need for traditional power generation sources that emit large amounts of carbon dioxide.

Sometimes there is a very long distance between the generating units and the customers. Consequently, there is a high likelihood that there will be many power outages.

II. PARAMETERS INFLUENCE THE STORAGE DEVICE

Following factors influence the storage device quality in a smart energy storage system:

a) Energy density refers to the amount of energy that can be stored per unit of weight or volume in a storage device.

b) Power density measures the rate at which energy can be supplied or withdrawn from a storage device.

c) Cycle life denotes the number of charge-discharge cycles a storage device can undergo before its performance significantly degrades.

d) Efficiency is the percentage of energy that can be effectively stored or retrieved from a storage device. Self-discharge rate (SDR). The rate at which a storage device expends the energy it has in reserve when not linked to an external load.

e) Operating temperature range: The temperature range in which a storage device can function properly.

f) The price for each unit of energy that is stored in the storage device.

g) Durability: The capacity of the storage de-vice to survive difficult operating circumstances, such as high temperatures, mechanical strain, and exposure to the environment.

III. LITERATURE REVIEW

A literature review on Smart Energy Storage Systems (SESS) typically covers the various aspects of the design, operation and control of these systems, including their applications, benefits, and challenges. Some of the key topics that are usually addressed in a literature review on SESS include

Information on Smart Energy Storage Systems in Micro grid is provided by Zhang [1]. X. Li, and L. Wang [3] give information on Energy Management Strategies for Smart Energy Storage Systems in Micro grid Applications. Z. Chen [2] gives his view on Optimal Operation of Smart Energy Storage Systems for Renewable Energy Integration published in Energies.

The authors [5, 6 & 7] provide details on several energy storage system types. Information on inte-grated energy system modeling is provided by Tahir and Ali [8]. Hierarchical stochastic scheduling of multi-community integrated energy systems in un-predictable contexts is discussed by Li, Y., and Wang [9]. Sharing perspectives on the most effective scheduling of integrated demand response enabled community integrated energy systems are Li, Y., Wang, and Yang [10]. Cost-Benefit Analysis and Markets of Energy Storage Systems for Electric Grid Applications are discussed by Kimber, A., and Wang [11].

Gao and J.J. Chen [12] discuss the use of compressed air energy storage and preventive action in cost-effective micro grid planning and scheduling. Information on distributed control strategies for micro grids is provided by Espina [13]. A coordinated planning method for the micrositing of tidal current turbines and collector systems is discussed by Ren, Z., Wang [14].

Hierarchical control of a hybrid energy storage system is discussed by Xiao, J., and Wang [15]. In an independent DC micro grid, Xu, Q [16] provides information on a decentralized dynamic power sharing technique. In his article Experimental examination of hybrid super capacitor energy storage systems for vehicles' starting, energy-saving, and emission-reducing capabilities, Zhang [17] provides details.

IV. STATE OF ENERGY STORAGE TECHNOLOGIES

The current state of energy storage systems is characterized by rapid growth and development, driven by the increasing demand for clean and reliable energy, the integration of renewable energy sources into the grid, and the need for improved energy efficiency.

In recent years, advancements in energy storage technologies, such as lithium-ion batteries, have led to increased energy density, longer lifetimes, and reduced costs. SESS can provide real-time monitoring and control of energy storage systems, optimizing their performance and integrating them seamlessly into the grid.

Overall, the current state of energy storage systems is one of rapid growth and innovation, with new technologies and applications emerging regularly. The continued development and adoption of energy storage systems will play a critical role in the transition to a more sustainable and efficient energy future.

ISSN (Online) 2393-8021
ISSN (Print) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology

3rd-International Conference on Muti-Disciplinary Application & Research Technologies (ICMART-2024)

Geetanjali Institute of Technical Studies

Vol. 11, Special Issue 2, May 2024

V. ENERGY STORAGE DEVICES

For storage purpose following energy storage devices are used in practice.

1-**Battery storage**

Battery storage is an important component in a smart energy storage system as it helps to store excess energy generated from renewable sources for later use. In fig 1 shows the lead acid battery with 03 cells which are most portable storage from ancient days. Storage capacity depends upon the numbers of cell included.

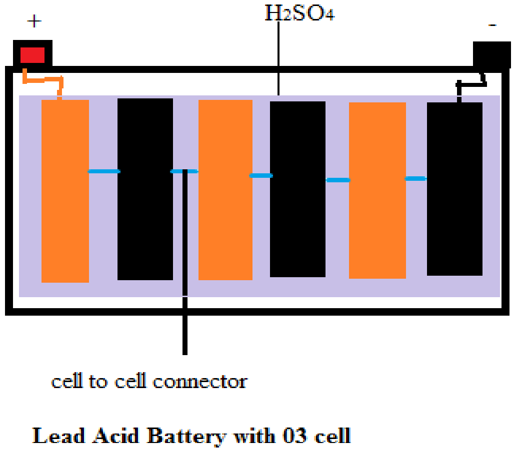

Fig 1: Lead Acid Battery

In India, the adoption of battery storage systems has increased in recent years due to the government's focus on promoting renewable energy sources. The benefits of battery storage in a smart energy storage system include improved energy security, reduced dependence on fossil fuels, and increased energy efficiency. With the ongoing technological advancements and declining costs, the demand for battery storage in India is anticipated to increase steadily in the coming years.

2. Thermal Storage

Thermal energy storage technology captures and retains heat or cold energy from various sources, such as renewable energy (e.g., solar thermal), conventional power plants, or industrial processes, for later use. In smart energy storage systems, thermal storage is vital for balancing energy supply and demand, enhancing grid reliability and stability, and reducing greenhouse gas emissions. In India, rising energy demand driven by population growth and economic development has led the government to promote renewable energy and develop smart energy storage systems. Thermal energy storage is recognized as a crucial technology for integrating renewable energy into the grid by storing excess energy for future use. Different types of thermal energy storage technologies include sensible heat storage, latent heat storage, and thermo-chemical storage, each with its own set of advantages and limitations. The choice of technology depends on the specific application and local conditions. Overall, thermal energy storage has the potential to play a significant role in the development of a sustainable energy system in India and support the country's transition to a low-carbon economy. The schematic representation is given in fig 2

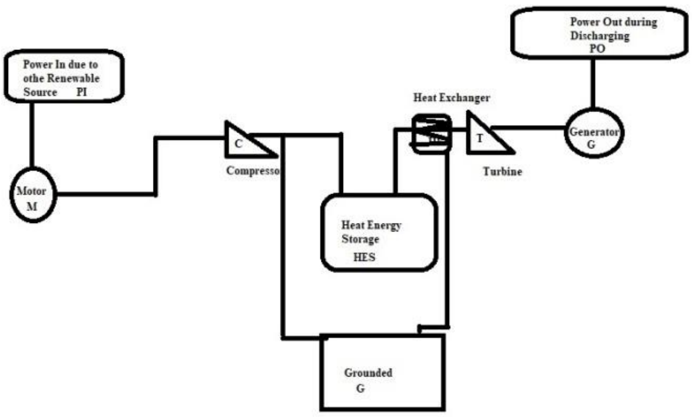

Fig 2: Thermal Storage System

IARJSET
ISSN (Online) 2393-8021
ISSN (Print) 2394-1588
International Advanced Research Journal in Science, Engineering and Technology
3rd-International Conference on Muti-Disciplinary Application & Research Technologies (ICMART-2024)
Geetanjali Institute of Technical Studies
Vol. 11, Special Issue 2, May 2024

3. Mechanical Storage

Mechanical storage systems are energy storage solutions that utilize physical components to store and release energy. Methods include flywheels, pumped hydro, and compressed air energy storage. In India, where energy demand is rapidly growing, mechanical storage systems are essential for balancing energy supply and demand, minimizing energy waste, and enhancing grid efficiency and reliability. These systems are crucial for providing flexible, efficient, and cost-effective storage solutions in the face of increasing energy needs. The process involves transferring work to matter, which increases its kinetic energy by altering its linear velocity.

S. No	Mechanical Storage Systems	Efficiency (%)
1	Flywheel	70-85
2	Compressed air(average of heat+ without heat)	50-55
3	Pumped Hydro plant	75-80

Table.1: shows overall efficiency of different types of Mechanical Storage Systems

Flywheel has longer life with low maintenance. It generated high quality, high reliable and uninterrupted power for commercial as well as industrial application with limitation of high capital cost and low storage. Compressed air technology for energy storage use for storing of large amount of energy with fast repose time with drawback of favourable geological structure. Pump hydro storage technology is world-wide accepted technology that store huge amount of energy for long period of time with the limitation of requirement of large land area and long reservoirs of water.

4. Hydrogen

Hydrogen storage, which is still in its infancy, would require electrolyzing power to create the gas, which would then be stored in tanks. From there, it can later be re-electronized or supplied to other applications including transportation, industry, or residential as a complement to or replacement for gas. In India, hydrogen trains will be used for public transportation.

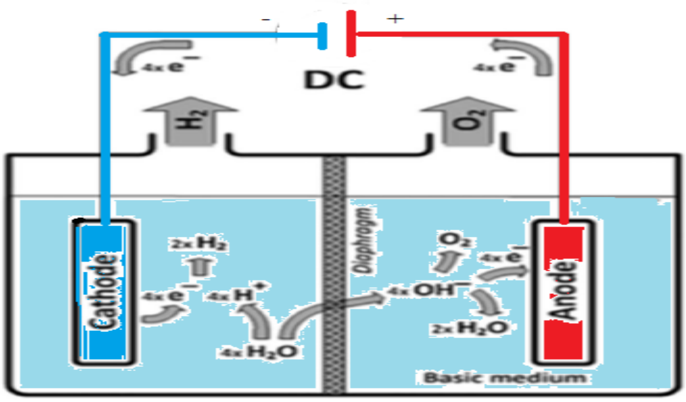

Fig 3: Electrolysis of Water showing generation of hydrogen and oxygen

Utilizing hydrogen as a form of energy storage allows for the storing of surplus electricity produced by renewable energy sources like wind and solar energy. Through the electrolysis process, the extra energy is used to create hydrogen, where water is split into hydrogen and oxygen. The hydrogen can then be stored and used as a fuel source in fuel cell vehicles or to generate electricity when needed through a process called reverse electrolysis. This technology offers a clean and renewable solution for energy storage, as the only by product of using hydrogen as a fuel is water. In figure 3 shows the generation of hydrogen and oxygen from water

5. Thermal Energy

Thermal energy, also known as heat energy, is the energy that is generated and transmitted by the movement of atoms and molecules within a substance. It is a form of energy that results from the temperature difference between two objects or systems. The transfer of thermal energy from one object to another can occur through conduction, convection, and radiation.

In physics, thermal energy is defined as the internal energy of a substance that is due to the random motion of its atoms and molecules. This type of energy is closely related to the temperature of an object, as the temperature of a substance is directly proportional to the average kinetic energy of its particles.

IARJSET

ISSN (Online) 2393-8021
ISSN (Print) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology

3rd-International Conference on Muti-Disciplinary Application & Research Technologies (ICMART-2024)

Geetanjali Institute of Technical Studies

Vol. 11, Special Issue 2, May 2024

Thermal energy system shown in figure 4 is used in many everyday applications, including heating and cooling systems, power generation, and industrial processes. It is also a key factor in the study of thermodynamics, which is the branch of physics that deals with the relationships between heat, work, and energy.

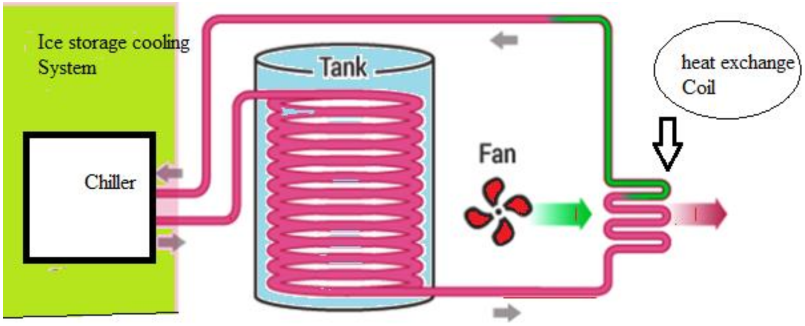

Fig 4: Thermal Energy System

VI. STATICS

The efficiency of various batteries, as illustrated in Figure 5, used in smart energy storage systems can vary based on the battery type and its capacity. Here, a statistical analysis should be included.

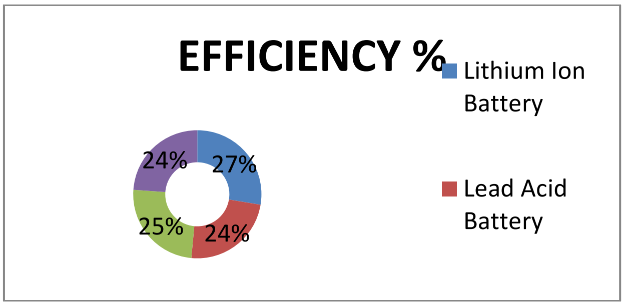

Fig 5: Efficiency of Batteries

Commonly used batteries for energy storage include

a) Lead-acid batteries: These traditional batteries have an efficiency ranging from 60% to 80%.
b) Lithium-ion batteries: Known for their high energy density, these batteries offer an efficiency of about 80% to 90%. They are prevalent in portable electronics, electric vehicles, and increasingly in energy storage systems.
c) Sodium-sulphur batteries: These batteries also boast high energy density and have an efficiency between 75% and 85%, typically used in large-scale energy storage systems.

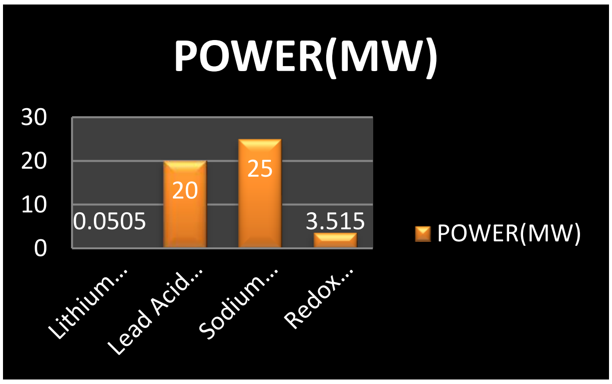

Fig 6: Power utilized by different Batteries

The power output of a battery, as depicted in Figure 6, used in a smart energy storage system is influenced by factors such as capacity, voltage, and discharge rate. Common battery types for smart storage systems include lithium-ion, lead-acid, and nickel-cadmium batteries.

a) Lithium-ion batteries: These typically have a capacity ranging from 2.5 to 20 kilowatt-hours (kWh) and a voltage between 3.7 and 48 volts.

b) Lead-acid batteries: These generally have a capacity of 0.5 to 5 kWh and a voltage of around 2 volts.

It is important to note that a battery's power output decreases over time as it discharges.

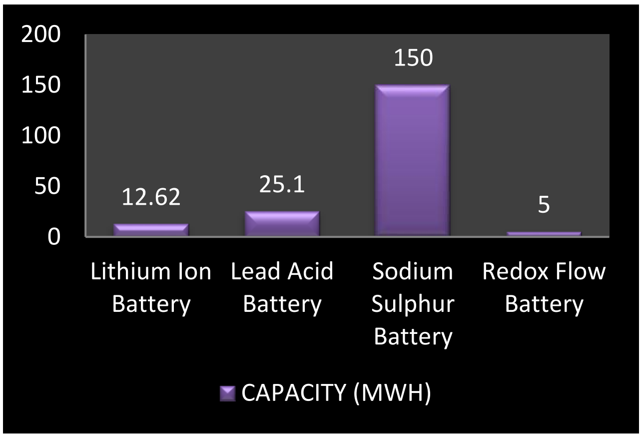

Fig 7: Capacity used in different batteries

The capacity of various batteries utilized in smart energy storage systems, as shown in Figure 7, can differ significantly based on system requirements and battery technology. Below are some common types of batteries used in smart energy storage systems, along with their typical capacities:

a) Lead-acid batteries: Widely used, these batteries typically range from 50Ah to several thousand Ah in capacity.

b) Lithium-ion batteries: Increasingly popular for their high energy density, long cycle life, and low self-discharge rate, capacities for lithium-ion batteries can vary from a few Ah to several hundred Ah.

c) Sodium-sulphur batteries: Employed in some large-scale energy storage systems due to their high energy density and long cycle life, capacities for sodium-sulphur batteries can span from a few kilowatt-hours to several megawatt-hours.

It's essential to consider that a battery's actual capacity depends on factors like discharge rate, temperature, and battery age.

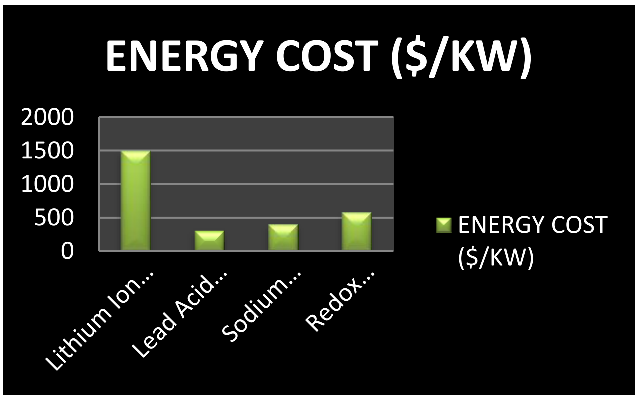

Fig 8: Energy costs for different batteries

The energy cost of different batteries shown in figure 8 used in smart energy storage systems varies. Here are some of the most common batteries used in smart energy storage systems, along with their estimated energy costs: Lead-acid batteries: They are widely adopted and known for their cost-effectiveness in smart energy storage systems, with an energy cost of around $100 to $200 per kilowatt-hour (kWh). Lithium-ion batteries: These are more expensive than lead-acid batteries, with an energy cost of around $300 to $500 per kWh, however, they provide superior energy density and longer lifespan. Sodium-ion batteries: These batteries have a similar energy cost to lithium-ion batteries, but are not as widely used in smart energy storage systems.

VII. SMART STORAGE

Smart power management play vital role in smart energy storage systems. In this case energy storage system shown in figure 9 directly linked with machine that store energy during peak generation and compensate it grid fault. This smart operation can be done by cloud intelligent capabilities. In smart storage paper battery has good identification with bio compatible properties, light and flexible weight with some limitation like cost efficiency. By the embedded of proper artificial intelligence, smart meter and senor in storage device we can make it more smart as per our requirement.

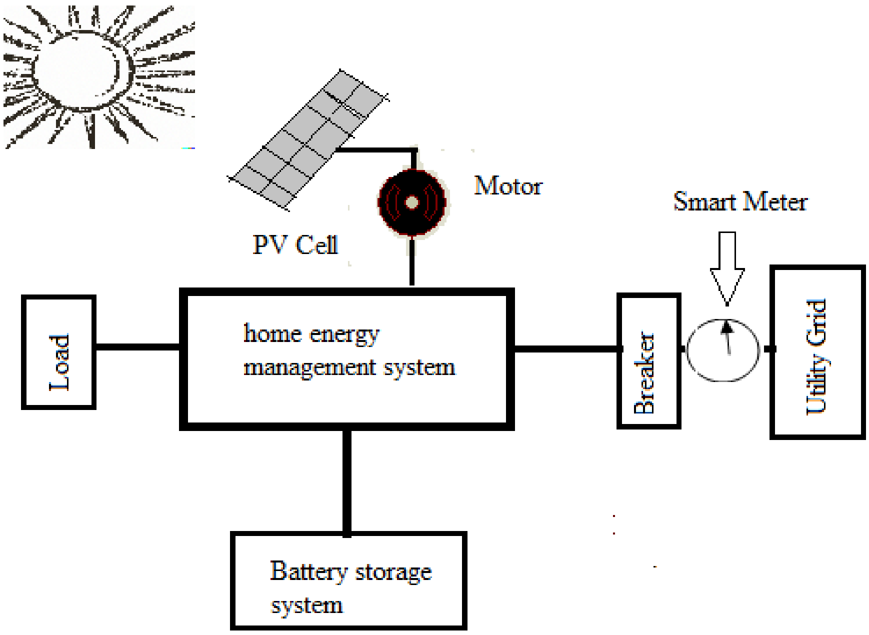

Fig 9: Smart Energy Storage

VIII. CONCLUSION

This research paper presents an in-depth examination of the potential of Smart Energy Storage Systems (SESS) in India. The analysis of SESS is intended to assess technical, economic, and regulatory aspects crucial for the country's energy sector development. This research also provides valuable insights for policy makers and stakeholders in the energy industry and will help to guide future investments in current technology.

Green energy will become more prevalent as the lithium ion battery is used more frequently in zero-emission transportation systems. Lithium ion batteries have a wider application in automotive systems than sodium sulphur batteries, while having a lower price and greater capacity.

REFERENCES

[1] S. M Zhang, Xing, et al. "Dynamic Energy Manage-ment for Smart Energy Storage System in Microgrid." Energies, vol. 15, no. 3, 2022, pp. 466.
[2] Li, Xiaohang, et al. "Optimal Energy Management of a Smart Energy Storage System for Residential Microgrid." Energies, vol. 15, no. 3, 2022, pp. 435.
[3] Li, Xin, et al. "A Review of Smart Energy Storage System for Renewable Energy Integration and Grid Support." Renewable and Sustainable Energy Re-views, vol. 140, 2022, pp. 110787.
[4] Huang, Xinyu, et al. "Smart Energy Storage System with Energy Management Strategies: A Comprehensive Review." Renewable and Sustaina-ble Energy Reviews, vol. 140, 2022, pp. 110751.
[5] Kebede, A.A.; Kalogiannis, T.; Van Mierlo, J.; Berecibar, M. A comprehensive review of stationary energy storage devices for large scale renewable energy sources grid integration. Renew. Sustain. Energy Rev. 2022, 159, 112213. [Google Scholar] [CrossRef]
[6] Tan, K.M.; Babu, T.S.; Ramachandaramurthy, V.K.; Kasinathan, P.; Solanki, S.G.; Raveendran, S.K. Empowering smart grid: A comprehensive review of energy storage technology and application with re-newable energy integration. J. Energy Sto-rage 2021, 39, 102591. [Google Scholar] [CrossRef]
[7] Jafari, M.; Botterud, A.; Sakti, A. Decarbonizing power systems: A critical review of the role of energy storage. Renew. Sustain. Energy Rev. 2022, 158, 112077. [Google Scholar] [CrossRef]
[8] Tahir, M.F., Haoyong, C., Mehmood, K., Ali, N., Bhutto, J.A., 2019. Integrated energy system mod-eling of China for 2020 by incorporating demand response, heat pump and thermal storage. IEEE Access 7, 40095–40108.
[9] Li, Y., Wang, B., Yang, Z., et al., 2022c. Hie-rarchical stochastic scheduling of multi-community integrated energy systems in uncertain environments via stackelberg game. Appl. Energy 308, 118392.
[10] Li, Y., Wang, B., Yang, Z., et al., 2022d. Optimal scheduling of integrated de-mand response-enabled community-integrated energy systems in uncertain environments. IEEE Trans. Ind. Appl. 58 (2), 2640–2651.

[11] Liu, J.; Hu, C.; Kimber, A.; Wang, Z. Uses, Cost-Benefit Analysis, and Markets of Energy Sto-rage Systems for Electric GridApplications.J. Energy Storage 2020,32, 101731.

[12] J. Gao, J.J. Chen, B.X. Qi, Y.L. Zhao, K. Peng, X.H. Zhang, A cost-effective two-stage optimization model for micro grid planning and scheduling with compressed air energy storage and preventive main-tenance, International Journal of Electrical Power & Energy Systems, Volume 125, 2021, 106547, ISSN 0142-0615

[13] Espina, E., Llanos, J., Burgos-Mellado, C., Cárdenas-Dobson, R., Martínez- Gómez, M., Sáez, D., 2020. Distributed control strategies for microgrids: An overview. IEEE Access 8, 193412–193448.

[14] Ren, Z., Wang, Y., Li, H., Liu, X., Wen, Y., Li, W., 2019. A coordinated planning method for micrositing of tidal current turbines and collector system optimization in tidal current farms. IEEE Trans. Power Syst. 34 (1), 292–302.

[15] Xiao, J., Wang, P., Setyawan, L., 2015. Hierarchical control of hybrid en- ergy storage system in DC microgrids. IEEE Trans. Ind. Electron. 62 (8), 4915–4924.

[16] Xu, Q., et al., 2017. A decentralized dynamic power sharing strategy for hybrid energy storage system in autonomous DC microgrid. IEEE Trans. Ind. Electron. 64 (7), 5930–5941.

[17] Zhang, Q., Liu, L., Zhang, J., Zhang, G., Chen, Y., Liu, S., Wu, H. and Huang, H., 2023. Experimental investigation of starting-up, energy-saving, and emission-reducing performances of hybrid superca-pacitor energy storage systems for automo-biles. Journal of Energy Storage, 60, p.106602. (2002) The IEEE website. [Online].. Available: http://www.ieee.org/